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FINAL
ENVIRONMENTAL IMPACT STATEMENT

Waste Isolation Pilot Plant

Volume 1 of 2

October 1980

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Defense Programs
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Foreword

In accordance with the National Environmental Policy Act (NEPA) of 1969, the U.S. Department of Energy (DOE) has prepared this document as environmental input to future decisions regarding the Waste Isolation Pilot Plant (WIPP), which would include the disposal of transuranic waste, as currently authorized. The alternatives covered in this document are the following:

1. Continue storing transuranic (TRU) waste at the Idaho National Engineering Laboratory (INEL) as it is now or with improved confinement.

2. Proceed with WIPP at the Los Medanos site in southeastern New Mexico, as currently authorized.

3. Dispose of TRU waste in the first available repository for high-level waste. The Los Medanos site would be investigated for its potential suitability as a candidate site. This is administration policy and is the alternative preferred by the DOE.

4. Delay the WIPP to allow other candidate sites to be evaluated for TRU-waste disposal.

This final environmental impact statement (FEIS) for the WIPP project is a revision of the draft environmental impact statement (DEIS) published in April 1979. It includes responses to comments received from the public and from government agencies, in writing and in a series of public hearings, and has been modified to reflect changing policies and legislative requirements.

Two principal differences between this FEIS and the DEIS arise from the deletion of an intermediate-scale facility for the disposal of spent fuel and licensing from the WIPP project, as directed by the DOE authorizing legislation for fiscal year 1980. Another difference is that the WIPP project, the preferred alternative in the DEIS, is now termed the authorized alternative. The preferred alternative is to continue storing TRU waste at the INEL until a high-level-waste repository is available to receive it, this time expected to be between 1997 and 2006. The preferred alternative is consistent with the President's message to Congress of February 12, 1980, establishing a comprehensive national program for the management of radioactive waste.

If this preferred alternative is pursued, additional NEPA documentation will be prepared for further site investigation and for decisions on the qualification of the Los Medanos site as a candidate for a high-level-waste repository. In all cases, future activities related to the Los Medanos site would be done in cooperation with the State of New Mexico.

The analysis of the authorized WIPP project is to provide input to decisions concerning TRU-waste disposal and associated experiments. To provide sufficient input for these decisions, this document also analyzes the radiological consequences of waste transportation and processing. Nevertheless, it is not intended to provide sufficient environmental analysis for decisions on actual routes or methods for transporting material to the repository or for decisions on the construction of facilities for processing the waste destined for the repository. These decisions will be addressed in subsequent documents.

The WIPP authorized alternative includes a site and preliminary-design validation (SPDV) program in which two deep shafts and an underground experimental area would be constructed. This program would allow the DOE to confirm the geologic adequacy of the Los Medanos site before a decision to proceed with full construction. Although designed to meet the requirements of the WIPP authorized alternative, the SPDV program would be compatible with the characterization activities that would be needed to qualify the Los Medanos site for a high-level-waste repository under the preferred alternative. Similarly, the technical information gained from the SPDV program could aid in the comparison of site adequacy intended by the fourth alternative (i.e., to delay the WIPP pending the evaluation of other candidate sites).

This environmental impact statement is arranged in the following manner: Chapter 1 is an overall summary of the analysis contained in the document. Chapters 2 and 4 set forth the objectives of the national waste-management program and analyze the full spectrum of reasonable alternatives for meeting these objectives, including the WIPP. Chapter 5 presents the interim waste-acceptance criteria and waste-form alternatives for the WIPP. Chapters 6 through 13 provide a detailed description and environmental analysis of the WIPP repository and its site. Chapter 14 describes the permits and approvals necessary for the WIPP and the interactions that have taken place with Federal, State, and local authorities and with the general public in connection with the repository. Chapter 15 analyzes the many comments received on the DEIS and tells what has been done in this FEIS in response. The appendices contain data and discussions in support of the material in the text.

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1 Summary

1.1 BACKGROUND

This document provides environmental input for certain decisions in the U.S. Department of Energy (DOE) program for managing the transuranic radioactive waste generated in the national defense program. This final environmental impact statement was preceded by a draft statement published by the DOE in April 1979.

Large quantities of radioactive waste have resulted from the production of nuclear weapons and the operation of military reactors in national defense programs. This waste includes both high-level waste (HLW) and transuranic (TRU) waste. (These terms are defined in the main text of this document and in the glossary.) The earliest decision on managing these wastes was made in the mid-1940s: to store high-level waste as liquids in tanks and to bury other waste in trenches. In the mid-1950s, a committee of the National Academy of Sciences suggested salt formations for the permanent disposal of high-level waste. Studies of salt, including experiments in a salt mine in central Kansas, led to a 1970 proposal to establish a high-level-waste repository in that mine; this proposal, however, foundered for a variety of technical reasons.

After the Kansas site was abandoned, there was a renewed examination of possible repository sites. Progressive elimination of less desirable sites led to the bedded salt of southeastern New Mexico and to the Los Medanos site in Eddy County, New Mexico. Work started in 1975 on a conceptual design for a repository at the Los Medanos site, primarily to dispose of TRU waste stored in retrievable form at the Idaho National Engineering Laboratory. The storage of this waste had begun in 1970 with a decision by the Atomic Energy Commission to store this waste by methods designed to keep it retrievable for at least 20 years rather than to continue shallow land burial.

Current legislation authorizes the construction of the Waste Isolation Pilot Plant (WIPP) as a defense activity of the DOE. The WIPP mission, as defined in this legislation, is to provide a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States.

The legislation appropriating funds to the DOE for fiscal year 1980 (PL 96-69) prohibited the expenditure of funds appropriated to the DOE under that act for any purpose related to the licensing of the WIPP by the Nuclear Regulatory Commission or to the disposal at the Los Medanos site of radioactive waste not resulting from the national defense activities of the DOE. Furthermore, that year's authorization act for the DOE's national security and military applications programs (PL 96-164) defined the WIPP so as to limit it to activities involving defense-related radioactive waste.

In the meantime, studies concerned with repositories for commercially generated radioactive waste continue under the National Waste Terminal Storage program. This program is considering sites in various regions and media.

On February 12, 1980, President Carter sent a special message to Congress (reproduced in Appendix C) establishing the nation's first comprehensive program for the management of radioactive waste. This message was consistent with the broad consensus that evolved from the efforts of the Interagency Review Group on Nuclear Waste Management.* The President decided that all repositories for the permanent disposal of highly radioactive waste should be licensed. He directed the DOE to expand and diversify its program of geologic investigations before selecting a specific site for repository development. He decided the WIPP project should be canceled and that defense and commercial waste should both be placed in the same repositories. The preferred alternative identified in this final environmental impact statement, disposal of TRU waste in the first available high-level-waste repository, is consistent with the President's proposed program.

In accordance with the Impoundment Control Act of 1974, on March 4, 1980, President Carter sent to Congress a proposal to rescind funds appropriated for the WIPP in fiscal year 1980. The proposal was not acted on by Congress.

This document examines the impacts of the preferred alternative, as well as the authorized WIPP project and other alternative plans, and compares the impacts of the alternatives.

1.2 ALTERNATIVES

This environmental impact statement analyzes alternatives for the long-term disposal of the TRU waste stored retrievably at the Idaho National Engineering Laboratory. It also considers potential alternative uses of the Los Medanos site. The use of the Los Medanos site in southeastern New Mexico for the construction and operation of a facility designed for the disposal of TRU waste and experiments with high-level radioactive waste is designated the authorized alternative. The other alternatives are evaluated in comparison with this alternative.

The alternatives considered in this document are as follows:

1. No action. The TRU waste remains stored at the Idaho National Engineering Laboratory as it is now or with improved confinement.

2. Construction of the WIPP facility at the Los Medanos site in southeastern New Mexico. This is the alternative authorized by legislation. The WIPP would include a 100-acre mined repository for the demonstration disposal of defense-program TRU waste, including the waste stored retrievably in Idaho, and a 20-acre underground area for research and development on the disposal of defense-program high-level waste.

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*The Interagency Review Group on Nuclear Waste Management, established by President Carter in March 1978, was made up of representatives of 14 government agencies. Its charter was to make recommendations for a national policy for the management of radioactive waste and supporting programs.

3. Disposal of TRU waste stored at the Idaho National Engineering Laboratory in the first available repository for high-level waste. The Los Medanos site would continue to be protected and investigated to determine its potential suitability as a candidate site for a high-level-waste repository. This is the alternative preferred by the DOE. By 1985 to 1989, four or five sites potentially suitable for a high-level-waste repository should have been found from among those examined in various media--bedded salt, domed salt, basalt, granite, shale, and tuff. Defense-program TRU waste would be disposed of in a high-level-waste repository built at one such site, planned to begin operation between 1997 and 2006.

4. Delay of the WIPP facility. By 1984 or so, evaluations of salt-dome and basalt sites should have been completed, allowing these sites to be considered, in addition to the Los Medanos site, in deciding on the location of a WIPP-like facility.

1.3 THE LOS MEDANOS SITE

The Los Medanos site is in southeastern New Mexico, about 25 miles east of Carlsbad. Its area is 18,960 acres, all Federal and State land, of which nearly 17,000 acres would be used for buffer zones around an underground repository. It has been extensively investigated and is a potential site for a repository under alternatives 2, 3, and 4.

The site is on a plateau east of the Pecos River, an area of rolling sand-covered hills and sand dunes with desert vegetation. The land is used for grazing at a density of about six cattle per square mile.

Sixteen people live within 10 miles of the center of the site; approximately 94,000 people live within 50 miles. Basic industries in the area are mining, manufacturing, and agriculture. Tourism is important because of the nearness of the Carlsbad Caverns National Park (41 miles west-southwest of the site and west of the Pecos River).

Southeastern New Mexico is arid. There is a wet season in late summer, but the total rainfall at the site is only about 13 inches a year. Winds are dominantly from the south to southeast throughout the year, although the storm winds of winter and spring tend to come from the west.

Geology

The site is in the north-central part of the Delaware basin, a region in which evaporation in a shallow sea deposited about 3600 feet of evaporites during the Permian period 280 to 225 million years ago. A repository at this site would be built in the nearly pure salt of the Salado Formation, itself almost 2000 feet thick, with a mined disposal level 2150 feet below the surface.

Potash minerals and hydrocarbons (oil and gas) are important resources in the region. The former occur sporadically in a layer 800 to 1000 feet below the surface, the latter in various strata from 4000 to 14,000 feet below the surface. There appear to be no economic reserves of crude oil at the site, but there is natural gas amounting to about 0.02% of U.S. reserves. The Carlsbad potash district is the principal domestic source of sylvite and langbeinite for fertilizers; the langbeinite minerals of the area may be unique in the free world. Langbeinite fertilizers are used where crops cannot tolerate the addition of chlorides. However, similar chloride-free fertilizers can be made from other minerals.

The site is in an area of low seismicity.

Hydrology

The Pecos River is 14 miles to the southwest, but there is no integrated surface drainage leading from the site to the river. The principal groundwater aquifer of the region is the Capitan Formation about 10 miles to the north. Aquifers at the site itself yield little water, and this water is of low quality.

Underneath the evaporite formations, there are about 3000 feet of rocks bearing brackish water. This water flows slowly toward the northeast, with some connections to the base of the Capitan. The evaporite formations themselves contain no circulating groundwater, although isolated pockets of pressurized brine have been found below the Salado. Above the salt-bearing formations there are two beds of dolomite that bear water sometimes used for stock. This water flows to the southwest, finally discharging in brine springs along the Pecos River.

Underground dissolution of salt is still an active process in the region. At the site itself, dissolution has removed some salt from above the Salado, but essentially no Salado salt. The shallow-dissolution front at the top of the Salado is about 2 miles west of the center of the site and is advancing horizontally along the top of the Salado salt toward the east at a rate estimated to be 6 to 8 miles per million years. The average vertical rate of dissolution, downward into the Salado salt, is about 0.33 to 0.50 foot per 1000 years. At these rates the zone of salt considered for a repository at the Los Medanos site would remain unaffected for 2 to 3 million years.

The possibility of dissolution at the base of the evaporites has been under investigation because this process appears to be active to the south in Texas. According to the investigations to date, this deep dissolution is not active within 10 miles of the site.

1.4 ENVIRONMENTAL EVALUATION OF ALTERNATIVES

This section compares the environmental impacts of the four alternatives. Alternative 2 is taken as the reference case for this comparison; its environmental impacts are evaluated in this statement. The costs and impacts of the high-level-waste repositories called for in alternative 3 are taken primarily from the draft generic environmental impact statement on the management of commercially generated radioactive waste (DOE, 1979).

Alternative 1: No action

Transuranic waste would be maintained at present storage sites at the Idaho National Engineering Laboratory, possibly with improved confinement. Because there are no locations suitable for deep geologic disposal at the Idaho National Engineering Laboratory, the waste would remain near the surface. No action would be taken on TRU-waste disposal at the Los Medanos site.

In the short term, the radiological consequences of no action are small. At the Idaho National Engineering Laboratory doses to individuals of no more than 0.0000036 rem per year could be expected. In the long term, on the other hand, some natural events that might produce large exposures are probable. The Laboratory is at the edge of the Arco Volcanic Rift Zone, which has been active as recently as 10,500 years ago and is likely to be the scene of volcanic action in the future. Individuals could receive 50-year radiation-dose commitments as high as 90 rem to the lung if volcanic activity disrupts the stored waste. Inadvertent human intrusion into the waste could produce individual dose commitments of up to 700 rem to the lung, with current storage methods. However, with improved confinement, the maximum individual 50-year radiation-dose commitments resulting from volcanic activity and inadvertent intrusion would be reduced by a factor of 100.

Alternative 2: The authorized WIPP facility

The authorized WIPP facility would consist of both surface and underground facilities, including a waste-handling building, an underground-personnel building to support underground construction, an administration building, four shafts to the underground area, underground openings at a single level for waste disposal and for experiments, and various support structures. There would be a storage pile for mined rock (primarily salt), an evaporation pond for runoff from the mined-rock pile, a sewage-treatment plant, a disposal area for construction spoils, and a landfill for sanitary wastes. The construction of the facility would take 4.5 years, and the plant would be designed for an operating life of about 25 years. The facility would be operational in 1987.

The development of the WIPP would occur in two distinct phases: (1) site and preliminary-design validation (SPDV), in which two deep shafts and an underground experimental area would be constructed; and (2) full construction in which the required surface and underground facilities and the remaining shafts would be built. The SPDV program has been planned to confirm the geologic adequacy of the site and to verify the engineering properties of the salt at the depth of the WIPP repository. After completion of the site verification activities, this environmental impact statement would be supplemented before a decision on the construction of the WIPP facility, if significant new information were developed during the SPDV program. The SPDV-program plan calls for a 2-year period for construction and site validation and an operational period of up to 5 years for design validation. Although designed to meet WIPP requirements, the SPDV program would be compatible with the characterization activities that would be needed to qualify the Los Medanos site for a high-level-waste repository, if exploration at repository depth should be required.

Over its 25-year operating life, the WIPP could receive about 6.2 million cubic feet of contact-handled TRU waste and as much as 250,000 cubic feet of remotely handled TRU waste. This would account for all of the TRU waste currently held in interim storage in Idaho, two-thirds of that expected to be generated at all DOE facilities between now and 1990, and all of that expected to be produced from 1990 through 2003. In addition, the WIPP could receive about 150 cubic feet of high-level waste for experiments.

The environmental impacts of both the SPDV program and the construction and operation of the complete facility have been examined. The impacts of the SPDV program are described in this document; the impact analyses are presented in greater detail in a technical report prepared for the DOE (Brausch et al., 1980).

The physical impacts of the SPDV program would be similar to those that accompany any small mining project: locally increased noise levels, local degradation of air quality from dust, disturbance of vegetation and wildlife habitat, and increased soil erosion. None of these impacts are judged to be significant. The noise levels generated could disturb local residents. The air pollution produced would not cause significant deterioration of air quality or result in violations of Federal or State air-quality standards. The increases in noise and air pollution would be short-lived, lasting only the 2 years or so of SPDV construction. Longer-term impacts on vegetation and wildlife would occur because of clearing about 67 acres of their present vegetation and removing this land from grazing. Some of this land (15 acres) would be removed for a very long time because it would be sterilized by salt. Access to the mineral and energy resources at the Los Medanos site would be denied during the SPDV program, but in the event that this site were not considered further for a repository these resources would again become available.

The socioeconomic impacts of SPDV activities, either beneficial or adverse, would be minimal because of the small size and short duration of stay of the SPDV work force. The SPDV program would require about $54 million (1979 dollars) to design and build and about $5 million a year to operate. If the WIPP or a high-level-waste repository were constructed at the Los Medanos site, after site validation the SPDV shafts and underground development would become a part of the complete facility.

Because no radioactive materials would be used in the SPDV program, there would be no radiological consequences.

The physical impacts of developing the complete WIPP facility would include the removal of 1072 acres of land from grazing and the denial of access to some subsurface minerals. Some of this land (37 acres) would be removed from grazing for a very long time because it would be sterilized by the salt stored on its surface. The important mineral reserve is langbeinite, a mineral used for fertilizer where chlorides cannot be used. Access to an estimated 3% to 10% of the U.S. reserves of this mineral would be denied throughout the operating life of the WIPP, and strict controls on its removal would be enforced after operations were completed. Although langbeinite is useful, similar minerals produced commercially from brine lakes can be used in its place.

The authorized WIPP facility would cost about $500 million (1979 dollars) to design and build and $24 million a year to operate. Jobs created directly and indirectly would peak at about 2100 during construction and drop to 950 during operation.

Transportation accidents of extreme severity, though not expected to occur, were postulated to analyze the worst possible consequences of transporting waste to the WIPP. Such an accident in the transportation of the experimental high-level waste could deliver to individuals a 50-year radiation-dose commitment that might reach seven times the dose delivered by natural background radiation. In an accident during the shipment of TRU waste, the maximally exposed individual could receive a dose 3.4 times that from background sources. The relation of radiation doses to health effects is discussed in Appendix O.

During operation, the most severe credible accident would be an underground fire in the disposal area for contact-handled TRU waste. The 50-year radiation-dose commitment received by the maximally exposed individual would be about 0.0001% of the dose from natural background radiation; this dose would be delivered to the bone.

After the WIPP has ceased operation and is closed, no release of radioactive material would be expected. Nevertheless, if someone were to drill directly into the stored TRU waste 100 years later, the geologist on the drill crew could be exposed to a whole-body dose of about 0.0015 rem. This dose is about 1.5% of the annual dose received from natural background radiation. Even if the worst imaginable release into groundwater occurred, the consequences would be very small: the radioactivity discharged into the Pecos River would deliver an annual bone dose of only 0.00003 rem to the person receiving the highest exposure. This is 0.03% of the dose he would receive from natural background radiation.

Included in the WIPP design are features that would reduce or mitigate the potential environmental impacts of facility construction and operation. The mitigation measures to be employed would reduce physical impacts during construction and operation by controlling air, water, and noise pollution and would restore the site to natural conditions after the facility is decommissioned. Radiological impacts during operations would be reduced by design features, such as high-efficiency particulate air (HEPA) filters, that would limit the amount of radioactivity released to the environment. In addition, potential radiological impacts would be mitigated by establishing detailed operating procedures to decrease the probability of accidents, by developing security measures to lessen the chances of intentional destructive acts, and by developing emergency procedures to reduce the effects of accidents. To enhance long-term waste isolation, the WIPP design would include warning monuments and the maintenance of records to aid in preserving knowledge of the repository and to reduce the probability of accidental intrusions.

<u>Alternative 3: The preferred alternative--combine the authorized WIPP activities with the first available repository for high-level waste</u>

In this alternative, there is no separate defense-waste facility. A number of potential sites for a repository for both TRU waste and high-level waste will be located, characterized, and evaluated. The Los Medanos site may be included in this evaluation; the SPDV program described for alternative 2 would be compatible with the site-characterization studies that would be required to qualify this site for a combined TRU-waste and high-level-waste repository. The other sites will be in a variety of host rocks such as bedded salt, salt domes, basalt, granite, shale, and tuff. When four or five sites have been found potentially suitable, one or more will be selected for development. This alternative is consistent with the program proposed by the President and that described by the DOE in its statement of position on the Nuclear Repository Commission's Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (DOE, 1980). Subsequent environmental impact statements are planned to support DOE decisions on reserving candidate sites for possible selection in the high-level-waste repository program. The first high-level-waste repository would be operational between 1997 and 2006.

This environmental impact statement discusses a conceptual repository in salt and a conceptual repository in basalt; a repository in other media would entail different impacts, which can be accurately predicted only after further study of these media and the identification of specific sites. The delay inherent in this alternative means that the Idaho TRU waste would remain longer in its present storage, increasing by about 10% per year. Barring a natural catastrophe, leaving it there for a short time would entail no significant consequences. The environmental impacts of the SPDV program conducted at the Los Medanos site would not be changed in this alternative from those described for this activity under alternative 2 (see also Brausch et al., 1980).

At the high-level-waste repository, the land required may be increased by not more than 6% with the addition of TRU waste, but combining TRU waste and high-level waste in one repository would decrease the overall land use by about 15%. The quantity of mined rock would increase by 3% to 7% at the high-level-waste site but remain basically unchanged overall. By including a TRU-waste repository, the construction and operating costs at the high-level-waste site would be increased by 8% to 25% and 15% to 30%, respectively, but decreased in comparison to the cost of separate repositories. The number of workers at the high-level-waste site would increase by 27% to 35%, but would decrease by 10% overall.

Transportation routes vary depending on the site selected for the combined repository. The consequences of individual accidents would remain essentially the same. There is no reason to expect any change in the probabilities of operational accidents.

Under alternative 3, the Los Medanos site could become a potential site for a commercial-high-level-waste (HLW) repository that would include the disposal of defense TRU waste. The characteristics of the Los Medanos site do not appear to conflict with the draft criteria of the National Waste Terminal Storage (NWTS) program for qualifying sites for the disposal of commercially generated high-level waste (ONWI, 1980). Moreover, although the analyses of environmental impacts have focused on the use of the site for TRU waste, interpretations of the results of these evaluations have not developed any information that would eliminate the Los Medanos site as a potential site for an HLW facility. However, before a decision to "bank" the Los Medanos site under the NWTS program, an environmental impact statement would be prepared in accordance with the National Environmental Policy Act strategy set forth in the DOE's statement of position on the Nuclear Regulatory Commission's Proposed Rulemaking (DOE, 1980).

In the long term, no release of radioactivity is expected from a repository at any candidate site. The credible events or processes that might impair the integrity of a repository would differ with the site, and analyses of the consequences of such phenomena at potential sites have not generally been performed. However, any potential site will be subjected to these analyses.

Alternative 4: A defense-waste facility built after the consideration of sites in addition to the Los Medanos site

This alternative is in essence alternative 2 delayed. The SPDV program described for the authorized WIPP alternative (alternative 2) could aid in the comparison of site adequacy intended under this alternative. During the delay, the Idaho TRU waste would remain in its present storage, with no significant consequences. The quantity of defense TRU waste stored at the surface would increase by about 10% per year.

The physical impacts of this alternative would be about the same as those of alternative 2 with respect to land use, resources used, effluents, and mined-rock disposal. If the repository were constructed in the salt domes inland of the Gulf of Mexico or in the basalt at Hanford, the conflict with mineral resources would potentially be reduced. However, the salt in domes is itself a resource. The environmental impacts of the SPDV program at the Los Medanos site would remain the same for this alternative as those described for the authorized WIPP alternative (see also Brausch et al., 1980).

Because the transportation routes from Idaho would be longer to a salt-dome repository, the probability of transportation accidents would be increased; the reverse would be true of a basalt repository. The predicted consequences of an accident and the radiation doses delivered to individual persons during normal transportation would remain basically unchanged, because the consequences are calculated under the assumption that the waste packaging alone provides the relied on containment.

Individual radiation exposures during plant operation (under both normal and postulated-accident conditions) would not be expected to change; population exposures would be higher in the vicinity of salt-dome and basalt repositories because of higher population densities.

There would be no changes in the predicted long-term consequences of a delayed TRU-waste repository if it were constructed at the Los Medanos site.

Although the actual construction and operating costs of a delayed TRU-waste repository would not be expected to change drastically from those of alternative 2 (if the costs are calculated in constant dollars), the overall cost of alternative 4 would be significantly higher. These increased costs would include the cost of storing increasing quantities of TRU waste at the Idaho National Engineering Laboratory and the cost of closing out and restarting the program. The cost of closing out the present effort is estimated to be about $3 million; starting the project up again, either at the Los Medanos site or elsewhere, could cost considerably more.

1.5 CONCLUSIONS

The alternative of no action (alternative 1) is unacceptable in the long term because it leaves the TRU waste stored near the surface at the Idaho National Engineering Laboratory, exposed to possible volcanic action or human intrusion.

The remaining three alternatives are predicted to have impacts that are small both in the short term during construction and operation and in the more distant future, and none of them is so clearly superior environmentally to the others that it can be selected on environmental grounds alone; any of these three alternatives can be carried out in a safe and environmentally acceptable manner. If the SPDV program is conducted, its impact at the Los Medanos site would be the same regardless of which of these three alternatives is selected for long-term waste disposal.

Alternative 3, the preferred alternative, is consistent with the comprehensive radioactive waste management program proposed by the President. Its predicted environmental impacts are generally small. It may deny access to some U.S. mineral resources, depending on the site selected for the combined repository. Combining TRU- and high-level-waste repositories would use less land than separate repositories. The first high-level-waste repository would be available between 1997 and 2006.

Alternative 2, the authorized alternative, is consistent with authorization and appropriation acts. The impacts predicted for it are also generally small. The use of the Los Medanos site in southeastern New Mexico would deny access to 3% to 10% of the U.S. reserves of the mineral langbeinite for the operating life of the repository and require strict controls on its extraction thereafter. The WIPP facility would be operational in 1987.

The radiological consequences of extremely unlikely accidents during the transportation of high-level waste could be severe, but they would be similar regardless of when or where the repository is built. The probabilities and the overall population doses would change depending on the location of the repository, but the radiation doses received by the maximally exposed individual would be the same.

Alternative 4, though an environmentally feasible alternative, is consistent neither with legislation nor with the President's program. Other than additional delay in removal of the TRU waste from Idaho, its impacts would be like those of alternative 2 if the Los Medanos site were selected after comparison with other sites.

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2 Background

This chapter presents information helpful in understanding the rest of this environmental impact statement. It begins by explaining the decisions for which the statement provides environmental information and by outlining in general terms the contents of the statement (Section 2.1). Then Section 2.2 reviews the investigations that have led to the consideration of a particular place, an area called Los Medanos, as the site for the WIPP facility. Then Section 2.3 describes the particular kind of radioactive waste that the statement principally deals with.

2.1 BRIEF INTRODUCTION TO THIS DOCUMENT

Since the early 1940s, the United States has been generating radioactive waste in national defense programs, including the production of nuclear weapons and the operation of military reactors. Because much of this radioactive waste is hazardous enough to require isolation from the biosphere, it has been stored on Government reservations, either buried in trenches or held in specially designed interim-storage areas. The U.S. Department of Energy (DOE) is responsible for developing and implementing methods for the safe and environmentally acceptable disposal of this waste.

During the last two decades, techniques for the disposal of radioactive waste have been studied through exploration, laboratory experiments, field tests, and analyses. Those efforts led the Energy Research and Development Administration, the predecessor of the DOE, to propose that a repository for defense waste, the Waste Isolation Pilot Plant (WIPP), be built near Carlsbad, New Mexico, in the area called Los Medanos. According to the fiscal year 1980 authorizing legislation (PL 96-164), the WIPP is "for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission." The design of the WIPP, providing for the initially retrievable disposal of defense transuranic (TRU) waste and for a research-and-development facility for defense-program high-level waste (HLW), is consistent with that authorization.

On February 12, 1980, President Carter sent a special message to the Congress establishing the nation's first comprehensive program for the management of radioactive waste. This program is consistent with the broad consensus that evolved from the efforts of the Interagency Review Group (IRG) on Nuclear Waste Management.* The President decided that all repositories for the permanent

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*The Interagency Review Group on Nuclear Waste Management, established by President Carter in March 1978, was made up of representatives of 14 government agencies. Its charter was to make recommendations on a national policy for the management of radioactive waste and supporting programs (IRG, 1979).

disposal of highly radioactive waste should be licensed. He directed the DOE to expand and diversify its program of geologic investigation before selecting a specific site for a repository. He decided that the WIPP project should be canceled and that defense and commercial waste should both be placed in the same repository. The full text of the President's message is in Appendix C.

In accordance with the Impoundment Control Act of 1974, on March 4, 1980, President Carter sent to Congress a proposal to rescind funds appropriated for the WIPP. The proposal was not acted on by Congress; consequently the DOE is required to continue project activities.

This document examines and compares the impacts of four alternatives for managing the TRU waste stored at the Idaho National Engineering Laboratory (INEL). The preferred alternative, the disposal of the TRU waste in the first available HLW repository, is consistent with the President's proposed program. The legislatively authorized alternative is to build an unlicensed demonstration repository for defense waste, according to a completed preliminary design, at the Los Medanos site in southeastern New Mexico.

2.1.1 Decisions for Which This Environmental Impact Statement Provides Environmental Input

This environmental impact statement (EIS), prepared in accordance with the requirements of the National Environmental Policy Act (NEPA) of 1969, provides environmental information for the following decisions:

1. What should be the strategy for the long-term management of the TRU waste stored at the INEL?

2. Should the TRU waste stored at the INEL be disposed of in the first available HLW repository or in a repository for TRU waste only, such as the authorized WIPP facility?

3. Should the WIPP facility at the Los Medanos site be constructed and operated?

4. If the WIPP facility is not to be constructed at the Los Medanos site, should the site be retained to preserve the option of characterizing it as a potential site for a combined TRU-HLW repository?

If the answer to the fourth question is yes, additional NEPA documentation will be prepared prior to decisions on the qualification of the Los Medanos site as a candidate for an HLW repository. The qualification of other sites, site selection, and repository construction and operation will also require NEPA documentation (DOE, 1980a).

2.1.2 Contents of This Environmental Impact Statement

This document, the final environmental impact statement (FEIS) for the WIPP project, is a revision of the draft environmental impact statement (DEIS) published in April 1979. It includes responses to comments received from the public and from government agencies, in writing and in a series of public hearings, and has been modified to reflect changing policies and legislative requirements.

One difference between this FEIS and the DEIS arises from the deletion of an intermediate-scale facility (ISF) from the WIPP project. In April 1979, the DOE proposed to include an ISF in the WIPP to be used for emplacing as many as 1000 assemblies of spent fuel from commercial nuclear reactors. The DOE also requested that the Nuclear Regulatory Commission (NRC) be authorized to license the proposed facility. The authorizing legislation for fiscal year 1980 (PL 96-164) does not include the ISF and directs the Secretary of Energy to proceed with a project that is limited to defense waste. The Congress also declined to authorize the licensing of the facility, and the appropriation legislation (PL 96-69) forbade the use of funds for licensing or activities not connected with defense. The President's policy statement of February 12, 1980, also does not provide for a separate ISF. Consequently, inclusion of an ISF is no longer considered to be a reasonable alternative. Since the demonstration of spent-fuel disposal contributed appreciably to the environmental impacts predicted in the DEIS, a number of changes were necessary.

Another difference is that the FEIS combines the two alternatives in the DEIS in which INEL TRU waste is disposed of in the first available repository for commercial high-level waste. The only difference between these alternatives was timing, and the timing of repositories for commercial high-level waste is considered in the draft generic environmental impact statement (GEIS) for the management of commercially generated radioactive waste (DOE, 1979).

A third difference is that the preferred alternative has changed. In the DEIS, the DOE expressed its preference for the construction of the WIPP repository at Los Medanos; the DOE now prefers to dispose of the TRU waste stored at Idaho in the first available repository for high-level waste. The preferred alternative in this FEIS is consistent with the Presidential policy summarized earlier in this section.

The remainder of the changes from the DEIS are updates of information and analyses as well as responses to requests for additional analyses and for the clarification of particular points. The comments that resulted in the most significant change were on the discussion of alternatives to the WIPP project. Chapter 3, "Development of Alternatives," is dedicated to this topic; it expands on the reasoning in Chapter 2 of the DEIS that led to concentration on deep geologic disposal and provides information on how the specific alternatives were derived.

<u>Structure</u>

This document consists of two parts. The first part consists of chapters 2 through 4. It begins with a description of the national program for the management of radioactive waste and the WIPP project (Chapter 2). Chapter 3 formulates four alternative plans for the disposal of the TRU waste now stored at the INEL. Chapter 4 analyzes the environmental impacts of these four alternatives.

The second part of this document presents the environmental impacts of the authorized alternative. It describes the waste to be received at the WIPP (Chapter 5); the methods and the environmental impacts of transporting the waste (Chapter 6); the environment of the Los Medanos site in southeastern New Mexico (Chapter 7); and the design of the facility (Chapter 8). These data are the basis for a detailed analysis of the environmental impacts induced by its construction and operation (Chapter 9). Because the WIPP is designed to keep the waste isolated far into the future, Chapter 9 discusses environmental impacts both in the short term, during the operating life of the repository, and in the long term, for hundreds of thousands of years into the future.

Retrieval of waste from the INEL

Among the actions covered by this document is the retrieval of the TRU waste stored at the INEL for transport to, and emplacement in, a geologic repository. About 3.0 million cubic feet of TRU waste is either currently stored or is to be stored at the INEL through 1990. This document describes how the retrieval of this waste would affect the environment of the INEL and analyses the impacts of transporting this waste to the Los Medanos site.

Withdrawal of land

If the preferred alternative is selected and the Los Medanos site is not used for the WIPP, the DOE will develop a cooperative agreement with the Bureau of Land Management (BLM) of the U.S. Department of the Interior to preserve the option of characterizing the site for a possible HLW repository. The land would be withdrawn permanently only if the Los Medanos site were actually selected for an HLW repository. Site characterization studies would be performed through a cooperative agreement with the BLM that would not require land withdrawal.

If the WIPP is to be constructed as authorized, the transfer, through legislation, to the DOE of about 17,200 acres of public lands currently controlled by the Bureau would be necessary. With the addition of 1760 acres of State lands, this acreage would compose the WIPP site in Eddy County, New Mexico. Further site characterization and validation studies would again be performed through the cooperative agreement with the BLM that would not require land withdrawal. One of the purposes of this document is to examine the environmental consequences of withdrawing these public lands.

Of principal concern under either alternative is the proposed use of public lands for a radioactive-waste repository in light of the multiple-use goal for the management of public lands. Accordingly, this document provides information on the current land uses of the area, an inventory and evaluation of the natural resources of these lands, and the changes that would result from the authorized WIPP project.

Site and preliminary-design validation

In accordance with the authorizing legislation, the DOE would proceed with activities leading to the construction of the WIPP at the Los Medanos site in southeastern New Mexico. As part of the continuing site-characterization program, the DOE would construct two site-validation shafts at the site before the construction of the full repository is begun and an in-situ experimentation facility to verify engineering properties of the salt. This program is referred to as the "site and preliminary-design validation" program, or the SPDV program. Such a program would provide useful input to any future characterization of a site for a repository for commercial radioactive waste, if a decision were made to do so at a later date.

This document specifically analyzes the environmental impacts of the SPDV program; they are presented along with the more extensive impacts of constructing and operating the complete facility. A technical report has also been prepared for the DOE, detailing the analyses of the environmental impacts of the SPDV program (Brausch et al., 1980). Even though the SPDV impacts are smaller than the complete-facility impacts, they are analyzed separately in order to show what the impacts would be if the SPDV program were conducted but the complete facility were not built. If the site-validation activities were to disclose significant new information, this EIS would be supplemented, as appropriate, before a decision to proceed with the construction of the WIPP facility.

WIPP construction

This document describes the environmental impacts of constructing, operating, and decommissioning the WIPP at the Los Medanos site. It compares these environmental impacts with those of possible alternatives. In order to provide a comprehensive picture, it also analyzes the impacts of activities required for the operation not only of the WIPP but of any repository (e.g., the impacts of waste transportation). Impacts of this kind are, or will be, the subject of subsequent reports, such as the safety analysis report for waste-transportation packagings.

2.2 WASTE-MANAGEMENT PROGRAMS LEADING TO THE CONSIDERATION OF THE LOS MEDANOS SITE

The Los Medanos site mentioned in Section 2.1 is the site for the action that would take place under the authorized alternative analyzed in this statement. It is described extensively in the second major part of the statement. This section reviews the investigations that led to the selection of Los Medanos as the place where the authorized alternative might be carried out.

2.2.1 Early History of Waste-Management Programs

In 1955, the U.S. Atomic Energy Commission (AEC) asked a committee of the National Academy of Sciences to examine the issue of permanent disposal of radioactive waste. They concluded (NAS-NRC, 1957) that "the most promising method of disposal of high-level waste at the present time seems to be in salt deposits." They recommended salt for further evaluation because of its thermal and physical properties and because its very existence for hundreds of millions of years has demonstrated its isolation from circulating groundwater and the stability of the geologic formations in which it is located. This recommendation led the AEC to sponsor several years of research (1957-1961) at the Oak Ridge National Laboratory (ORNL) on phenomena associated with the disposal of radioactive waste in salt.

In 1962, Pierce and Rich (1962) reported on salt deposits in the United States that might be suitable for the disposal of radioactive waste. The Permian basin, which includes the Delaware basin in eastern New Mexico and large areas in Kansas, West Texas, and Oklahoma, was one of the areas discussed (Figure 2-1).

In 1963, the ORNL research was expanded to include a large-scale field program in which simulated waste (irradiated fuel elements), supplemented by electric heaters, was placed in Permian-basin salt beds for observation. This experiment, called Project Salt Vault (Bradshaw and McClain, 1971), was conducted in an already existing salt mine at Lyons, Kansas, from 1963 to 1967.

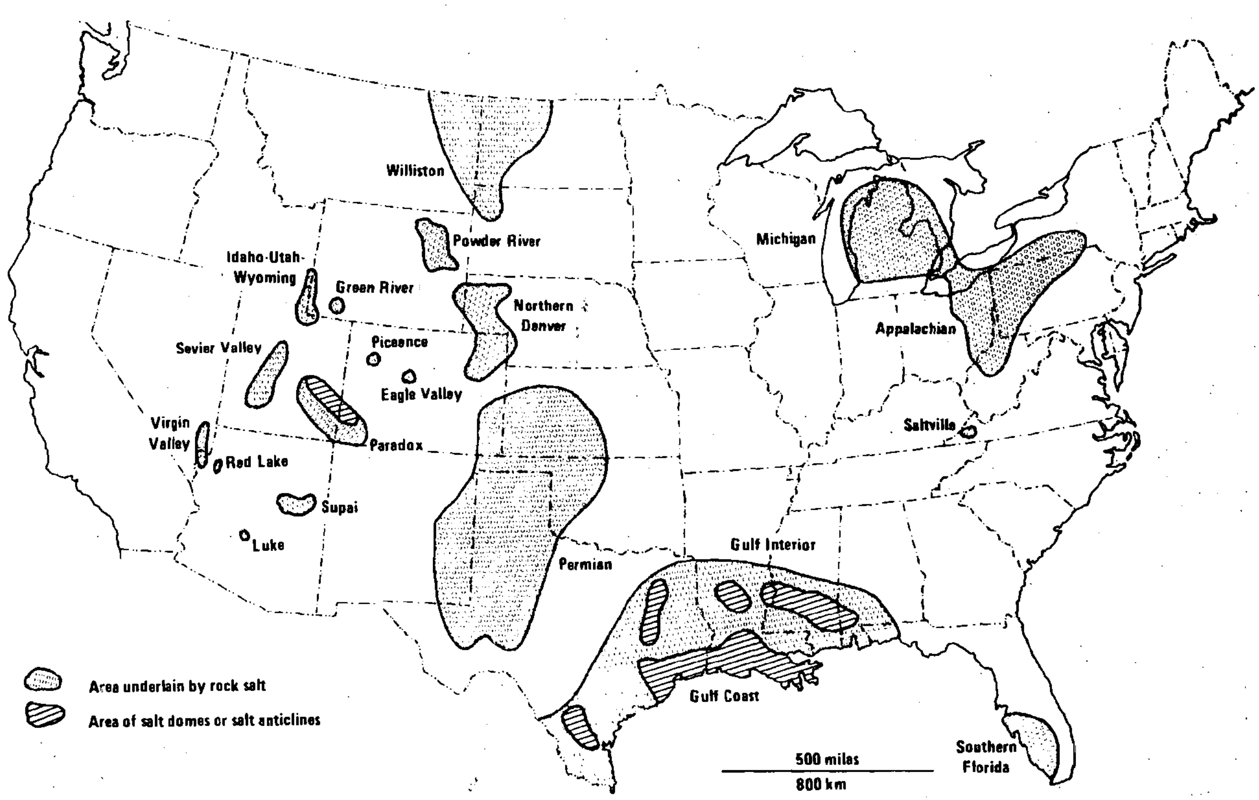

Figure 2-1. Map of rock-salt deposits in the United States.

In June 1970, the Lyons site was selected by the AEC as a potential location for a radioactive-waste repository; the selection, however, was conditional on the satisfactory resolution of site-specific issues under study. The concept and location were conditionally endorsed by the National Academy of Sciences committee in November 1970. A conceptual design for a repository accommodating both high-level waste and TRU waste was completed in 1971. In 1972, however, the Lyons site was judged unacceptable for technical reasons: there were previously undiscovered drill holes nearby, and water used in nearby solution mines could not be traced. Accordingly, the decision was made to abandon that site. The rejection of the Lyons site led the AEC, with the assistance of the U.S. Geological Survey (USGS), to seek sites elsewhere in the United States.

2.2.2 The Site-Selection Process

The site-selection process applied to the WIPP project can be thought of as a set of information screens (Table 2-1) proceeding from general ideas to specific details, from large areas of the country to small, well-defined ones, and from surveys of the literature to measurements in the field. This information screening involves a progressively more stringent application of site-selection criteria and occurs in several stages.

Stage 1 involves general information gathering to select geologic media and geographic regions. The application of general criteria at this level of knowledge leads quickly to a few regions that warrant further investigation.

Stage 2 is a careful study of the literature to narrow down the remaining regions and to identify promising sites according to site-selection criteria. Each candidate site thus chosen becomes the focal point for detailed engineering, safety, and environmental evaluations.

Stage 3 includes extensive field studies at the candidate sites: detailed investigations of geologic structure and stratigraphy, hydrologic characteristics, and resources present; an archaeological and historic site survey; demographic and biological studies; and the operation of a meteorological station. At this stage of the screening process the site-selection criteria may be refined or amended. It is possible that these detailed studies will reveal some aspects of the sites that are less than ideal, but it is not necessary that a site be ideal with respect to all selection factors. However, a site may be rejected at this stage; if this occurs, the process reverts to stage 2.

Stage 4 is the detailed site analysis, including radiation-safety and environmental-impact analyses. The basic question, acceptability of the candidate sites, can be answered only after taking account of the full repository system: the specific geologic environment, the waste form, the plant design, and potential failure modes. The importance of analyzing the full system must be emphasized because the medium selected (e.g., salt, shale, granite) is only one component of the system. The analysis of the sites evaluates their ability to isolate the waste for as long as it presents an unacceptable hazard. If a candidate site is acceptable, the selection process is completed, and the site may be used immediately or held for future use; if not, the process may be started over again. This four-stage process has been used since 1972 in the search for acceptable sites.

This site-selection process followed in the WIPP project has many characteristics of the process used in the National Waste Terminal Storage (NWTS) program for commercial high-level wastes. In the NWTS program, candidate sites are selected by a systematic process that includes three phases: (1) site exploration, characterization, and banking; (2) detailed site characterization; and (3) site selection. The various activities included in these phases are described in the DOE's statement of position on the Nuclear Regulatory Commission's Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (DOE, 1980a). If the Los Medanos site is included in the NWTS program, site-characterization activities will continue with the possibility of banking it for future consideration.

Table 2-1. Site Selection as a Screening Process

Stage	Function	Action	Decision
1	General information	Select disposal media; define geographic regions where they occur; consider their characteristics in terms of tentative selection criteria	Select one (or more) regions for further study
2	Regional studies	Identify potential study areas and apply selection criteria	Select most promising study areas and candidate sites for further study
3	Site studies	Conduct detailed field studies to characterize candidate site(s); determine in detail how each site meets the selection criteria; identify site factors that are less than ideal	Proceed to step 4 or reject sites and select alternative candidate site or sites
4	Site analysis	Analyze site-specific characteristics and environmental impacts; determine risks of using each site	Accept or reject each site

2.2.3 History of Site Selection Leading to the Los Medanos Site

Stage 1 of the process

In 1973, the Atomic Energy Commission, the Oak Ridge National Laboratory, and the U.S. Geological Survey began seeking repository sites. As described in Section 2.2.2, the first task in stage 1 of the selection process is to choose disposal media; the search in 1973 was directed primarily toward sites in salt, although shale and limestone sites were also considered (ORNL, 1972).

The tentative selection criteria (ORNL, 1973) used in the second task of stage 1, evaluating the regions where salt occurs, were as follows:

Depth of salt	1000-2500 feet
Thickness of salt	At least 200 feet
Lateral extent of salt	Sufficient to protect against dissolution
Tectonics	Low historical seismicity, no salt-flow structures near
Hydrology	Minimal groundwater
Mineral potential	Minimal
Existing boreholes	Minimum number
Population density	Low
Land availability	Federal land preferable

These criteria are mostly geologic and logistic; they are primarily concerned with radiation safety, mine safety, and ease of construction. The criterion of minimal groundwater recognizes that, as a barrier to the release of radioactivity, an inefficient hydrologic transport system is second in importance only to the salt itself. The criteria for the thickness of salt, the lateral extent of salt, and the number of boreholes are to protect the repository from dissolution. The criterion of low population density and the preference for Federal lands minimize the potential for risks to human populations and for land-use conflicts.

During this search, criteria were added to require that there be no deep boreholes within 2 miles and that the available land area include 3 square miles and a 2-mile-wide buffer zone as well. Bedded-salt regions appeared at the time to be the most promising; however, salt domes and anticlines (upward folds) were also considered.

The U.S. Geological Survey (and the Kansas Geological Survey for that State) gathered information about most of the larger rock-salt deposits shown in Figure 2-1 (Barnes, 1974). Four of them remain potential alternatives for waste disposal in salt and are being evaluated by the NWTS program for the disposal of commercial waste. These four are the Gulf interior salt-dome region (Appendix B.7; Bechtel, 1978a); the Paradox basin (Appendix B.6; Bechtel, 1978b); the Salina region (Appendix B.5; NUS, 1979a); and the Texas portion of the Permian basin (Appendix B.4; NUS, 1979b).

Stage 2 of the process

From the bedded-salt regions surveyed in stage 1, the U.S. Geological Survey and the Oak Ridge National Laboratory selected eastern New Mexico as the area in the United States best satisfying their site-selection guidelines. This area is well known geologically and is the part of the Permian basin with the flattest bedding at reasonable depths outside of Kansas. In some parts of the Permian basin, there has been much deep drilling for oil and gas; the choice of eastern New Mexico maximized the opportunity to avoid drill holes.

Three locations in New Mexico were examined in more detail: the Carlsbad potash area (Brokaw et al., 1972), the Clovis-Portales area (Jones, 1974a), and the Mescalero Plains of Chaves County (Jones, 1974b). The survey narrowed the search to the Carlsbad potash area. The Clovis-Portales area was determined to be inadequate because the shallow salt is very clayey and the purer salt is too deep. In the Mescalero Plains area, where the salt depth is adequate, there is extensive oil-field development. The Delaware basin (Jones et al., 1973) was considered the most desirable portion of the Carlsbad potash area. Other areas outside it had nonuniform bedding, water-bearing rocks under the Salado Formation (the principal salt-bearing formation), and extensive oil and gas fields. Accordingly, a site in the Carlsbad potash area in the northern part of the Delaware basin was chosen for exploratory work. One of the more restrictive site-selection criteria, adopted primarily because of the Lyons experience, proved to be the avoidance of drill holes penetrating through the salt within 2 miles of the repository border. This criterion caused the potential site to be shifted twice as new oil or gas wells were drilled nearby. The eventual site selected by the Oak Ridge National Laboratory for further study was on the Eddy-Lea County line, about 30 miles east of Carlsbad.

Stage 3 of the process

Field investigations begun in 1974 were halted when the AEC shifted emphasis to the concept of surface storage facilities, rather than mined repositories, for high-level waste. In 1975, the successor of the AEC, the Energy Research and Development Administration (ERDA), restarted the program in the Delaware basin. The program was reoriented toward a mined repository for the disposal of TRU waste with a research-and-development capability for experimentation with high-level waste in salt.

The first task was to confirm the adequacy of the then-current site area. Additional drilling and geophysical investigation produced unexpected results: rock strata were much higher than expected; beds showed severe distortion, with dips of up to 75 degrees; sections of the upper Castile Formation (the formation below the Salado Formation) were missing, and fractured Castile anhydrite encountered at a depth of 2710 feet contained a pocket of pressurized brine. The geologic structure appeared to be unpredictable because of the nearness of this site to the Capitan reef, a major aquifer in the region. The structure could have been delineated by drilling, but extensive drilling would have been contrary to the principle of minimizing the number of holes drilled into the repository. That site was given up.

In late 1975, the New Mexico portion of the Delaware basin was reexamined by the U.S. Geological Survey and the ERDA. The criteria used in looking for a new location were the following (Griswold, 1977):

1. The site should be at least 6 miles from the Capitan reef. This criterion was added as a result of the earlier experience. It serves also to avoid any possible dissolution hazard related to the nearness of the reef.

2. The central 3 square miles designated for the repository itself should not be in the Known Potash District, and as little as possible of the surrounding buffer zone should be in the district. This criterion was to avoid conflict with mineral resources. As indicated in Section 7.3.7, later exploration disclosed that the potash resources are more extensive than was thought at the time.

3. No part of the central area should be less than a mile away from holes drilled through the Castile Formation into underlying rocks. This distance was reduced from the earlier 2-mile criterion as a result of analysis based on the work of Snow and Chang (1975), which indicated that dissolution by water flowing through an inadequately plugged borehole through the Salado Formation would not travel a mile in less than 250,000 years.

4. Known oil and gas trends should be avoided. This criterion was to avoid conflict with these resources.

5. The nearest dissolution front should be at least 1 mile from the site. (The nearest one to the Los Medanos site is the Nash Draw dissolution front. It is at the top of the Salado Formation, 1220 feet above the planned repository level; there is probably another dissolution front near San Simon Sink. The former front is advancing at a rate of 6 to 8 miles per million years horizontally and 500 feet per million years vertically.)

6. Bedding should be nearly flat, so far as can be determined by surface geophysical investigations. This criterion was to insure mine safety and to ease construction. It also avoids the need for many exploratory holes with a consequent risk to the integrity of the repository.

7. Salt of high purity should be available at depths between 1000 and 3000 feet. The depth requirements are to insure mine safety and to ease construction. In addition, a salt thickness of 200 feet or more is preferred to confine thermal and mechanical effects to the salt.

8. The use of State and private land should be minimized, especially in the central area. There is no way to avoid State land completely, because 4 square miles out of every 36-square-mile township in New Mexico are State land. The avoidance of private land simplifies land acquisition and makes it unnecessary to relocate people.

Figure 2-2 shows some of these criteria applied to the Delaware basin. The criteria shown are the first, second, third, and fifth criteria; the remainder do not lend themselves to a graphical presentation on this scale. The most restrictive criterion is the third, which calls for a distance of at least 1 mile from deep drill holes. Eight small areas in the basin that meet this criterion are shown; areas 1 and 8 are actually parts of one very large area, but they have been split in two for this discussion. Table 2-2 applies the eight criteria to these eight areas and adds information about the distance to, and the size of, the nearest town.

Three areas survived the screening based on the eight criteria, although not without questions about each of the areas. Such questions do not necessarily rule out an area; a site need not meet every criterion. Instead, as a recent national review group puts it, "most site suitability criteria will need to be rather general because the systems view dictates that the overall, cumulative effects of the geologic environment and its interaction with the waste is more important than any particular characteristic of a site" (IRG Subgroup, 1978, p. 78).

Of the five areas that did not survive the screening, four were too close to the Capitan reef front; one, area 8, was largely within the Known Potash District; two were near known oil fields; four were probably too near the dissolution front that must be around San Simon Sink; three did not have flat enough bedding; three were nearly too deep or too lacking in infra-Cowden salt or both; and four would involve private land. (Infra-Cowden salt, which lies near the base of the Salado Formation, is the purest salt of the formation. It is still not clear, however, how important the salt-purity criterion is.)

Conditions peculiar to area 3 eliminated it from further consideration. It was the smallest of the surviving areas. It was almost, but not quite, excluded by criterion 1. Most important, it is near three deep holes (shown by the black triangle in Figure 2-2) that had been drilled while exploring for oil and gas. They were described as having had brine flows that were in turn described as "strong," 20,000 barrels per day, and 36,000 barrels per day. By comparison, the brine pocket intercepted by drill hole ERDA-6 flowed at the rate of only 660 barrels per day. These three holes would be in the buffer zone if area 3 were to be selected.

Thus two areas remained. Between the two, area 1 was then and remains today preferred over area 2 because it satisfied the criteria better than did area 2. In area 2, the salt is deeper than in area 1; mining would be more difficult, and mine safety would be harder to insure. There is no infra-Cowden salt in area 2. Area 2 is next to two shallow oil fields in which water flooding may eventually be used. Seismic activity on the Central Basin platform 25 to 65 miles to the east is believed to be the result of such flooding (Section 7.3.6), and it would be well to avoid this possibility. However, the Delaware basin is quite stable tectonically in comparison with the Central Basin platform and less likely to be subject to induced seismic activity. In area 1, on the other hand, the remaining questions either do not affect the integrity of the repository or are found to be insignificant.

Area 1 met the second criterion imperfectly; interference with possible future potash mining remains. When the sites were being screened, it appeared

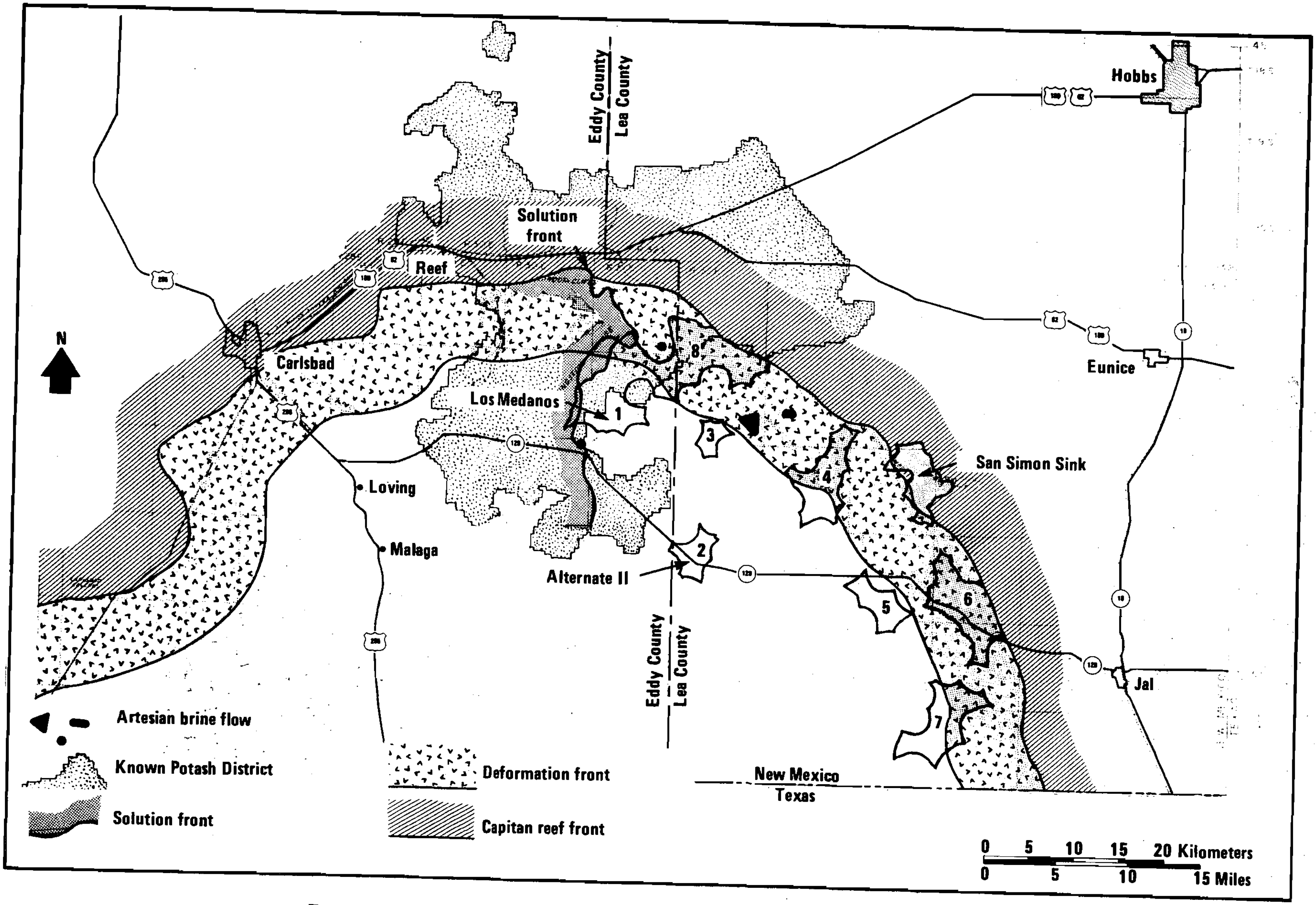

Figure 2-2. Application of the site-selection criteria to the Delaware basin.

Table 2-2. Application of Site-Selection Criteria to Eight Areas in the Delaware Basin

Criterion	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8
1. At least 6 miles from Capitan reef	6-10 miles	11-15 miles	5-8 miles	6-8 miles	0-8 miles	0-4 miles	2-9 miles	0-6 miles
2. Site proper not in Known Potash District (KPD)	(a)	No overlap	No overlap	No overlap	No overlap	No overlap	No overlap	Half of area in KPD
3. Deep drill holes at least 1 mile away	Area chosen to meet this criterion	Same	Same	Same	Same	Same	Same	Same
4. Avoid known oil and gas anticlines	(b)	Near several	Monocline near Red Tank Field	Near Cruz Field	None known near	None known near	Near Arena Roja Field	None known near
5. At least 1 mile from nearest dissolution front	(c)	Over 5 miles from Nash Draw front	Over 8 miles from Nash Draw front	Probably near San Simon Sink front	Probably near San Simon Sink front	Probably near San Simon Sink front	May be near San Simon Sink front	Over 1 mile from Nash Draw front
6. Flat bedding, less than 2° dip	Less than 1°	Less than 1/2°	Less than 1/2°	About 2°	Flat	Over 2°	Varies, 0-1.2°	Over 2°, and drilling proved unacceptable
7. Good salt 200 ft thick between 1000- and 3000-ft depths	Salado 860-2836 ft; infra-Cowden 290 ft	Salado 1500-3400 ft; infra-Cowden missing	Salado 1350-3350 ft, infra-Cowden 225 ft	Salado 1850-3850 ft, infra-Cowden 200-300 ft	Salado 2100-4100 ft, infra-Cowden missing	Salado 1900-3900 ft, infra-Cowden thin (100-150 ft)	Salado 1800-3800 ft, infra-Cowden missing	Salado 800-2900 ft, folded infra-Cowden 300 ft
8. Minimize use of State and private land	Area chosen has no private land, 2.7 sq mi State land	No private land, small amount State land	No private land small amount State land	Mostly State land, 0.4 sq mi private	Over half private land	About half private land, some State land	Criterion not examined	Some private land, several square miles State land
9. Nearest town Population Distance	Loving 1100 18 miles	Malaga 300 22 miles	Malaga 300 24 miles	Eunice 2500 24 miles	Jal 2700 12 miles	Jal 2700 10 miles	Jal 2700 12 miles	Loving 1180 23 miles
Criteria in conflict	2?, 4?, 5?	4?, 7	1?, 4?	1, 4, 5?, 6, 8	5?, 7, 8	1, 5?, 6, 7, 8	1, 4, 5?, 7	1, 2?, 6, 8

[a] Area chosen had part of buffer zone in KPD, rest free.
[b] Synclinal area next to a producing gas well.
[c] Nash Draw front overlaps part of area.

that a site (the Los Medanos site) could be chosen in which the central area would be outside the Known Potash District and that the site would be in minimal interference with potash minerals. However, information from potash exploratory holes the DOE has drilled since then has caused an enlargement of the Known Potash District to include most of the Los Medanos site. Control zone I remains largely free of indicated potash mineralization. Thus area 1 remains in conflict with the second criterion. Although this criterion does not affect repository integrity per se, the existence of mineral deposits might attract drilling after control over the site has been lost in a few hundreds of years.

In determining how well area 1 satisfies the fourth criterion, avoiding known oil and gas resources, subsequent analysis has shown that there are no oil reserves under the Los Medanos site. There are some gas reserves, a small fraction (0.02%) of the U.S. reserves, under the site, but a major portion of this gas can be withdrawn from outside the site or from within control zone IV.

Area 1 satisfies the fifth criterion, the one concerned with the nearness of the Nash Draw dissolution front. There are 1200 feet of salt over the repository level; given a vertical dissolution rate of 500 feet per million years, this thickness would provide an isolation time of 2.4 million years.

Thus area 1 became the Los Medanos site. Since 1975, the ERDA and its successor, the DOE, have sponsored continuing and intensive studies there; the results to late 1978 are reported in the Geological Characterization Report (Powers et al., 1978) and together with more recent information are summarized in Chapter 7 of this document and in the WIPP Safety Analysis Report (DOE, 1980b). These studies constituted a principal part of the stage 4 analysis. This environmental impact statement is also a major part of stage 4.

2.2.4 The Continuing Program of Characterizing Sites for HLW Repositories

Along with the investigations in the Delaware basin, the ERDA continued its site-characterization program for mined repositories for the disposal of commercially generated high-level waste. The current NWTS program is considering a wide variety of media in diverse regions of the country in addition to bedded salt for high-level commercial waste (Appendices A and B).

Rocks, other than bedded salt, that are being studied are crystalline rocks (basalt and granite), argillaceous rocks (shale), and tuff. Rock salt has received most of the attention in waste-disposal studies over the past two decades; hence a great deal more is known on the properties of salt than on the properties of the other rocks.

No intrinsic environmental or safety-related problems have been identified that would clearly preclude the use of any of these media for a repository. On the contrary, it appears that problems associated with these media could be solved by judicious site selection, by engineering design using state-of-the-art technology, or by both methods. At the present, however, the investigations of nonsalt media are not as advanced as the studies of salt.

2.3 DEFENSE TRANSURANIC WASTE

The element common to all the action alternatives formulated in Chapter 3 is the disposal of transuranic (TRU) waste generated in U.S. defense programs and currently in storage at the INEL. This section explains what transuranic waste is, where it comes from, and how much of it is in storage.

The U.S. defense program has already generated large quantities of contact-handled TRU waste, which requires no shielding. Smaller quantities of remotely handled TRU waste, which requires shielding to protect the workers who handle it, have also been generated. Transuranic waste is any solid radioactive waste, other than high-level waste, that is contaminated with nuclides heavier than uranium to the extent that it is not suitable for surface disposal. It results from almost every industrial process involving transuranic materials, but predominantly from the fabrication of plutonium for nuclear weapons. It would be produced in spent-fuel reprocessing and mixed-oxide-fuel fabrication for recycling to nuclear reactors; these processes, however, are not currently in commercial use in the United States.

Transuranic waste exists in a wide variety of physical forms, ranging from unprocessed general trash (e.g., absorbent papers, protective clothing, plastics, rubber, wood, and ion-exchange resins) to decommissioned tools and glove boxes.

The major producers of defense TRU waste have been the Rocky Flats Plant near Denver, the Hanford complex of facilities near Richland, Washington, and the Los Alamos National Scientific Laboratory in northern New Mexico. Smaller producers include the Mound Facility near Miamisburg, Ohio, the Savannah River Plant near Aiken, South Carolina, the Argonne National Laboratory near Chicago, the Oak Ridge National Laboratory in Tennessee, and the Lawrence Livermore National Laboratory in Livermore, California. Most of this readily recoverable waste has been stored at the Idaho National Engineering Laboratory near Idaho Falls and at Hanford (Table 2-3). Smaller inventories are stored at the Pantex Works at Amarillo, Texas, and at the Nevada Test Site.

Table 2-3 distinguishes between TRU waste that is buried and TRU waste that is stored. The buried waste is more difficult to retrieve than the stored waste. The buried waste was emplaced before 1970, when waste containing TRU nuclides was not segregated from other waste contaminated with low levels of radioactivity. Therefore, a large volume of material now considered contact-handled TRU waste was buried in a manner similar to conventional sanitary-landfill operations, with additional handling precautions appropriate for radioactive materials. The waste was placed in open unlined trenches and then covered with several feet of earth. At the time of its burial, this waste was not intended to be retrieved.

In 1970, the Atomic Energy Commission adopted a policy requiring that waste containing TRU nuclides producing more than 10 nanocuries of alpha activity per gram be packaged and stored separately from other radioactive waste. This waste is now stored in such a way that it "can be readily retrieved in an intact, contamination-free condition for 20 years" (ERDA Manual, Chapter 0511). It is stacked on pads of concrete or asphalt and covered, usually with sheets of plastic and a shallow layer of earth. This stored waste is the waste referred to in the decisions listed in Section 2.1.1.

Table 2-3. TRU Waste at DOE Storage Sites[a]

Site[b]	Volume (thousands of cubic feet)					
	Buried		CH waste--stored		RH waste--stored	
	10/1/77	10/1/86	10/1/77	10/1/86	10/1/77	10/1/86
LASL	580	580	54	249	0	9
Pantex	1	1	0	0	0	0
ORNL	215	222	10	32	27	52
Hanford	5483	5483	247	855	3	8
INEL	2102	2102[c]	1202	2376	(d)	20
NTS	0	0	6	39	0	0
SRP	1085	1085	56	109	0	0
Total	9466	9473	1575	3664	30	89

[a]Data from Dieckhoner (1978 and private communication, 1978). See also Appendix E of this document.

[b]Key: LASL, Los Alamos National Scientific Laboratory, New Mexico; Pantex, Pantex Works, Amarillo, Texas; ORNL, Oak Ridge National Laboratory, Tennessee; Hanford, Hanford Site, Richland, Washington; INEL, Idaho National Engineering Laboratory; NTS, Nevada Test Site; SRP, Savannah River Plant, South Carolina.

[c]It is estimated that experimental retrieval programs will reduce this volume to 2 million cubic feet by 1985. However, if all of INEL's buried TRU waste is retrieved for shipment to a Federal repository, the total volume recovered will be 6.25 million cubic feet, including 3.75 million cubic feet of contaminated soil and 500,000 cubic feet of low-level beta- and gamma-emitting waste that is intermixed with TRU waste. If this waste is treated by slagging-pyrolysis incineration, the total volume of waste shipped to the repository will be on the order of 2.4 million cubic feet (the overall volume-reduction ratio in the incineration process is estimated to be 2.6:1). (This 2.4 million cubic feet is not included in the total of 6.2 million cubic feet for which the WIPP is designed.)

[d]A very small amount (300 cubic feet).

Remotely handled TRU waste has always been handled separately. Much of it has been put into 1- to 2-foot-diameter pipes placed vertically in the ground, with a shielding plug at the top of each pipe (Bartlett et al., 1976, Chapter 20).

The radionuclide content of TRU waste varies widely. Weapons-oriented plants like Rocky Flats produce waste in which plutonium-239 is the dominant TRU nuclide; waste from the Mound Facility is high in plutonium-238; and some waste from the Oak Ridge National Laboratory contains curium-244. On a volume basis, weapons waste is by far the most important component of the total TRU-waste inventory; the Rocky Flats Plant alone produces 40% of all DOE TRU waste. For this reason, Rocky Flats waste is taken in this document as representative of all DOE contact-handled TRU waste. The characteristics of such TRU waste are described in Chapter 5 and Appendix E (Tables E-1, E-2).

There are virtually no fission products in defense contact-handled TRU waste, and its heat output is essentially zero.

At the end of 1977, the accumulated volume of TRU waste amounted to 11 million cubic feet of material, only 1.6 million cubic feet of which is readily retrievable. By the end of 1986, this volume is projected to become 13 million cubic feet, including 3.7 million cubic feet retrievably stored (Table 2-3). The estimated quantity of transuranic nuclides stored at the various DOE sites at the end of 1977 is presented in Table 2-4. About 30,000 cubic feet of remotely handled TRU waste from defense programs is now in storage; this volume is expected to grow to about 89,000 cubic feet by 1986. The rate at which contact-handled TRU waste is produced is about 0.25 million cubic feet per year (DOE, 1978, pp. 43, 121).

This EIS analyzes the alternatives for disposing of the readily retrievable waste expected to be stored in Idaho through 1990. This waste includes the 2.4 million cubic feet shown in Table 2-3 for 1986 plus an additional two-thirds of the 0.25 million cubic feet generated annually between 1986 and 1990. In addition, the WIPP would be designed to accommodate all defense TRU waste generated between 1990 and 2003.

Table 2-4. Transuranic Content of DOE TRU Waste (Estimates as of October 1, 1977)[a]

Site[b]	Buried waste (kg of TRU)	Stored waste (kg of TRU)
LASL	13	27
Pantex	0	0
ORNL	13	17
Hanford	365	78
INEL	361	273
NTS	(c)	3
SRP	7	52
Total	759	450

[a]Data from Dieckhoner (1977).
[b]See Table 2-3 for key to abbreviations.
[c]A very small amount.

This document does not analyze alternatives for the disposal of the TRU waste stored retrievably at sites other than the INEL or for the disposal of the TRU waste now buried at the INEL and other DOE sites. Other documents will analyze alternatives for these actions.

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3 Development of Alternatives

The preceding chapter reports the existence of large quantities of transuranic (TRU) radioactive waste generated in national defense programs. It points out the need for taking action to dispose of this waste permanently and to develop disposal methods for other kinds of waste generated in the defense programs. This chapter summarizes the alternative actions evaluated in this environmental impact statement.

Section 3.1 defines the alternative of taking no action to remove the defense TRU waste stored at the Idaho National Engineering Laboratory (INEL).

The chapter then discusses the formulation of other alternatives by reviewing the availability of disposal methods and the selection of disposal sites. Section 3.2 discusses various methods that have been proposed for the disposal of radioactive waste. One of these methods is the use of mined geologic repositories; it is described more fully in Sections 3.3 and 3.4, which discuss alternative geologic media (salt, igneous and volcanic rocks, and argillaceous rocks) and alternative sites in salt, the medium that has been studied most extensively. The status of site selection in the national waste-management program is summarized in Section 3.5.

Finally, Section 3.6 develops the three action alternatives evaluated in this document.

3.1 THE ALTERNATIVE OF NO ACTION

If no action is taken to remove the TRU waste from the INEL, the waste will be held there for an indeterminate period; waste will continue to be shipped there and held in storage throughout the same indeterminate period. There are three options for this retention: (1) to hold the waste in its present retrievable storage, (2) to place the waste in improved storage at the INEL, and (3) to dispose of the waste permanently on the land occupied by the INEL.

Chapter 4, drawing on an analysis in Appendix N, summarizes the environmental impacts of the first two of these options. Neither of them is acceptable as a long-term method of dealing with the waste. Although the analysis finds no environmental reasons that TRU waste cannot be left at the INEL for several decades or even a century, the present storage methods do not protect the waste from future volcanic activity or from human intrusion after government control over the site has been lost.

The third option, disposing of the waste at the INEL, is also unacceptable: there is no suitable geologic environment. The INEL is on the Snake River Plain, underlain by a series of Pleistocene basaltic lava flows interspersed with beds of unconsolidated sediments. The hydrologic system of the Snake River Plain is dominated by the Snake River aquifer, which is approximately 200 miles long and 30 to 60 miles wide. The permeability of the aquifer is large in the upper and lower basaltic flows, which are characterized by voids, fissures, and other fracture networks. The top of the aquifer is 200 to 900 feet below the surface; the thickness of the aquifer is not known precisely, but estimates range from 1000 to 2700 feet. This hydrologic system precludes any attempt to construct a geologic repository in or above it or to drill through it to underlying rocks.

The only part of the INEL that is not located over the aquifer is the Lemhi Range on the north edge of the reservation. This area is not considered a promising site for the permanent disposal of radioactive waste. The rocks are mostly limestone of unknown hydrologic characteristics, existing mines in the region are troubled by groundwater, and hydrologic connections with the aquifer are suspected.

In summary, none of the options for leaving the TRU waste at the INEL is acceptable. For this reason, all the action alternatives evaluated in this document include a demonstration of the permanent disposal of this waste.

3.2 ALTERNATIVE DISPOSAL METHODS

A number of alternative methods for the disposal of radioactive waste have been proposed, and a great deal of information is available on this subject. Although the emphasis is usually on high-level waste (Schneider and Platt, 1974; Pittman, 1974), the most recently published surveys also address low-level and intermediate-level wastes generated in commercial reactors (Bartlett et al., 1976; Hebel et al., 1978). Much of the material on commercial waste is summarized in the draft generic environmental impact statement on the management of commercially generated radioactive waste (DOE, 1979) and the DOE's statement of position for the Nuclear Regulatory Commission's Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (DOE, 1980).

Because of their long-lasting radioactivity, high-level waste and TRU waste raise similar concerns about long-term isolation. In terms of safety during disposal operations, they differ in that high-level waste is more difficult to handle since it requires radiation shielding. The major difference between the two types of waste, however, is in their volumes and hence in the methods that may be feasible for their disposal. Methods that could be economically feasible for the small volumes of high-level waste may be impractical for the large volumes of the less radioactive TRU waste.

Five candidate methods for the disposal of defense TRU waste are reviewed in this section: emplacement in deep ocean sediments, emplacement in very deep drill holes, transmutation, ejection into space, and disposal in conventionally mined geologic repositories. Except for geologic disposal, none of these methods have been shown to be technically or economically feasible, and a decade or more of research will be needed before any demonstration of their feasibility can begin. The time at which the different options would be available varies considerably:

- The technology for disposal in conventionally mined geologic repositories is available now.

- The development of the technology for disposal in deep ocean sediments or in very deep drill holes would take 12 to 25 years (DOE, 1979, pp. 3.3.34 and 3.6.27).

- The development of the technology for transmutation or ejection into space is even more distant (DOE, 1979, p. 4.11).

3.2.1 Emplacement in Deep Ocean Sediments

Isolation in deep seabeds would involve implanting canisters of radioactive waste tens of meters into deep ocean sediments by free-fall penetration or other techniques. It is possible to find sediments that are thick, uniform, and stable; that have accumulated over millions of years; and that are in the process of becoming sedimentary rocks. The concept of subseabed disposal is still in the evaluation stage, and its feasibility has yet to be established, although the transportation and the means of emplacement appear to be achievable with straight forward extensions of existing technology.

The remaining uncertainties pertain to the breaching of waste containers and the subsequent migration of radionuclides in ocean sediments. The retrieval of waste appears to be impractical for this disposal method. Moreover, the potential sites are located in international waters beyond the territorial limits of the United States; international agreements would be required for disposal in these waters.

These uncertainties in engineering, safety, environmental impact, and inter national politics indicate that subseabed disposal is many years away. Because the techniques for disposal in deep ocean seabeds are much less advanced than those for disposal in mined geologic repositories and because the potential risks and environmental impacts of subseabed disposal show no promise of being substantially smaller than those of geologic disposal, the DOE proposes to proceed first with conventional geological repositories (DOE, 1979, p. 1.36). This plan is in accordance with the program proposed by the President (Appendix C).

3.2.2 Emplacement in Very Deep Drill Holes

Another potential alternative for disposal is to drill or sink a shaft to isolate radioactive wastes in a very deep hole. This concept relies on using the surrounding rock to contain the wastes and on the great depths to delay the release and reentry of radioactive material into the biosphere. The utility of the deep-hole concept is affected by three principal factors, which depend on the specific characteristics of the site and the size of the hole.

The first factor is the geologic characteristics of the site, including hydrologic conditions, rock strength, and the interactions between the waste and the rock. Because these characteristics are not well known at great depths, the depth that is deep enough is not well defined. A good selection for a deep hole site would be strong, unfractured rock like crystalline rock which typically has a low water content, or some rocks in deep sedimentary basins.

The second factor is the capability to excavate a very deep hole; this capability has been partially established already. It is possible today to drill a narrow deep hole to 35,000 feet or to sink a wide shaft to about 15,000 feet. Whether the hole would have to be cased depends on the strength of the rock and on confining pressures.

The third factor is the safe emplacement of wastes, which may present severe engineering problems. Lowering waste canisters 30,000 to 40,000 feet on a wire through high-density muds could significantly increase the short-term risks. Also, the number of holes (800-1300) required may be prohibitive.

The deep-hole concept cannot be evaluated as an alternative for the disposal of radioactive wastes without more information on the deep groundwater system, rock strength under increased temperatures and stresses due to heat from the decay of wastes, and the sealing of the holes over long periods of time. Once this information is available, then the question of depth can be answered, and the capability of isolating radioactive wastes in very deep holes can be evaluated.

Deep holes could be used for the disposal of all types of high-level waste. Because of volume constraints, however, they would not be feasible for the disposal of TRU waste (DOE, 1979, p. 1.25), and hence they are not considered further in this document.

3.2.3 Transmutation

The transmutation of long-lived radionuclides into short-lived or stable ones would probably be carried out in a nuclear reactor. The fission products from the transmutation, together with those resulting from reactor operation, would have to be separated and disposed of by some other method, presumably emplacement in a geologic repository. Some other form of disposal would therefore still be necessary, but the time over which isolation would have to be insured would be shortened.

It is questionable whether any waste can be sufficiently purified of TRU nuclides to reduce its long-term hazard significantly. This is particularly true of TRU waste, much of which is the high-volume residue left after separation. For this reason, transmutation is not considered as a process in the disposal of TRU waste in this document.

3.2.4 Ejection into Space

If ejection into space were to be used, the waste package would be lifted by a space shuttle into a near-earth orbit. The waste package would then be transferred into an unmanned orbital transfer vehicle, which may have to be carried by a second space-shuttle orbiter, and injected into an appropriate solar orbit.

There appears to be no fundamental scientific impediment to space disposal, but many technical questions remain to be resolved. The technical feasibility depends on a reliable space-flight system and on high-integrity waste containers that could withstand rocket failure or an explosion on the launch pad. A concept-definition study is under way, and a rigorous safety assessment is expected to be completed by 1981; a decision will then be made on whether to continue with the development of a space-disposal system. Full-scale demonstration of the concept could probably not be established before the turn of the century. Furthermore, the cost for ejection into space is likely to exceed $1000 per pound, which would impose a severe economic penalty on this mode of disposal because of the large total mass of TRU waste (Bartlett et al., 1976). For these reasons, extraterrestrial disposal was eliminated from further consideration as an alternative for TRU-waste disposal.

3.2.5 Disposal in Conventionally Mined Geologic Repositories

A repository mined by conventional techniques would be located deep under the ground in an environment whose geologic, hydrologic, geochemical, and tectonic characteristics are judged suitable for long-term isolation. The fate of radionuclides in a mined repository will be determined by the joint effects of several factors: the characteristics of the regional environment, the physical and chemical properties of the host rock and the surrounding geologic formations, the physical and chemical form of the waste, the engineered barriers deliberately built into the repository, and future human activities. The most significant questions about geologic repositories are those related to human intrusion and breaching by groundwater. The various geologic formations now under study are discussed in the next section.

3.3 ALTERNATIVES FOR GEOLOGIC DISPOSAL

Three general classes of candidate geologic media are being considered for the disposal of radioactive wastes in conventionally mined repositories:

- Salt in bedded, anticlinal, and dome formations.
- Igneous and volcanic rocks (granite, basalt, and tuff).
- Argillaceous rocks (shale).

The general geologic characteristics of candidate host formations are discussed in more detail in Appendix A.

An important characteristic of a geologic medium is the long-term environmental impacts of a repository built in it. The short-term impacts (i.e., those related to construction, operation, and transportation) are fundamentally the same regardless of the medium.

3.3.1 Salt

Rock salt in bedded, anticlinal, or dome formations has received most of the attention in waste-disposal studies over the last two decades. The original report of a committee established by the National Academy of Sciences

(NAS-NRC, 1957) recommended that salt be evaluated as a disposal medium because of its thermal and physical properties and because its very survival for hundreds of millions of years has demonstrated its isolation from circulating groundwater and the stability of the geologic formations in which it is located.

The U.S. Geological Survey gathered information about 36 salt domes inland from the Gulf of Mexico (Figure 2-1) during its investigations in the early 1970s (Section 2.2.3). Salt domes are formed when salt flows upward, piercing overlying rocks. Where these processes are active, one might question the long-term stability of the domes, but there is reason to suspect that the ones farthest from the Gulf of Mexico are no longer growing or are growing very slowly (Bartlett et al., 1976, p. C.67). These phenomena need more clarification, but salt domes remain potential alternatives for the disposal of radioactive waste, and they are being evaluated in the National Waste Terminal Storage (NWTS) program for commercial waste (Appendix B; Bechtel, 1978a).

The Paradox basin of southeastern Utah and southwestern Colorado (Figure 2-1) contains a series of northwest-trending salt-cored anticlines in which the salt reaches within 500 to 3000 feet of the surface along the northeastern edge of the basin. In the larger structures there has been some flow of salt from flanking areas into the anticlines under pressure from the overburden. The dissolution of salt from the upper surfaces of the central cores has developed a caprock of insoluble material along the crests of the salt anticlines, with the result that further dissolution is proceeding only very slowly (Bartlett et al., 1976, pp. C.97-118). Thus, salt anticlines are alternatives for waste disposal, and they are also being evaluated in the NWTS program (Appendix B; Bechtel, 1978b).

Bedded-salt formations are believed to have been stable over very long periods of geologic time, and bedded strata are typically associated with long groundwater flow paths to the biosphere. Two desirable features of many bedded-salt basins, a result of their evaporitic origin and subsequent tectonic history, are their relatively simple structure and predictable stratigraphic characteristics. It is often possible to establish with relative ease the geologic structure of these formations and to predict their lithologic characteristics over a wide area. Because of the early start on investigations of salt, a wealth of information is available on its properties.

Experiments on salt characteristics, including responses to heat and radiation, have been conducted in Project Salt Vault (Bradshaw and McClain, 1971) and over the past decade at the Asse experimental repository in the Federal Republic of Germany (Kuehn et al., 1976). In addition, extensive salt mining in many locations around the United States and abroad has resulted in a well-developed salt-mining technology (D'Appolonia Consulting Engineers, Inc., 1976). One particular advantage of salt mining is that, after shaft construction, explosives are not needed. Continuous-mining machines can be used to excavate the disposal rooms, avoiding shock-produced cracks.

The desirable intrinsic properties of the salt include a uniformly low permeability, a high thermal conductivity (this criterion is more important for the heat-generating high-level waste than for TRU waste), and a plasticity that enables fractures to heal themselves at feasible repository depths. However, like every other medium considered for disposal, salt presents some problems. Recent reviews (OSTP, 1978; Hebel et al., 1978) have identified several factors that should be considered in locating and evaluating specific repository sites in salt.

It has been asserted that, since interstitial water can lower the mechanical strength of salt, the presence and variable concentration of water could be a problem. The mean water content in salt is low (typically less than 1%), but local variations over wide ranges occur within salt masses. The water content tends to be the lowest in salt domes along the Gulf Coast; the deformation and flow process that has formed the domes seems to have kneaded the water from the salt. Bedded-salt strata such as those in New Mexico, Utah, and the Midcontinental and Eastern United States are generally more variable than salt domes in their chemical composition and mineralogic characteristics.

The high sensitivity of salt to solution processes requires the acquisition of extensive data on regional and site hydrologic systems and some understanding of possible future groundwater flow regimes before a repository site can be selected. Such understanding depends in part on the ability to evaluate the impacts of possible climatic variations on the integrity of the repository. The solubility of rock salt in water is a hundred times higher than that of any other candidate medium (Table A-1 in Appendix A). If man-induced or natural events caused a breach in the repository, any available circulating groundwater could conceivably transport the radionuclides into the biosphere. The geologic materials along the path of groundwater flow will slow this transport by capturing and binding the radionuclides through reactions collectively called sorption. Since the sorptive capacity of salt is low and dependent on impurities, in a salt repository sorption could be provided only by other rocks in the path of groundwater flow.

Salt differs from basalt and shale in the potential environmental impacts of the mined rock that is stored at the surface. A salt-storage pile would have to be designed to limit wind erosion and rainwater runoff in order to minimize environmental impacts during and after repository operation.

In summary, salt is the best understood of all candidate geologic media with respect to its possible use as a waste-repository medium. The Interagency Review Group on Nuclear Waste Management concluded (IRG Subgroup, 1978, Appendix A, p. 67) that "with appropriate selection of a site and appropriate hydrogeology and conservative engineering, salt could be an appropriate repository medium."

3.3.2 Igneous and Volcanic Rocks

Basalt, granite, tuff, and other crystalline igneous and volcanic rocks have been considered as geologic media for a repository. Crystalline rocks are attractive because of their strength and structural stability. The little water they contain lies largely in fractures. Basalt and granite have fair sorptive capacities. Because of these favorable natural conditions, it has been estimated that the waste containers stored in a crystalline-rock repository could maintain their integrity over hundreds of years.

The design and the operating procedures for a crystalline-rock repository would be similar to those for a salt repository. However, the use of continuous-mining machines may not be practical in crystalline rock, and conventional drilling and blasting mining techniques would be needed.

The paths of groundwater flow through crystalline rocks are normally, but not always, shorter than those in bedded strata like shale or salt. The path lengths depend, of course, on the geohydrologic setting. Crystalline rocks commonly occur in geohydrologic environments that have experienced complex tectonic events during which these brittle rocks were fractured. Alterations in rock properties probably occurred during these events; rock properties may have been homogenized by pervasive events or may be variable and difficult to ascertain adequately for repository design. The geohydrologic characterization of crystalline terrains presents challenging problems.

Granites and basalt are usually fractured, and the permeability of the rock mass depends on flow through a network of fractures rather than flow through porous media. Flow through a fracture depends on the size of the opening, which to a large extent is controlled by the stresses acting across the fracture. Since these stresses increase with depth, the permeability of crystalline rock usually decreases with depth. The development of a model for fracture flow is a difficult problem that is receiving considerable attention. At depths of 1500 feet or more below the surface, the permeability may be low enough not to present a threat of releasing radionuclides into flowing groundwater. An engineered approach to the control of fracture flow would be to inject a grout into the fractures to reduce permeability.

Tuff is an extrusive rock produced by volcanic eruptions. There are two forms of tuff that are of interest for repository use, and they are quite different. The first form is densely welded tuff, which has a high density, a low porosity and water content, and the capability of withstanding high temperatures. The compressive strength, thermal conductivity, and thermal expansion of densely welded tuffs are comparable to those of basalt. Welded tuffs locally have significant fracture permeability and are important aquifers (Winograd, 1971). The second form is zeolitic tuff, which has a low density, a high porosity, a very low permeability, a high water content, and an extremely high capacity for sorbing radionuclides. Zeolitic tuff has a moderate compressive strength and a moderate thermal conductivity. The dehydration of some zeolites begins at about 100°C; unless the fluids released can escape through the rock, they will contribute to changes in the state of stress that could result in fracture. Heat may also cause some zeolites to decompose to new minerals with lower sorptive capacities.

The design concept for a repository in tuff is to emplace radioactive waste in welded tuff and to obtain a significant benefit from the highly sorptive barriers of zeolitic tuff surrounding the welded tuff. Local heating of the zeolitic tuff must be kept below the temperature at which its beneficial properties are affected. A 2-year research program is under way at the Nevada Test Site to ascertain whether sequences of welded and zeolitic tuffs would be a valid medium for geologic disposal. Areas of welded and zeolitic tuff are widespread and occur in thick sections in the western states, though they have not yet been sufficiently characterized as to their homogeneity and their hydrologic characteristics. Most of these tuffs are relatively young geologically, and they have been broken into blocks by tectonic forces that were active during and after the time of their formation. Faults are still active in some areas, jeopardizing such regions for repository use. The hydrogeologic environments in which tuffs occur are dominated by the tectonic activity. However, a single hydrogeologic system in the Western United States can be large enough to include many faulted blocks that contain satisfactorily extensive sequences of welded and zeolitic tuffs.

The current NWTS program plan calls for detailed site-characterization plans to be available in 1984 for a site in basalt at the Hanford Site in the State of Washington. Plans for sites in granite and tuff are to be available in 1985.

3.3.3 Argillaceous Rocks

Shale and related rocks have a number of attributes that make them attractive as media for the isolation of radioactive wastes: low permeability, the capability of deforming plastically under lithostatic load, good sorptive capacity, and low solubility in water. Such rocks are abundant in thick masses throughout the Midwestern and Western United States. However, only illitic shales may be suitable for repositories: carbonaceous shales may generate organic gases on decomposition, and montmorillonitic shales have properties that change significantly in the presence of water. Accordingly, it is necessary to perform very detailed studies at each potential site in shale, because the widely varying character and composition of shales make some areas suitable but many others unsuitable. In general, shales possess many of the characteristics that make bedded salt and salt domes attractive. However, shales are not so plastic and tend to have a somewhat higher fracture permeability than salt; they also have a somewhat higher density and may require some blasting during mining. The largest drawback to shales is the above-mentioned local variability, which presents difficulties in adequately characterizing a potential site.

The preparation of a detailed site-characterization plan for a potential repository site in shale will not be completed until after 1985.

3.4 ALTERNATIVE AREAS IN BEDDED SALT

Large areas in the United States are underlain with bedded salt (Figure 2-1). During its search in the early 1970s, the U.S. Geological Survey (Section 2.2.3) looked particularly at the Supai salt basin, the Salina region, the Williston basin, and the Permian basin (Barnes, 1974). Of these four, only the Salina region and the Permian basin are still being investigated in the national waste-management program.

The Salina region consists of bedded-salt deposits of Late Silurian age in portions of New York, Pennsylvania, West Virginia, Ohio, Michigan, and southern Ontario. Strata both above and below the salt are occasionally water-bearing. However, in many areas the salt beds are overlain with massive anhydrite and dolomite units or shales that are potential water barriers. The greatest aggregate thickness of salt is found in Michigan, where it ranges from 500 feet at the margins to 1800 feet in the center. This bedded salt is considered one of the better alternatives to the salt of southeastern New Mexico. However, the area is much more densely populated, the land is more intensively used, and the complex hydrologic characteristics are likely to be much more difficult to define and evaluate (Appendix B; NUS, 1979a).

The Permian basin in the Western United States is a series of sedimentary basins in which rock salt and associated salts accumulated during Permian time over 200 million years ago. The region includes the western parts of Kansas, Oklahoma, and Texas and the eastern parts of Colorado and New Mexico. (The Kansas salt beds considered in Project Salt Vault are in the northern portion of the Permian basin.) Since Permian time the basin has been relatively stable tectonically, although some parts of it have been tilted and warped, have undergone periods of erosion, and have been subject to a major incursion by the sea. Subsidence, collapse of the land surface from dissolution, has been common in the basin (Appendix B; Bachman and Johnson, 1973; NUS, 1979b).

Section 2.2.3 describes the process by which the Delaware basin was selected from potential sites in the Permian basin and the process by which the Los Medanos site was selected from potential sites in the Delaware basin.

3.5 ALTERNATIVE SITES IN ALTERNATIVE MEDIA

No method other than emplacement in a mined geologic repository is feasible at present for the disposal of TRU waste, nor can the feasibility of any of the other disposal methods still being investigated be established for at least a decade. The NWTS program is investigating salt and other host media, and potential repository sites will be identified starting in 1983. Although these sites are being sought for the disposal of commercial high-level and TRU waste, they may also be suitable for the disposal of defense TRU waste.

The President's program recommends that one or more repositories be selected from among sites in a wide variety of host rocks with diverse geohydrologic characteristics. Since the NWTS program is directed at identifying and characterizing sites for a system of repositories, its activities will continue after the site for the first NWTS repository is selected. Any sites that meet the site-selection criteria but are not selected remain "banked" and thus available for possible selection at a later time.

In the next 5 years, the NWTS program is expected to characterize several sites and then to recommend one site in a process that includes documented comparisons of environmental, technical, and institutional aspects (DOE, 1980). The earliest possible dates for issuing the final environmental impact statement on banking and a detailed site-characterization report supporting a decision to bank a site are as follows:

Geologic medium and location	Date
Dome salt (Gulf interior region)	1983
Basalt (Hanford)	1984
Nevada Test Site	1985
Other hard-rock sites	1985
Bedded salt (other than Los Medanos)	1985

Each of these sites will have been taken through the NWTS site-exploration and site-characterization phases. Thus, in late 1985, for example, it will probably be possible to consider several sites in the selection process. An environmental impact statement will be required prior to site selection (DOE, 1980).

The dates shown are based on the assumption that all site-characterization activities can be conducted from surface exploration only. If underground exploration at the proposed repository horizon is required for licensing, as presently proposed by the Nuclear Regulatory Commission, the schedules would be extended, and it would not be possible to select from among the characterized sites until 1989.

3.6 FORMULATION OF ALTERNATIVES

Taking no action to remove TRU waste from its present near-surface storage in Idaho has been identified as the first alternative to be analyzed in this environmental impact statement. This section delineates alternatives involving its removal and the research and development of disposal methods for other types of wastes. Options for the research and development are also discussed.

3.6.1 Alternatives for TRU-Waste Disposal

Four alternatives are considered for demonstrating the disposal of defense TRU waste: no action (as already described); building the WIPP facility at the Los Medanos site in southeastern New Mexico; disposal of the TRU waste stored at the INEL in the first available HLW repository, which involves delay in moving this waste; and delaying the WIPP for the sake of considering other sites as well as the Los Medanos site.

3.6.2 Options for Research and Development

In order to advance the state of the art of radioactive-waste disposal, it is thought necessary to conduct in-situ, full-scale experiments with wastes. Many technical experts believe that continued laboratory studies in salt are producing diminishing returns; the general properties of salt, for instance, are well known, but its bulk properties should be evaluated in the particular formations where waste may be emplaced. Accordingly, continued laboratory experiments should be accompanied by in-situ testing.

One place to conduct the in-situ research and development would be in a specially mined underground area not associated with a waste repository. The development of such a stand-alone, full-scale experimental facility would allow many design-verification, rock-mechanics, fluid-migration, and thermal-response tests to be performed. The usefulness of a stand-alone facility would be greatest if it were located at a site on which a repository might be constructed in the future. In a stand-alone facility, the costs of buildings, shafts, and underground openings would have to be charged against the experiments alone.

A research-and-development (R&D) area at a repository would have advantages over the stand-alone facility. Its results would be helpful in future planning for that site. It would be more cost-effective than a stand-alone facility. It would have no long-term impacts as long as the waste used in the experiments were removed at the end of the experiments, although its short-term impacts might not be negligible. Finally, the earlier an R&D facility is built, the more valuable its results will be. This suggests that it would be useful to include such a facility in the first repository to be built in each geologic medium.

The options of not having an R&D facility or of having a stand-alone facility are not considered further in this document. The discussions to follow assume that an R&D facility is included in the WIPP, if alternative 2 or 4 is chosen. The matter is left for later decision in alternative 3.

3.6.3 Alternatives Involving the Removal of Waste from Idaho

The demonstration of the disposal of defense TRU waste and the R&D studies with defense TRU and high-level waste are complementary. Thus, all the action alternatives discussed in this document include an R&D facility, although a TRU-waste repository and a stand-alone R&D facility could be built separately.

There are two choices for the disposal of TRU waste: it could be disposed of in a repository dedicated to TRU waste alone, or it could be put into a repository for high-level waste. In addition, the decision to build a TRU-waste repository could be delayed until other sites have been characterized. The action alternatives, therefore, are the following:

- Alternative 2, the authorized alternative. A repository for demonstrating the disposal of TRU waste and including an R&D facility for high-level waste is built now at the one presently available site, the Los Medanos site in southeastern New Mexico.

- Alternative 3, the preferred alternative. The TRU waste stored at the INEL is disposed of in the first available repository for high-level waste.

- Alternative 4. The decision on where to build a facility like the WIPP is delayed until at least 1984, when two or three sites in addition to the Los Medanos site should be available for consideration.

These alternatives are described in more detail in the next three sections.

3.6.3.1 Alternative 2, the Authorized Alternative

Alternative 2, the authorized WIPP project, consists of the following:

1. A repository for demonstrating the disposal of TRU waste generated in U.S. defense programs. It would receive the waste stored at the INEL through 1990 and all defense-generated TRU waste produced from 1990 through 2003. The waste would be emplaced in such a manner that it could be retrieved for a period of 5 to 10 years after a decision for retrieval is made. That decision would be made separately for each kind of TRU waste (contact-handled and remotely handled) not more than 5 years after the first containers of it had been emplaced. The underground excavation would create a 100-acre mine that would be large enough to accommodate this waste; future expansion could provide a mine of up to 2000 acres for the disposal of additional TRU waste, if this were later determined to be desirable.

2. A 20-acre underground area for research and development. Experiments performed there with all types of radioactive defense waste would answer technical questions about the disposal of waste, particularly high-level waste, in salt. All the waste used in these studies would be removed when the experiments are completed. No commercial high-level waste would be included.

The WIPP would be constructed at the Los Medanos site in Eddy County, New Mexico (Figure 3-1). The project would require the withdrawal of 17,200 acres of Federal land, the acquisition of 1760 acres of State land, and the acquisition of existing lease rights. Another 620 acres would be required for rights-of-way for roads, a railroad, an electrical-power line, and a water line.

In order to provide final site validation and to verify the analyses used in the design of the underground facility, the construction of the WIPP facility would be preceded by the construction of two deep shafts and an underground experimentation facility at the Los Medanos site. (This is the site and preliminary-design validation (SPDV) program referred to in Section 2.1.2.) The shafts and underground area would be instrumented to measure rock response, and various experiments to observe waste-package performance under repository conditions would be conducted. No radioactive waste would be used in the SPDV program. The SPDV-program plan calls for a 2-year period for construction and site validation and an operational period of up to 5 years for design validation. The SPDV program would require about $54 million (1979 dollars) to design and build and about $5 million a year to operate. If the WIPP (or an HLW repository) were constructed at the Los Medanos site after the SPDV program, the SPDV shafts and underground development would become a part of the complete facility. Based on the results of the site-validation activities, this EIS would be supplemented, if necessary to incorporate significant new information, before a decision to proceed with the full construction and operation of the WIPP facility.

Disposal of TRU waste in the WIPP

Once the complete facility became operational, railcars and trucks would be unloaded inside a waste-handling building, where the waste would be prepared for movement underground. Each of four shafts would reach the underground disposal level. This underground area, about 2150 feet below the

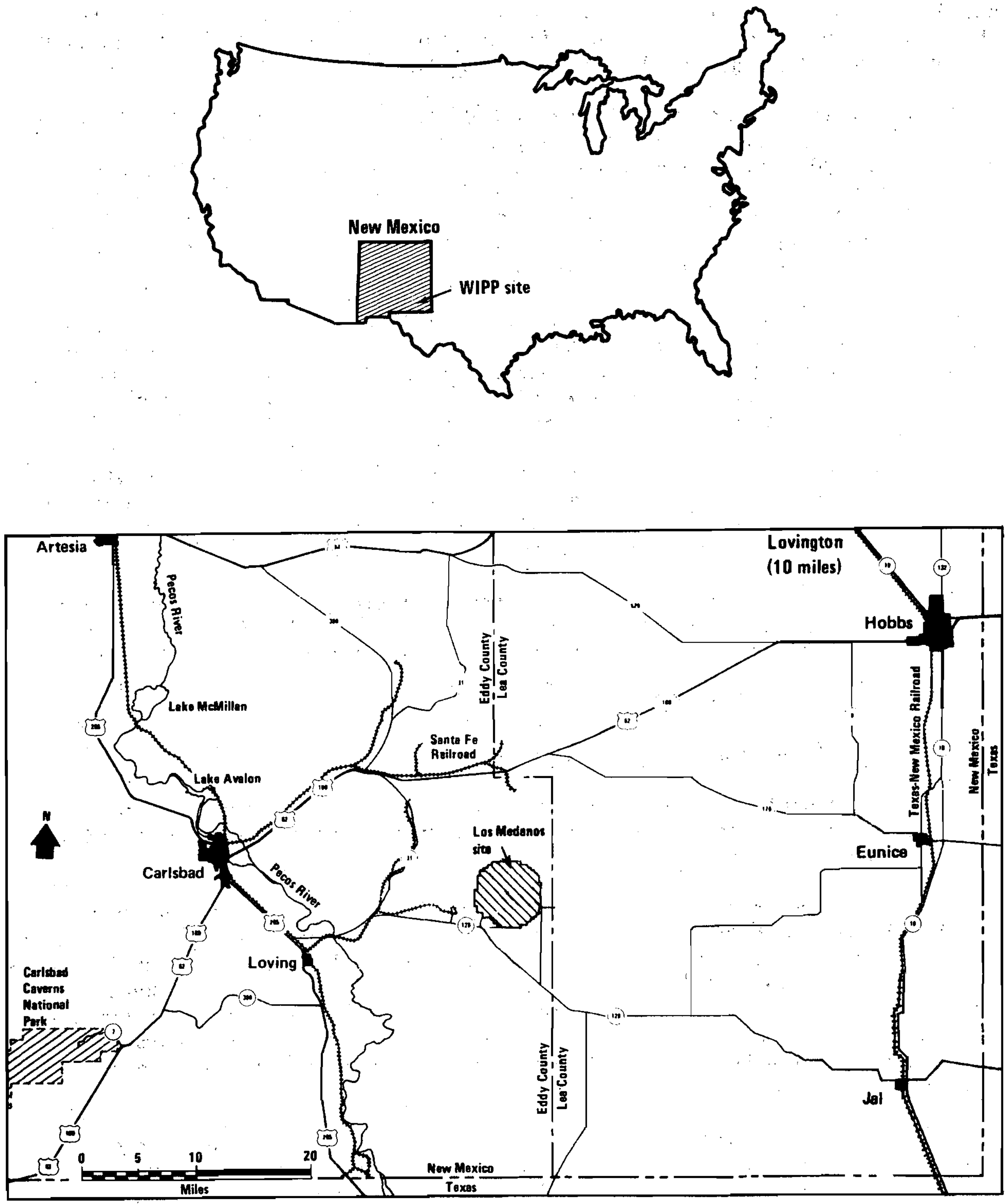

Figure 3-1. General location of the Los Medanos site.

surface, would be used for the disposal of contact-handled and remotely handled TRU waste and for experiments with defense high-level waste. The disposal mine would be in the Salado Formation, a thick layer of bedded salt that extends from about 850 to 2825 feet below the surface at the center of the site. Detailed information on the site is given in Chapter 7 and Appendix H. Chapter 8 presents a detailed description of the WIPP and its operation.

It is estimated that the construction of the WIPP would cost $292 million (1979 dollars) spread over nearly 4.5 years and about $24 million a year to operate. In addition, engineering, construction management, and technical support would cost $205 million. The construction work force is expected to number about 950 people on the average during the year of largest employment; peak employment for a period of a few months is expected to be near 1300. The operational staff would number about 440.

The WIPP is designed to handle up to 1.2 million cubic feet of waste per year. It is intended to accommodate the readily retrievable waste expected to be stored in Idaho through 1990 and other defense TRU waste generated between the years 1990 and 2003, for a total of 6 million cubic feet. A 100-acre repository will be large enough for this purpose.

The WIPP could be expanded in the future to accommodate the remaining retrievably stored TRU waste listed in Table 2-3. If the decision should be made to retrieve the buried waste at all sites and process it for storage, there is enough area at the Los Medanos site to receive it as well.

Thus, although the mission of the authorized WIPP project is now limited to a subset of the total TRU-waste inventory, there is a possibility that a repository of 2000 acres will eventually be needed for the disposal of all defense TRU waste. Any decision to add other sources of waste, however, would require further environmental review.

<u>The research and development program in the WIPP</u>

The experimental program described in Section 8.9 is designed to provide an in-situ laboratory to answer technical questions about the disposal of high-level waste in bedded salt.

In the experimental area, it would be possible to accelerate the interactions between the high-level waste and the salt and to experiment with canister materials, overpack or backfill materials, and other multiple-barrier techniques. The experimental program could produce information on the means of protecting the waste canisters from brine attack for long periods of time, on the products of waste interactions with salt, and on various concepts for immobilizing any leached radionuclides within or near the original waste-emplacement locations.

The experiments would use a form of defense waste that produces high levels of heat and gamma radiation. In the interest of accelerating the interactions, some of the waste will be emplaced without a surrounding container, and some will be ground into small particles before being emplaced. The experiments would be intended to produce enough stress on the salt environment to simulate adverse conditions that might appear in a future repository for high-level waste. All the high-level waste used in experiments would be recovered and removed from the WIPP at the end of the experiments.

The source of the waste to be used in these experiments is not as yet defined; solid high-level waste from defense programs is not readily available, as little of it has been produced. By the late 1980s, solid defense high-level waste may be available from the Savannah River Plant; however, it will not be available until several years after the WIPP experiments would be scheduled to begin. To increase its levels of radioactivity, this waste could be fortified with cesium-137.

3.6.3.2 Alternative 3, the Preferred Alternative

This alternative presumes that Idaho TRU waste is held until an HLW repository is available; then the waste is disposed of there. A comprehensive description of the plans for these repositories, to the extent that these plans have advanced, is given in the draft generic environmental impact statement on the management of commercially generated radioactive waste (GEIS) (DOE, 1979) and its supporting documents. According to these plans, an HLW repository would consist of the following:

1. A repository for the disposal of high-level waste generated in the commercial power program. This repository could be in salt, granite, shale, or basalt. The first such repository would operate for 15 to 25 years and would contain between 70,000 to 250,000 canisters of high-level waste. Initially at least, the waste would be implaced in such a manner that it could be retrieved if necessary. The underground mined openings would take up an area of 2000 acres.

2. A portion of the repository given over to the disposal of TRU waste from both the defense and the commercial programs. As in alternative 2, the quantity of this waste is assumed to be 6 million cubic feet needing 100 acres of storage space.

3. Possibly, an area for research and development. It is undecided at this time whether part of the repository should be set aside for experiments or whether an R&D facility should be constructed at the site prior to construction of the repository.

As indicated in Section 3.5, the areas being investigated for siting the first HLW repository are inland from the Gulf of Mexico for dome salt, the Hanford Site for basalt, and the Nevada Test Site for granite or tuff. According to current plans, the first HLW repository will become available between 1997 and 2006. The Los Medanos site would also be considered for this HLW repository.

Site validation may require one or two shafts and a small underground experimental area comparable to the site and preliminary-design validation program of alternative 2.

The GEIS estimates that the total cost of construction and operation of an HLW repository would be $1590, $4960, $2110, and $5490 million in dome salt, granite, shale, and basalt, respectively, spread over a time period of 15, 24, 17, and 24 years, respectively. These estimates assume the once-through fuel cycle, which involves no reprocessing of spent fuel.

3.6.3.3 Alternative 4

The advantage of this alternative would be to gain the possibility of picking a location for a WIPP-like facility from among several sites and media. As indicated in Section 3.5, the earliest possible date at which three sites may be available is 1984. The earliest date on which the finished repository would be available is 1997.

A repository built under this alternative would consist of a facility for demonstrating the disposal of radioactive waste generated in U.S. defense programs. Site validation could require the development of facilities comparable to those described for the site and preliminary-design program under alternative 2. It would receive the 6 million cubic feet of TRU waste spoken of under alternative 2 above (Section 3.6.3.1). This waste would be emplaced in such a manner that it could be retrieved, at least initially. As in alternative 2, part of the repository would be set aside for experiments with high-level waste.

This repository would be of roughly the same description as the WIPP. In a medium other than bedded salt, the early shafts and the small underground experimental area might also be required. The cost figures for HLW repositories in various media quoted in the previous section imply that the costs for TRU-waste-only repositories in various media would differ.

3.6.4 Summary of Alternatives

The four alternatives are considered in this environmental impact statement are summarized below. Their environmental impacts are discussed in Chapter 4.

Alternative 1, no action. The TRU waste stored at Idaho would remain there, perhaps in improved storage.

Alternative 2, the authorized alternative. The WIPP described in Chapter 8 would be built at the Los Medanos site in southeastern New Mexico. It would be a facility for the demonstration disposal of TRU waste only and for research and development with high-level waste.

Alternative 3, the preferred alternative. The TRU waste stored at Idaho would be disposed of in the first available repository for high-level waste. According to present plans, a site will be selected between 1987 and 1990, and the repository itself will be available between 1997 and 2006. The Los Medanos site will be considered as well as sites in other geologic media.

Alternative 4. The decision on where to build a WIPP-like facility would be delayed until at least 1984, when two or three sites in addition to the Los Medanos site should be available for consideration.

A site and preliminary-design validation program at the Los Medanos site would be part of the authorized WIPP alternative. Although designed for WIPP requirements, this program would be compatible with the site-characterization studies required for alternatives 3 and 4.

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4 Environmental Impacts of Alternatives

This chapter evaluates and compares the environmental impacts of the four alternatives developed in Chapter 3. Section 4.1 discusses alternative 1, no action. Section 4.2 summarizes the detailed analysis of alternative 2 that appears in Chapters 6 and 9. Alternative 2, the authorized Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico, is the most completely analyzed of the alternatives; it forms the reference against which the other alternatives are compared. The remaining two alternatives are taken up in Sections 4.3 and 4.4. In the discussion of alternative 3, the preferred alternative, which places both defense TRU waste and commercial high-level waste (HLW) in one combined repository, the point of view is twofold: (1) the changes in impacts (usually increases) brought about by expanding the mission of the HLW repository and (2) the changes in impacts (usually decreases) brought about by having one repository rather than two. Section 4.5 compares the environmental impacts of alternatives 2, 3, and 4 in a single table.

4.1 ALTERNATIVE 1: NO ACTION

If neither the WIPP nor any other Federal repository should become available, TRU waste would have to remain at its present storage sites (or be transferred between them). The consequences of following this alternative are analyzed in Appendix N in terms of the impacts that would occur at the Idaho National Engineering Laboratory (INEL). Three general methods for managing the waste are considered in Appendix N:

1. The waste could be left in place, as is. Additional waste received would be stored similarly.

2. The confinement of the waste could be improved without moving it. At the INEL this in-place improvement would consist of adding clay and basalt rip-rap over the storage pads; injecting grout below the pads would further improve the confinement. Alternatively, the waste could be immobilized by injecting grout directly into the waste and the ground beneath it.

3. The waste could be retrieved, processed, and disposed of at a better location at the INEL. The methods considered in Appendix N are disposal in an aboveground engineered concrete structure, engineered shallow burial, and disposal in deep rock.

In the short term (i.e., up to 100 years), no releases of radiation would be expected from the first two subalternatives. The processing involved in the third would produce small releases resulting in a maximum whole-body dose commitment of 1.9×10^{-10} rem per year of operation or 3.6×10^{-6} rem per year to the bone at the point (on the INEL site) of maximum airborne concentration. The dominant accident during processing would produce a maximum dose commitment to the lung of about 0.1 rem.

Over the long term, disasters could disrupt the waste and release radionuclides. The INEL is at the edge of the Arco Volcanic Rift Zone, which has been active as recently as 10,500 years ago; it is likely to be the site of future volcanic action. Therefore, the dominant natural disaster would be volcanic action, either lava flow over the waste or an eruption through or near it. Human intrusion by a small group of people is also credible.

Drawn from a study of many possible release mechanisms (DOE, 1979a), Table 4-1 gives estimates of the possible radiation doses resulting from these disruptions. Natural disasters could deliver significant dose commitments (up to 90 rem to the lung) to maximally exposed individuals if the first subalternative were used; the second subalternative would reduce this dose commitment to 0.9 rem. Human intrusion could deliver much higher dose commitments to a few people. Improved confinement (subalternative 2) gives the possibility of a hundredfold-smaller individual and population dose commitments, but leaves the waste at the surface.

In summary, no environmental reasons have been found why TRU waste could not be left at the INEL stored as it is for several decades or even a century; over such a time volcanic action is unlikely, and government control of the site will prevent inadvertent human intrusion. In the long term, however, volcanic action that could produce large exposures to radiation is probable.

Table 4-1. Possible Long-Term Consequences, Alternative 1

Release mechanism	Individual dose commitment (rem)			Population[a] dose commitment (man-rem)		
	Whole body	Bone	Lung	Whole body	Bone	Lung
	SUBALTERNATIVE 1: WASTE LEFT AS IS[b]					
Volcano	0.006	8	20	40	40,000	80,000
Lava flow	0.03	50	90	100	200,000	400,000
Intrusion[c]	10	500	700	90	4,000	6,000
	SUBALTERNATIVE 2: IMPROVED CONFINEMENT[d]					
Volcano	0.00006	0.08	0.2	0.4	400	800
Lava flow	0.0003	0.5	0.9	1	2,000	4,000
Intrusion[c]	0.1	5	7	0.9	40	60

[a]Population is 130,000 for volcanic action and lava flow, 10 for human intrusion.
[b]Data from Table N-1 in Appendix N.
[c]Dose from inhalation.
[d]Data from Table N-2 in Appendix N.

4.2 ALTERNATIVE 2: THE AUTHORIZED WIPP FACILITY

A detailed analysis has been made of the Waste Isolation Pilot Plant in the bedded salt of the Delaware basin in southeastern New Mexico, at a site called Los Medanos. It is reported in Chapters 6 and 9 and summarized in this section. This authorized alternative is used as the reference against which this environmental impact statement compares the other two alternatives that call for the disposal of TRU waste away from the INEL. The impacts of a site and preliminary-design validation (SPDV) program at the Los Medanos site are included in this discussion; these impact analyses are presented in greater detail in a separate report (Brausch et al., 1980).

The impacts of the WIPP include

1. Physical impacts during construction and operation: changed land use, commitment of resources, effects of effluents, denial of mineral resources.

2. Socioeconomic impacts.

3. Radiological impacts of transportation, including transportation accidents.

4. Radiological impacts of normal and accidental releases during the time that waste is being emplaced in the WIPP (the short-term, or operational, period).

5. Possible radiological impacts after the WIPP is closed and decommissioned (the long-term period).

6. Impacts of removing waste from its present storage and processing it for shipment to the WIPP.

4.2.1 Physical Impacts

The physical impacts of the authorized alternative would occur primarily during construction and operation. These impacts are summarized in Table 4-2.

The commitment of the site for repository development would primarily affect grazing; the land surface currently has few other uses. National and local food production would sustain no appreciable loss, for the 1072 acres affected normally support fewer than 12 head of cattle. The 169 acres used in the SPDV program would result in even less impact.

Table 4-2 categorizes surface land use as "temporary" and "long-term." Probably the only long-term use that would be truly permanent is the land to be used for the mined-rock (salt) pile and the evaporation pond to receive the drainage from this pile; these 37 acres, sterilized by salt, would not support grazing again. The other parcels of land included in the long-term category are the portions of the rights-of-way actually covered by roads and railroads and the land occupied by buildings. After the project is over, this area will largely regain its natural vegetation if the buildings are razed. The temporary category includes the rights-of-way for electricity and water lines because the land on which they are built would be allowed to return to its

Table 4-2. Physical Impacts of the WIPP Authorized Alternative[a]

Parameter	Quantity			Section
Use of land surface				
Temporary	878 acres			8.1 and
Long-term	224 acres			9.1.1
Resources				
Materials for construction[b]				
Concrete	125,000 bbl cement	0.032%	of U.S. pro-	9.2.2
Steel	15,000 tons	0.012%	duction per	9.2.2
Copper	150 tons	0.009%	year	9.2.2
Aluminum	200 tons	0.003%		9.2.2
Lumber	0.5 x 10^6 board feet	0.0005%		9.2.2
Water				
Construction[b]	15 acre-ft/yr	0.17%	of Carls-	9.2.2
Operation	20 acre-ft/yr	0.23%	bad use	9.3.3
Electricity				
Construction[b]	4 x 10^6 kW-hr	0.12%	of Carls-	9.2.2
Operation	2 x 10^4 kW	23%	bad use	9.3.3
Liquid fossil fuels				
Construction[b]	2.6 x 10^6 gal			9.2.2
Operation	540 gal/day			9.3.3
Effluents				
Construction period				
Carbon monoxide	26 tons/yr	0.1%		9.2.1
Nitrogen oxides	142 tons/yr	2.4%	of Eddy County	9.2.1
Sulfur oxides	9 tons/yr	0.04%	emissions	9.2.1
Dust	720 tons/yr	3.5%		
Other particulates	29 tons/yr	0.14%		9.2.1
Operational period				
Carbon monoxide	9.7 tons/yr	0.1%		9.3.1
Nitrogen oxides	49 tons/yr	0.82%	of Eddy County	9.3.1
Sulfur oxides	31 tons/yr	0.14%	emissions	9.3.1
Hydrocarbons	3.2 tons/yr	0.04%		9.3.1
Salt particulates	42 tons/yr	0.21%		8.7.5, 9.3.1
Other particulates	3.2 tons/yr	0.02%		9.3.1
Solid nonradioactive waste (uncompacted)	2500 yd^3/yr			8.7.2
Sanitary waste (treated effluent)	30,000 gal/day			8.7.1
Radioactive[c]				
Solid	1420 ft^3/yr			8.5.2
Natural radon	0.94 Ci/yr			8.6.3
Other gases	0.004 Ci/yr			8.6.3
Mineral reserves				
In entire withdrawal area				
Sylvite	3.7 x 10^6 tons K_2O	1.8%		9.2.3
Langbeinite	4.4 x 10^6 tons K_2O	[d]10%	of U.S.	9.2.3
Crude oil	0		reserves	
Natural gas	45 x 10^9 cubic feet	0.02%		9.2.3
Distillate	0.12 x 10^6 barrels	0.0003%		9.2.3
In inner zones				
Sylvite	0			
Langbeinite	1.21 x 10^6 tons K_2O	[e]2.7%		9.2.3
Crude oil	0		of U.S.	
Natural gas	21 x 10^9 cubic feet	0.01%	reserves	9.2.3
Distillate	0.03 x 10^6 barrels	0.00008%		9.2.3

[a]The impacts of the SPDV program are included in or bounded by the quantities listed in this table. The SPDV impacts are discussed in the referenced sections.

[b]For a 54-month construction period.

[c]The SPDV program will not produce radioactive effluents other than naturally occurring radon gas.

[d]The tonnage estimate of langbeinite reserves, made by the U.S. Bureau of Mines (USBM), is used in the analyses presented in this document, for reasons explained in Section 7.3.7. It is not, however, directly comparable to the available estimates of total U.S. reserves. An estimate that is comparable has been made by Agricultural and Industrial Minerals, Inc. (AIM); this estimate shows that about 10% of the U.S. reserves lie beneath the entire withdrawal area.

[e]Because the USBM estimates that 27% of the reserves lie beneath the inner zones, 2.7% of the U.S. reserves may be assumed to lie there.

natural vegetated state after they are constructed. The SPDV program is designed to be temporary and involves only 169 acres; it will include site restoration if there is to be no further activity at the Los Medanos site.

The resources to be used in building and operating the SPDV facility or the complete WIPP facility could be used elsewhere. Nevertheless, supplying them would not strain the resources of the nation, the State, or the local area. As shown in Table 4-2, the required amounts all are small in comparison with the annual production of these resources in the United States.

Most of the effluents from the SPDV facility and the repository would have little effect on the environment, although salt dust from the mined-rock pile and from mining would have effects like those of a normally operating salt or potash mine--that is, it could suppress some species of plants nearby. Sewage treatment and the disposal of solid wastes in a local landfill would be about equivalent to that of a small town with a population of less than 500 persons. The effluents listed in Table 4-2 come mostly from the operation of diesel equipment in the plant.

The impacts of the radioactive effluents from the repository are given in Section 4.2.4 below. The SPDV facility would not release any radioactive effluents other than natural radon gas generated during mining.

The development of most of the subsurface mineral reserves* listed in Table 4-2 would be denied temporarily; all of the sylvite, three-quarters of the langbeinite, about half of the natural gas, and three-quarters of the distillate are expected to become available for exploitation. Sections 9.2.3 and 9.6.5 explain how some of the subsurface-development rights could be restored: mining (other than solution mining) and drilling for oil and gas may be allowed in the outer control zone. More than half of the natural gas could be recovered by drilling outside the central portion of the site. Deviated drilling from the outermost buffer zone to locations beneath the repository could allow recovery of all of the natural gas present at the site. It is uncertain when the restrictions on access can be relaxed, but the delay could be several decades. Access to these resources would be denied during the SPDV program, but if the Los Medanos site were not considered further for a repository, these minerals would again become available.

In summary, the most important physical impacts of the development of alternative 2 would be the use of land, especially that required for the mined-rock pile, and the denial of access to subsurface mineral reserves. The most important of these reserves is the potassic mineral langbeinite, used for fertilizer where chlorides must be avoided. Because Carlsbad is the only known langbeinite district in the United States, it will eventually be necessary to substitute other minerals. These other minerals are currently being produced commercially, at competitive prices, from brine lakes. The use of the total reserves at the site would forestall this depletion by a maximum of 15 years; if the DOE permits mining in the outer buffer zone, the remaining WIPP reserves would account for only 4 years of production. The impacts of the SPDV program are a small fraction of those for the complete WIPP facility.

*Reserves are the portions of resources that are recoverable under today's economic conditions with today's technology.

4.2.2 Socioeconomic Impacts

These impacts are summarized in Table 4-3 from information given more fully in Section 9.4.

The WIPP would cost about $292 million to build and about $24 million a year to operate (1979 dollars). In addition, it would cost $205 million for engineering, construction management, and technical support, for a total of about $500 million. Only a portion of the first two costs would be spent locally; during the period of construction (assumed in the analysis to be 54 months), the economy of Eddy and Lea Counties would receive $138 million in direct new expenditures for labor and local procurement. Indirect, or spin-off, effects in the private sector would add $112.4 million. During repository operation, the total direct and indirect impact on the private sector of the economy would be about $33 million annually (just over $17 million directly and nearly $16 million indirectly). The SPDV program would require $54 million (1979 dollars) to design and construct and about $5 million a year to operate.

New jobs would be created. The number of jobs would rise until 1983, when an average of approximately 950 people would be directly employed on the project and about 1200 indirect jobs would exist; during two brief peaks in 1982 and 1983, the project would provide more than 1200 direct jobs. These totals would drop back to 440 direct and 514 indirect jobs during operation. About half of the people filling these jobs would be hired locally. At the peak of the construction activity, the project would add as many as 2250 people to the population in the area; during operation this number would drop back to about 1000. The maximum direct employment for the SPDV program is estimated at 124 people. Because of this small influx of workers and the short duration of their stay, socioeconomic impacts, either beneficial or adverse, would be minimal.

Table 4-3. Socioeconomic Impacts of the WIPP Authorized Alternative in Eddy and Lea Counties

Impact	Construction	Operation	Source section
Expenditures[a]			
Direct	$137.9 million[b]	$16.9 million[c]	9.4.1.1
Indirect	$112.4 million[b]	$16.1 million[c]	9.4.1.1
Total	$250.3 million[b]	$33.0 million[c]	9.4.1.1
Jobs			
Direct	922[d]	440[e]	9.4.1.3
Indirect	1215[d]	514[e]	9.4.1.3
Total	2137[d]	954[e]	9.4.1.3
Population changes			
Direct	1200[d]	600[e]	9.4.2.1
Indirect	1050[d]	400[e]	9.4.2.1
Total	2250[d]	1000[e]	9.4.2.1

[a]In 1979 dollars.
[b]Total costs for the whole period of construction.
[c]Annual costs.
[d]Peak year.
[e]Full operational period.

Two alternative assumptions were made in the socioeconomic analysis. The first assumed the present residency pattern for potash-industry workers: the work force lives mostly in Carlsbad, which would receive by far the major impact of the project. The second assumed that a significant fraction of the workers live in Lea County; Hobbs would then receive more than one-third of the impacts.

Under the first assumption, there might be a temporary housing shortage in Carlsbad during the peak construction period. Under the second assumption, housing in Hobbs would keep up with demand, but would have to spread beyond the present city limits and municipal utilities. In both cities community services are judged to be adequate. Because their populations are expected to increase steadily even without the WIPP, both cities will have to increase the services they offer during the next decade. The impact of the extra population due to the WIPP would be simply to require that the increased services be provided perhaps 6 months to 1 year earlier. Existing laws and statutes provide authority for the DOE and other agencies to provide planning and mitigation assistance for adverse socioeconomic impacts (Section 9.6.6).

4.2.3 Radiological Impacts of Transportation

These impacts are summarized in Table 4-4 from information given more fully in Sections 6.7 and 6.8.

The analysis of transportation to the WIPP assumed that stored TRU waste would be shipped from the INEL over a period of 10 years and that TRU waste would be shipped from the Rocky Flats Plant as it is produced. There would be about 500 shipments a year to the repository, distributed between the two types of TRU waste as shown in Table 4-4. During each of the 2 or 3 years after the WIPP opens, the plant would receive two or three shipments of high-level waste for experiments.

The analysis of normal, accident-free transportation calculated the doses received by the general public along transportation routes to the WIPP. The total annual doses are 5.4 man-rem from contact-handled TRU waste and 1.2 man-rem from remotely handled TRU waste. Shipments of high-level waste would contribute less than 0.14 man-rem during each of the 2 or 3 years when this waste would be received. These doses would be spread over many hundreds of thousands of people; they would be much smaller than the doses those people would receive from natural background radiation.

To calculate an upper limit to the dose a person might receive from transportation to the WIPP, the analysis postulated a person who, for an entire year, watches every shipment of TRU waste from a point 25 feet from the path of the shipments. Such a person would receive a dose of 0.00015 rem during that year, a dose many times smaller than the dose he would receive from natural background sources.

Most transportation accidents would not be severe enough to release any radioactivity at all because of U.S. Department of Transportation (DOT) regulations on packaging for shipment. Statistics show that only 0.5% of truck accidents and 0.4% of rail accidents have impacts more severe than those that

Table 4-4. Radiological Impacts of Transportation

EXPOSURE DURING ACCIDENT-FREE TRANSPORTATION

Waste type	Number of shipments per year	Population exposure (man-rem/yr)
CH TRU waste	459	5.4
RH TRU waste	41	1.2
Total for TRU waste	500	6.6
Experimental high-level waste	less than 6 for 2-3 years	less than 0.14

EXPOSURE DURING ACCIDENTS: DOSES RECEIVED BY AN INDIVIDUAL[a]

Scenario	Dose commitment (rem)		
	Bone	Lung	Whole body
CH TRU waste (rail)	17.4	0.87	0.42
CH TRU waste (truck)	5.8	0.29	0.14
RH TRU waste (rail)	0.008	0.002	0.007
RH TRU waste (truck)	0.0016	0.0004	0.0014
Experimental high-level waste (rail)	37	9.1	33

EXPOSURE DURING ACCIDENTS: DOSES RECEIVED IN A SMALL URBAN AREA[b]

Scenario	Dose commitment (man-rem)		
	Bone	Lung	Whole body
CH TRU waste (rail)	7,680	390	190
CH TRU waste (truck)	2,560	130	62
RH TRU waste (rail)	3.6	0.9	3.2
RH TRU waste (truck)	0.6	0.2	0.7
Experimental high-level waste (rail)	16,600	4050	14,800

EXPOSURE DURING ACCIDENTS: DOSES RECEIVED IN A LARGE URBAN AREA[c]

Scenario	Dose commitment (man-rem)		
	Bone	Lung	Whole body
CH TRU waste (rail)	13,200	660	330
CH TRU waste (truck)	4,410	220	110
RH TRU waste (rail)	6.2	1.5	5.4
RH TRU waste (truck)	1.2	0.3	1.1
Experimental high-level waste (rail)	28,500	6960	25,400

Sources: Sections 6.7 and 6.8.

[a]Maximum dose to an individual 100 meters from the accident.
[b]Approximately 6000 people are affected by the plume.
[c]Approximately 105,000 people are affected by the plume.

the regulations provide protection against, and fewer than 0.2% have fires as severe. While the total number of accidents statistically expected, at all levels of severity, is about eight per year, an accident exceeding in severity the conditions specified in DOT regulations would be expected only about every 140 years (Section 6.7.3).

For the analysis, severe accidents were hypothesized. The severity of these accidents is so great that they would be expected to occur only once in 40,000 years. Accident analyses were performed for both a small urban area and a large urban area. They were assumed to happen under atmospheric conditions that would hold the plume of released material together, thus maximizing the concentration of material, and blow it in the direction of the densest population, thus maximizing the number of people affected. Details are given in Section 6.8.

According to Table 4-4, the maximum individual dose commitment that might be received from any of the hypothetical accidents with TRU waste would be 17.4 rem to the bone. This 50-year dose commitment is more than three times the bone dose received from natural background radiation during 50 years. The 50-year dose commitments to other organs would be smaller than the corresponding doses from natural background. The hypothetical accident with high-level waste might deliver a greater dose commitment, but shipments of this waste would be so few that its expected frequency of occurrence is less than once in a million years.

In all the hypothetical accidents with TRU waste, the 50-year dose commitments delivered to the general population would be smaller than the doses received from natural background radiation during the same 50 years.

4.2.4 Radiological Impacts During Plant Operation

These impacts are summarized in Tables 4-5 and 4-6 from analyses described in more detail in Sections 9.3.2 and 9.5.1.

Table 8-5 in Section 8.6 indicates that during normal waste-handling operations the WIPP would release radioactivity to the atmosphere at a rate of about 0.004 curie per year. The natural radon gas released from the rock during the mining would enter the atmosphere at a higher rate, about 1 curie per year.

Because the releases from waste handling are smaller than the release from mining, the consequences shown in Table 4-5 would be expected to be small. The maximum individual dose commitment (to the bone) is only 0.0065% of the dose received from natural background radiation. The whole-body dose commitment is 0.000096% of the dose from background radiation.

A number of possible operational accidents were studied, and Table 4-6 shows the doses that the worst of these would deliver to a person at the nearest inhabited point, James Ranch, just outside the boundary of the site to the south-southwest. The worst accident is an underground fire in areas where contact-handled waste is emplaced. It could expose a person at the boundary of the site to a bone-dose commitment of about 0.0001% of the 50-year dose commitment from background radiation.

Table 4-5. Radiological Impacts of Normal Plant Operation

Recipient of exposure	50-year dose commitment from 1-year exposure[a]		
	Bone	Lung	Whole body
Individual living at James Ranch, the nearest inhabited point[b]	6.5×10^{-6}	3.0×10^{-7}	1.6×10^{-7}
Population within 50 miles of the WIPP[c,d]	8.8×10^{-3}	4.0×10^{-4}	2.2×10^{-4}

Source: Section 9.3.2.

[a]In units of rem for the individual dose and man-rem for the population dose.

[b]The annual doses received from natural background are 0.1 rem to the bone, 0.18 rem to the lung, and 0.1 rem to the whole body.

[c]The population within 50 miles of the repository was taken as 96,000 in these calculations.

[d]The annual population doses from natural background are 9200 man-rem to the bone, 17,000 man-rem to the lung, and 9600 man-rem to the whole body.

Table 4-6. Radiological Impacts of Operational Accidents: Dose or Dose Commitment Received by a Person Living at the Site Boundary[a]

Group	Dose or dose commitment (rem)[a]		
	Bone	Lung	Whole body
CH-waste area			
Hoist drop	6.0×10^{-7}	1.5×10^{-8}	1.5×10^{-8}
Underground fire	4.4×10^{-6}	1.0×10^{-7}	1.0×10^{-7}
RH-waste area			
Canister drop in transfer cell	1.2×10^{-8}	6.0×10^{-10}	3.6×10^{-10}
Hoist drop			
RH TRU waste	2.1×10^{-7}	1.0×10^{-8}	6.2×10^{-9}
Experimental high-level waste	1.6×10^{-6}	7.3×10^{-7}	7.8×10^{-7}

Source: Section 9.5.1.

[a]The doses received from natural background radiation during the 50 years of these dose commitments are 5 rem to the bone, 9 rem to the lung, and 5 rem to the whole body.

4.2.5 Possible Long-Term Impacts

During the long term after the WIPP would cease operation and was closed up, no release of radioactive material to the biosphere would be expected.

Nevertheless, there are a number of possible man-made and natural events that could cause such a release: the drilling of holes, for example, or failures of plugs in shafts or holes. Although no release appears likely at the Los Medanos site, the analysis in this document instead assumes the occurrence of breaches in the repository and assesses their consequences (Section 9.7.1).

Table 4-7 tabulates the most severe consequences found. Scenario 1 assumes an open hole that connects water-bearing rocks above and below the waste-disposal level and admits flowing unsaturated water to the waste. Scenario 4 is a so-called bounding case, the worst imaginable release through flowing groundwater, in which all the water in the rocks of the overlying Rustler Formation is diverted down to the waste level and then back up into its original course. Scenario 5 assumes that drilling into the repository brings up material that exposes the drill crew directly and people on a downwind farm indirectly. For each of these scenarios, Table 4-7 shows the dose or 50-year dose commitment to the maximally exposed individual.

Scenarios 1 and 4 produce 50-year bone-dose commitments that are less than 0.001% of the dose received from natural background radiation in 50 years.

Table 4-7. Consequences to Maximally Exposed Person of Possible Long-Term Releases of Radiation

Scenario[a]	Type of consequence	Organ receiving greatest dose	Dose received by organ (rem)
1	Combined effects of CH and RH TRU waste (50-year dose commitment)	Bone	1.3×10^{-5}
4	Combined effects of CH and RH TRU waste (50-year dose commitment)	Bone	2.6×10^{-5}
5	Direct pathways (dose from single exposure after drilling through one type of waste)	Whole body	2.4×10^{-5} (CH TRU waste)[b] 1.5×10^{-3} (RH TRU waste)[c]
5	Indirect pathways (50-year dose commitment)	Bone	2.2×10^{-4} (CH TRU waste)[b] 2.7×10^{-4} (RH TRU waste)[b]

[a]As defined in Section 9.7.1.3.
[b]Drilling is assumed to occur 80 years after WIPP decommissioning.
[c]Drilling is assumed to occur 100 years after WIPP decommissioning.

Scenario 5 presents the possibility of higher doses. It presumes coring right through the buried waste and exposing the geologist who examines the core. This person could receive a whole-body dose of 2.4 x 10^{-5} rem if the core holds contact-handled waste or 1.5 x 10^{-3} rem if it holds remotely handled waste. If there were a farm nearby, an improbable development, people who live and subsist on the food produced there could be exposed to bone-dose commitments of about 3 x 10^{-4} rem. Accordingly, even under very severe postulated repository breaches, the maximum dose commitments are insignificant.

Although other scenarios for the release of waste have been suggested, scenario 4 bounds the consequences of other liquid-breach and transport scenarios conveivable at the Los Medanos site. Solution-mining release scenarios postulated for domed salt are not considered conceivable in the bedded salt of the Los Medanos site because of the relationship of the repository to geologic features (i.e., the presence of numerous thin layers of relatively impermeable anhydrite and polyhalite in the Salado), lack of economic incentive as compared to other salt deposits, and lack of large quantities of water.

The waste to be emplaced in the WIPP would release so little heat that thermal effects will not threaten its integrity. At the center of the repository itself the maximum temperature rise would be less than 2°C at 80 years after waste emplacement; buoyant forces arising from the heating of the salt would produce displacements of 10 millimeters at most.

As the mined cavities close, an area of less than 1000 acres over the repository would subside slowly. At the center of this area the surface may sink by as much as 1.6 feet. Because the natural variations in the terrain are greater, this subsidence would be little noted.

4.2.6 Impacts of Removing the TRU Waste from Storage

The removal of the TRU waste from its present storage pads at the INEL is analyzed in Section 9.8 and summarized in Table 4-8. The analysis includes processing by slagging pyrolysis.

The largest radiological impacts from each year of normal operation would be bone-dose commitments of 3.6 x 10^{-6} rem to the maximally exposed person and 0.033 man-rem to the surrounding population. This release would be from processing by slagging pyrolysis.

Table 4-8 shows the consequences of the most severe accidents among those assumed to occur during the retrieval and the processing of waste. The maximum dose commitments from accidents would be 0.1 rem (lung) to the maximally exposed individual and 200 man-rem (lung) to the surrounding population. These doses would come from a highly unlikely event: an explosion in the slagging-pyrolysis building coupled with a loss of the confinement afforded by the building.

The radiological effects of the exposures from normal operation and from all but the most unlikely accidents would be far smaller than the corresponding effects from natural background radiation. Nonradiological effects would be limited to minor commitments of manpower and other resources.

Table 4-8. Radiological Consequences of Removing Waste from Storage and Preparing It for Shipment

Process	Organ[b]	Individual dose commitment[a] (rem)	Population dose commitment[a] (man-rem)
		NORMAL OPERATION	
Retrieval	Bone	4.6×10^{-10}	4.2×10^{-6}
Processing			
Pyrolysis	Bone	3.6×10^{-6}	3.3×10^{-2}
Repackaging	Bone	5.0×10^{-7}	4.6×10^{-3}
		ACCIDENTS	
Retrieval	Lung	4×10^{-4}	0.8
Processing			
Pyrolysis	Lung	0.1	200
Repackaging	Lung	2×10^{-5}	0.04

Source: Section 9.8.

[a]50-year dose commitment received by the organ listed. For rough comparisons, the doses delivered by natural background radiation to the whole body during 50 years are about 7.5 rem to a person and 1×10^6 man-rem to the population affected by the processes listed here, about 130,000 people.
[b]Organ that receives the greatest dose commitment.

4.2.7 Summary of Major Impacts

The largest impacts entered in Tables 4-2 through 4-8 are brought together in Table 4-9. Each impact except land use is compared with some relevant standard, such as an existing condition without the WIPP. Radiation doses, for example, are compared with the doses received from natural background radiation.

The largest adverse impacts listed are the following:

1. Denial of mineral reserves. About one-tenth of the known U.S. reserves of the mineral langbeinite will be kept from exploitation for a time that may be as long as several decades. Substitutes can, however, be extracted from brine lakes. Conducting the SPDV program alone would not result in a long-term denial of mineral reserves.

2. Possible accidents during transportation. An extremely severe accident in transporting TRU waste could deliver to a nearby individual a 50-year dose commitment three times the dose delivered by natural background radiation during 50 years.

3. Possible long-term releases of radioactivity. If people were to drill directly into a canister of remotely handled TRU waste after the repository is sealed, the drill-crew geologist might be exposed to a radiation dose of 1.5×10^{-3} rem; and persons living on a nearby farm might receive a bone-dose commitment of 3×10^{-4} rem. If the repository were breached by flowing water that carried radionuclides to the biosphere, the maximum dose commitments received by people would be even smaller. Accordingly, using very conservative analyses of postulated events, it is concluded that the maximum dose commitments are insignificant.

Table 4-9. Summary of the Major Impacts of the WIPP Repository[a]

	PHYSICAL IMPACTS		
Land use			
Temporary	878 acres (121 acres)		
Long term	224 acres (48 acres)		
Mineral reserves--langbeinite			
Temporary denial[b]	4.4×10^6 tons K_2O	10%	of U.S. reserves
Long-term denial[b]	1.2×10^6 tons K_2O	2.7%	of U.S. reserves
	SOCIOECONOMIC IMPACTS		
Jobs, direct and indirect			
Peak	2137 (124)	4.7%	of the two-county employment (1979)
Long term	954 (0)	2.1%	of the two-county employment (1979)
Population changes, direct and indirect			
Peak	2250	2.1%	of the two-county population (1979)
Long term	1200	1.1%	of the two-county population (1979)
	TRANSPORTATION IMPACTS[c]		
Normal, accident-free			
Population dose	6.6 man-rem/yr	0.001%	of background dose
Accidents with TRU waste, maximum bone-dose commitment[d]			
Individual	17 rem	340%	of 50-year background dose
Small urban population	7680 man-rem	26%	of 50-year background dose
Large urban population	13,200 man-rem	2.5%	of 50-year background dose
	IMPACTS OF NORMAL PLANT OPERATION[c]		
Bone-dose commitment			
Individual	6.5×10^{-6} rem	0.0065%	of annual background dose
Population, worst sector	8.8×10^{-3} man-rem	0.000001%	of annual background dose
	IMPACTS OF OPERATIONAL ACCIDENTS[c]		
Individual bone-dose commitment from fire in disposal area for CH waste[e]	4.4×10^{-6} rem	0.00009%	of 50-year background dose
	LONG-TERM IMPACTS[c]		
Expected release	0		
Drilling[f] through RH TRU waste			
Crew member (bone dose)	1.5×10^{-3} rem	1.5%	of annual background dose
Farmer (bone-dose commitment)	3×10^{-4} rem	0.006%	of 50-year background dose
Drilling[f] through CH-TRU waste, farmer (bone-dose commitment)	2×10^{-4} rem	0.004%	of 50-year background dose
Water carries waste to biosphere,[g] maximally exposed person (bone-dose commitment)	2.6×10^{-5} rem	0.0005%	of 50-year background dose

[a]The impacts of the SPDV program, where applicable, are provided parenthetically.

[b]Quantities listed are derived from USBM and AIM estimates; see footnotes d and e to Table 4-2.

[c]No radioactive materials will be used during the SPDV program. These types of impacts will not occur.

[d]From extremely severe hypothetical accident with contact-handled or remotely handled TRU waste.

[e]The worst of the hypothetical accidents analyzed.

[f]Drilling 100 years after repository is closed, bringing waste to surface.

[g]The worst of the scenarios that assume water breaches the repository and transports radionuclides.

4.3 ALTERNATIVE 3, THE PREFERRED ALTERNATIVE: COMBINE THE AUTHORIZED WIPP ACTIVITIES WITH THE FIRST AVAILABLE HIGH-LEVEL-WASTE REPOSITORY

Under alternative 3 no repository dedicated to the disposal of TRU waste is built. Instead, TRU waste stored at the INEL is held until a repository for high-level waste is built; then the TRU waste is disposed of in the HLW repository. Sites to be considered for the HLW repository include sites in bedded salt, salt domes, basalt, granite, shale, and tuff. The Los Medanos site may also be considered. This alternative is consistent with the program proposed by the President and with the program described by the DOE in the Waste Confidence Rulemaking (DOE, 1980). The first HLW repository is planned to begin operation between 1997 and 2006.

The impacts of alternative 3 are presented from two points of view: (1) the local changes in impacts (usually increases) that would occur at the HLW repository because its mission had been expanded to include TRU-waste disposal and (2) the overall national changes in impacts (usually decreases) that would occur because one combined repository had replaced two separate ones--one for TRU waste only and one for high-level waste.

To present impacts from either point of view, predictions of the impacts of HLW repositories are needed. To compute them accurately would require for each site the results of detailed explorations and at least a conceptual design for the plant to be built there. Programs now investigating the disposal of high-level waste in salt and other rocks will eventually produce these basic data and a thorough prediction of impacts. These programs are, however, still in early stages: no specific sites have been selected, and no conceptual designs are available. In this section the discussion of HLW-repository impacts is therefore based largely on environmental impacts predicted generically in the GEIS, the draft generic environmental impact statement for the management of commercially generated radioactive waste (DOE, 1979b). The information from the GEIS is supplemented where possible by more recent data or estimates from the ongoing programs. The predictions available from these sources describe the impacts of the HLW repositories alone, without the addition of defense TRU waste. The predictions made in this section assume an HLW repository like those described in the GEIS but modified and enlarged to accept the defense TRU waste that would go to the WIPP if alternative 2 were followed. The analyses assume that the repository is in bedded salt in the Delaware basin, in dome salt in the Gulf interior region, or in basalt at Hanford. If a site is selected in salt or basalt at some other location, the impacts are likely to be similar; impacts at locations in other media would be less similar.

Tables 4-10 and 4-11 present the impacts of alternative 3 from the two points of view. Table 4-10 describes changes in the predicted local impacts of an HLW repository if it is expanded to accept TRU waste. Table 4-11 describes differences in impacts on a national scale. By combining the impacts of the WIPP with those at the expanded HLW repository, alternative 3 would generally achieve a reduction in overall impacts; for this reason most of the entries in Table 4-11 are decreases.

Table 4-10. Local Impacts of Alternative 3: Changes in Predicted Impacts at an HLW Repository Because of the Addition of TRU-Waste Disposal

Impact	Change: At HLW repository in salt[a]	Change: At HLW repository in basalt at Hanford
Physical impacts		
Land use, excluding rights-of-way	Increase of less than 6% (25 acres)	Increase of less than 4% (25 acres)
Resources		
Construction materials	Increase of perhaps 30-50%	Increase of up to 40%
Water and electricity	Substantial increase: water 90%, electricity 25%	Substantial increase: water 110%, electricity 35%
Liquid fossil fuels	Increase of about 2%	Increase of about 2%
Effluents	Small increase: 3-10%	Small increase: 3-10%
Mined-rock pile	Small size increase: 7%	Slight size increase: 3%
Conflict with mineral resources	No conflict in Gulf interior region; no additional conflict in Delaware basin	Probably no conflict
Socioeconomic impacts		
Construction costs	Small increase: 25%	Small increase: 8%
Operating costs	Possible increase up to 30%	Small increase: less than 15%
Work force	Increase of perhaps 35%	Increase of perhaps 27%
Population changes and service demands	Increase probably not a significant impact on resources of area	Increase probably not a significant impact on resources of area
Transportation impacts		
Radiation doses from normal transportation	Little change; increased population dose spread over many people	Little change; increased population dose spread over many people
Radiation doses from accidents	Small increase in probability of an accident	Small increase in probability of an accident
Impacts during operation		
Routine radiation doses to population	Little change	Little change
Radiation doses from accidents	No change that would produce doses comparable to those from natural background radiation	No change that would produce doses comparable to those from natural background radiation
Possible long-term impacts		
Possibilities for breach of repository	Scenarios similar to those at the WIPP; site selection will insure no increase in predicted risk	Scenarios different from those at the WIPP; site selection will insure no increase in predicted risk

[a]Dome salt in the Gulf interior region or bedded salt in the Delaware basin.

Table 4-11. National Impact of Alternative 3: Differences Between the Impact of an Expanded HLW Repository and the Combined Impacts of Separate Repositories for High-Level Waste and for TRU Waste

Impact	Difference: Expanded HLW repository in salt[a]	Difference: Expanded HLW repository in basalt at Hanford
Physical impacts		
Land use, excluding rights-of-way	Decrease of about 15%	Decrease of about 10%
Resources		
Construction materials	Decrease of perhaps 20-25%	Decrease of perhaps 15-20%
Water and electricity	Decrease of perhaps 15-35%	Decrease of perhaps 20-35%
Liquid fossil fuels	Decrease of less than 3%	Decrease of less than 4%
Effluents	Little difference	Little difference
Mined-rock pile	No difference in total volume	No difference in total volume
Conflict with mineral resources	In Gulf interior region, removal of conflict; in Delaware basin, no difference in conflict	Removal of conflict
Socioeconomic impacts	Small decrease: perhaps 17%	Small decrease: perhaps 7%
Construction costs	Decrease: perhaps 20%	Decrease: perhaps 10%
Operating costs	Decrease: about 10%	Decrease: about 10%
Work force	Little difference	Little difference
Population changes and service demands		
Transportation impacts		
Radiation doses from normal transportation	Predicted small increase: 1 man-rem over several million people	Predicted small decrease: 1 man-rem over several million people
Radiation doses from accidents	Little difference	Little difference
Impacts during operation		
Routine radiation doses to population	No difference	No difference
Radiation doses from accidents	No difference	No difference
Possible long-term impacts		
Possibilities for breach of repository	Site selection will insure no increase in predicted risk	Site selection will insure no increase in predicted risk

[a]Dome salt in the Gulf interior region or bedded salt in the Delaware basin.

4.3.1 Assumptions

Each of the expanded repositories will receive spent fuel, defense high-level waste, and a lesser amount of other high-level waste such as spent-fuel cladding; it will handle about 45 to 65 HLW packages per day. It will be designed to receive defense TRU waste at the rates for which the WIPP has been designed: 1.2 million cubic feet per year of contact-handled waste with three-shift-a-day operation and 10,000 cubic feet per year of remotely handled waste. The extra buildings required for TRU-waste disposal will not be so numerous as those in the complete WIPP plan, because many of the WIPP buildings--the administrative buildings, for example--will not need to be duplicated. Furthermore, the designs for the WIPP include provision for remote handling that will not need to be duplicated in the extensive HLW-handling areas. The expanded repositories will require an extra shaft for moving TRU waste underground.

The extra underground excavation required at an HLW repository in salt will be extensive--approximately the entire 2 million tons of salt proposed in the WIPP design. The excavation estimate for an HLW repository in a Gulf interior salt dome calls for the removal of 33 million tons of salt (DOE, 1979b, p. 3.1.102). The excavation for TRU waste, to be performed on a second level in the dome, will therefore add about 6% to the excavation for HLW emplacement. A similar increase will be needed at a repository in the Delaware basin.

Because heat-producing waste can be emplaced more densely in basalt than in salt, more waste can be put in a basalt repository than in a salt repository, and the basalt repository will operate longer; for this reason the GEIS predicts that 90 million tons of basalt will be removed. The addition of TRU-waste disposal will add roughly 2% to the mined weight, or about 3% to the mined volume, since basalt is roughly 20% more dense than salt. There will be no separate level for the disposal of TRU waste, which will be emplaced at the same depth as high-level waste; the 3% increase in mined volume will therefore come from a horizontal expansion of the single HLW level assumed in preliminary plans for a basalt repository.

4.3.2 Physical Impacts

The GEIS assumes that land preempted for an HLW repository, not including rights-of-way, will total about 440 or 700 acres in salt or basalt, respectively (DOE, 1979b, p. 3.1.107). The comparable area at the Los Medanos site is about 110 acres (Section 9.1.1); the total addition to the HLW repository would probably not exceed 25 acres because most of the WIPP land uses listed in Section 9.1.1 would not have to be duplicated. The local increase in land use at the HLW-repository site would therefore be less than 6%. On a national scale, the land used would decrease by 10% to 15% from the land used by the separate repositories for high-level and TRU waste.

The resources used in building the expanded repository for both high-level and TRU waste would not be greatly increased over those used for the HLW repository alone. The amounts of construction materials needed depend sensitively on details of the plant design. The GEIS predicts (DOE, 1979b, pp. 3.1.113, 116), for example, the use of 15,000 tons of steel for the first HLW repository in salt and 20,000 tons for the first repository in basalt; the comparable figure for the WIPP facility is 15,000 tons, only a fraction of which will be required at the expanded repository. If this fraction is roughly 0.5, the local increase in steel use would be about 50% at the dome-salt repository and about 40% at the basalt repository; the local increases in the use of copper (40% and 30%) and lumber (30% and 22%) would be smaller. On a national scale, the use of resources in construction would decrease; the decreases would range from 20% to 25% in salt and from 10% to 20% in basalt.

The resources used in operating the WIPP would be comparable to those used at HLW repositories. The GEIS predicts (DOE, 1979b, p. 3.1.116) electrical power demands of 43,000 and 29,000 kilowatts at the salt and basalt repositories; the WIPP estimate of 20,000 kilowatts suggests that the use of electrical power at the expanded repository might be substantially increased over the GEIS estimates--perhaps by 25% to 35%. Water use at the WIPP, estimated at roughly 6.5 million gallons per year, is larger than the uses predicted by the GEIS: 3.5 and 3.0 million gallons per year. On the other hand, the annual use of liquid fossil fuels at the WIPP (200,000 gallons) would be so much smaller than the use at HLW repositories (3.3 and 1.9 million gallons per year) that the incremental impact of TRU-waste disposal would be negligible. The entries in Tables 4-10 and 4-11 assume that half the use of resources predicted for the WIPP would occur at the expanded repository.

The amounts of effluents released during the operation of the WIPP would be small compared to those released from HLW repositories in salt and basalt. The GEIS predictions (DOE, 1979b, p. 3.1.117) for the release of nitrogen oxides, for example, are 625 and 565 tons per year; the WIPP prediction is only 49 tons per year. The GEIS predictions for particulate emissions (excluding dust) are 41 and 40 tons per year; the comparable WIPP prediction is only 3.2 tons per year. An expanded repository would accordingly produce only slightly more effluents than an HLW repository, and little decrease in national impacts would result from alternative 3.

The mined-rock pile would be larger at an expanded repository than at an HLW repository. About 6% more rock would be added to the pile if TRU-waste disposal were added to an HLW repository in salt. At an expanded repository in basalt, the pile would be only slightly larger than the pile predicted by the GEIS. Although this basalt pile would be three times as large as the pile predicted for an HLW repository in salt, a comparison of the two piles cannot rest only on their volumes. In the humid climate near the Gulf of Mexico measures must be taken to contain or remove the pile, which would otherwise wash onto the surrounding land. At Hanford, which has a dry climate, the basalt pile can probably be left standing at the surface.

Conflict with mineral resources may not be an impact of the expanded repositories in salt domes or basalt. Although hydrocarbon resources are sometimes found near salt domes, none exist within or beneath the domes themselves. No mineral resources are thought to exist beneath the basalt at Hanford, though further exploration would be required to establish this expectation rigorously. The conflict with mineral resources beneath the Los Medanos site would probably continue at an expanded repository in the Delaware basin.

4.3.3 Socioeconomic Impacts

The socioeconomic impacts of adding TRU-waste disposal to an HLW repository stem from the expenditure of additional money for construction and operation and from the creation of additional jobs.

The GEIS estimates (DOE, 1979b, p. 3.1.133) construction costs of $1000 million and $3100 million for HLW repositories in salt and basalt, respectively; the WIPP design and construction cost is $497 million. If roughly half of the WIPP costs were to be incurred in the additions to an HLW repository, the local increases in construction costs would amount to about 25% and 8% in salt and basalt, respectively; the national cost reductions would be about the same percentages. The changes in impacts arising from construction costs would therefore be barely appreciable.

The GEIS estimates (DOE, 1979b, p. 3.1.134) operating costs for a salt repository at $590 million over 15 years and for a basalt repository at $2390 million over 24 years. The corresponding cost for the WIPP, over 25 years, would be $600 million. To predict accurately the operating cost of an expanded repository for both HLW and TRU waste would require a careful estimate of the fraction of the WIPP cost to be added to the HLW repository cost. In the absence of designs for an expanded repository, this prediction is difficult to make. Since the two predicted operating costs of separate repositories in salt are roughly equal, the operation of the expanded repository in salt might be as much as 1.3 times as costly as the operation of an HLW repository there. At a basalt site the added cost of operation would probably be less than 15% of the original cost. Under these assumptions, the national reductions in operating costs might be 26% and 10% in salt and basalt, respectively.

A prediction of the work force at an HLW repository is uncertain because the plant designs are still in early stages. The GEIS predicts (DOE, 1979b, p. 3.1.127) 870 employees at an HLW repository in salt; other, unpublished, estimates range from 1000 to 1500. The GEIS predicts 1100 employees at an HLW repository in basalt. Of the 440 employees predicted for WIPP operation, probably all the underground workers (140) would be needed at an expanded repository; an undetermined number of the 300 employees at the surface would also be needed. Under the assumption that about 150 of these WIPP surface workers would be needed, the number of jobs added to an HLW repository would be about 300, an addition of 35% at a salt repository and 27% at a basalt repository. The national reductions in work force would be about 10% at either repository.

These increases in the work force would increase the socioeconomic impacts predicted for the HLW repositories. The GEIS predicts these impacts in terms of the number of people expected to move into the area around a repository and in terms of the increased demands for social services. Its predictions of these impacts vary among the repositories because the sites are in different areas of the United States. For example, the impacts are generally smaller at sites in the southeast than in the southwest; for this reason the socioeconomic impacts of the WIPP cannot be added directly to those of the dome-salt repository. Since none of the socioeconomic impacts predicted by the GEIS are likely to strain the resources of the areas near the repositories, the addition of TRU-waste disposal to HLW repositories would not severely affect those areas. The national impacts would change little.

4.3.4 Radiological Impacts of Transportation

The added impacts of transporting TRU waste to an HLW repository have been predicted by calculations of the population dose commitments that would result from shipping defense TRU waste to the Gulf interior region and to Hanford. Performed by the methods used in Section 6.7 to analyze normal transportation, these calculations predict dose commitments of 7, 8, and 6 man-rem for the transportation of TRU waste to the Delaware basin, to the Gulf interior region, and to Hanford, respectively. According to these figures, the impacts of transportation would, in principle, be barely larger in the Gulf interior region and smaller at Hanford; the smaller impact of transportation to Hanford is due primarily to the short distance between Hanford and the INEL, the primary source of TRU waste. On a national scale, the population dose commitments could be barely reduced by placing an expanded repository at Hanford; they would be increased by carrying the INEL waste to the Gulf interior region instead of the Delaware basin. Since all these population dose commitments are spread over several million people, there would be little change in transportation impacts, either locally or nationally, if alternative 3 is selected.

Because the addition of TRU-waste disposal to an HLW repository will require an increased number of shipments, the probabilities of transportation accidents on the way to the expanded repository would be greater than the probabilities associated with transportation to an HLW repository. If the HLW repositories receive 50 HLW packages each day, however, the added 2 packages a day of TRU-waste shipments will not greatly increase these probabilities. The possible accidents with TRU waste would not change. On a national scale, the probabilities would change slightly because of the changed distances.

4.3.5 Radiological Impacts During Plant Operation

The GEIS predicts (DOE, 1979b, p. 3.1.120) that emissions of radioactivity from an HLW repository, whether in salt or in basalt, will contribute a 70-year dose commitment to a regional population that will be no more than 100 man-rem. Since the corresponding dose commitments from WIPP operation are much smaller than 100 man-rem, adding TRU-waste disposal to an HLW repository would add little to the local impacts of routine operation; the same amounts of TRU waste would be handled in either the expanded repository or the separate repositories. Alternative 3 would offer no change in routine emissions on a national scale.

The consequences of accidents at an expanded repository for high-level and TRU waste would be dominated by the consequences of dropping a spent-fuel canister--the accident identified as the most severe at the HLW repositories examined in the GEIS (DOE, 1979b, p. 3.1.125). Because this accident is more severe than any of the WIPP handling accidents, adding TRU-waste disposal to an HLW repository would not make possible any additional accidents of greater severity than those already possible there. Handling the TRU-waste packages would increase the probability of an accident with waste of lower activity than spent fuel; as pointed out in Table 4-6, however, the population dose commitments from such accidents are much smaller than those from natural background radiation.

4.3.6 Possible Long-Term Impacts

As at the WIPP or at an HLW repository, no long-term release of radioactive material is expected at an expanded repository. Analyses of the consequences of hypothetical releases from HLW repositories are nevertheless under way; using methods similar to those of Section 9.7.1, these studies will postulate scenarios and determine their consequences.

The scenarios for release from salt domes in the Gulf interior region will probably be similar to those postulated in the WIPP studies (Section 9.7.1); most of them will involve intrusion by water that dissolves the salt and carries the waste. Some of the hypothetical events that breach the expanded repository will be different from the WIPP events because salt domes and salt beds have different geologic and hydrologic characteristics. Concern has been expressed for other potential long-term impacts of an HLW repository in a salt dome. Solution mining in the future could result in high radiation exposures if it inadvertently encountered the emplaced waste and if the radioactivity in the salt, used in food, were not detected. Extensive solution mining of an HLW repository is probably not credible, however, because of the markers and engineered barriers that will protect the sealed repository from inadvertent intrusion (DOE, 1980, p. II-225).

The scenarios for release from Hanford basalt will be much different from the WIPP scenarios. Because basalt is practically insoluble and shows little plasticity, the hypothetical events that introduce and drive the water are likely to be different; for example, flow along existing joints can be postulated in basalt, but not in salt. The effects of glaciers will appear in the scenarios for basalt. Direct drilling into a basalt repository is even more unlikely than drilling into a salt repository.

Although the conceivable mechanisms for breaching a repository are clearly different among the bedded-salt, dome-salt, and basalt sites, there is at present no evidence that any of the sites is safer than the others. Although each site has characteristics that could conceivably give rise to a breach of a repository in the far-distant future, the probability is low that such a breach could produce hazardous releases of radioactive material.

At an expanded repository for both TRU and high-level wastes, the effects of spent fuel would dominate the impacts of long-term releases; the releases from spent fuel have much more severe effects than the releases from TRU waste. Adding TRU-waste disposal to an HLW repository would barely increase the effects of long-term release. More important, no site will be selected if it appears to offer significant risks from long-term releases of either high-level or TRU waste.

4.3.7 Potential Use of the Los Medanos Site

Under alternative 3, the Los Medanos site could become a potential site of a repository for commercial high-level waste and defense TRU waste. The Los Medanos site does not appear to be in conflict with the draft criteria of the National Waste Terminal Storage (NWTS) program for qualifying sites for the disposal of commercial high-level waste (ONWI, 1980). Moreover, although the analyses of environmental impacts have focused on the use of the site for TRU waste, interpretations of the results of these evaluations have not developed any information that would eliminate the Los Medanos site as a potential site for an HLW repository.

Before there can be any decision to "bank" the Los Medanos site for possible use under the NWTS program as a site for the disposal of high-level waste, an environmental impact statement would have to be prepared (DOE, 1980). The analysis that would underlie this statement has not been done, but an idea of the effects at the Los Medanos site can be obtained by a comparison of information from the WIPP design and from the GEIS.

This comparison differs from that made in Sections 4.3.2 through 4.3.6 in that the point of view is the addition of high-level waste to a TRU-waste repository rather than the addition of TRU waste to an HLW repository.

No more land would need to be withdrawn, although the surface facilities could be four times as large, including a mined-rock pile 10 to 20 times as large. Because control zone II would remain 2000 acres in size, its interference with mineral resources would be unchanged.

Construction and operation would cost twice as much. The size of the work force would double. The use of resources would increase.

Transportation impacts would increase. The transportation of high-level waste would increase routine exposures and the probability of accidents; the increases would be similar to the exposures and probabilities predicted by the GEIS for an HLW repository. If an accident of extreme severity should occur, it could, in principle, be more severe than the accident postulated for the WIPP because there would be a larger amount and variety of radionuclides in a spent-fuel package than in an experimental-waste package.

During normal operations, careful handling of high-level waste will keep radiation doses to the surrounding population small. An accident with high-level waste would probably release more radioactivity than an accident in a repository for TRU waste alone.

The use of the Los Medanos site for HLW disposal would increase the predicted radiation exposure from hypothetical liquid-breach scenarios, mostly because of the much greater total quantity of radionuclides in a 2000-acre HLW repository than in a 100-acre TRU-waste repository. The direct-access scenario in which someone drills through an HLW canister would result in much higher radiation doses than the scenario for drilling through a TRU-waste canister.

The impacts of a subsurface exploratory program at the Los Medanos site for a potential HLW repository would be equivalent to those of the SPDV program described in discussing the impacts of alternative 2 and would be included in and bounded by the impacts of an HLW repository.

4.3.8 Summary and Comparisons

Adding TRU-waste disposal to an HLW repository in a Delaware basin salt bed, a Gulf interior region salt dome, or basalt at Hanford would slightly increase the local environmental impacts of the HLW repository. The local physical impacts would increase by fractions of the original impacts, probably no more than 50% and, for most of the impacts, much less. The local socioeconomic effects might increase appreciably around the salt-dome site because the expenditures for TRU-waste disposal might be a significant fraction of the costs of HLW disposal there; at a basalt site, where operating costs are higher, the added impacts would be smaller. The predicted exposures during the transportation of TRU waste to a salt dome are barely larger than the exposures during transportation to the Los Medanos site; the exposures during transportation to Hanford are barely smaller. None of these exposures is, however, comparable to exposures from natural background radiation. The predicted releases of radioactivity during repository operations with TRU waste are so small that they would not be a significant addition to the predicted small releases from an HLW repository. There is no reason to expect that adding TRU waste to an HLW repository in either salt or basalt would appreciably increase the probability of long-term releases of radioactive material.

At a site selected in the salt of the Delaware basin or the Gulf interior region or in the basalt at Hanford, the local impacts are likely to be similar; the principal differences would probably arise from differences in climatic conditions affecting the mined rock stored at the site and from differences in socioeconomic conditions around the site. The effects of breaching the repository in the distant future may differ from site to site; they cannot be evaluated, however, until specific sites have been selected.

At a site in shale, granite, or tuff, the local impacts are likely to be different. The GEIS (DOE, 1979b, pp. 3.1.104ff) analyzes HLW repositories in shale and granite; that analysis, which does not consider specific sites, predicts impacts about like those of the salt and basalt repositories. Until further study of shale, granite, and tuff has been carried out and sites have been identified, the impacts of repositories in them cannot be predicted. No analyses performed to date have suggested environmental reasons for rejecting these types of rock.

On a national scale, the disposal of TRU waste in an expanded HLW repository would decrease some of the impacts of operating separate HLW and TRU-waste repositories. The physical impacts would be reduced by amounts ranging up to 40%. The predicted socioeconomic impacts, many of which are beneficial to the local communities and states involved, would decrease by amounts ranging up to 25%. The impacts of transportation would be slightly greater if the expanded-repository site is in salt than if it is in basalt; the difference would, however, produce effects far smaller than those of natural background radiation. On a national level, there would be no difference in impacts from repository operation or, probably, from unexpected long-term releases of radioactivity.

4.4 ALTERNATIVE 4: A DEFENSE-WASTE FACILITY BUILT AFTER THE CONSIDERATION OF SITES IN ADDITION TO LOS MEDANOS

If the decision to build a facility for defense TRU waste is deferred until approximately 1984, additional sites will have been investigated. If these sites are suitable, it will then be possible in principle to choose a site in the Delaware basin or some other part of the Permian basin, the Gulf interior region, or Hanford. This section predicts the environmental impacts of repositories in these places. A full discussion of impacts at a site in the Delaware basin is not needed here, because they are discussed in Section 4.2; selecting a Delaware basin site in 1984 would simply delay the onset of the impacts. The effects of this delay are discussed in Section 4.4.1. Section 4.4.2 discusses the impacts of TRU-waste repositories in dome salt and in basalt. The impacts of a subsurface exploratory program to verify the suitability of the Los Medanos site under this alternative would be the same as those discussed for the SPDV program under alternative 2.

4.4.1 Impacts of Delaying the Authorized WIPP Project

The environmental impacts discussed in Section 4.2 are largely independent of the time when construction of the WIPP begins. For that reason the issues involved in delay are primarily other than environmental.

Delay of a project can be environmentally helpful if the time gained can be used to decrease the environmental impacts of the project; delay in the WIPP program, however, is not expected to reduce the impacts. Studies at the Los Medanos site will continue as needed whether or not the project is delayed, but the supplemental information these studies will provide is not expected to change the predicted impacts and risks significantly. Rather, this information will improve confidence in the risk predictions and narrow the uncertainties in them. Bounding calculations using the existing data are already sufficient to evaluate the potential impacts of the WIPP.

If the WIPP were delayed, the amount of TRU waste stored above the ground at the INEL would increase by about 10% per year at current generation rates, with corresponding increases in the costs of the current temporary-storage methods.

A major impact of delaying the WIPP would be the cost of closing out the current project and then reopening it several years later. To end the current programs would require carefully compiling, cataloging, and storing for future use all the documents already developed; negotiating and paying contractors' fees; and reimbursing contractors for the costs they will incur in terminating the programs. The total close-out cost is estimated at $3.2 million.

After a delay of roughly 4 years, the costs of designing and building the WIPP would have increased. Inflation, estimated at 8% per year for this analysis, would increase all the currently estimated costs of design, developing special waste-handling equipment, and constructing the plant. Moreover, restarting the design would require funds for assembling a new design team; it would also be necessary for this new team to review the earlier design work and revise it according to whatever new standards and methods have become applicable since the closing of the project. After the addition of a 25% contingency allowance to cover any other possibilities, the estimated cost of restarting the project would amount to an increase of $25 million (excluding inflation and including the $3.2 million close-out cost) over presently estimated costs.

Two alternatives have been considered for delay in removing TRU waste from the INEL, where it is now stored:

1. Delaying retrieval and processing until the waste is to be moved.

2. Retrieving the waste in the near future, processing it, and putting it into storage for the duration of the delay.

The differences between the environmental effects of these alternatives have been shown to be minimal in an analysis of INEL waste that assumed a 20-year delay for the first alternative and a starting date of 1985 for the second (DOE, 1979a, pp. 2-10 through 2-21). Even a 20-year delay would cause virtually no change in the environmental effects and radiological risks associated with retrieving, processing, and shipping TRU waste to the WIPP or another Federal repository. The radiological risk from the first alternative is negligibly larger than the risk from the second; the radiological exposures of either alternative would be much less than those from natural background radiation. The nonradiological effects would generally be limited to those associated with a commitment of manpower and the use of other resources. Maintenance and surveillance will be required even if the waste is left in place, as is.

Some degradation of the waste containers at the INEL could occur if retrieval were delayed for 20 years, but no release of radionuclides to the environment would be expected. Leaving the waste in Idaho for 20 years would slightly increase the probability of the release of radionuclides as a result of an improbable natural disaster. The risk, however, is small in comparison with that from natural background radiation.

Of the two delay alternatives, delaying retrieval at the INEL would cost, in constant dollars, an estimated $6 million less than retrieving and processing immediately (DOE, 1979a, p. 15-5). However, the cost savings would be only about 3% of the total cost of removing the waste from Idaho.

4.4.2 Impacts of TRU-Waste Repositories

If a TRU-waste repository is built in bedded salt in the Permian basin, in a salt dome in the Gulf interior region, or in basalt at Hanford, the general design of the plant would remain nearly the same as the WIPP design. The rates at which the waste is received and the handling methods would change little, if at all. The predicted environmental impacts would also change little; the changes would result mostly from differences in rock types, surrounding areas, and transportation routes.

Because there are no conceptual designs for TRU-waste repositories in dome salt and basalt, predictions of the changes in impacts must be qualitative. Table 4-12 compares the impacts of TRU-waste repositories at the alternative sites with the impacts of the WIPP (Section 4.2). Because the two alternative repositories in salt would exert similar impacts, Table 4-12 presents their impacts in only one column and notes differences where they are appreciable. The remainder of this section explains the entries in Table 4-12.

Physical impacts

Because the plant design and the operating methods will probably remain the same, a TRU-waste repository in a salt dome or in basalt would exert nearly the same physical impacts as a TRU-waste repository in bedded salt. The principal differences would appear in the effects of the mined-rock pile and in the conflict with mineral resources.

Although the mined-rock pile would be the same size at both sites in salt, the humid climate in the Gulf interior region could change its impacts. The impacts of the salt pile in the Delaware basin are expected to be small (Section 9.2), principally because of the dry climate there. Because heavier rainfall could, in theory, wash the mined rock onto surrounding land, preliminary plans for an HLW repository in the Gulf interior region involve special precautions to contain the pile. As another precaution, the salt not needed

Table 4-12. Changes from the Authorized-Alternative Impacts if a TRU-Waste Repository Is Built in Salt or Basalt

Impact	Change: Repository in salt[a]	Change: Repository in basalt at Hanford
Physical impacts		
Land use	No change	No change
Resources used	No change	No change
Effluents	No change	No change
Mined-rock pile	No size change; extra measures necessary to contain pile in Gulf interior region	Possible small decrease in size; little possibility of contaminating land
Conflict with mineral resources	Much reduced in Gulf interior region; perhaps reduced in Permian basin, depending on site	None known
Socioeconomic impacts		
Construction costs	No change	Increase
Operating costs	No change	Increase
Work force	No change	Little change
Population changes and service demands	Significant decrease in Gulf interior region; little change in Permian basin, depending on site	Significant decrease
Transportation impacts		
Radiation doses from normal transportation	No appreciable change in these small doses: 30% increase in Gulf interior region, and little change in Permian basin	No appreciable change: 10% decrease
Radiation doses from accidents	No change	No change
Impacts during operation		
Routine radiation doses to population	Increase in Gulf interior region because of larger surrounding population; little change in Permian basin; no change in maximum doses, all well below background	Increase because of larger surrounding population; no change in maximum doses, all well below background
Radiation doses from accidents	Same as for routine doses	Same as for routine doses
Possible long-term impacts		
Possibilities for breach of repository	Scenarios similar to those at WIPP; site selection will insure no increase in predicted risk	Scenarios different from those at WIPP; site selection will insure no increase in predicted risk

[a]Dome salt in the Gulf interior region or bedded salt in the Permian basin.

for backfilling would probably be removed from the site. These measures would probably keep the impacts of the mined rock from exceeding the impacts estimated for the Delaware basin site.

A basalt mined-rock pile may be slightly smaller because the storage cavities in the competent rock may be mined at a higher extraction ratio, with less necessity for strong pillars between tunnels. Furthermore, a basalt pile is not expected to be as damaging to surrounding land as a salt pile might be, especially in the arid climate of Hanford.

Conflict with mineral resources is one of the principal impacts of a repository in the Delaware basin. A repository elsewhere in the Permian basin might or might not exert this impact, depending on the specific site. A repository in dome salt, which overlies no valuable mineral deposits, would not exert this impact. Although it is not completely certain that no mineral resources lie beneath the Hanford basalt, no evidence has suggested that they are present.

Socioeconomic impacts

The impacts resulting from expenditures for construction and operation would change little if the TRU waste is disposed of at the alternative sites. These costs would be greater at Hanford because mining hard rock is more expensive than mining salt; a reliable prediction of the difference in cost would require a conceptual design for a TRU-waste repository there.

The size of the work force would probably not change unless the increased difficulty of mining basalt requires a significantly larger group of miners at Hanford. The population changes and demands for additional services will be smaller than those in the Delaware or the Permian basins because of the larger work force and increased social services already available in the Gulf interior region and at Hanford.

Transportation impacts

The impacts of transporting TRU waste to the alternative sites have been evaluated through calculations of population dose commitments. Performed by the methods used in Section 6.7 to analyze normal transportation, these calculations predict dose commitments of 7, 9, and 6 man-rem for the transportation of TRU waste to the Delaware basin (assumed to represent the Permian basin), to the Gulf interior region, and to Hanford, respectively. Since all three dose commitments are small, there would be little change in the transportation impacts summarized in Section 4.2.

The analyses of transportation accidents in Section 6.3 remain valid for alternative 4 because the same materials would be shipped in the same types of containers.

Impacts during operation

The normal release of radioactivity during routine plant operations would remain unchanged if the plant is built at one of the alternative sites. The maximum dose commitments received by persons near the plant would also remain the same. The total population dose commitment, expressed in man-rem, would increase because the population densities in the Gulf interior region and near

Hanford are greater than the population density in the Delaware basin. Because the dose commitments will remain much smaller than those from natural background radiation, the predicted effects of routine plant operation would change little.

The accidents postulated for the repository would remain the same at any of the alternative sites. Except for delivering doses to the larger population, their consequences would also remain unchanged, and no doses comparable to those from natural background radiation would be expected.

Possible long-term impacts

As explained in Section 4.3, the scenarios for breaching a decommissioned repository in the distant future will differ among the alternative sites, which have significantly different geologic and hydrologic characteristics. The development of these scenarios is now under way. The scenarios for breaching a dome-salt repository will probably resemble those postulated for the WIPP, with possibly more concern given to solution mining for the reasons discussed in Section 4.3; the scenarios for breaching a basalt repository are likely to be much different. Until these scenarios are completed and detailed analyses are carried out, no rigorous comparison of the long-term impacts of TRU-waste repositories at the alternative sites can be made. Studies to date, however, have shown no reason to expect that any of the sites is clearly safer than the others. No long-term releases are expected from any TRU-waste repository.

Summary

The environmental impacts of a defense-waste facility at one of the alternative sites would be nearly the same as the impacts of such a repository in the Delaware basin. The principal differences in the predicted impacts are due to the different mined-rock piles, to the absence of valuable mineral resources at the alternative sites, and to the different socioeconomic conditions prevailing in the alternative regions.

4.5 TABULAR COMPARISON OF ALTERNATIVES

Table 4-13 lists in highly condensed form the major impacts of the authorized alternative; it compares these impacts with those of alternatives 3 and 4. This summary of the material presented in this chapter omits many facts that must be considered in comparing the alternatives. The table is an oversimplification unless used with the discussions and tables presented in the rest of the chapter.

Alternative 1, the no-action alternative, would be expected to exert only small environmental impacts in the short term, during the next several decades, barring an unlikely natural catastrophe. In the long term, however, it is environmentally unacceptable as an option for the permanent disposal of TRU waste because it leaves the waste at the surface, exposed to possible volcanic action or human intrusion. Although the remaining three alternatives have impacts that are predicted to be small in both the short term and the long term, none of them is so clearly superior to the others that it can be selected on environmental grounds alone. Alternative 2, the WIPP in southeastern New Mexico, is the alternative authorized by legislation. Alternative 3, the disposal of the TRU waste stored at the INEL in the first HLW repository, is the preferred alternative because it is the one that is the most compatible with the President's proposed national program for the management of radioactive waste. The environmental impacts of alternative 4 would be comparable to those of alternative 2.

Table 4-13. Comparison of the Environmental Impacts of Alternatives 3 and 4 with the Environmental Impacts of Alternative 2

	Alternative 2	Alternative 3	Alternative 4
Basis for comparison with alternative 2		The changes in impacts caused by expansion of HLW repository	The impacts of alternative 2
Physical impacts	Withdrawal of about 1100 acres now used for grazing by fewer than 16 cattle	Commitment of about 25 additional acres at HLW repository	Same amount of land withdrawn; current uses depend on site
	Sterilization of 30 acres by mined-rock pile	Increase in stored-rock volume of up to 7%	Little difference in volume of mined-rock pile; long-term effects could be smaller if rock is other than salt
	Denial of access to 3% to 10% of U.S. langbeinite	Possible avoidance of conflict with mineral resources, depending on site	Possible avoidance of conflict with mineral resources, depending on site
Socioeconomic impacts	Injection of $138 million into two-county economy; permanent population increase of 1200	Increase in spending near HLW repository of up to 25% in construction and of up to 30% in operation; roughly 30% increase in work force	Spending equal to WIPP spending or significantly higher, depending on site; little or no change in population from WIPP estimates
	Possible temporary housing shortage; need to increase community services several months earlier than without the project	Possibly no significant increase in demands for services near HLW repository, depending on site	Possible decreases in demands for services, depending on site
Radiological impacts of transportation and operation	Normal transportation and operation: dose commitments much smaller than natural background doses	Normal transportation and operation: little change in dose commitments	Little change in impacts of normal transportation; slight increase in population doses from normal operation
	Accidents: extremely severe transportation accident could produce dose commitments seven times natural background doses; accidents at plant contribute a fraction much below 1%	Accidents: slight increase in probability of accidents; no increase in severity of possible accidents	No change in predicted impacts of transportation accidents; slight increase in population doses from accidents during operation

Table 4-13. Comparison of the Environmental Impacts of Alternatives 3 and 4 with the Environmental Impacts of Alternative 2 (continued)

	Alternative 2	Alternative 3	Alternative 4
Long-term impacts	No release of radioactive material expected Hypothetical unlikely releases could produce doses or dose commitments amounting to a small fraction of natural background doses	No release of radioactive material expected Effects of hypothetical unlikely releases probably unchanged; detailed modeling unavailable	No release of radioactive material expected Effects of hypothetical unlikely releases probably little different from those at the WIPP; detailed modeling unavailable
Impacts of removing waste (impacts at retrieval sites, not at repository site)	Normal operation: dose commitments far below doses from natural background radiation Accidents: extremely severe, highly unlikely accidents could produce dose commitments smaller than doses from natural background radiation	Same as alternative 2 except for increase in volume of stored waste during delay	Same as alternative 2 except for increase in volume of stored waste during delay
Impacts of not proceeding with the authorized alternative		Cost ($3.2 million) of closing WIPP project	Cost of closing and reopening project

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5 Waste Forms

The design and the operation of the WIPP are based on the types and characteristics of the waste to be received there. This chapter presents the formal criteria that will govern the acceptance of waste at the WIPP; these criteria constitute a detailed description of the characteristics of the waste. A second section of the chapter presents the waste-acceptance criteria that were assumed in the analysis of environmental impacts; these assumed criteria were made more conservative than the actual criteria in order to predict upper limits to the impacts of the WIPP. The final section of the chapter discusses the selection of a technique for processing the waste before it is shipped for disposal.

Further information is provided in Appendix E, which details the radionuclide content and the radioactive-decay characteristics of the waste, and Appendix F, which outlines the waste-processing techniques that have been considered.

5.1 WASTE-ACCEPTANCE CRITERIA

In 1977, the U.S. Department of Energy (DOE) formed the Waste Acceptance Criteria Steering Committee (WACSC). The Committee initially consisted of technical personnel from DOE headquarters, DOE field offices controlling defense wastes, the Office of Waste Isolation, and the WIPP staff from Sandia National Laboratories. The Committee was later expanded to include representatives from the Rocky Flats Plant (the DOE's largest producer of defense transuranic (TRU) waste), the Office of Nuclear Waste Isolation,* and the Westinghouse Electric Corporation (the Technical Support Contractor for the WIPP).

The WACSC's task was to reconcile the interests of various agencies involved with the production, treatment, and disposal of defense TRU waste and to formulate workable, practical criteria for the acceptance of these wastes. In preparing the draft environmental impact statement for the WIPP, tentative acceptance criteria dated July 1977 were used. Since the draft was prepared, the WACSC has recommended criteria that have been formally approved by the DOE, and the WACSC has been disbanded. It is these revised, approved waste-acceptance criteria that are the basis of this document. They are summarized in Table 5-1.

*On July 1, 1978, the responsibilities of the Office of Waste Isolation were transferred to the newly created Office of Nuclear Waste Isolation, under the management of the Battelle Memorial Institute, Columbus, Ohio.

Table 5-1. Waste-Acceptance Criteria for Contact-Handled and Remotely Handled TRU Waste

Criterion	Contact-handled TRU waste	Remotely handled TRU waste
	WASTE FORM	
Combustibility	No limit, must be packaged in steel containers or overpack.	Same as for contact-handled TRU waste
Gas generation	Gas generation by all mechanisms must not exceed 10 moles/m^3 of disposal-room volume per year under repository conditions. In terms of waste composition, this criterion may be interpreted to mean that the average organic content of contact-handled TRU waste may not exceed 14 lb/ft^3 for waste in 55-gallon drums and 6 lb/ft^3 for waste in other containers.	No criterion; quantities are insignificant
Immobilization	Powders, ashes, etc., must be bound in glass, concrete, ceramic, or other approved matrix; free liquids are not allowed.	Same as for contact-handled TRU waste
Explosives	Not allowed.	Same as for contact-handled TRU waste
Pyrophorics	Small quantities (up to 1% of the waste by weight) of radionuclide-metal pyrophorics may be accepted with other waste forms if they are dispersed throughout the waste.	Same as for contact-handled TRU waste
Toxic and corrosive materials	Toxic materials allowed only with special materials procedures and precautions; corrosive materials will not be accepted.	Same as for contact-handled TRU waste
Sludges and free liquids	Sludges and other waste forms containing readily desorbable water under repository conditions will not be accepted; free liquids will not be accepted.	Same as for contact-handled TRU waste
	CONTAINER	
Design life	10 years to allow retrievability.	Same as for contact-handled TRU waste
Structure	Type A requirements.	Same as for contact-handled TRU waste
	PACKAGE	
Structure	Type A; any damaged container must be overpacked.	Same as for contact-handled TRU waste
Handling	Devices to allow handling by a forklift.	Axial lifting pintle
Weight	Less than 25,000 pounds.	Less than 7000 pounds
Dimensions	Not larger than 8 by 12 by 8.5 feet.	24-inch diameter, 10-foot length
Surface-dose rate	Not exceeding 200 mrem/hr; containers with a surface-dose rate in excess of 10 mrem/hr must be color coded.	Less than 100 rem/hr
Surface contamination	5% of 49 CFR 173.397.	5% of 49 CFR 173.397
Criticality	30-gallon drum, 100 grams fissile; 55-gallon drum, 200 grams fissile; DOT-7A, 350 grams fissile or less than 5 grams in any cubic foot.	49 CFR 173, Subpart H; less than 5 grams in any cubic foot
Thermal power	Container must be color coded if the thermal power exceeds 0.1 W/ft^3.	Less than 500 watts per canister

5.1.1 Definitions

Discussions of waste-acceptance criteria frequently use several terms that need to be defined clearly: container, package, overpack, combustible material, gas-producing material, and immobilized material. Each term is defined below according to its accepted meaning in this chapter. These are not official definitions, as precisely described in the WIPP waste-acceptance criteria. Rather, they are abstracted versions of the official definitions; they convey concepts and avoid specific detail.

Container: A drum, box, or canister that immediately surrounds the waste is the waste container. Any associated hardware such as liner material or "spiders" for spacing is considered part of the container.

Package: Once waste is placed inside the container, the container becomes an integral part of the waste. The waste and its container are called the waste package. It is the package that is emplaced in the WIPP.

Overpack: If required by the physical condition of the container or by surface-contamination levels, a supplementary layer of containment is placed over the original container that is then considered to be part of the waste. The supplementary containment is the overpack.

Combustible material: Any material that will sustain combustion in air when exposed to a temperature of 1475°F or less for a period of 5 minutes is combustible.

Gas-producing material: Any material that produces gas during its decomposition is gas-producing. Many materials, particularly organic materials, produce hydrogen, methane, carbon monoxide, and carbon dioxide by bacterial decomposition, radiolytic decomposition, thermal decomposition, or chemical reaction (corrosion).

Immobilized material: Any solid material that contains less than 1% (by weight) of powder (less than or equal to 10 microns in size) is considered immobilized. The intent of immobilization is to minimize the amount of respirable material in the waste packages.

5.1.2 Transuranic Waste

Transuranic waste is defined as waste contaminated with certain alpha-emitting radionuclides, the level of contamination exceeding 10 nanocuries per gram. The nuclides included are uranium-233 (and its daughter products), plutonium, and transplutonium nuclides; they characteristically have long half-lives and high radiotoxicity. Transuranic waste is categorized in two classes: contact-handled (CH) and remotely handled (RH).

A qualitative distinction between contact-handled and remotely handled TRU waste is made in this document: contact-handled waste emits so little radiation that workers can handle it without extensive shielding; remotely handled waste requires shielding or remote handling to protect operating personnel. Therefore, contact-handled TRU waste is distinguished from remotely handled

TRU waste on the basis of the surface-dose rate. Waste packages with surface-dose rates no higher than 200 millirem per hour are designated contact-handled TRU waste, and those with surface-dose rates higher than 200 millirem per hour are designated remotely handled TRU waste.

Contact-handled TRU waste

Contact-handled waste is that TRU waste whose radiation levels on the surface of the waste containers are low enough to allow contact (as opposed to remote) handling methods. About 98% (by volume) of the TRU waste produced in DOE installations is classified as contact-handled TRU waste.

Contact-handled TRU waste exists in a wide variety of physical forms, ranging from unprocessed general trash and concrete-stabilized sludge to decommissioned machine tools and glove boxes. For acceptance at the WIPP, the following criteria restrict the form of the waste:

- Combustibility. Combustible TRU-waste materials will be accepted at the WIPP if they are packaged in containers that do not allow the spread of any credible fire.

- Gas generation. Total gas production from radiolytic decomposition, pyrolysis, corrosion, and bacterial decomposition is restricted to preclude any credible long-term gas-pressure hazard that could result in fracturing the sealed repository. The total gas produced from contact-handled waste by all mechanisms may not exceed 10 moles per cubic meter of disposal room in the WIPP.

- Immobilization. Dry powders, ashes, and similar particulate materials will not be accepted for disposal at the WIPP unless they are immobilized in a binder like glass, concrete, or ceramic.

- Sludges and free liquids. Sludges and other waste forms containing water that can seep from the waste under repository conditions will not be accepted at the WIPP. Free liquids will not be accepted.

- Explosives and compressed gases. Explosives and compressed gases will not be accepted for emplacement at the WIPP.

- Pyrophoric materials. Pyrophoric materials other than radionuclides will be accepted at the WIPP only if they have been rendered safe by mixing with chemically stable materials (e.g., concrete, glass) or have been processed to remove their hazardous properties. Also, up to 1% by weight of the waste in each package may contain pyrophoric forms of radioactive metals provided they are dispersed throughout the waste.

- Toxic and corrosive materials. Toxic substances contaminated with transuranic nuclides will be accepted at the WIPP provided that the toxic materials are identified and the WIPP operator is notified and grants approval before shipment. Corrosive materials contaminated with transuranic nuclides must be neutralized or otherwise rendered non-corrosive. Waste packages containing toxic materials must be color coded in accordance with WIPP standards.

The containers currently in use for contact-handled TRU waste are listed in Table 5-2. Most of the pre-1970 (buried) waste is in 55-gallon drums. Although drums are still widely used, the present trend is toward large plywood and metal boxes, which not only cost less per unit volume than drums but also make more efficient use of storage volume. At present, about 70% (by volume) of all contact-handled TRU waste is put into boxes, most of it in special plywood boxes. These boxes are about 4 by 4 by 7 feet in outside dimensions, are covered with a 3-millimeter layer of fiberglass-reinforced polyester (FRP), and are lined with polyvinyl chloride and fiberboard. They are approved by the U.S. Department of Transportation (DOT) and are known as DOT-7A containers. Since the WIPP waste-acceptance criteria require a metal overpack for all combustible boxes as a fire protection measure, the contact-handled TRU waste arriving at the WIPP will be in metal containers. The maximum acceptable size of a container is 8 by 12 by 8.5 feet. The maximum weight permitted is 25,000 pounds. All containers meet the minimum structural requirements of 49 CFR 173.398(b) for Type A shipping containers, and their designs are such that they can be expected to remain intact for a 10-year period to allow retrieval.

The radioisotope composition of contact-handled TRU waste varies widely among the DOE facilities that generate the waste. By volume, weapons-program waste is the largest component of the total TRU-waste inventory. The Rocky Flats Plant alone produces 40% of all DOE TRU waste. For this reason, the typical isotope composition of Rocky Flats waste is taken as representative of contact-handled TRU waste. Its composition is given in Appendix E, Tables E-1 and E-2.

The fissile-material content, based on transportation regulations, is a maximum of 200 grams for a 55-gallon drum and 350 grams for boxes. The average content has been observed to be 7.5 grams for a drum and 12.2 grams for the most common box used to store waste (4 by 4 by 7 feet). For other boxes, the maximum fissile-material content is 5 grams in any cubic foot of waste, with a maximum of 350 grams per box.

The maximum allowable surface-dose rate for a container of contact-handled TRU waste is 200 millirem per hour. The average surface-dose rate observed at the Idaho National Engineering Laboratory (INEL), where the Rocky Flats waste is stored, is about 3.1 millirem per hour, substantially below this limit. The average for 4- by 4- by 7-foot boxes is less than 1 millirem per hour, and the average for steel bins, 4 by 5 by 6 feet, is about 51 millirem per hour.

The thermal power of weapons-grade plutonium is about 2.4×10^{-3} watt per gram. Accordingly, a drum containing the maximum permitted plutonium content (200 grams) has a thermal power of about 0.5 watt, and a box containing 350 grams of plutonium has a thermal power of 0.8 watt. Of all the contact-handled TRU waste expected at the WIPP, a very small percentage is heat-source plutonium, which has the greatest thermal power because of the presence of large amounts of the nuclide plutonium-238. The thermal power of heat-source plutonium is 0.45 watt per gram. Packages containing heat-source plutonium are limited in thermal power output by transportation regulations. A 55-gallon drum is limited to 10 watts. The limit for 4- by 4- by 7-foot boxes is 250 grams or 113 watts. This limit has seldom, if ever, been reached.

Table 5-2. Types of Containers Used for Contact-Handled TRU Waste

Package description	Dimensions	Maximum gross weight (lb)	Package volume (ft^3)	Volume % of waste in fiscal year 1976-76A	Source: Hanford	Source: Savannah	Source: Los Alamos	Source: Oak Ridge	Source: Rocky Flats	Source: Mound Facility	Source: Other
DOT-7A FRP-coated[a] plywood box	4 by 4 by 7 feet	10,000	112	42.6					X	X	
55-gallon drum[b]	24 inches in diameter, 35 inches high	840	7.42	24.6	X	X	X	X	X	X	X
30-gallon drum	19 inches in diameter, 29 inches high	4.0	1.5				X	X			
Welded steel box	Random			0.8							X
FRP-coated plywood box	Random			24.2	X		X				
Corrugated metal pipe	2.5 inches in diameter, 20 feet long		98	2.4			X				

[a]FRP = fiberglass-reinforced polyester.
[b]The interior and exterior surface treatment and the weight of the drum (DOT-17C or 17H) vary with the user.

Remotely handled TRU waste

A small fraction (about 2% by volume) of the TRU waste generated by DOE facilities exceeds the limit of 200 millirem per hour on the surface-dose rate of contact-handled TRU waste. This waste is designated remotely handled TRU waste. The surface-dose rates of packaged remotely handled TRU waste range from 200 millirem per hour up to 100 rem per hour. This waste will be handled by shielded equipment designed especially for the purpose. The physical and chemical form of remotely handled TRU waste has not been well characterized.

The canister assumed for the remotely handled TRU waste is a right circular cylinder made of carbon-steel pipe 24 inches in outside diameter. The overall length of the canister is 10 feet. Inside, the waste occupies approximately 25 cubic feet. Containers are designed to Type A DOT specifications and are designed to remain intact for 10 years to allow for retrieval. Table 5-3 summarizes the canister properties.

There is no predominant source of remotely handled TRU waste. The existing waste contains a wide range of radionuclides. For design purposes and for use in analyzing postulated accidents, a hypothetical "reference" waste was assumed. This waste contains a fission-product distribution typical of the waste the Oak Ridge National Laboratory (ORNL) calls intermediate-level waste and an actinide inventory typical of weapons-grade plutonium at a maximum density of 5 grams per cubic foot of waste. Appendix E, Table E-3, characterizes the radionuclide content of this waste under average and upper-limit conditions.

An upper limit of 100 rem per hour is the maximum allowed dose rate at the surface of a canister containing remotely handled TRU waste. At present, there is no data base for estimating the average surface-dose rate. The surface-dose rate is a conservative maximum used for performing on-site radiation-shielding calculations and the safety analysis.

The thermal power density of the reference remotely handled TRU waste is 2.8 watts per cubic foot. The waste volume results in a thermal power of about 70 watts per canister.

5.1.3 High-Level Waste for Experiments

An isolated area of the WIPP will be dedicated to experiments intended to define the long-term behavior of various waste forms in a bedded-salt storage environment (Section 8.9). Most of the experiments will involve waste that produces high levels of heat and radiation; much of the waste will undoubtedly be prepared especially for the experiments.

The acceptance criteria for experimental waste have not been fully developed. It is planned to use both solid and granular bulk high-level waste in the experimental program. Granular bulk waste is simply solid vitrified waste broken into pieces ranging from about 1/64 to 4 inches in diameter. Intact (unbroken) experimental waste is used in the analysis to represent all waste in the experimental program at the WIPP. The solidification of these products gives rise to wastes with different nuclide contents because the amount of waste placed in each container is adjusted to limit the thermal loading.

For design purposes and postulated-accident analysis, a reference experimental waste has been chosen. It is the output of the proposed Savannah River solidification plant and is spiked with cesium-137 to increase its thermal power density.

The properties of the canister assumed for the experimental waste are included in Table 5-3. The reference canister is a right circular cylinder made of stainless-steel pipe that is 12.75 inches in outside diameter, with end caps welded at both ends. The overall length is 6 feet. The weight of a filled high-level-waste canister is about 1000 pounds. With allowances for glass shrinkage on cooling and with an appropriate weld-zone clearance, the net volume of solidified high-level waste in a canister is 3.8 cubic feet (107 liters).

In Appendix E, Table E-4, the radionuclides present in high-level waste are quantified in terms of curies per liter of waste.

5.2 ACCEPTANCE CRITERIA ASSUMED FOR ANALYSES REPORTED IN THIS DOCUMENT

The following assumed criteria are used in predicting the environmental impacts of shipping TRU waste and handling it at the WIPP:

- No explosive materials
- No pressurized gases
- No free liquids
- Pyrophoric materials allowed (1% assumed)
- Combustibles allowed (25% assumed)
- 10% of waste in powder form

These assumptions produce the maximum environmental impacts in transportation and in-plant accidents (fires and container failures followed by releases). There would be no releases due to container failure if no portion of the waste were in powder form; releases due to fire would be minimized if the containers did not contain combustible and pyrophoric materials. These assumed criteria, allowing combustibles and pyrophorics and 10% of the waste in powder form, are therefore conservative in that they tend to overestimate potential impacts.

Inasmuch as a decision has yet to be made on how to prepare the TRU waste for shipment for disposal in a geologic repository, the INEL studied several reprocessing options (Section 9.8.3), ranging from complete incineration by slagging pyrolysis to simply shipping the waste as is. Incineration has the greatest impact at the INEL. However, if the waste is incinerated by slagging pyrolysis, the resulting waste form will not have pyrophoric or combustible materials left in it, and none of it will be in powder form.

Thus, the assumptions made for the analysis of reprocessing are inconsistent with those made for the analyses of impacts of transportation and of handling accidents during operation. The use of different assumptions for

Table 5-3. Characteristics of Remotely Handled Waste Containers

Characteristic	Remotely handled TRU waste	High-level waste for experiments
Construction material	Schedule 10 carbon steel	Schedule 40 stainless steel
Outside diameter, inches	24	12.75
Length,[a] feet	10	6
Container volume, cubic feet	31.4	4.4
Volume of waste, cubic feet	25	3.8
Loaded weight, pounds	Varies	1000
Maximum design weight, pounds	7000	NA[b]
Thermal power, watts	70	1070
Maximum design thermal power, watts	500	NA

[a]Includes handling pintle.

[b]NA = not applicable; reference-waste properties (container weight, thermal power) constitute maximum design levels.

waste characteristics is conservative. One "worst-case" set is used in analyzing the impacts of shipping the TRU waste to, and handling it at, the WIPP. Another "worst-case" set is used in analyzing the impacts of preparing the waste for shipment.

5.3 PROCESSING OF TRANSURANIC WASTE

The waste-acceptance criteria described in Section 5.1 and listed in Table 5-1 do not specifically require that existing TRU waste be processed before being sent to the WIPP. The decision on whether to process is yet to be made; nevertheless, processing may be desirable for disposal in the WIPP or the first available high-level-waste repository. It would make assaying the waste for TRU-nuclide content easier, reduce the waste volume, and be a means of insuring that the waste meets the acceptance criteria by eliminating moisture and fine particulates and thus exceeding the requirements of those criteria.

Incineration is considered the most feasible processing alternative, if the decision is made to process the waste. Numerous analyses have been conducted at the INEL to evaluate the merits of various incineration systems. The analyses were made in terms of the July 1977 draft acceptance criteria; they assumed that 10% combustible and no pyrophoric or gas-producing material would be allowed in the processed waste. In addition, they assumed that the product had to be immobile to meet the waste-acceptance criteria. The analyses examined, in addition to incineration, combinations of pretreatment processes, incineration, and residue-immobilization processes.

The first analysis (FMC, 1977) evaluated the nine radioactive-waste incineration processes described in Appendix F. Because many of the investigated incineration processes produce residues that are not immobile, it was necessary to consider immobilization for treating the residues. The 11 immobilization processes that were considered are also described in Appendix F.

The waste-treatment process judged most desirable in four separate studies was slagging pyrolysis (FMC, 1977; Cox et al., 1978, EG&G, 1977; Kaiser Engineers, 1977), which requires a minimum of waste preparation before incineration and no further immobilization after incineration. In the slagging-pyrolysis process, the waste and an inert material like soil are melted together, driving off all moisture and volatiles and incinerating all combustibles. The output of this process is a basaltlike glass slag that is inert, has no combustible or gas-forming material, is resistant to leaching, and can be cast into any shape or size. The superiority of the slagging-pyrolysis incinerator comes from its ability to accept a waste feed with a minimum of sorting and sizing and to produce a residue that, when cast and cooled, does not need further processing. The process also reduces the volume of the original waste material by 50%.

Although some of the studies were conducted for the buried waste at the INEL, their findings are also applicable to the processing of waste that is retrievably stored at the INEL. Furthermore, the analyses, although based almost solely on the characteristics of the defense TRU waste at the INEL, are believed to be applicable to defense TRU waste from other sources.

REFERENCES FOR CHAPTER 5

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6 Transportation of Waste to the WIPP

This chapter reviews and evaluates the main features of transporting radioactive waste to the WIPP: the regulations governing such transport and the organizations responsible for them, the packages and packaging systems used for the waste, the routes over which the waste is likely to travel and the range of routing controls that can be exercised, the volume of transported waste and the number of shipments, the cost of transporting the waste, the radiological effects of waste transportation under both normal and accident conditions as well as under conditions simulating intentional destructive acts, the nonradiological effects of transportation accidents, and the insurance coverage of shipments.

6.1 REGULATIONS

The transportation of radioactive waste to the WIPP will comply with the regulations of the U.S. Department of Transportation (DOT) and the corresponding regulations of the U.S. Nuclear Regulatory Commission (NRC). These regulations are designed to protect the public from the potential consequences of radioactive-material transport. The specific regulations that apply to the WIPP are found in the Code of Federal Regulations (CFR) under the following headings:

49 CFR 107	Rule-making Procedures of the Materials Transportation Bureau
49 CFR 127	(Proposed) Requirements of the International Atomic Energy Agency
49 CFR 171	General Information, Regulations and Definitions
49 CFR 172	Hazardous Materials Table and Hazardous Materials Communications Regulations
49 CFR 173	Shippers--General Requirements for Shipments and Packagings
49 CFR 174	Carriage by Rail
49 CFR 177	Carriage by Public Highway
49 CFR 178	Shipping Container Specifications

These regulations insure safety through standards for packaging, handling, and routing radioactive materials.

The terms "packaging" and "package" are used throughout this section. Packaging is defined as the shipping container; package is defined as the container and its radioactive contents.

6.1.1 Packagings and Packages

The primary means for insuring safety during the transport of radioactive material is proper packaging. Consequently, most of the regulations for the transport of radioactive materials are concerned with packaging standards.

Three aspects of packaging that apply to WIPP shipments are considered by the regulations:

1. Containment of the radioactive material, with allowance for heat dissipation if required.

2. Shielding from the radiation emitted by the material.

3. Prevention of nuclear criticality in fissile materials.

This section discusses each of these three aspects.

Regulations to insure adequate containment

Each radionuclide is classified in one of seven transport groups according to its potential hazard and toxicity. (The current transport groups may be replaced by those proposed in 49 CFR 127.) Radionuclides in the more hazardous transport groups are restricted to smaller amounts per package; that is, for any single type of packaging, less activity of a more hazardous radionuclide is allowed per package. For example, since plutonium-239 is in Transport Group I (the most hazardous group) and strontium-90 is in Group II, less plutonium-239 activity is allowed per package than strontium-90 activity.

The regulations allow radionuclides to be shipped in different types of packagings, depending on the total radioactivity in the package. Of importance to this document are Type A and Type B packages. A Type B package is allowed to contain more activity of a particular nuclide than a Type A package. The limits for these two package types are different for each transport group. For example, the current regulations allow up to 0.001 curie of plutonium-239 (Transport Group I) to be shipped in a Type A package; for strontium-90 (Transport Group II) this limit is 0.05 curie.

All packagings must at least meet the requirements for a Type A packaging as described in 49 CFR 173.393 to prevent the dispersal of their radioactive contents and to shield people from the contents during normal transport. These packagings must pass tests that simulate the extreme conditions of normal transport; the tests are outlined in 49 CFR 173.398.

Quantities of radioactive material exceeding Type A packaging limits can be transported only in Type B packagings, which are strongly accident-resistant containers of various shapes and sizes. Any Type B packaging design placed in service must be certified by either the NRC or the DOE. The DOE may certify the design of a packaging, such as those designed by a DOE contractor for use by the DOE, if it satisfies the general packaging and shipment requirements found in 49 CFR 173.393. In addition to meeting the standards for Type A packagings, a Type B packaging must survive certain severe hypothetical-accident conditions that demonstrate resistance to impact, puncture, fire, and submersion in water (49 CFR 173.398). The ability of the packaging to survive must be proved by full-scale testing or by analysis. To be judged as surviving, a Type B packaging must not release any of its radioactive contents except for limited releases of contaminated coolant or gases. The allowable releases are defined in 49 CFR 173.398. Furthermore, the radiation-dose rate outside a Type B packaging must not exceed 1 rem per hour at a distance of 3 feet (49 CFR 173.398) after the testing sequence.

Surface contamination on packages, which might be transferable or even dispersible, is limited to levels specified in 49 CFR 173.397, a regulation that also describes the method for assessing the amount of contamination on the surface.

Regulations controlling radiation exposure

As a practical matter, the radiation emitted by the radioactive contents of a package is not completely absorbed by the packaging, but the radiation that is allowed to escape packaging must be below specified limits that minimize the exposure of the public. Packages that will be handled only by the shipper and the receiver (i.e., packages shipped in exclusive-use or sole-use vehicles) may not exceed the following dose-rate limits:

1. 1000 millirem per hour at a distance of 3 feet from the external surface of the package (in a closed transport vehicle only).

2. 200 millirem per hour at any point on the external surface of the car or vehicle (in a closed transport vehicle only).

3. 10 millirem per hour at any point 6 feet from the vertical planes projected by the outer lateral surfaces of the car or vehicle; or if the load is transported in an open transport vehicle, at any point 6 feet from the vertical planes projected from the outer edges of the vehicle.

4. 2 millirem per hour in any normally occupied position in the car or vehicle, except that this provision does not apply to private motor carriers.

Almost all, if not all, packagings will provide sufficient shielding to reduce radiation levels well below these specifications.

Regulations to prevent nuclear criticality

The criticality standards for packages containing fissile materials are found in 49 CFR 173.396. A packaging used to ship fissile material must be so designed that it is subcritical in the most reactive configuration that is credible for the form of the material and for optimal conditions of neutron moderation and reflection by water. The number of such packages that may be transported together is also limited. Some quantities and forms of fissile materials cannot be made critical under credible conditions and are exempted from special fissile-material requirements.

6.1.2 Handling

During handling, the carrier of radioactive materials must perform special actions in addition to those required for other hazardous materials. Since the safety of radioactive-material transport is primarily governed by packaging-design regulations, the special actions are largely limited to administrative actions such as documenting, certifying, and placarding. However, one important action is to insure that radiation levels are not exceeded in any shipment. A special transport index (dose rate in millirem per hour at 3 feet from the accessible exterior surface of the package) was developed to aid the carrier in maintaining radiation levels within allowable limits.

6.1.3 Routing

The DOT is establishing routing regulations for the transport of radioactive materials by public highway. When officially adopted, they will be included in 49 CFR 177. The objectives are to reduce the impacts of transporting radioactive waste and to identify the role of state or local governments in the routing of radioactive materials. The proposed regulations are based on the belief that reducing the time in transit will decrease the overall transportation impacts. The proposed regulations, as applicable to WIPP shipments, require that shipments be made on interstate highways that are not restricted by state regulations or on alternative highways proposed by states through which shipments are made. Other requirements that apply to WIPP shipments include regulations requiring written route plans that must be prepared by the carrier in advance and specific regulations for driver training. The proposed regulations also allow states and local authorities to regulate routes provided their regulations are not inconsistent with those of the DOT.

Concurrently with the DOT, the New Mexico Environmental Improvement Board has also written a set of proposed regulations. The 1979 New Mexico Legislature gave the Board authority to regulate the transport of radioactive waste on New Mexico highways. The present draft regulations, however, do not clearly define to whom the regulations apply. The State regulations, if they apply to the WIPP, would require State licensing of WIPP truck carriers; restriction of trucks carrying WIPP shipments to interstate highways, when possible, to minimize the time in transit; avoidance of highly populated areas and hazardous road conditions when traveling on roads other than interstate highways; and advance notice of shipments for large quantities (more than 1000 curies) of radioactive material like the remotely handled TRU waste to be emplaced in the WIPP and the defense high-level waste to be used in WIPP experiments.

Other states traversed by potential routes to the WIPP, such as Colorado and Texas, are considering routing regulations. The State of Louisiana has issued routing prohibitions for high-level-waste shipments. Even though there may be some differences among them, the regulations promulgated by the various states will all have to be consistent with the forthcoming DOT regulations, or else they will be preempted. As a result, the preceding discussion of DOT and New Mexico regulations should adequately describe most routing contingencies for truck shipments to the WIPP.

The DOT and State of New Mexico regulations are proposed and have not been promulgated. Once in effect, these regulations may affect truck routing to the WIPP since the DOE will comply with DOT and any State or local regulations that are applicable to the transport of waste to the WIPP.

No additional regulations are currently proposed for rail transport. Any special routing regulations to be proposed in the future must consider many factors: distances, road-bed conditions, population distributions, and the use of special trains. Specific regulations must be reviewed carefully and individually because the risk from transportation accidents has two components: probability of occurrence (determined, for example, by distances, road-bed conditions, and equipment) and consequences (determined, for example, by the population distribution). If the consequences are reduced by avoiding population centers, for example, the extra mileage traveled may increase the probability of an accident, possibly increasing the risk. Furthermore, rails between and through population centers are often in better condition than those in lesser-used routes skirting population centers. The poor road-bed conditions encountered by avoiding population centers might therefore increase the probability, and hence the risk, of an accident. Actions like these would intuitively seem to reduce risk, but they may, in fact, increase risk.

If a particular route is specified for rail shipments, the shipper must use a "special train." A special train is dedicated to the transport of radioactive waste with no other freight on board; it is operated under restrictions governing, for example, speed and passing. Several studies have examined the change in impact resulting from the exclusive use of special trains for shipping radioactive materials.

These studies concluded that the use of special trains would not significantly reduce the radiological risk of radioactive-material transport or increase its overall safety. Justification for not using special trains, despite recommendations to the contrary by members of the Association of American Railroads, can be based on the conclusions of three documents: an environmental statement published by the NRC (1977), a report issued by Sandia National Laboratories (Smith and Taylor, 1978), and an environmental impact statement issued by the Interstate Commerce Commission (ICC, 1977). After considering the benefits of special trains cited by the Association of American Railroads (benefits that include the likelihood of less accident damage, fewer derailments, less switching, easier cleanup after an accident, and less time in transit), the NRC document concludes that the reduction of normal and accident risks for the shipment of spent fuel would be very small. Smith and Taylor (1978) conclude that, for the transport of radioactive materials associated with the nuclear fuel cycle, the use of special trains slightly increases the total radiological impact. Finally, the ICC (1977) environmental impact statement on the transportation of radioactive materials by rail concludes that special trains increase both nonradiological and radiological risks under normal conditions while decreasing radiological risks under accident conditions, although the estimated incremental increases or decreases are very small. In summary, the use of special trains does not measurably reduce the radiological impacts of transportation and in some cases may even increase them.

6.1.4 Vehicle Safety

No additional or special vehicle regulations are imposed on the carrier of radioactive materials beyond those required for a carrier of any hazardous material. Vehicle safety is insured by other Federal regulations, which are not specific to vehicles carrying radioactive material. For example, truck safety is governed by the Bureau of Motor Carrier Safety, which imposes vehicle-safety standards on all truck carriers (49 CFR 325, 386-398). Along with other functions, the Bureau conducts unannounced roadside inspections of vehicles and drivers. During an inspection, the condition and loading of the vehicle and the driver's documents are checked. These checks are performed on all truck carriers, however, not just those carrying radioactive material.

6.2 ORGANIZATIONS RESPONSIBLE FOR REGULATING TRANSPORTATION

6.2.1 Definition of Terms

Goods being transported are classified in two general categories: hazardous materials and nonhazardous materials. Hazardous materials are subject to more stringent controls during transport than nonhazardous materials. Radioactive materials are considered hazardous materials, and any material containing 0.002 microcurie or more of radioactivity per gram is considered radioactive material for regulating purposes.

The transport of radioactive materials is commonly carried out by three participants who have separate functions: shippers, carriers, and warehousers. Shippers offer materials for transport; they are responsible for packaging, marking, and labeling shipments before they give the shipments to a carrier. Carriers actually transport goods; they must properly identify their vehicles as carrying radioactive material and use the precautions specified by regulations while transporting shipments. Warehousers store materials, but no warehousers will be involved in the transport of radioactive waste to the WIPP because no waste will be stored at intermediate locations.

Carriers have been further classified into three types: private, contract, and common. Private carriers transport their own materials; that is, the shippers are the carriers. Contract carriers selectively transport materials for shippers under specific contracts. Common carriers transport materials for the general public under published tariffs and rate schedules. Any of the three types could be used for transporting waste to the WIPP; however, shipments will probably be made by contract or common carriers.

6.2.2 Organizations

Four Federal agencies will be involved in the transportation of radioactive materials to the WIPP: the Department of Transportation (DOT), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Interstate Commerce Commission (ICC). The DOT, the NRC, and the DOE deal primarily with safety, while the ICC deals primarily with the economics of transportation. Because the primary concern of this document is safety, the regulatory function of the ICC will not be discussed.

The DOT is responsible for regulating safety in the transportation of all hazardous materials; its regulations apply to shippers and all carriers. Under the Hazardous Materials Transportation Act of 1974, the DOT is authorized "to protect the nation adequately against the risks to life and property which are inherent in the transportation of hazardous materials in commerce." The DOT is specifically responsible for categorizing nuclear materials, providing design and performance specifications for packagings that will carry small quantities of nuclear materials not exceeding Type A quantities (see Section 6.1.1), and regulating the carriers that transport nuclear materials. In fulfilling these responsibilities, the DOT has promulgated detailed regulations that govern the packaging, shipping, carriage, stowage, and handling of radioactive materials by all transport modes.

The NRC is the regulator of the commercial nuclear industry. Specifically, it regulates the safety of certain commercial nuclear operations: the receipt, possession, use, and transfer of byproduct, source, and special nuclear materials (terms defined in 10 CFR 40.4 and 50.2). The regulatory authority of the NRC extends to most nuclear operations except the research-and-development operations of the Department of Energy and the Department of Defense. For the transport of nuclear materials, NRC regulations apply primarily to shippers. Another NRC responsibility is the provision of design and performance criteria for packagings that will carry quantities of nuclear materials greater than Type A quantities.

The DOE, through its management directives and contractual agreements with contractors, guarantees the protection of public health and safety by imposing on its transportation activities standards similar to those of the DOT and the NRC. The DOE has authority, granted by a 1973 memorandum of understanding between the DOT and the Atomic Energy Commission (Federal Register, Vol. 38, p. 8486), to certify DOE-owned packagings in accordance with existing DOT and corresponding NRC regulations. The DOE may design, procure, and certify its own Type B packagings (described in Section 6.1.1) to be used by the DOE or its contractors, provided the packagings comply with existing criteria.

The responsibilities of the three organizations overlap but can be stated simply. The DOT has primary responsibility for safety in transporting all hazardous materials, including nuclear materials, and it regulates shippers and carriers. The NRC is responsible for regulating the Type B packagings (see Section 6.1.1) used by commercial shippers, while the DOE has the authority to certify its own packagings for government shippers. The DOE certificate must indicate compliance with DOT and corresponding NRC regulations. Both the DOE and the NRC must require the shippers and private carriers under their authority to conform to DOT regulations, and efforts are made by both agencies not to duplicate DOT regulations with their own.

The responsibilities and authorities of the agencies are defined by several pieces of Congressional legislation and memorandums of understanding. The DOT's responsibilities are defined by the Transportation of Explosives Act, the Dangerous Cargo Act, the Federal Aviation Act of 1958, the Department of

Transportation Act, and the Hazardous Materials Transportation Act of 1974. The NRC's responsibilities are defined by the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, and Public Law 94-79. The DOE's responsibilities are defined by the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, and the Department of Energy Organization Act. Because of their overlapping responsibilities, these agencies have issued memorandums of understanding among themselves. The memorandum of understanding between the DOT and the Atomic Energy Commission in 1973 (Federal Register, Vol. 38, p. 8486) is partly superseded by the memorandum of understanding between the DOT and the NRC on the regulation of safety in the transportation of radioactive materials (Federal Register, Vol. 44, p. 38690), issued in 1979. Further clarification of responsibility will be provided by forthcoming memorandums drafted between the DOT and the DOE and between the DOE and the NRC.

In fulfilling its responsibility to comply with DOT and NRC regulations, the DOE, through its WIPP Project Office, will direct an operating contractor with management directives and contractual provisions. The DOE will also evaluate designs for packagings to be used for transporting waste to the WIPP; such packagings are presently being designed. The evaluation of designs must include the engineering tests described in later sections of this chapter, engineering evaluations, or comparative data; the engineering tests required by the DOT and the NRC demonstrate resistance to impact, fire, puncture, and submersion in water. The DOE contractor that ships waste to the WIPP will package the waste in these packagings for transport by a carrier. If contract or common carriers are used, the DOE will specify the destination of the shipment, but will not have the authority to direct routing; the DOT will regulate these carriers. If the DOE or the DOE's contractor operating the WIPP decides to become a private carrier, the DOE will select the routes to be followed as long as they are consistent with DOT routing regulations. No matter which type of carrier is selected, the shipment of waste to the WIPP will be governed by the regulations of the DOT.

6.3 PACKAGES AND PACKAGING SYSTEMS

Proper packaging design is the foundation of safety in the shipment of radioactive materials. All wastes transported to the WIPP will be shipped in packagings that comply with the regulations detailed in Section 6.1. To insure that packagings are safe and meet Federal regulations, the DOE will test and analyze packagings to be used for the WIPP. Work now under way is developing and testing these packagings. Most development and testing will be performed by a model-and-analysis approach that uses computer-modeling techniques to reduce the required number of full-scale experiments. Once the models have been thoroughly confirmed and validated, they will be used extensively to test the design of the packagings, eliminating much of the need for expensive full-scale testing. Even after the computer analysis has been performed, however, full-scale testing will be conducted for WIPP packagings. A formal safety analysis report for packaging, a report describing the packaging system and the analyses and tests performed to determine its acceptability, will be prepared for each packaging system. In addition, a quality assurance program will be carried out during the construction of the packagings and maintained during their actual use.

6.3.1 Contact-Handled TRU Waste

Most of the waste to be transported to the WIPP is contact-handled (CH) TRU waste. Contact-handled TRU waste is currently shipped from the Rocky Flats Plant near Denver, Colorado, to the Idaho National Engineering Laboratory near Idaho Falls in ATMX-600 series railcars under the provisions of DOT Exemption 5948, which allows the shipment of contact-handled TRU waste in ATMX railcars provided it is packaged in Type A polyethylene-lined drums or plywood boxes coated with fiberglass-reinforced polyester. In addition, drums are prepackaged in steel cargo containers (8 by 8 by 20 feet) that provide an effective third barrier for containment. Even though the ATMX system has not been tested under the hypothetical-accident conditions described in 49 CFR 173.398, it forms a containment system of multiple barriers that, as a single unit, is considered to be equivalent to a Type B packaging (Adcock and McCarthy, 1974).

Since the ATMX packaging system is presently used for shipping contact-handled TRU waste, it will be described in detail. The DOE-owned ATMX railcar has many safety devices, including roller-bearing wheels, shock-absorbing draft gear, interlocking couplers to prevent uncoupling in a derailment, and locking-type center pins to prevent the loss of the trucks (swiveling wheel carriages at each end of the railcar) under most circumstances. The underframe is a heavy one-piece steel casting reinforced by welded steel plates to produce a continuous floor. The superstructure is also very strong because of its massive cross-braced sides. The sides, constructed from steel armor, are designed not to buckle during a rollover. The ends of the car are heavily reinforced and designed with a slope that will deflect following or preceding cars over the roof of the car should an accident occur. This extremely strong railcar is appropriately described as able to withstand major catastrophes (Adcock and McCarthy, 1974).

Additional protection for contact-handled TRU waste shipped in the ATMX railcar is afforded by the Type A packagings placed inside. These Type A packagings can be either drums or boxes. Typically, the Rocky Flats drum is a DOT-17C 55-gallon steel drum with a molded polyethylene liner. The Rocky Flats box is a DOT-7A plywood box (4 by 4 by 7 feet) overcoated with a laminate of fiberglass-reinforced polyester and lined with polyvinyl chloride and fiberboard (Wickland, 1976).

A distinctly different packaging, called a Super Tiger, is currently certified for shipping Type B quantities of radioactive materials by both truck and rail. This alternative packaging for contact-handled TRU waste is presently the only packaging used for truck shipment. Although designed as a general-use packaging for the shipment of materials in Type B quantities, the Super Tiger is frequently used to hold Type A drums or boxes. It has the dimensions of a standard cargo container (8 by 8 by 20 feet) and can be handled, stored, and shipped like any standardized shipping container. The packaging is constructed from two rectangular steel shells separated with rigid fire-retardant polyurethane foam (Hansen, 1970).

The entire outer shell is fabricated from ductile low-carbon-steel plate. This material can elongate by nearly 40%, thus allowing the shell to deform severely without cracking. All corners are lap-doubled, continuously seam-welded along the overlapping edge, and reinforced with a layer of steel plate.

In addition, all external edges are protected with a diagonal gusset plate. One end of the shell is removable. Ten high-strength 1-inch-diameter bolts secure the end of the container to the body, and additional joint integrity is provided by four 1-inch-diameter steel dowel pins.

A special formulation of fire-retardant rigid polyurethane foam was developed for the Super Tiger. This foam, poured in place and allowed to expand between the two steel shells, provides excellent thermal protection and, because of its high energy-absorbing capability, an ideal shock-isolation medium as well.

The steel inner shell, approximately 6 by 6 by 14 feet, has a removable end cap. All edges or joints in the shell are overlapped and double-seam-welded like those in the outer shell. The inner end cover is attached by bolts and has a silicone seal.

The Super Tiger has been certified (Hansen, 1970) in accordance with the tests specified in 10 CFR 71, Appendix B, or 49 CFR 173.398. Nevertheless, some commentors on the draft of this environmental impact statement have alleged that the tests performed to certify the Super Tiger were not consistent with the requirements. Specifically, questions have been raised about the length of the pin used in the puncture test. The puncture test used to certify the Super Tiger is described below.

One of the tests described in 10 CFR 71, Appendix B, for the certification of Type B packagings is a 40-inch drop onto a 6-inch-diameter pin that is 8 inches long; this test is referred to as the 40-inch puncture test. The test was used not only to certify the Super Tiger but to provide design information for wall construction. A special Super Tiger was constructed, with each of its four sides fabricated to different design specifications. Three of the sides were made with breakaway plates of varying thicknesses, and a fourth was not. The fourth side also had the thinnest wall. The puncture test was conducted four times, once on each side. The three sides with breakaway plates were not indented more than 6 inches by the 8-inch-long pin. The fourth side--the one without breakaway plates and with the thinnest walls--was expected to fail. To obtain additional design information from the test of the fourth side, the 8-inch-long pin was replaced by a 24-inch-long pin, which could puncture the inner wall when the outer wall failed. The 40-inch drop onto the fourth side did, as expected, cause the failure of both the outer and the inner walls. The information obtained in this test made it possible to select the design of one of the other three sides that performed satisfactorily.

It is important to reiterate that each of four sides, constructed to different specifications, was subjected to the puncture test. One side was expected to fail and was made to fail more completely by increasing the length of the puncture pin. The design of this side was abandoned; it was not and is not used for Super Tigers.

Cost-effective packagings that can safely contain drums or boxes of contact-handled TRU waste are currently being developed for the WIPP. The packagings now being developed are expected to be used instead of the Super Tiger and the ATMX railcar for two reasons: the existing systems are not of the right shape and size for efficiently packing the drums and boxes that will be transported to the WIPP, and the existing systems, now 10 years old, can be improved by using recent advances in technology. As presently conceived, the design of these packagings, referred to as transuranic package transporters (TRUPACTs), calls for inner and outer containers that are separated by polyurethane foam. The inner container has a steel inner frame with stainless-steel sheets for sides; the outer container is similarly constructed except that carbon steel is used for the sides. The access to each container is through a hinged door that is sealed after loading; the seals on the two doors insure double containment. According to present proposals, a TRUPACT used for rail transport will contain forty-eight 55-gallon steel drums or eight metal boxes measuring 4.3 by 3.3 by 6.2 feet. With external dimensions of approximately 24 by 8.9 by 9.8 feet, this packaging is expected to weigh 12 tons and to have a maximum payload of 21 tons.

The development of a packaging proceeds in sequence through design, analysis, scale and prototype tests, and commercial fabrication. The conceptual design for the rail version of the TRUPACT was formalized during 1979. Detailed design and scale-model tests are scheduled for 1980, and a safety-analysis report will be prepared during 1980 and 1981. A prototype of the rail TRUPACT will be fabricated during 1981, and prototype testing and licensing will be completed during 1982 and 1983. Commercially produced TRUPACTs for rail transport are expected to be available during 1986. A TRUPACT for truck transport will be developed concurrently, with the development sequence paralleling the sequence for rail TRUPACTS. Commercially produced TRUPACTs for truck transport are also expected to be available during 1986. Production units could be available by 1987.

The packaging systems now being designed for the WIPP are intended to be totally compatible with regulatory requirements. They will be subjected to a full range of engineering tests. In addition, full-scale accident-simulation tests will be conducted with provisions for public participation and observation.

6.3.2 Remotely Handled TRU Waste

Remotely handled (RH) TRU waste, which will account for a small percentage of shipments to the WIPP, is commonly generated during the decontamination or decommissioning of facilities that have handled radioactive materials. Generally composed of piping, valves, machine tools, concrete rubble, etc., remotely handled TRU waste must be shipped in shielded containers. Although several packagings could be used for shipment to the WIPP, two likely configurations are (1) disposable shielded packagings (e.g., the concrete-shielded drums used by the Federal Republic of Germany at the Asse repository) transported like contact-handled waste and (2) canisters placed in reusable shielded packagings similar to those used for high-level waste. In either configuration, the waste shipments must be made in packagings that meet Type B specifications.

6.3.3 High-Level Waste for Experiments

High-level waste to be used in the WIPP experimental program will be placed in canisters before being transported. Canister designs under consideration range from 1 to 2 feet in diameter and 6 to 15 feet in length. The longer canisters could be transported in the casks now used for moving spent fuel from nuclear reactors; the shorter canisters would be transportable in shorter, lighter shipping casks, if such casks become available.

At present, there are no shipping casks designed specifically for transporting canisters of high-level waste. There are, however, two conceptual cask designs; each of these casks, if fabricated, would weigh 60 to 100 tons. One design (Peterson and Rhoads, 1978) uses a stainless-steel cavity lining surrounded by a lead gamma-radiation shield. The lead, in turn, is enclosed by a thick stainless-steel structural wall surrounded by a borated-water neutron shield. A thick stainless-steel outer wall equipped with cooling fins completes the body of the cask. The lid of the cask is made of depleted uranium and a solid hydrogenous material to provide shielding for gamma and neutron radiation, respectively. This cask, 14.5 feet long and 8.2 feet in diameter, would have a capacity of nine 1-foot-diameter, 10-foot-long canisters. Another design (Sutherland, 1978) uses a stainless-steel cavity lining surrounded by a layer of depleted uranium or lead as gamma shielding encased by a stainless-steel structural wall. Water or solid hydrogenous material provides neutron shielding. Copper fins for heat conduction extend from the outer structural wall through the neutron-shield zone. A layer of depleted uranium, incorporated into the end forgings, and a thick layer of hydrogenous material provide radiation shielding at the ends of the cask. This cask, 13.5 feet long and 5.5 feet in diameter, would have a capacity of seven 1-foot-diameter, 10-foot-long canisters.

6.4 ROUTES

The contact-handled TRU waste to be emplaced in the WIPP is currently intended to come primarily from the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Plant. At present, the Rocky Flats Plant ships its waste to the INEL, and most of the inventory at the INEL has come from Rocky Flats. By the time the WIPP is in operation, Rocky Flats is expected to process its waste and, for impact analysis, was assumed to ship it directly to the WIPP instead of to Idaho. Other sites that would ship their waste to the WIPP but are not directly considered in the impact analysis include the Hanford complex in southeastern Washington, the Los Alamos National Scientific Laboratory in north-central New Mexico, and the Savannah River Plant in South Carolina.

In arranging for waste transportation, the DOE will select the mode of transport (rail or truck) and the type of carrier; the DOE may also select major junction and interchange points along the routes to be followed by contract and common carriers. Should the DOE or its contractor become a private carrier, specific routes could be designated by the DOE. The contract and common carriers will make whatever routing arrangements are necessary and appropriate within the operating authority granted them by the Interstate Commerce Commission. They will select routes for safety and shortest transit time. A selection of typical rail-transportation routes to the WIPP from each source of contact-handled TRU waste is shown in Figure 6-1. A number of routes could be selected by the railroads, but the number of routes within 200 miles of the WIPP is probably limited to the routes shown in Figure 6-2. On either rail route, the waste shipments would travel through Clovis, Roswell, Carlsbad, and Loving, New Mexico.

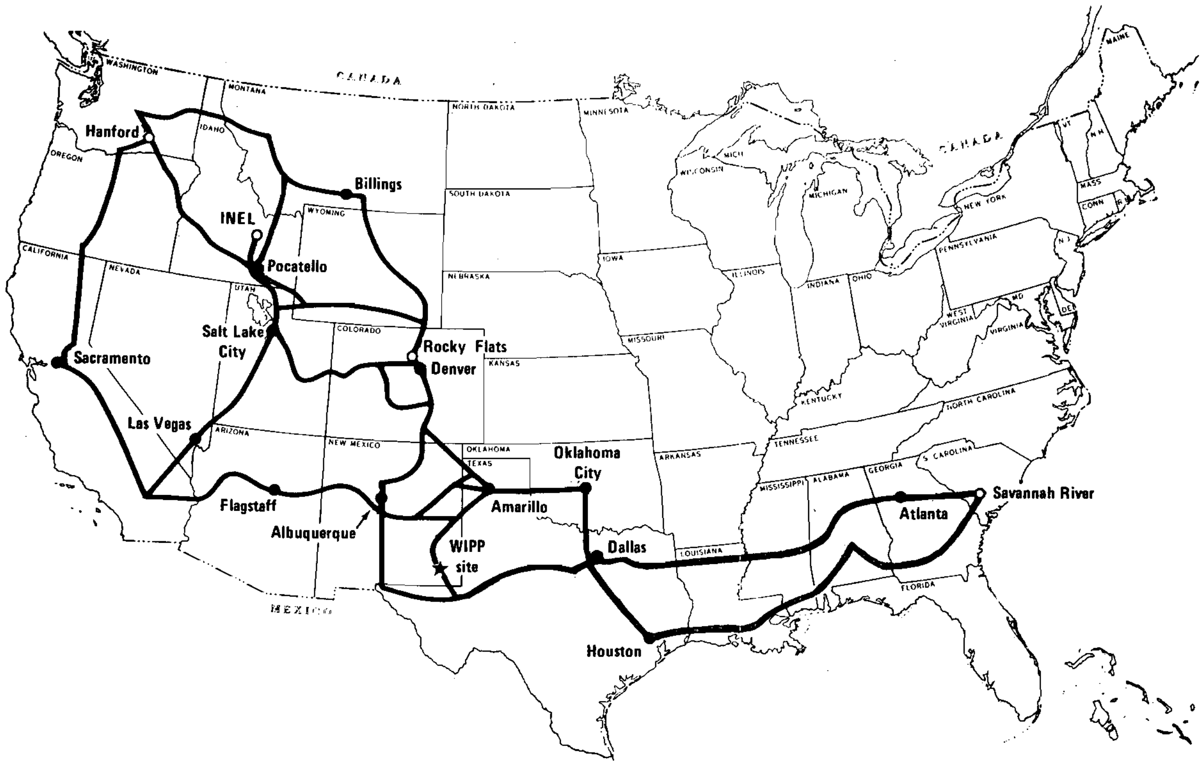

Figure 6-1. Typical rail transportation routes from principal sources (open circles).

A number of truck routes could be used, as shown in Figure 6-3, but once the truck is within 200 miles of the WIPP, the number of likely routes is probably decreased to one. As shown in Figure 6-4, shipments from the INEL and Rocky Flats would most likely come through Vaughn, Roswell, and Carlsbad, New Mexico. It is assumed for this analysis that truck shipments will follow approximately the same routes as rail shipments. The approximate shipping distances between the WIPP and the DOE sites are given in Table 6-1.

Table 6-1. Shipment Distances

Location	Distance (miles)	
	Truck	Rail
Idaho National Engineering Laboratory	1200	1750
Hanford Site	1750	2300
Los Alamos National Scientific Laboratory	340	NA
Savannah River Plant	1500	1500
Rocky Flats Plant	700	750
Oak Ridge National Laboratory	1300	1600

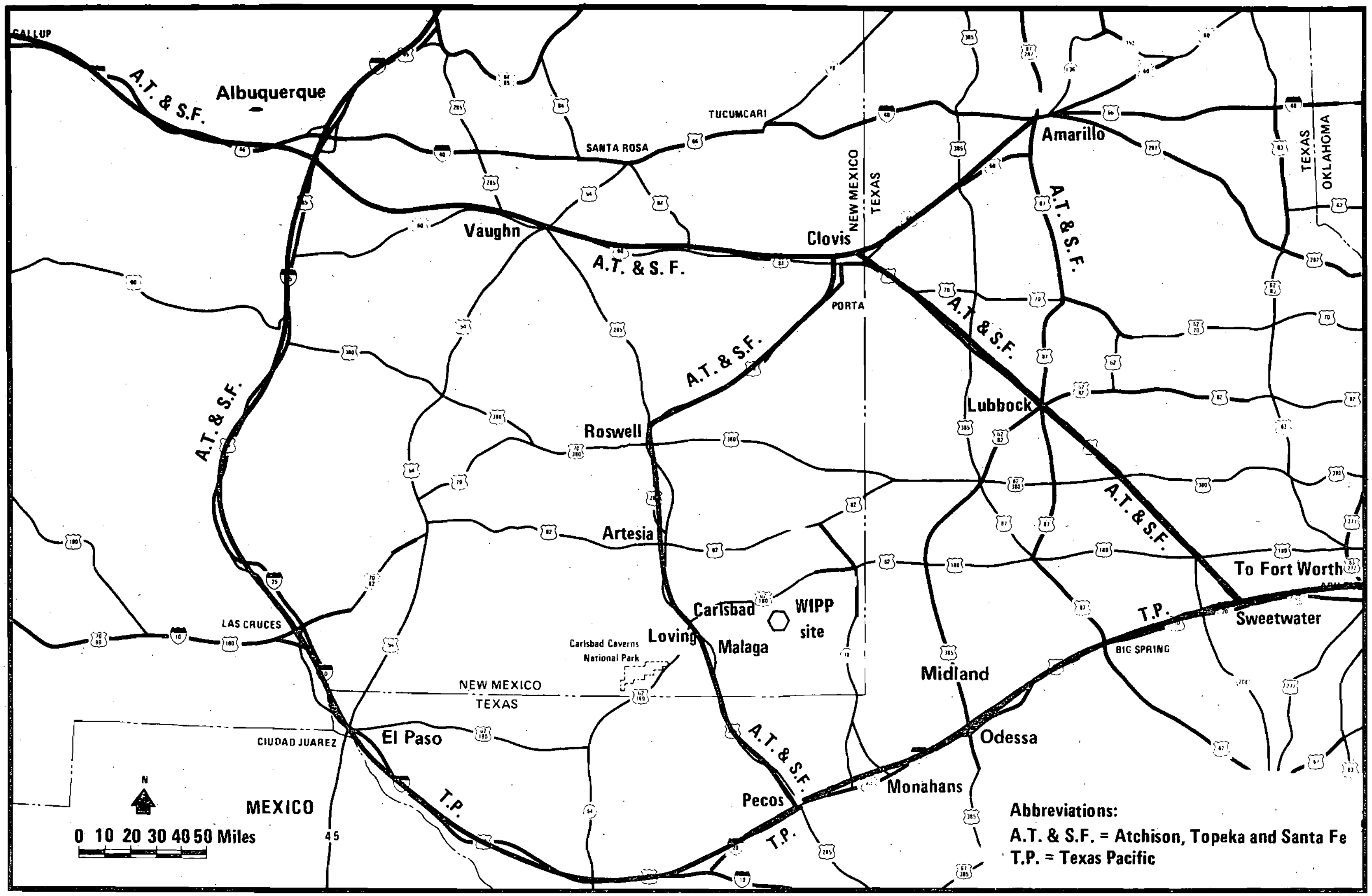

Figure 6-2. Probable rail routes within 200 miles.

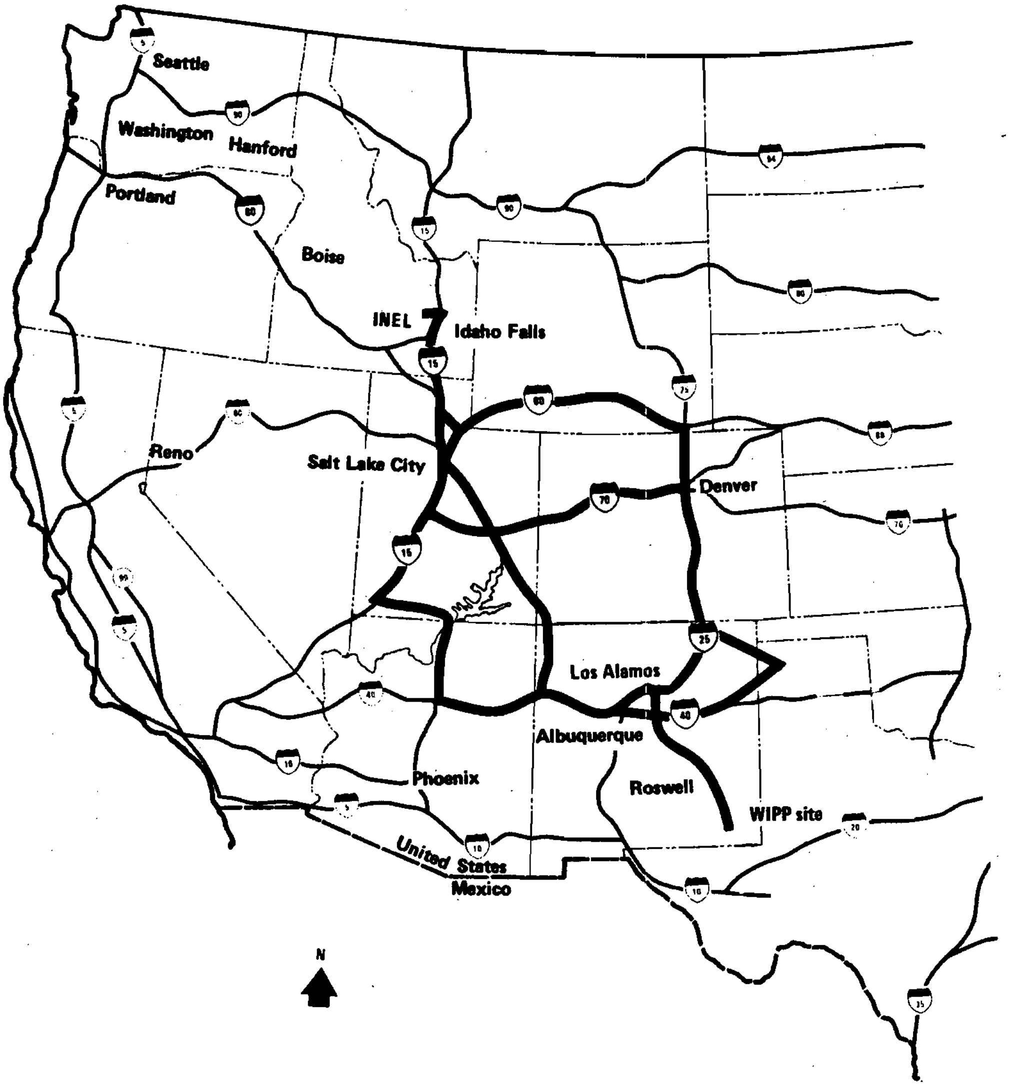

Figure 6-3. Typical truck transportation routes to the WIPP.

The INEL will ship a small quantity of remotely handled TRU waste to the WIPP. Other sources of remotely handled TRU waste are the Oak Ridge National Laboratory in Tennessee, the Hanford Site in southeastern Washington, and Los Alamos; this analysis does not consider the latter three sources, however. The routes for remotely handled TRU waste from the INEL are expected to be the same as those for contact-handled TRU waste.

Sources of the high-level waste to be used in the experimental program are not defined at present. It is expected, however, that this waste will come by rail either from the Pacific Northwest Laboratory (PNL) near the Hanford Site in the State of Washington or from the Savannah River Plant in South Carolina. If the high-level waste comes from the PNL, the routes through New Mexico could be the same as those described for the contact-handled TRU waste; if it comes from Savannah River, however, it will probably traverse Texas and turn toward New Mexico at Pecos, Texas. Shipments would then pass through Malaga and Loving in New Mexico.

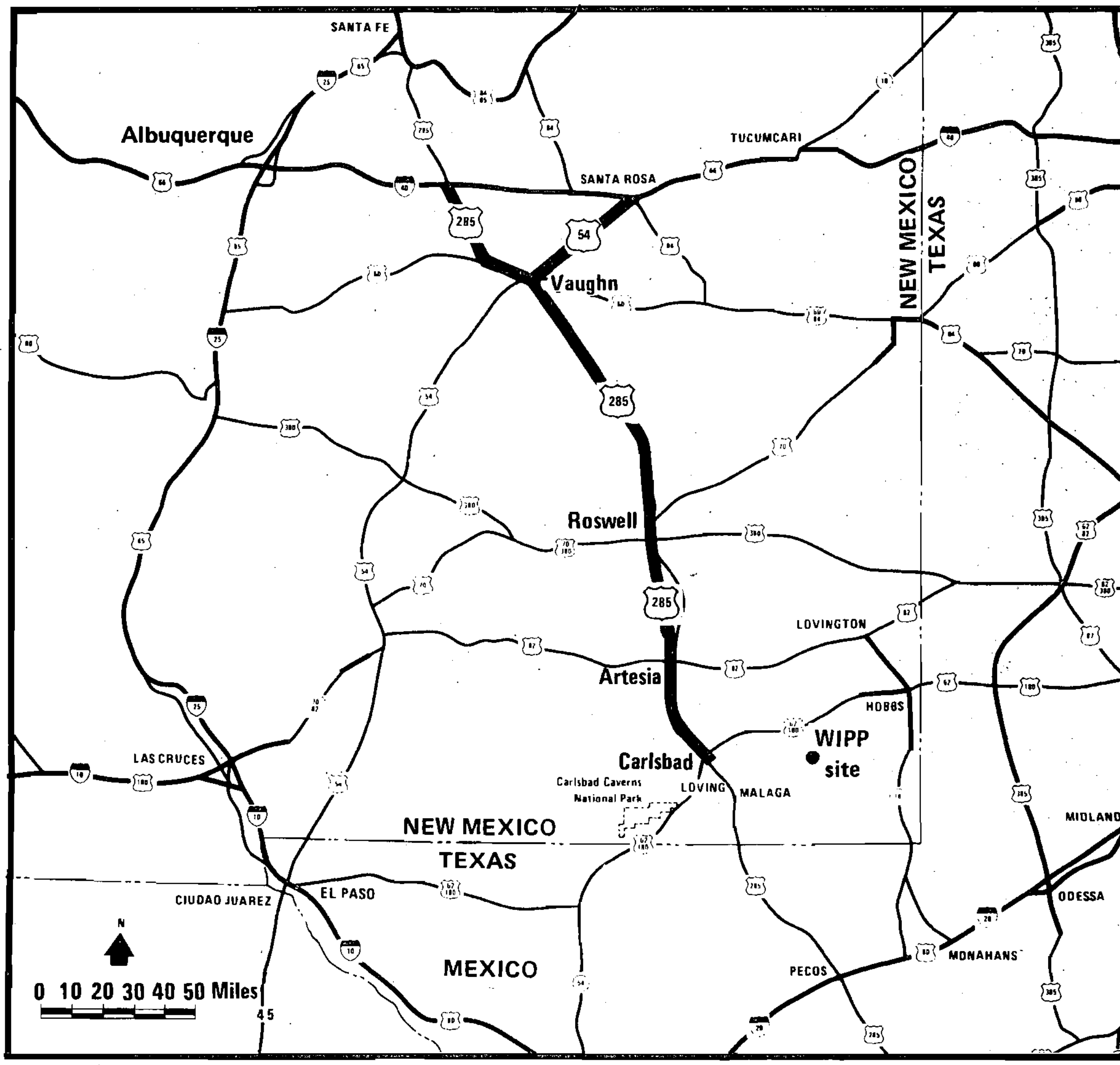

Figure 6-4. Probable truck routes within 200 miles.

6.5 VOLUMES OF WASTE AND NUMBER OF SHIPMENTS

The quantities of waste stored at the various DOE sites are not precisely known; that is, the estimates of these quantities (Dieckhoner, 1978--see Appendix E in this document) have large uncertainties associated with them. This section estimates the shipment volumes for the various waste types and details how the number of shipments is calculated.

6.5.1 Contact-Handled TRU Waste

Table 6-2 gives the volume of waste shipped per year and the volumes of contact-handled TRU waste stored at the INEL. The waste volumes stored at the INEL were obtained from Appendix E. It is assumed that the waste shipped from the INEL to the WIPP is limited to the waste now stored above the ground. The Rocky Flats Plant (RFP) produces much contact-handled TRU waste that has been and is being shipped to the INEL; this practice is assumed to continue until the WIPP becomes operational. By that time, Rocky Flats is expected to be processing all of the waste it generates and to ship it directly to the WIPP.

For contact-handled TRU waste, no volume reduction was assumed because no processing technique has been specified; reduction factors would vary significantly with the technique used.

It is estimated that one-third of all INEL contact-handled TRU waste will be shipped in boxes and two-thirds in drums. The waste shipped directly from Rocky Flats is expected to be two-thirds boxes and one-third drums. It is estimated that the backlog of waste will be eliminated during a 10-year campaign, although the existing fleet of ATMX railcars and Super Tigers is insufficient to accommodate the backlog in 10 years. New production volumes for the INEL were taken from Appendix E; new production at Rocky Flats was estimated. The total volume shipped each year is the sum of backlog elimination and new production. Even if the backlog volume is worked off in 10 years, the total volume shipped each year, as estimated in this analysis, will be less than the maximum throughput of the WIPP as defined in Chapter 8.

Table 6-3 presents estimates of the waste volumes that will be contained in the shipments of contact-handled TRU waste. Both boxes and drums are considered. The volume-per-shipment numbers were generated from the numbers of boxes or drums that could be shipped in a Super Tiger or an ATMX railcar since the design dimensions of new packagings are still subject to change.

Table 6-2. Volume of Waste Shipped per Year

Location	Volume (ft^3)			
	Backlog waste	Backlog waste transported per year[a]	New waste production per year	Total waste shipped per year
		CONTACT-HANDLED TRU WASTE		
INEL (box)	700,000	70,000	23,000[b]	93,000
INEL (drum)	1,300,000	130,000	45,000	180,000
RFP (box)	None	None	67,000	67,000
RFP (drum)	None	None	33,000	33,000
Total	2,000,000	200,000	170,000	370,000[c]
		REMOTELY HANDLED TRU WASTE		
INEL	14,000	1,400	2,800	4,200

[a]Assumes backlog volume is transported in 10 years.
[b]From limited sources other than the INEL.
[c]This value is a best estimate, but the uncertainties in it may be as high as +200%, -50%.

Table 6-3. Volume of Waste in a Shipment

Mode	Container	Volume of container (ft^3)	Number of containers per shipment	Waste volume per shipment (ft^3)
		CONTACT-HANDLED TRU WASTE		
Rail[a]	Box	112	24	2700
Rail	Drum	7.4	126	930
Truck[b]	Box	112	8	900
Truck	Drum	7.4	42	310
		REMOTELY HANDLED TRU WASTE		
Rail		42	5	210
Truck		42	1	42

[a]ATMX railcar assumed for rail shipment.
[b]Type B container for truck shipment assumed to hold eight boxes.

Tables 6-2 and 6-3 were used to generate Table 6-4, which presents the number of shipments of contact-handled TRU waste to the WIPP site each year. One additional assumption was made in estimating the number of shipments: 25% of the total volume was assumed to be shipped by truck and 75% by rail.

6.5.2 Remotely Handled TRU Waste

The number of shipments of remotely handled TRU waste was determined by methods identical with those used for contact-handled TRU waste. The backlog-waste volumes were obtained from a DOE report (Appendix E). As suggested in Section 6.3.2, remotely handled TRU waste could be shipped in at least two configurations. To determine the number of shipments, this waste was assumed to be canistered and placed in heavily shielded casks. Five canisters were assumed for each rail shipment and one canister for each truck shipment. Using the volume-shipped-per-year values from Table 6-2 and the volume-per-shipment values from Table 6-3, the annual number of shipments of remotely handled TRU waste was calculated (see Table 6-4).

6.5.3 High-Level Waste for Experiments

Very small quantities of high-level waste will be shipped to the WIPP for use in experiments. The experimental program is being developed, and the expected quantities of high-level waste are estimated to establish baseline transportation requirements. Current estimates will require the equivalent of

Table 6-4. Annual Shipments of Waste

Location	Rail		Truck	
	Waste volume (ft^3)	Number of shipments	Waste volume (ft^3)	Number of shipments
	CONTACT-HANDLED TRU WASTE			
INEL (box)	70,000	26	23,000	26
INEL (drum)	140,000	155	50,000	161
RFP (box)	50,000	19	17,000	19
RFP (drum)	25,000	27	8,000	26
Total	290,000	227	100,000	232
	REMOTELY HANDLED TRU WASTE			
INEL	3,100	15	110,000	26

40 canisters of high-level waste. Since only rail casks have been designed for high-level waste and since the designs allow a maximum of seven canisters per cask, it has been assumed for a conservative consequence analysis that a total of six shipments will be made during the operating life of the WIPP. It is more likely, however, that more shipments would be made because the casks may not be completely loaded with canisters; the high-level waste will probably be shipped only as the experiments are set up. Not all of the shipments are likely to be made during the first year, but they should be completed within the first 2 or 3 years of operation.

6.6 COST OF TRANSPORTING CONTACT-HANDLED TRU WASTE TO THE WIPP

The estimated cost of transporting to the WIPP the contact-handled TRU waste currently stored in Idaho and the waste to be generated at Rocky Flats over a period of 30 years is $230 million. This cost includes the costs of developing the packagings, of producing 14 rail and 13 truck packaging systems, and of shipping the waste from the INEL and Rocky Flats. The development costs are expected to be $10 million. The production costs for the rail and the truck systems are estimated to be $22 million. (The number of systems required was based on the assumption that 25% of the waste is shipped by truck and 75% by rail.) The remaining $198 million will be the cost of shipping the waste. In calculating this cost, the current rates of waste transportation from Rocky Flats to the INEL were extrapolated to 1990 using an inflation rate of 10% and were adjusted for distances to the WIPP. The shipments were assumed to be limited by the volume of the waste in the packaging and not by the weight of the waste in the packaging; loads will normally be limited by volume if the waste is not processed. The $230 million cost estimate does not include the costs of shipping remotely handled TRU waste or high-level waste for experiments.

6.7 RADIOLOGICAL IMPACTS OF WASTE TRANSPORT UNDER NORMAL CONDITIONS

Different forms of radioactive waste will be shipped to the WIPP from three or four locations, by various modes of transport, and in various packagings. All shipments will comply with DOT requirements to protect the public from exposure to radiation. After defining the conditions of normal transport and outlining the procedures used in the impact analysis, this section presents the predicted impacts of waste transport under normal conditions.

6.7.1 Conditions of Normal Transport

In normal transport, the package of radioactive material arrives at its destination without releasing its contents. The potential exposure of people to radiation arises from the radiation emitted by the radioactive material inside the shipping containers. Even though the packaging has radiation shields to protect the public and the workers involved in waste transport, a radioactive-waste shipment exposes the population near the route to radiation; this exposure, however, occurs at a very low dose rate that will not exceed Federal regulations.

The population groups exposed to radiation are, in order of decreasing exposure, those who directly handle waste packages; people working in the vicinity of the packages and those accompanying them (members of the train crew or truck drivers); and bystanders, including people living or working along the route, passing motorists, and train passengers. People nearest the transported radioactive materials receive the highest doses.

In the analysis of waste transport to the WIPP site, the evaluations of radiological impacts under normal conditions considered the doses received by shipping crews as well as by the public.

6.7.2 Procedures Used in Analysis

This analysis uses the methods recommended and used by the NRC in its environmental statement on the transportation of waste (NRC, 1977). These methods provide quantitative estimates of doses that might be delivered to the public by the transport of radioactive material to the repository. The normal transportation dose was evaluated by the RADTRAN computer code (Taylor and Daniel, 1977), a code used by the NRC as well.

The normal transportation dose is estimated from information entered into the three models that RADTRAN comprises (Figure 6-5). The standard-shipment model requires input about the materials shipped, the transport index (dose rate in millirem per hour at 3 feet from the accessible exterior surface of the package), the type of shipping container, the number of shipments per year, the number of miles per shipment, and the mode of shipment. The transportation model requires such information as traffic patterns and miscellaneous shipment information. The population-distribution model is used to define population densities along shipping lanes.

The assumed number of shipments of contact-handled TRU waste from the INEL and Rocky Flats is given in Section 6.5. All INEL waste stored above the

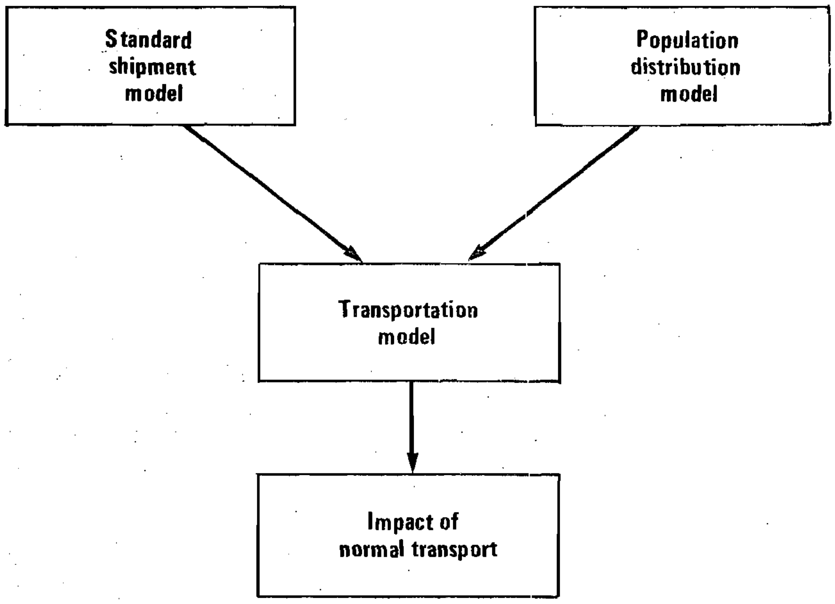

Figure 6-5. RADTRAN models used in calculating the impacts of transportation under normal conditions.

ground would be sent to the WIPP; buried waste would not. The Rocky Flats Plant produces much of the contact-handled TRU waste that has been shipped to Idaho in the past; this practice is assumed to continue until the WIPP becomes operational. It is assumed that by then Rocky Flats will have begun processing all of its waste and shipping it directly to the WIPP. The number of shipments of remotely handled TRU waste and high-level waste for experiments is also given in Section 6.5.

Table 6-5 presents selected data used as input to RADTRAN. Much of the information was based on engineering judgment and is consistent with a recent RADTRAN analysis of truck and rail transport (Smith and Taylor, 1978). Much of the information is conservative and will result in overestimates of doses.

The maximum individual dose was calculated from an equation that is central to RADTRAN:

$$D(x) = 2\,\frac{k}{v}\int_{x}^{\infty}\frac{e^{-\mu r}\,B(r)\,dr}{r(r^2 - x^2)^{1/2}} \qquad (6\text{-}1)$$

where

- K = dose-rate factor (mrem-ft^2/hr)
- v = velocity (mph)
- x = perpendicular distance from shipment path (feet)
- μ = absorption coefficient for air (0.0118 per foot)
- r = distance from source (feet)
- B = Berger buildup factor in air (B(r) = 0.0006r + 1)
- D(x) = dose at perpendicular distance x

Table 6-5. Miscellaneous Input to the RADTRAN Code

Parameter	Truck	Rail
Number of crewmen	2	5
Mean velocity while crew is aboard, mph	51.5	38
Distance from source to crew, feet	10	500
Stopover, hours		
In high-population zone	1	0
In medium-population zone	5	0
In low-population zone	2	24
Speed, mph		
In high-population zone	15	15
In medium-population zone	25	25
In low-population zone	55	40
Fraction of travel		
In high-population zone	0.05	0.05
In medium-population zone	0.05	0.05
In low-population zone	0.90	0.90
Traffic count, cars or trains per hour		
In high-population zone	2800	5
In medium-population zone	780	5
In low-population zone	470	1
Number of people per vehicle	2	5
Dose rate, mrem/hr		
Contact-handled TRU waste (surface of Super Tiger or ATMX car)	2	2
Remotely handled TRU waste (6 feet from surface of Super Tiger or ATMX car)	10	10
High-level waste (6 feet from cask surface)	10	10
Dose-rate factor, mrem-ft^2/hr		
Contact-handled TRU waste	325	780
Remotely handled TRU waste and high-level waste	1000	1000

Equation 6-1 is used to calculate the dose received from a shipment by a person standing x feet away along a line perpendicular to the shipment path. The person is assumed to remain stationary while the shipment passes. The average velocities for truck and rail and the dose-rate factors, all given in Table 6-5, were used. The person receiving the highest exposure was assumed to be only 25 feet from both shipment paths and to watch every shipment to the WIPP. In other words, this most-exposed person would watch 459 shipments of contact-handled TRU waste (232 by truck and 227 by rail) as well as 41 shipments of remotely handled TRU waste (26 by truck and 15 by rail) annually from a vantage point that is only 25 feet from the shipment path.

The dose delivered to a person who is riding in a car stopped behind a stalled truck is calculated from the equation

$$\varphi = \frac{Ke^{-\mu r} B(r)\Delta T}{r^2} \qquad (6\text{-}2)$$

where

φ = dose (mrem)
K = dose-rate factor (325 mrem-ft^2/hr for truck)
μ = absorption coefficient for air (0.0118 per foot)
r = distance from source (feet)
B = Berger buildup factor in air (B(r) = 0.0006r + 1)
T = time during which the person stays near the truck (hours)

The equation is used to calculate the dose resulting from an occurrence in which a truck carrying contact-handled TRU waste stalls, congests traffic, and prevents following cars from proceeding. It was assumed that for 2 hours the truck cannot be moved to the side of the road to allow cars to pass. The distance from the car passenger to the cask is assumed to be 20 feet; the passenger is assumed to remain in the car for the entire 2 hours while the truck is stalled. No credit is taken for the shielding provided by the glass and steel of the car. The dose-rate factor is calculated to be 325 mrem-ft^2/hr, the value given in Table 6-5.

6.7.3 Results of the Analysis

The results of the RADTRAN analysis are presented in Tables 6-6, 6-7, and 6-8. The population doses in Tables 6-6 and 6-7 are given in units of man-rem. These results are the total doses received by persons living along each shipment route, motorists traveling in the same and opposite directions, and people around the shipment while it is stopped. The doses to the transportation crews are given in Table 6-8.

The significance of the population doses can be examined by comparing them with the doses received by the same population from natural background radiation. The doses for persons living along each shipment route, for example, can be compared directly with the natural-background doses that would be received by people living within half a mile of the shipping route. At this distance doses from transportation become negligible. This comparison can be made as specific as possible by considering the truck route from Rocky Flats.

Approximately 450,000 people live in the 1-mile-wide strip along the route from Rocky Flats to the WIPP site. This population estimate is probably high, but it is the number that was calculated by RADTRAN from the conservative input; the conservatism is a result of averaging population densities for routes from all sources. If each person along the route receives an average of 0.1 rem annually from natural background sources (Appendix O), the population dose resulting from natural radioactivity is 45,000 man-rem for the truck route from Rocky Flats. The additional annual population dose of 0.4 man-rem from normal transportation, given in Table 6-6 for the sum of box and drum shipments, is thus only about 0.001% of the dose received by the same population from natural sources.

Similar comparisons can be made for the other doses predicted by the RADTRAN analysis. They show that the dose received by the public from the transport of waste to the WIPP is many times smaller than the dose received from natural background.

Table 6-6. Calculated Radiation Doses from the Normal Transportation of Contact-Handled TRU Waste

Origin and mode	Number of shipments per year	Miles per shipment	Miles per year	Annual dose (man-rem) Population along shipping routes	Passing motorists	Population surrounding shipments at rest stops	Total
INEL (box)							
Truck	26	1200	31,000	0.096	0.049	0.16	0.31
Rail	26	1750	46,000	0.34	0.0003	0.007	0.35
INEL (drum)							
Truck	161	1200	190,000	0.59	0.31	0.99	1.89
Rail	155	1750	270,000	2.1	0.002	0.04	2.14
RFP (box)							
Truck	19	700	13,000	0.04	0.02	0.12	0.18
Rail	19	750	14,000	0.11	0.0001	0.005	0.12
RFP (drum)							
Truck	26	700	18,000	0.06	0.03	0.16	0.25
Rail	27	750	20,000	0.15	0.0001	0.008	0.16
Total	459		602,000	3.5	0.41	1.5	5.4

Table 6-7. Calculated Radiation Doses from the Normal Transportation of Remotely Handled TRU Waste and High-Level Waste for Experiments

Origin and mode	Number of shipments per year	Miles per shipment	Miles per year	Annual dose (man-rem) Population along shipping routes	Passing motorists	Population surrounding shipments at rest stops	Total
REMOTELY HANDLED TRU WASTE							
INEL							
Truck	26	1200	31,000	0.29	0.15	0.49	0.93
Rail	15	1750	26,000	0.26	0.0002	0.005	0.26
Total	41		57,000	0.55	0.15	0.50	1.19
HIGH-LEVEL WASTE							
Hanford, rail	6	2300	13,800	0.14	0.00012	0.002	0.14

Table 6-8. Calculated Radiation Doses Received by Transportation Crews from All Waste Types

Mode	Annual dose (man-rem)					
	CH TRU waste (box)		CH TRU waste (drum)		RH TRU waste	High-level waste
	INEL	RFP	INEL	RFP		
Truck	2.4	1.0	14.9	1.4	2.4	(a)
Rail	0.01	0.004	0.08	0.006	0.01	0.006

[a]Not applicable.

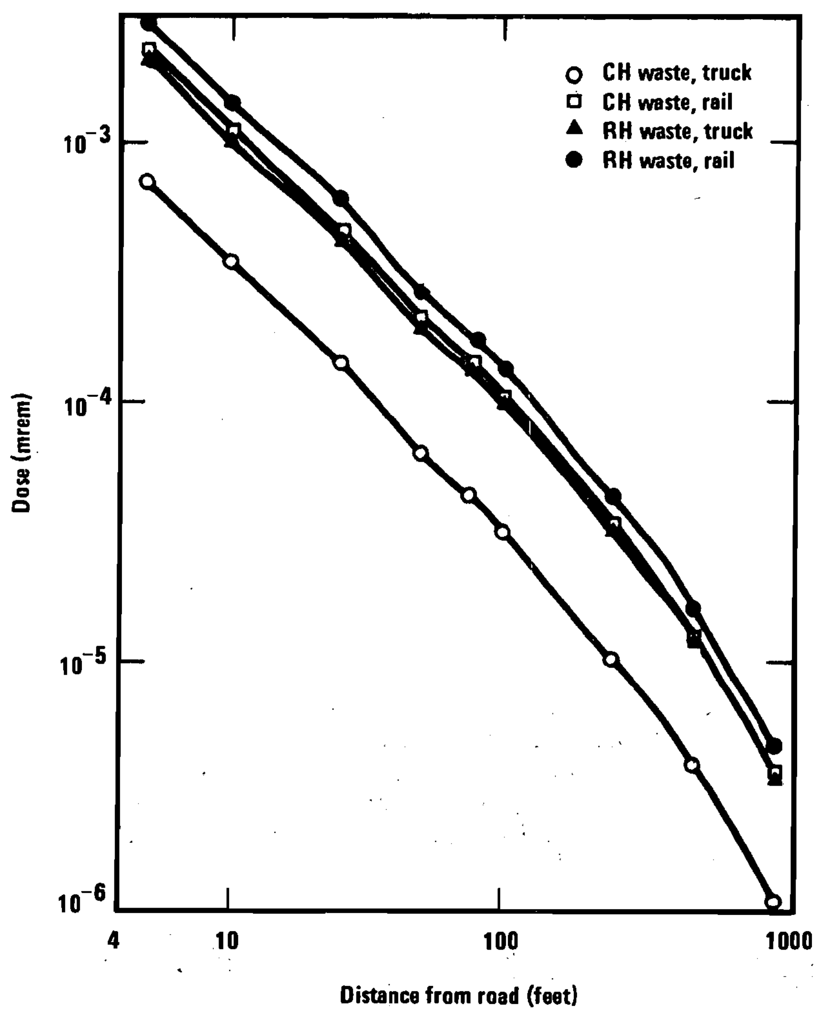

Figure 6-6. Radiation doses received by a person standing near various waste shipments as they pass.

The most-exposed person (described in Section 6.7.2) would receive an additional 0.00015 rem annually. This dose can be compared directly with the 0.1-rem background dose he would receive annually. Figure 6-6 presents additional data for an individual exposed to a single waste shipment. Each curve on the graph defines the dose received from one shipment of waste at varying distances from the shipment path; each curve represents a different waste type. For example, a person standing 10 feet from the path of a truck that is carrying contact-handled TRU waste would receive about 0.0000003 rem per shipment (0.1 rem for every 3300 shipments).

The person detained in a car for 2 hours while waiting for the stalled truck to move would receive an external dose of about 0.0016 rem.

In all scenarios examined for normal transport, the additional increment of exposure received by the public is very small when compared with annual exposures to background radiation. The health effects resulting from this exposure would be undetectable (Appendix O).

6.8 RADIOLOGICAL IMPACTS OF WASTE TRANSPORT UNDER ACCIDENT CONDITIONS

This section discusses the potential impacts of transportation accidents on the public. It addresses these questions: What is the likelihood of these accidents? What are the effects of accidents that result in some release of radioactive material?

To answer these questions, accident scenarios were developed; they model low-probability transportation accidents. Accidents that could release some radioactive material would have to be severe enough to break open a Type B packaging. Accidents of such severity have a low probability; accidents that could occur with a high probability would not be severe enough to release appreciable amounts of radioactivity.

After the scenarios were developed, the quantities of released radioactive material were estimated. Using these release estimates, an assumed population distribution surrounding the accident location, and assumed weather conditions at the time of the accident, an assessment was made of the effects of the accident on the public. Using the assumed conditions of release, the probability of release was estimated from published data (Dennis et al., 1977; NRC, 1977).

6.8.1 Accident Conditions Exceeding Regulatory Test Conditions

Most transportation accidents would not be severe enough to release any radioactive waste from the packagings that will be used for the WIPP. In all the scenarios, DOT Type B packagings were assumed because the radioactivity content of all the expected shipments will exceed the limits for Type A packagings. A description of their behavior under accident conditions (NRC, 1977) was used in estimating the amount of material released in all the scenarios.

Figures 6-7 and 6-8, taken from a study (Dennis, 1978) of actual accidents, show the cumulative probability of rail and truck accidents as a function of the change in velocity experienced by the packaging or the duration of a fire. These figures can be used to determine what percentage of accidents result in environments at least as severe as the environments produced during the testing of Type B packagings.

All Type B packagings are certified to survive sequential exposure to a series of test environments. These test environments, described in 49 CFR 173.398, are designed to simulate very severe transportation accidents. The complete sequence consists of the following tests in the order indicated:

1. Drop test: a 30-foot drop onto an unyielding target.
2. Puncture test: a 40-inch drop onto a 6-inch-diameter probe.
3. Thermal test: a 30-minute-duration fire at 1475°F.
4. Water-immersion test: an 8-hour submersion in water.

The existing certification-test standards for Type B packagings are superimposed on Figures 6-7 and 6-8. Figure 6-7 shows the cumulative probability of truck and rail transport accidents versus the velocity change that occurs during these accidents. Normally, the greater the packaging velocity is at impact, the greater the severity of the impact. Similarly, Figure 6-8 shows the cumulative probability of occurrence versus the duration of a fire in a truck or rail accident. The measure of fire severity is the duration of the fire. The minimum protection levels provided by the certification-test sequence for Type B packagings for the impact and fire environments are given in Table 6-9.

The information in Table 6-9 can be stated in a different manner. In the drop test the packaging strikes an unyielding surface at an impact velocity of 30 miles per hour. The transporting vehicle would have to be traveling at a much greater velocity (more than 60 miles per hour) in order for its package to impact at 30 miles per hour; experiments show that the crushing of the vehicle would slow a package from 60 to 30 miles per hour. Furthermore, there are few, if any, truly unyielding surfaces along transportation routes. For these reasons, more than 99.5% of all truck accidents and more than 99.6% of all rail accidents are less severe (less intense) than the regulatory requirements for the impact environment. Similarly, the fire environment of the standards provides protection against fire environments that are not likely to be exceeded in 99.9% and 99.8%, respectively, of all truck and rail accidents resulting in fire.

Table 6-9. Percentage of Accidents That Do Not Exceed the Test Conditions in Regulatory Standards

Transport mode	Impact	Fire
Truck	99.5%	99.9%
Rail	99.6%	99.8%

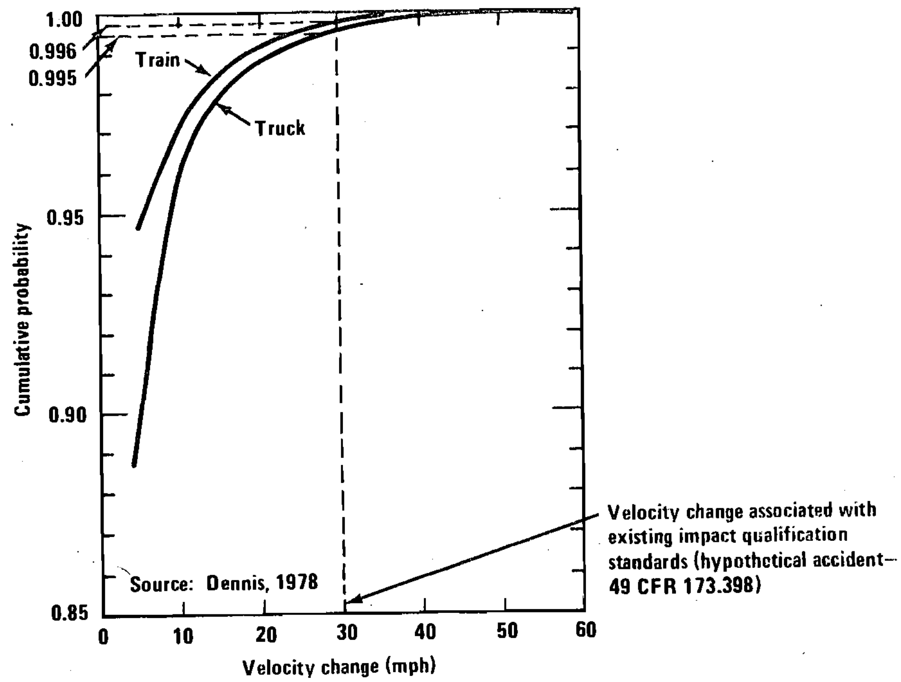

Figure 6-7. Cumulative probability of velocity changes due to impact, given a reportable truck accident or a reportable train accident.

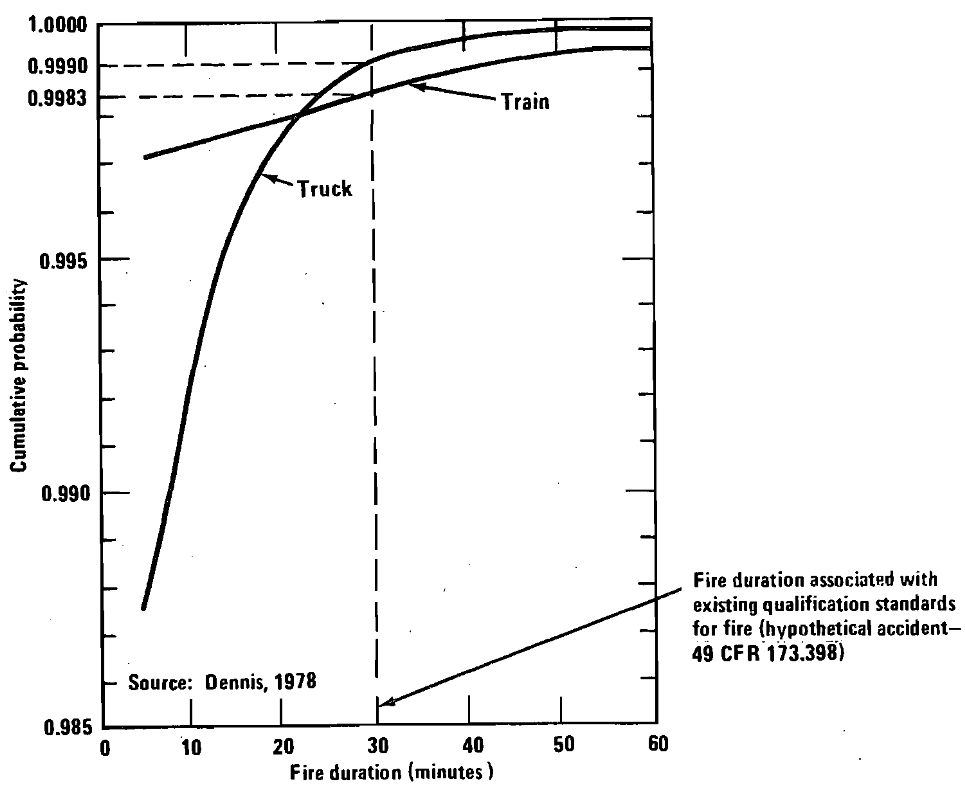

Figure 6-8. Cumulative probability of fire durations, given a reportable truck accident or a reportable train accident.

As shown in Table 6-9, the 49 CFR 173.398 licensing-criteria tests provide complete protection for all but a very small fraction of truck and rail accidents involving Type B packagings. However, in the remainder of this section, accidents more severe than those covered in 49 CFR 173.398 are considered for purposes of analysis.

6.8.2 Accident Conditions for Scenarios

Five hypothetical accidents (one for each type of waste and mode of transportation) are considered in this section. They would be spectacular accidents that would require a compounding of unlikely circumstances. The shipping data and accident rates discussed earlier were used to calculate the annual number of accidents of all types and modes. The probabilities of these hypothetical accidents are given in Table 6-10. Since many parameters (plume size, cloud height, wind direction, packaging damage, and population densities) have been selected conservatively in order to bound the consequences of transportation accidents, the probabilities of the accidents hypothesized here are very small. The scenario analysis described below was performed for accidents whose effects are much more severe than those of the vast majority of actual transportation accidents. The likelihood that such severe accidents will occur at all is nearly zero, as can be seen in the third column of Table 6-10.

6.8.3 Procedure: Construction of Accident Scenarios

This analysis is based on the five different accident scenarios described below. Each of the scenarios was assumed to take place in two locations with different population densities and distributions. To model typical urban population centers along the routes that will carry waste to the WIPP, the study uses detailed population data for a large urban area (Albuquerque, New Mexico) and for a small urban area (Carlsbad, New Mexico). The use of specific data does not restrict the applicability of the results of the study; these particular urban areas were selected because their population densities are representative of many other cities along potential routes.

Climatic conditions were selected to produce the greatest credible population doses. Because conditions prevailing at the time of an accident are likely to vary widely, there are no typical conditions representative of all the urban areas along the route. Pasquill atmospheric stability category F (stable conditions), a wind speed of 2.2 miles per hour (1 meter per second) and an inversion layer at 3300 feet (1000 meters) were used to calculate the dispersion of the radioactive material released. These are typical of night conditions with limited atmospheric mixing and therefore the greatest concentrations of dispersed materials. It has been suggested that other atmospheric stability categories will not produce greater impacts, because of the higher wind speeds associated with them. Even though other categories may result in higher ground-level concentrations than category F if the wind speeds are the same, category F results in the greatest concentrations at the wind speeds that accompany the categories. In setting up the mathematical analysis of the accidents, a virtual point source was used to simulate a dispersed source 49 feet high, a release height that, while representative of

Table 6-10. Approximate Frequency of the Hypothetical Accidents Presented in This Section

Waste type and transportation mode	Frequency of all accidents (per year)	Frequency of accidents exceeding regulatory test conditions (per year)	Estimated interval between accidents under scenario conditions (years)
Contact-handled TRU waste			
Rail	3.5	0.007	40,000
Truck	0.6	0.0006	450,000
Remotely handled TRU waste			
Rail	0.3	0.0006	450,000
Truck	0.07	0.00007	4,000,000
High-level waste for experiments, rail	0.14[a]	0.00028	1,000,000

[a]For 1 year only.

release heights in accidents involving fire, maximizes the exposure of a close-in individual. The released radioactive material was assumed to pass into the most densely populated areas in the modeled regions; in all probability, the wind would actually blow toward the most densely populated areas only a fraction of the time. Population densities out to a distance of 50 miles were used in the calculation.

The computer code AIRDOS-II (Moore, 1977), used to compute the dispersal of the radioactive material and to predict its transport to the public, assumes that the accident location and the surrounding terrain are flat and that the plume of dispersing radioactive material does not interact with buildings or other surface irregularities. In an urban environment with buildings, surface irregularities, and thermal anomalies, a plume will disperse more rapidly than in open country. Consequently, stability category E (slightly stable) or F (stable) is more appropriate than category G (extremely stable). Diffusion conditions typical of stability category F were chosen to obtain a conservative midrange atmospheric condition. No scavenging of radioactive material from the plume by rain or snow was assumed. The quantity of radionuclides released, population densities, and meteorological data were input to AIRDOS-II.

The output from the AIRDOS-II code is the effects experienced by the general public. In this study these effects were evaluated in terms of radiation doses received from external exposures and 50-year radiation-dose commitments received from continuing exposure to inhaled radioactive material. The more important of these effects were the 50-year dose commitments.

Although it is possible that a severe transportation accident would contaminate crops or animals, the affected areas would be small enough to be placed under strict controls shortly after the accident. After accidents whose severity even approaches the severity of those postulated in this analysis, crops, milk, and animals would be inspected; if contaminated, they would be condemned and destroyed (NRC, 1977, pp. 5-33 and 5-38). Radiation exposures from eating contaminated food are therefore not credible results of a transportation accident. Accordingly, this analysis predicts no dose commitments received by the ingestion pathway; only dose commitments from inhalation appear in the results.

Hypothetical rail accident involving contact-handled TRU waste (probability of 1 in 40,000 years)

The assumed rail accident involves a flatbed railcar loaded with three Type B packagings. Each packaging contains 42 drums of contact-handled TRU waste (drums only are considered in the scenarios because, for any single shipment, they would provide a greater level of radioactivity). The flatbed car is assumed to derail during a violent train collision near the center of an urban area. The violent collision is followed by a fire that is assumed to last for about half an hour. It must be emphasized that such a violent accident in an urban area is nearly incredible because in all urban areas speeds are decreased for movement through other rail traffic and over switches. The crushing forces from the impact are assumed to cause half the drums to release their contents within the packaging. Only half these drums are assumed to release their contents because the drums, contained by the Type B packaging, provide their own buffer; that is, the drums away from the impact surface are cushioned by surrounding drums. The release fraction of one-half was based on actual accident experience involving unprotected 55-gallon drums: a shipment of yellowcake (uranium ore concentrate) near Springfield, Colorado (NRC, 1978), and a shipment of yellowcake near Wichita, Kansas (NRC, 1979). In both accidents, about half the drums released their contents. The drums were not in a Type B packaging, however, so these results, when applied to this scenario, provide bounding conditions. Approximately 10% of the material released from the drums within the Type B packaging is assumed to be released, as assumed by the NRC (1977) for a similar accident. Thus, under the assumptions proposed here, the equivalent of approximately 6.3 drums of contact-handled TRU waste might be exposed.

It should be pointed out that the contact-handled TRU waste described in this section is not assumed to be processed or immobilized. The impacts of transportation are thus bounded since unprocessed waste is more readily dispersed under accident conditions.

Two mechanisms that cause the exposed material to become airborne are the burning of combustibles and the entrainment of fine particulates in air. To calculate the effects of burning, this study assumes that, of the 6.3 drums of contact-handled TRU waste that are exposed, 25% is combustible material in the form of rags and paper. Data have been obtained from experiments in which combustible materials contaminated with simulated TRU nuclides were burned. Mishima and Schwendiman (1970, 1973a) have measured releases for a variety of waste forms and confinements. Those measurements suggest the conservative assumption that 1% of the TRU waste in the released combustible material is airborne and respirable. The fire will therefore produce an airborne and respirable release of the equivalent of 1.6% of a drum's content.

Additional material may become airborne as a result of entrainment by the wind. For the climatic conditions assumed in this scenario (low wind speeds and generally stable conditions), only the finest powder is likely to be entrained in the air and transported beyond the immediate vicinity of the packaging. It is expected that much of the contact-handled TRU waste shipped to the WIPP will be metal scrap, rags, sludge, and sludge-concrete mix. Considering data presented by Shefelbine (1978), this study assumed that 10% of the contact-handled TRU waste will be in a fine-powder form after the accident. Thus, of the exposed contact-handled TRU waste, only 0.63 drum is assumed to be in the form of a powder that could become airborne. This assumption is likely to be conservative because one of the waste-acceptance criteria limits the allowed quantity of particles smaller than 10 microns in diameter to 1% by weight.

Empirical data have been obtained for the entrainment in air of dry powders deposited on various surfaces (Mishima and Schwendiman, 1970, 1973b); the measured entrainment fractions for a dry powder deposited on a roadlike surface were used in analyzing this scenario. Mishima and Schwendiman found empirically that 0.14% of a dry powder was entrained after being subjected to a 2.5-mph wind for 6 hours. This value was obtained under carefully controlled conditions in which dry powder was placed gently on the roadlike surface. This percentage is probably not large enough for this scenario, in which some of the powder might be dispersed as it falls to the road bed. For this reason, 1.4% of the dry powder (a value 10 times the experimental value) is estimated to be entrained in air during the estimated 6-hour cleanup of the accident scene. The experiments also indicated that only 62% of the airborne powder is of respirable size. The equivalent of 0.63 drum is exposed to the air as a dry powder, 1.4% of the powder is entrained in the air, and 62% of the entrained powder is respirable. Thus, the wind will produce an airborne and respirable release of the equivalent of 0.55% of one drum.

The total release that is airborne and respirable is the sum of the releases from the two mechanisms, fire and wind; the total release is the equivalent of 2.2% of a drum. From Appendix E, the radioactivity airborne and respirable is

Isotope	Release (Ci)
Pu-238	0.00086
Pu-239	0.01
Pu-240	0.0025
Pu-241	0.061
Am-241	0.00016

Hypothetical truck accident involving contact-handled TRU waste (probability of 1 in 450,000 years)

A truck carrying one Type B packaging containing 42 drums is assumed to crash near the center of an urban area. A subsequent fire is assumed to engulf the packaging and its contents for half an hour. As in the rail accident, half the drums are crushed from shifting caused by the impact force. They release their contents within the packaging, and 10% of the loose material within the packaging is released. Thus, the equivalent of 2.1 drums of uncontained waste may be exposed to the fire. About 25% of the contact-handled TRU waste is assumed to be in the form of rags and paper and therefore combustible. It is thus assumed that about 0.5 drum of contact-handled TRU waste is exposed and combustible.

In addition to respirable material released by the fire, there may be additional respirable material released from solid noncombustible materials by the wind, as discussed for the hypothetical rail accident. These two sources provide the total airborne release, about 0.7% of a drum's contents. From inventories given in Appendix E, the radioactivity airborne and respirable is

Isotope	Release (Ci)
Pu-238	0.00029
Pu-239	0.0034
Pu-240	0.00084
Pu-241	0.02
Am-241	0.000055

Hypothetical rail accident involving remotely handled TRU waste (probability of 1 in 450,000 years)

A shipping cask for remotely handled TRU waste will be heavily shielded and capable of dissipating heat generated by the waste inside. A cask used for rail transport would be larger and heavier than a cask used for truck transport and would carry greater quantities of waste.

The hypothetical accident involves a rail flatcar loaded with a cask containing five canisters of remotely handled TRU waste. After a violent train wreck in an urban area, the cask becomes enveloped in a fire that lasts about an hour. As a result of impact and fire, volatile fission products contained in the canisters are assumed to be released, even though breaching the cask and heating the waste to the point of volatilizing the cesium-137 are highly unlikely because the casks are so massive. Making such an unlikely assumption adds even more conservatism to this scenario. It is further assumed that 1% of the cesium-137 is released from the canisters to the interior of the cask and that 10% of the released cesium-137 escapes from the cask to the environment; 0.1% of the cesium inventory, therefore, reaches the environment. That this assumed release fraction is reasonable is suggested by the results of another study (NRC, 1976), which estimates that 0.06% of the cesium inventory in spent fuel would be released in a high-temperature environment. Since there are 65.3 curies of cesium-137 in each of the five canisters (see Appendix E), the release to the atmosphere during this scenario is

Isotope	Release (Ci)
Cs-137	0.33

Hypothetical truck accident involving remotely handled TRU waste (probability of 1 in 4 million years)

The same assumptions are made for the truck accident as for the rail accident except that only one canister of remotely handled TRU waste is carried in a truck cask. The release to the atmosphere, which is only one-fifth of the release in the rail accident, is

Isotope	Release (Ci)
Cs-137	0.066

Hypothetical rail accident involving high-level waste for experiments (probability of 1 in 1 million years)

Since high-level waste will probably be in a solid form (glass or ceramic) and will be shipped in a rail cask, the hypothetical conditions for the rail accident involving remotely handled TRU waste are assumed: a violent wreck, a subsequent fire, and release of volatiles. The only volatiles in high-level waste available for release are cesium-134 and cesium-137. The released fraction of each isotope (0.001) is the same as the fraction used in the scenarios for remotely handled TRU waste.

Since there are 1.4 million curies of cesium-137 and 13,000 curies of cesium-134 (as described in Appendix E), the releases to the atmosphere during this scenario are

Isotope	Release (Ci)
Cs-134	13
Cs-137	1420

6.8.4 Results of the Analysis

In this accident analysis, the inhalation of radionuclides is the primary pathway to people. When radioactive material is inhaled, a fraction of it is retained in the body. Retained material continues to irradiate the body until it can decay or be removed by biological processes. By convention, the dose given off by radioactive material while in the body is integrated over a 50-year period after inhalation. This integrated dose is called the 50-year dose commitment (Appendix O). For materials that decay rapidly or are removed quickly, most of the dose commitment is received during the first year or two. For long-lived materials that remain in the body, the dose is relatively uniform over the entire 50 years. The results of the accident analysis are given in terms of the 50-year dose commitment to the whole body, to the bone, and to the lungs.

For the assumed climatic conditions, the individual receiving the maximum dose will be a person who remains 330 feet downwind from the accident during the entire time the cloud of radioactive material is passing; Table 6-11 presents the doses received by this hypothetical person. Figure 6-9 shows plots of distance versus dose to the whole body, the bone, and the lungs of the maximally exposed person in the hypothetical accident with contact-handled TRU waste. From this graph, it is seen that a person standing 100 feet from the scene would receive a smaller dose than a person standing 330 feet from the scene. As the distance increases beyond 330 feet, the doses decrease steadily. Because it takes time for particles released above the ground to fall to the surface, the calculated doses also decrease steadily as the distance decreases below 330 feet. The point where the maximum dose is received can be closer to the accident or farther away, under different meteorological assumptions and different limitations on the model.

The calculated doses may be compared with the doses received from natural background radiation. An average individual in the general public will

Table 6-11. Doses Received by an Individual[a]

Scenario	50-year dose commitment (rem)[b]		
	Bone	Lung	Whole body
Contact-handled TRU waste			
Rail	17.4	0.87	0.42
Truck	5.8	0.29	0.14
Remotely handled TRU waste			
Rail	0.008	0.002	0.007
Truck	0.0016	0.0004	0.0014
High-level waste for experiments	37	9.1	33

[a]The maximum dose is received by a person 330 feet from the accident.

[b]Doses from natural background radiation are 5 rem to the bone and the whole body during 50 years and 1.8 rem to the lung during 10 years, as explained in the text.

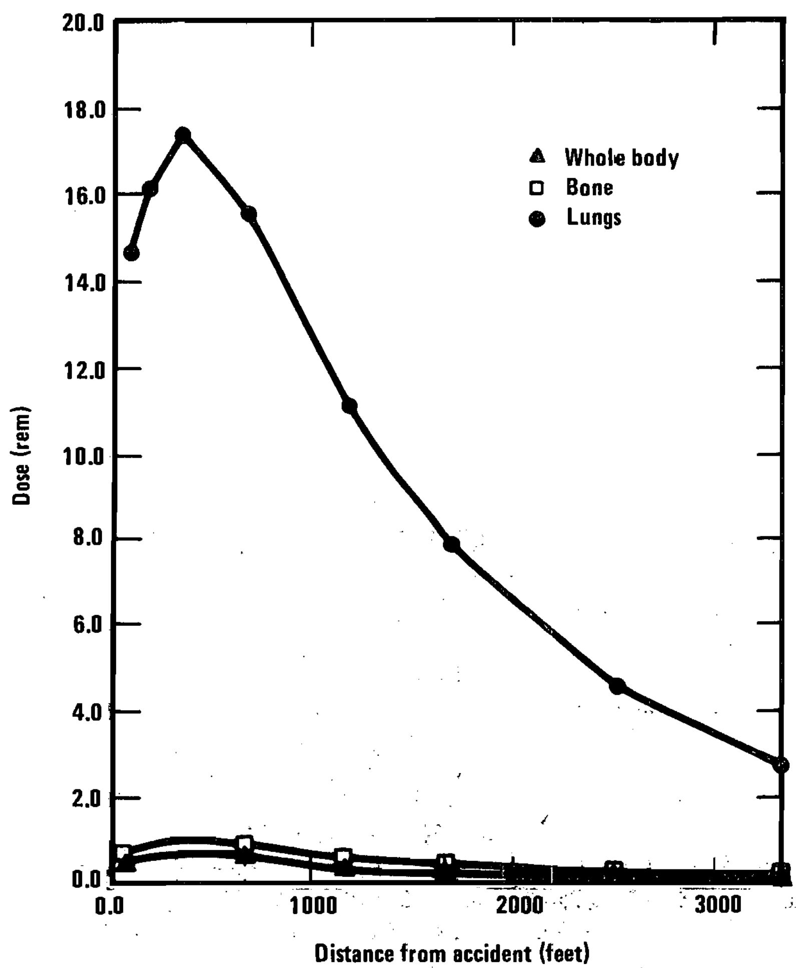

Figure 6-9. Radiation doses received by a person from the accident scenario for contact-handled TRU waste.

receive 5 rem of whole-body dose over 50 years from natural radioactive sources (NCRP, 1975). The maximum whole-body dose commitment received by an individual from the most severe accident scenario is 33 rem, which is almost seven times the 50-year natural-background dose (5 rem) he would receive to the whole body. The bone- and lung-dose commitments from the tables can also be compared with background values. The average dose rates from natural-background sources are approximately 0.1 rem per year to the bone and 0.18 rem per year to the lungs (NCRP, 1975). As an indication of the significance of the bone- and lung-dose commitments in the tables, the bone dose should be compared directly to the 5 rem received by the bone from natural radiation in 50 years, and the lung-dose commitment should be compared to the 1.8 rem received by the lung from natural radiation in 10 years. Because of biological clearance, the 50-year dose commitment to the lung is received within 10 years of intake. Consequently, a comparison is more accurately made to a 10-year cumulative background dose.

The population dose commitments in Tables 6-12 and 6-13 represent the sum of the dose commitments received by all individuals affected by the dispersion of the radioactive material.

In an emergency situation, local government control could keep people from handling the wastes or remaining at the scene of the accident. Emergency personnel, however, may be forced to go much nearer the accident scene in order to rescue injured people or save equipment. Estimates were made of the exposure they might receive from the releases assumed in the high-level-waste scenario. This scenario was used for the analysis because it had been shown to have the worst impact. The following assumptions were made: the wind blows in one compass quadrant at 2.2 mph; the emergency worker moves to a point within 16 feet of the accident wreckage and cannot proceed further because of the intense heat; he remains there for 5 minutes; the source is at

Table 6-12. Dose to a Small Urban Area[a]

Scenario	Dose commitment (man-rem)[b]		
	Bone	Lung	Whole body
Contact-handled TRU waste			
Rail	7680	390	190
Truck	2560	130	62
Remotely handled TRU waste			
Rail	3.6	0.9	3.2
Truck	0.6	0.2	0.7
High-level waste for experiments	16,600	4050	14,800

[a]Approximately 6000 people are affected by the plume.

[b]The doses received by this population from natural background radiation are 30,000 man-rem to the bone and to the whole body during 50 years and 11,000 man-rem to the lung during 10 years.

Table 6-13. Dose to a Large Urban Area[a]

Scenario	Dose commitment (man-rem)[b]		
	Bone	Lung	Whole body
Contact-handled TRU waste			
Rail	13,200	660	330
Truck	4410	220	110
Remotely handled TRU waste			
Rail	6.2	1.5	5.4
Truck	1.2	0.3	1.1
High-level waste for experiments	28,500	6960	25,400

[a]Approximately 105,000 people are affected by the plume.

[b]The doses received by this population from natural background radiation are 525,000 man-rem to the bone and to the whole body during 50 years and 189,000 man-rem to the lung during 10 years.

ground level. Calculations using these assumptions predict that a rescue worker would receive 50-year dose commitments of 50 rem to the bone, 8 rem to the lung, and 44 rem to the whole body. These doses are large but certainly not fatal, and it is likely that the traumatic bodily injuries sustained while contending with the wreckage and fire would be much more significant.

6.8.5 Cost of Decontaminating the Scene of the Accident

The radioactive contamination resulting from very severe accidents, similar in magnitude to the scenarios described previously, is expensive to control and clean up. The expenses are great because many actions are required for the control and cleanup of contamination. Emergency crews, responding quickly, may have to clean up buildings and streets, perform radiological surveys, evacuate highly contaminated areas, secure the areas being cleaned, and deny the use of land if the situation requires such action. In general, the overall cost of cleaning up after an accident increases with the amount of contamination.

The costs of controlling the contaminated areas and cleaning up after an accident have been studied in considerable detail in the Urban Study (Finley et al., 1980), which estimates these costs for a densely populated urban environment. By using figures presented in the Urban Study, the costs of controlling and cleaning up were estimated for accidents that produce releases equal to the releases in the scenarios; the estimated costs are presented in the fourth column of Table 6-14. The costs given are the costs that would be necessary to reduce contamination to levels that are currently recommended by the Environmental Protection Agency (0.2 microcurie per square meter for both short-lived and long-lived nuclides). The costs are large, ranging from $13,000 to $500 million (1979 dollars), but these scenarios might be expected to occur only once in 40,000 years to once in 4 million years. Since these estimates are for a densely populated urban environment, they are much higher than the costs expected for an accident in a suburban or rural environment. They are even much higher than the costs would be in most urban environments.

These cost estimates are made using many assumptions. They are crude at best, and such factors as inflation, court settlements, and psychological impacts cannot be included in them.

Table 6-14. Decontamination Costs for Accidents in Urban Environments

Scenario	Radioactivity released (Ci)	Expected rate of occurrence (per year)	Estimated cost (1979 dollars)
Contact-handled TRU waste			
Rail	0.074	1/40,000	80,000
Truck	0.025	1/450,000	13,000
Remotely handled TRU waste			
Rail	0.33	1/450,000	3,000,000
Truck	0.066	1/4,000,000	40,000
High-level waste for experiments	1430	1/1,000,000	500,000,000

6.9 NONRADIOLOGICAL IMPACTS OF WASTE TRANSPORT UNDER ACCIDENT CONDITIONS

As with any new transportation activity, the shipment of waste to the WIPP will result in an incremental increase in the number of injuries and deaths expected for the transportation industry. These deaths and injuries are not in any way related to the radioactive material being transported; if the WIPP shipments contained cargo other than radioactive material, the number of these injuries and deaths would be the same.

The number of miles traveled by all WIPP shipments, calculated from Tables 6-6 and 6-7, are presented in Table 6-15. Also contained in the table are accident statistics (DOE, 1979, pp. 7.2.12 and 7.2.7) for the expected number of injuries and accidents per mile of travel. From the miles traveled and the accident statistics, the numbers of expected injuries and deaths were calculated. For each year of shipments, nearly one injury would be expected; for every 12.5 years of shipments, one death would be expected.

Table 6-15. Expected Injuries and Deaths from Nonradiological Causes

Transport mode	Total shipment including return trip (miles/yr)	Expected consequences per million miles of travel		Expected consequences per year	
		Injuries	Deaths	Injuries	Deaths
Rail	770,000	0.6	0.06	0.44	0.04
Truck	570,000	0.7	0.07	0.40	0.04
Total				0.84	0.08

6.10 INTENTIONAL DESTRUCTIVE ACTS

The public is concerned about the safety and security of shipments of radioactive materials if subjected to terrorist attack. While the public perceives a terrorist attack on a radioactive shipment as being both easy and harmful, such an attack is difficult to implement, requires skilled and trained personnel, and has no guaranteed impact. Nevertheless, terrorists might attempt to threaten to release radioactivity from radioactive waste because of the expected highly emotional reaction of the public.

The Urban Study (Finley et al., 1980) estimated the consequences of successful attacks on spent fuel in very densely populated areas; these estimates have created sufficient concern among Federal agencies to prompt the NRC to write interim regulations for the physical protection of spent-fuel shipments by truck and rail. The regulations will remain in effect until ongoing research projects that are examining the response of spent fuel under sabotage conditions determine what controls are actually required.

Radioactive materials to be shipped to the WIPP, including contact-handled and remotely handled TRU waste, do not pose as serious a hazard as spent fuel and do not present as attractive a target for terrorist activities. The mass of the packagings and the relatively small radioactivity content of the TRU waste make these WIPP shipments a less attractive target than spent-fuel shipments. For rail shipments, there would be tremendous difficulty in moving the massive overpacks or casks to a location where a release would do the most public harm. For truck shipments, the truck would have to be diverted to a location where it would do the most harm. However, stealing a truck laden with a massive packaging is not likely to occur without detection. For solidified or immobilized waste (e.g., processed contact-handled TRU waste, most remotely handled TRU waste, and high-level waste for experiments), dispersal could be accomplished only using very large charges of high explosives. For unprocessed waste, large quantities of high explosives might scatter material over a large area and present a "pick-up" problem but not a health problem. The major impact of such events would be the blast and missile damage, which would far overshadow any radiological effect. Fire is not very effective as a means of either generating or dispersing respirable material. In a densely populated area, where most public harm could be inflicted, the time required for a fire to threaten the packaging would allow time for a fire department to extinguish the blaze.

Even though a successful attack is highly unlikely, it is assumed to occur in this analysis because no absolute assurance can be made that it will not occur. The fractions of material released as a result of a successful attack were estimated by using the Urban Study as a guide. The release fractions that might be used for WIPP shipments are given in Table 6-16. The release fractions for remotely handled TRU waste and high-level waste are the same as those given in the Urban Study for spent fuel. The value was considered applicable to these waste types because they will probably be transported in casks similar in shape and dimension to spent-fuel casks. The release fraction for processed contact-handled TRU waste is slightly smaller. Unprocessed contact-handled TRU waste has such a low radionuclide content and potential for harm that no release fraction is given for it.

Table 6-16. Release Fractions Assumed for Intentional Destructive Acts

Waste type	Release fraction
Contact-handled TRU waste	
Unprocessed	Very low
Processed	0.0005
Remotely handled TRU waste	0.0007
High-level waste for experiments	0.0007

Because of its higher radioactivity content per shipment, the most potentially harmful target is the high-level waste to be used for experiments. Since the number of shipments of high-level waste would probably be no more than six or seven during the lifetime of the WIPP, high-level waste presents minimal exposure to the possibility of attack. The impact of a sabotage attack on the high-level waste was calculated from the meteorological conditions and population distributions used for the transportation accidents, in order to make a direct comparison of the two sets of impacts.

Assuming that an attack is successful, the expected impacts would be serious. The calculated whole-body dose is about 2.5 times higher than that of the high-level-waste accident (as described in Tables 6-11, 6-12, and 6-13), but the lung and bone doses are nearly 20 times and 70 times higher, respectively. The bone dose is so much higher because the isotopes of plutonium are not released to the atmosphere in the high-level-waste transportation accidents but would be released in an intentional act. The bone and whole-body doses are high and would certainly harm people; however, it should be emphasized that the release fractions used are very conservative estimates that have no experimental basis. It must also be remembered that, while the likelihood of such a terrorist attack or its success cannot be estimated, a successful attack would be extremely difficult.

An experimental program designed to simulate conditions created by a terrorist attack is in progress. Its general purpose is to determine package response to terrorist attacks and to determine the characteristics of any released material. The program will provide information on the released fraction of material and the particle-size distribution of the material, information that is needed for the accurate assessment by analytical models of the radiological consequences to the public.

The first phase of the program is evaluating the response of spent fuel and spent-fuel packagings. Experiments are proceeding from model tests with a spent-fuel surrogate to scaled generic tests with spent fuel. A second phase will examine other radioactive materials, including contact-handled TRU waste, should it be shown that a significant hazard to the public results from intentional destructive acts involving spent fuel.

6.11 EMERGENCY PROCEDURES

As discussed in Section 6.3, the packagings in which the wastes will be transported to the WIPP are designed to withstand the most severe accidents without releasing their contents. However, as an additional precaution to protect public health and safety during waste shipments to the WIPP, emergency-response capabilities and procedures for transportation accidents will be developed. The current status of these capabilities and procedures, as well as the plans for their future development, are discussed in this section.

The DOE WIPP Project Office, under the requirements of ERDA Manual Chapter 0601 (ERDA, 1976), will develop an overall emergency-preparedness plan for the WIPP. The preparation of the plan will involve several groups that have various kinds of responsibility or authority for it. The DOE is responsible for informing concerned persons about the hazardous nature of the transported materials in situations where emergency-response plans would be put into effect. States have the authority, if not the responsibility, to develop emergency-preparedness plans for transportation accidents involving potentially hazardous materials. Most states have emergency plans that are under development but are not yet completed. The DOE WIPP Project Office will work with potential carriers, state law-enforcement officials, state radiological-health officials, and the DOE Albuquerque Operations Office to develop the procedures to be followed after a transportation accident with radioactive waste. The expected emergency procedures and responses are discussed below.

During the first 15 to 30 minutes after an accident occurs, emergency action may be required for attending to injured persons, identifying immediate threats to life or property, and deciding what steps are necessary to prevent further damage. It is the responsibility of the carrier to notify law-enforcement officials, the DOT, and the carrier's own management at the earliest possible moment. However, the driver and helper may be victims of the accident and unable to act; if they are, other people will have to report the accident to law-enforcement officials. State and local police and emergency crews are normally the persons who take the necessary immediate action for protecting the health and safety of the public. These officials have the authority to take such actions as clearing the immediate area of all unauthorized persons, controlling traffic, extinguishing fires, and rescuing persons trapped in the wreckage; they will also carry out mitigating measures such as covering spilled material with tarpaulins or heavy plastic sheets to minimize airborne dispersion.

During or immediately after the initial establishment of control over the accident scene, the emergency-response personnel of the state radiological-health department and of the DOE will be contacted, either by the carrier or by public-safety officials. These personnel will arrange for assistance in monitoring the accident scene. The DOT regulations require that a description of the transported material accompany the shipment to provide information that can be used in assessing potential hazards. If the contamination from an accident is great enough to require a decision regarding the evacuation of persons from the surrounding area, the decision and subsequent actions must be made by responsible local public-safety officials.

The cleanup phase of the emergency procedures includes the removal of any radioactive contamination and the restoration of the accident scene to its original state. The carrier has the basic responsibility to insure that cleanup is completed. The state or local government agencies, such as police, health, and environmental departments, will typically exercise their police and emergency powers to direct the cleanup of both public and private property. General standards for cleanup are being developed by the Environmental Protection Agency.

The carrier is responsible for keeping people from reaching the packages and spilled radioactive materials and for insuring that any vehicles, areas, and equipment that have become contaminated are not placed in service again until they have been decontaminated and surveyed.

The DOE WIPP Project Office will offer to train state and local police and emergency personnel in the proper procedures to be followed after a transportation accident. This training will be made available throughout the operating life of the WIPP.

The WIPP operating contractor has the responsibility for assisting in training local hospital personnel in the immediate area of the WIPP site (i.e., at Hobbs and at Carlsbad) in the handling and care of patients contaminated by radioactive materials.

Other hospitals along the transportation route may also be capable of providing medical attention to persons contaminated during transportation accidents. In Albuquerque, for example, the personnel of the Kirtland Air Force Base Hospital are trained in handling persons contaminated with radioactive materials and would be available to treat persons so injured during a transportation accident.

6.12 FINANCIAL RESPONSIBILITY FOR ACCIDENTS

Ordinarily, liability for WIPP-related nuclear accidents (including transportation accidents) would be determined in accordance with the generally applicable state-law rules of tort liability as applied by the courts. Financial responsibility for such liability would be assumed by the Federal Government as provided in the Price-Anderson Act. The Price-Anderson Act was originally passed by Congress in 1957, and is found in Section 170 of the Atomic Energy Act of 1954, as amended (42 USC 2210).

The Price-Anderson Act is designed to insure, through a system of private insurance and Government indemnity, that the public would be protected in the event of a nuclear accident connected with a facility operated under a contract with, or a license issued by, the Government. Under the Price-Anderson Act, the DOE is authorized to enter into indemnity agreements with contractors operating nuclear facilities. Through these indemnity agreements, financial protection is currently afforded up to a limit of $560,000,000 per accident.

A significant feature of Price-Anderson coverage is the extension of protection, not only to the DOE contractor having an indemnity agreement, but to all other "persons indemnified," which term is defined to include anyone who may be subjected to public liability as a result of a nuclear incident covered by the indemnity. The WIPP will be operated by a DOE contractor under a contract that will contain this broad Price-Anderson indemnity protection.

The standard indemnity provision used by the DOE for facilities like the WIPP covers a nuclear incident at the site of contract activity and also incidents that might occur in the transportation of material to and from the site. Thus, there will be overlapping coverage for transportation accidents to the extent that material destined for the WIPP is shipped from DOE facilities that are now being operated under contracts containing Price-Anderson indemnity provisions (e.g., the INEL). Price-Anderson indemnity coverage extends to nuclear incidents caused by sabotage, terrorism, or other illegal activity that takes place at the site of contract activity or along planned routes of transportation.

The Price-Anderson Act and its implementing indemnity agreements provide for simplification of liability determinations through the mandatory waiver of certain legal defenses by persons indemnified in the event of an "extraordinary nuclear occurrence." An "extraordinary nuclear occurrence" is a nuclear incident in which injury, damage, or contamination exceeds DOE criteria comparable to the NRC criteria published in 10 CFR 140.83-85. However, in the case of the WIPP, only an extraordinary nuclear occurrence in the transportation of waste material from a "production or utilization facility," as those terms are defined in 42 USC 2014(v) and (cc) (e.g., the INEL), would be subject to the waiver-of-defenses provisions. An extraordinary nuclear occurrence at the WIPP site itself or in the transportation of material from a DOE location other than a production or utilization facility, while fully covered by the Price-Anderson indemnity, would not be subject to the waiver-of-defenses provisions in the determination of liability.

The statutory limit of liability of $560,000,000 per nuclear incident has been reevaluated on several occasions by the Congress and considered appropriate. This "limit," however, is in reality only a threshold for further reevaluation by the Congress should any nuclear incident result in public liability exceeding that amount. The Price-Anderson Act provides that if an incident should result in public liability exceeding the stated limit "the Congress will thoroughly review the particular incident and will take whatever action is deemed necessary and appropriate to protect the public from the consequences of a disaster of such magnitude" (42 USC 2210(e)).

REFERENCES FOR CHAPTER 6

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7 The Los Medanos Site and Environmental Interfaces

The region surrounding the Los Medanos* site has been under study for many years. Before this project was proposed, the region was studied intensively by the U.S. Geological Survey because of its potash and oil-and-gas resources. In the WIPP context, two exploratory holes were drilled northeast of the present site in 1974, and intensive geologic studies started in 1975. Biological studies began in 1975, meteorological studies in 1976, and economic studies in 1977. The results of these studies are given in numerous reports cited later in this chapter and in Appendix H.

Because the WIPP would be located in a deep geologic formation, the results of the geologic and hydrologic studies are of the greatest importance. For this reason, this chapter starts by summarizing the others, combining them under the general categories of the biophysical environment (climate, vegetation, and wildlife) and the sociocultural environment (history, archaeology, land use, demography, and economics). A much more extensive coverage of these subjects is provided in Appendix H. Thereafter this chapter takes up in some detail the interrelated subjects of the geologic and hydrologic characteristics of the site.

7.1 BIOPHYSICAL ENVIRONMENT

The Los Medanos site is in Eddy County, New Mexico, about 25 miles east of Carlsbad (Figure 7-1).

The site is on a plateau east of the Pecos River, an area of rolling sand-covered hills and sand dunes. There is no integrated surface drainage; what rain does fall usually soaks into the sand or evaporates directly.

The site is covered with vegetation characteristic of semiarid climates. The land is used for ranching, and cattle are often to be seen. Ranch buildings are miles apart; in between there are a few windmills, several stock-watering tanks, and an occasional drilling rig. There are many roads in the area, the better ones surfaced with caliche, the poorer ones often little more than tracks in the sand. The most noticeable man-made features are the potash mines and processing plants with their large buildings and stacks. Their emissions often create a haze heavy enough to obscure locally the view of the mountains 40 to 60 miles to the west.

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*In this chapter the terms "Los Medanos site" and "WIPP site" are synonymous.

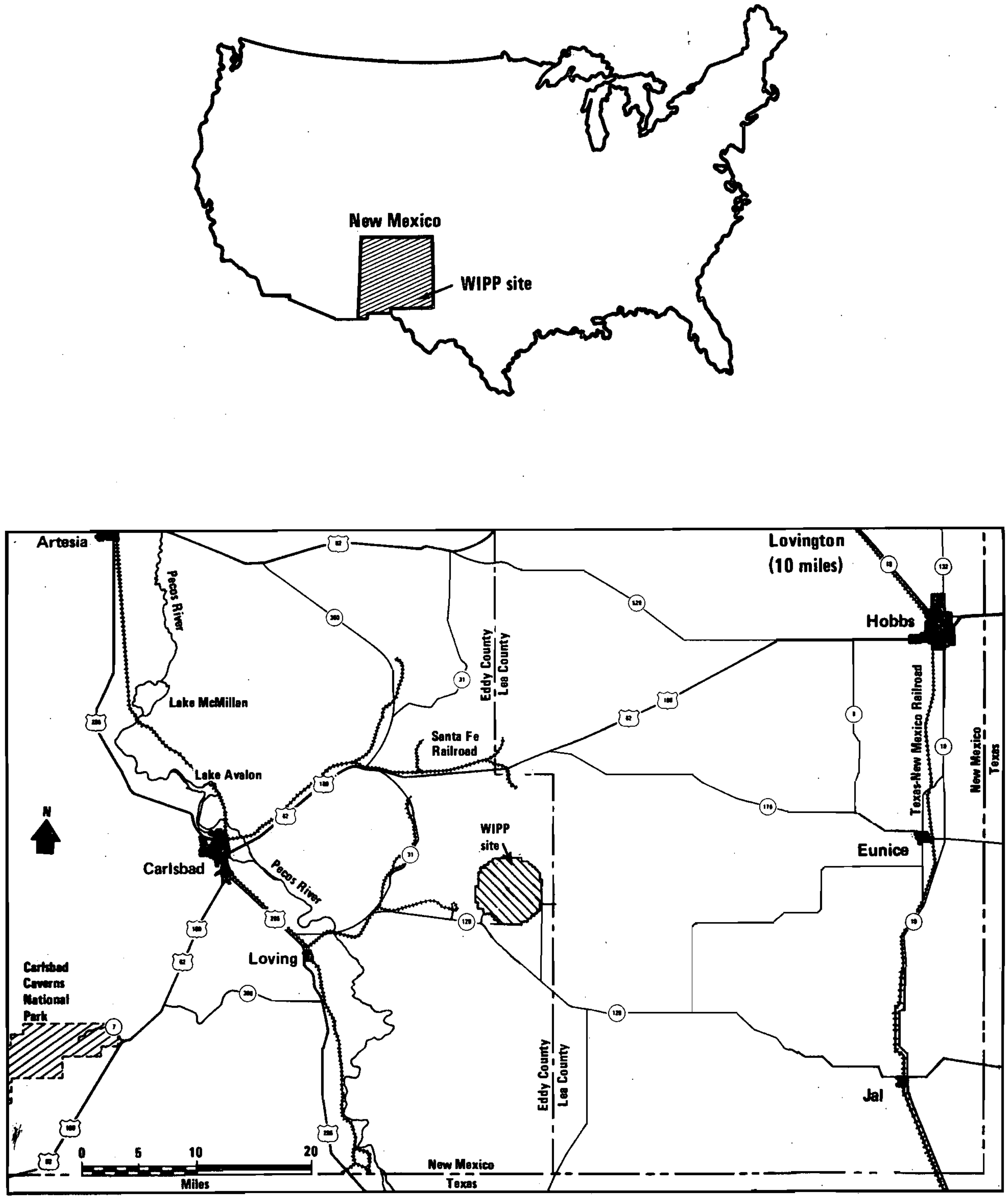


Figure 7-1. General location of the WIPP site.

7.1.1 Climate

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are mostly from the southeast and moderate. In late winter and spring, there are strong west winds and dust storms. During the winter, the weather is often dominated by a high-pressure system situated in the central portion of the Western United States and a low-pressure system located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona.

Temperatures are moderate throughout the year, although seasonal changes are distinct. Mean annual temperatures in southeastern New Mexico are near 60°F (Eagleman, 1976). In the winter (December through February) nighttime lows average near 23°F and average maximums are in the 50s. The lowest recorded temperature at the nearest class A weather station in Roswell was -29°F, in February 1905. In the summer (June through August), the daytime temperature exceeds 90°F approximately 75% of the time. The highest recorded temperature at Roswell was 110°F, in July 1958.

Precipitation is light and unevenly distributed throughout the year, averaging 11 to 13 inches. Winter is the season of least precipitation, averaging less than 0.6 inch of rainfall per month. Snow averages about 5 inches per year at the site and seldom remains on the ground for more than a day at a time because of the typically above-freezing temperatures in the afternoon. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region.

7.1.2 Terrestrial Ecology

Vegetation

The vegetation in the vicinity of the WIPP site is not a climax vegetation, at least in part because of past grazing management. The composition of the plant life at the site is heterogeneous, because of variations in terrain and in the type and the depth of soil. Shrubs are conspicuous members of all plant communities. The site lies within a region of transition between the northern extension of the Chihuahuan Desert (desert grassland) and the southern Great Plains (Short Grass Prairie); it shares the floral characteristics of both.

Grazing, primarily by domestic livestock, and the control of fire are largely responsible for the shrub-dominated seral communities of much of southeastern New Mexico. A gradual retrogression from the tall- and mid-grass-dominated vegetation of 100 years ago has occurred throughout the region. The cessation of grazing would presumably not alter the domination by shrubs, but it would result in an increase in grasses. Experimental exclosures have been established to study site-specific patterns of succession in the absence of grazing, but long-term results from them are not yet available.

The semiarid climate makes water a limiting factor in the entire region. The amount and timing of rainfall greatly influence plant productivity and therefore the food supply available for wildlife and livestock. The seeds of desert plants are often opportunistic: they may lie dormant through long periods of drought to germinate in the occasional year of favorable rainfall. Significant fluctuations in the abundance and distribution of plants and wildlife are typical of this region. Several examples of such fluctuations have been documented in the study area: the area within 5 miles of the center of the WIPP site, which has been intensively studied.

Two introduced species of significance in the region are the Russian thistle, or tumbleweed, a common invader in disturbed areas, and the salt cedar, which has proliferated along drainageways.

No endangered plant or animal species are known to occur within the study area.

Several distinct biological zones occur on or near the site: the mesa, the central dunes complex, the creosotebush flats, the Livingston Ridge escarpment, and the tobosa flats in Nash Draw west of the ridge.

A low, broad mesa named the Divide lies on the eastern edge of the study area and supports a typical desert-grassland vegetation. The dominant shrub and subshrub are mesquite and snakeweed, respectively. The most abundant grasses are black grama, bush muhly, ring muhly, and fluffgrass. Cacti, especially varieties of prickly pear, are present.

Where the ground slopes down from the Divide to the central dune plains, the soil becomes deep and sandy. Shrubs like shinnery oak, mesquite, sand sagebrush, snakeweed, and dune yucca are dominant. In some places, all of these species are present; in others, one or more are either missing or very low in density. These differences appear to be due to localized variations in the type and the depth of soil. Thus, a number of closely related but distinct plant associations form a "patchwork" complex, or mosaic, across the stabilized dunes in the central area. Hummocky, partially stabilized sand dunes occur, and large, active dunes are also present. The former consist of "islands" of vegetation, primarily mesquite, separated by expanses of bare sand. The mesquite-anchored soil is less susceptible to erosion, mainly by wind, than is the bare sand. The result is a series of valleylike depressions, or blowouts, between vegetated hummocks. Active dunes running east to west are found south and east of the James Ranch headquarters. Typical views of the site are shown in Figures 7-2 through 7-5.

To the west and southwest the soil again changes, becoming more dense and shallow (less than 10 inches to caliche) than in the dune area. The composition of the plant life is radically altered, and creosote bush becomes dominant. Toward Livingston Ridge to the west and northwest, creosote bush gradually gives way to an Acacia-dominated association at the top of the escarpment. The western face of the ridge drops sharply to a valley floor (flats) densely populated with tobosa grass, which is rare elsewhere in the study area.

This vegetation complex supports populations of mammals (including domestic livestock) and reptiles as well as a diverse population of birds. Insects and other arthropods are also numerous. The fauna of the central dunes area immediately surrounding the WIPP site have been most intensively studied.

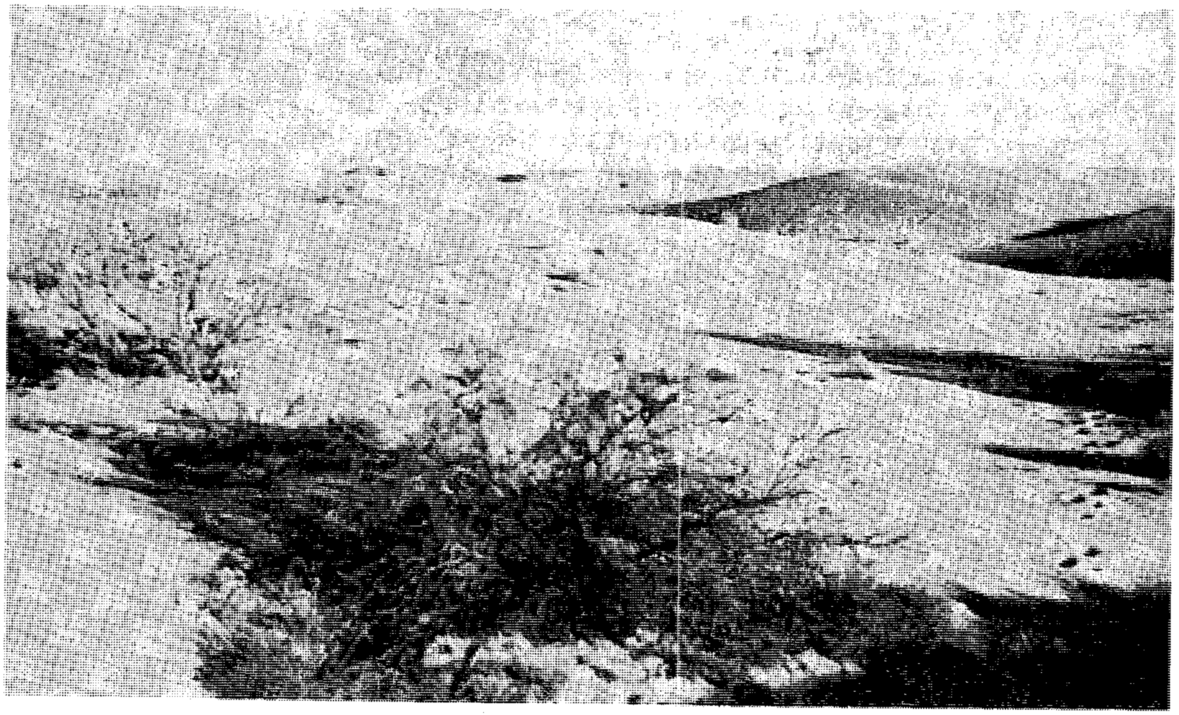


Figure 7-2. Sand dunes at the WIPP site.

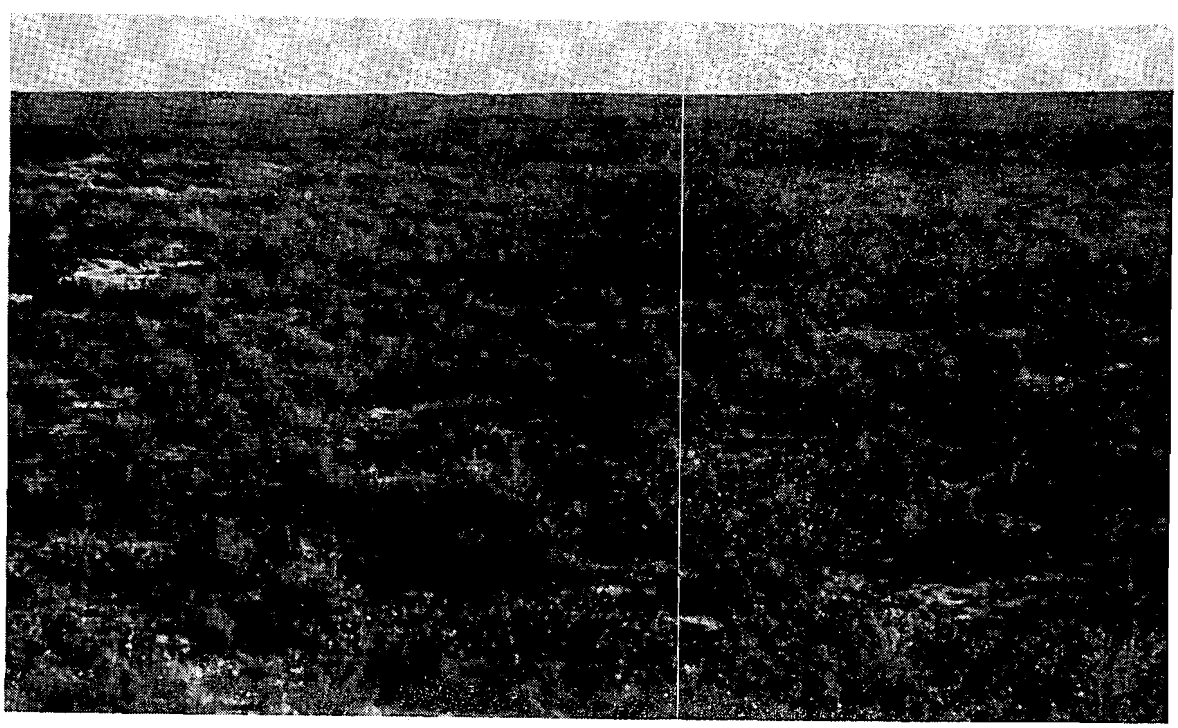


Figure 7-3. Typical view of the WIPP site.

Figure 7-4. A patch of bare ground resulting from wind erosion.

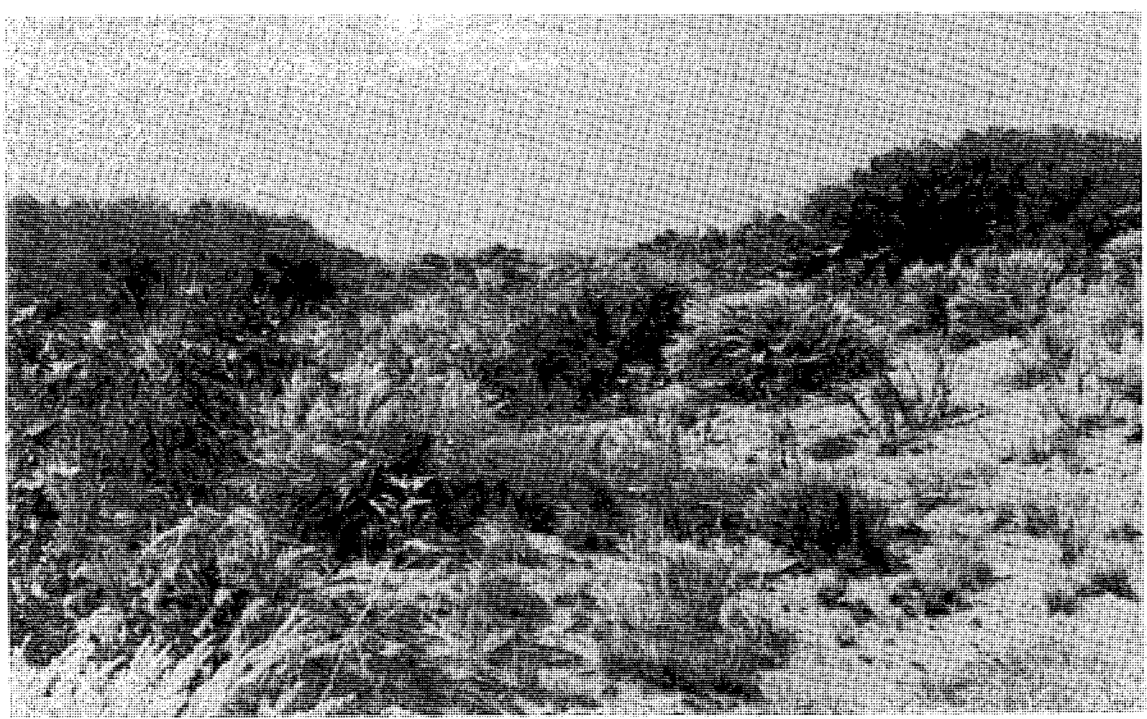


Figure 7-5. Hummocks around the bases of mesquite bushes.

Mammals

Thirty-nine species representing seven mammalian orders have been observed in the study area. The most abundant small mammals are Ord's and bannertail kangaroo rats, the Plains pocket mouse, the spotted ground squirrel, the northern grasshopper mouse, and the Southern Plains woodrat. These are not equally abundant in all habitats. Many species are restricted to specific habitats. Of those listed, the Southern Plains woodrat is the least fastidious, being found in all central dunes habitats as well as on the Divide and the creosote-bush flats. It is most numerous in the shallow-soiled creosote-bush areas. Ord's kangaroo rat and the northern grasshopper mouse are found on the Divide and in all dunes habitats. The Plains pocket mouse appears to avoid snakeweed-dominated areas and active dunes but is common in shinnery oak-mesquite associations. The fastidious spotted ground squirrel is restricted mainly to shinnery oak-mesquite associations, which have sandy soils, whereas the bannertail kangaroo rat prefers the shallow mesa and soils of the creosote-bush flats and avoids sandy areas. Vegetation and soil type are the two most influential factors in determining the distributions of these animals. Soil type is of special importance for many burrowing mammals.

The desert cottontail and the black-tailed jackrabbit are common in all habitats, as is the most frequently sighted predator, the coyote.

Two big-game species, the mule deer and the pronghorn, are present. Mule deer, by far the more common of the two, frequent shinnery oak-mesquite associations. Pronghorn are usually observed on the Divide.

Three species of bats have been collected within the study area: the cave myotis, the pallid bat, and the Brazilian free-tailed bat. The last is the bat found in Carlsbad Caverns; occasional foraging on the site is expected, as the site lies just within the 40-mile range of the Cavern colony. It is nevertheless notable that the specimens collected in the study area are the first recorded in southeastern New Mexico east of the Pecos; for the cave myotis, the collection constitutes the first record east of the Pecos for all of eastern New Mexico. This is mainly because little or no collecting had been done in the area before the WIPP-related work. Suitable habitat for bat colonization in the immediate vicinity of the study area is limited.

Reptiles and amphibians

Commonly observed reptiles in the study area are the side-blotched lizard, the western box turtle, the western whiptail lizard, and several species of snakes, including the bullsnake, the western rattlesnake, the coachwhip, the western hognose, and the glossy snake. Of these, only the side-blotched lizard is found in all habitats. The others are mainly restricted to one or two associations within the central dunes area, although the western whiptail lizard and the western rattlesnake are found in creosote-bush-dominated areas as well. The yellow mud turtle is found only in the limited number of aquatic habitats in the study area (i.e., dirt stock ponds and metal stock tanks), but it is common in these locales.

Amphibians are similarly restricted by the availability of aquatic habitat. Nevertheless, the green toad, the Plains spadefoot, and the tiger salamander are common where there is water.

Birds

A total of 122 species of birds representing 36 families have been observed on or near the WIPP site. Observation points outside the study area include the nearby salt lakes and the intersection of New Mexico Highway 31 and the Pecos River. Of the 40 breeding bird species included in this total, 28 occur within the study area. Among these are two important game species, the mourning dove and the scaled quail; others include the white-necked raven, the loggerhead shrike, the black-throated sparrow, Cassin's sparrow, the cactus wren, and the mockingbird. The roadrunner, the burrowing owl, the great-horned owl, Swainson's hawk, and Harris' hawk also nest here.

The densities of birds in the study area show considerable annual and seasonal variations. For example, the density of mourning doves in the summer of 1979 was 10 times the summer 1978 density. Similar dramatic increases were noted for the loggerhead shrike and Cassin's sparrow. Many other species showed little change in density over the same 2-year period. Favorable spring rains in 1979 resulted in a very abundant summer seed crop in comparison with that for 1978, when spring rainfall was low. This correlates closely with the increased number of doves and other birds. Factors other than food supply (e.g., availability of nesting sites) may limit the populations of many species, however.

Arthropods

About 1000 species of insects have been collected in the study area. Of special interest are subterranean termites. Vast colonies of these organisms are located across the study area; they are detritivores and play an important part in the recycling of nutrients in the study area. Their biomass per acre is as large as that of the cattle grazing the surface.

7.1.3 Aquatic Ecology

Aquatic habitats within the 5-mile-radius study area are limited. Stock-watering ponds and tanks constitute the only permanent surface waters. Ephemeral surface-water puddles form after heavy thunderstorms. At greater distances, seasonally wet, shallow lakes (playas) and permanent salt lakes are to be found.

Laguna Grande de la Sal is a large, permanent salt lake at the south end of Nash Draw. Natural brine springs, effluent brine from nearby potash refineries, and surface and subsurface runoff discharge into the lake. It is likely that surface runoff from the WIPP site reaches the lake. One of the natural brine springs at the northern margin of the lake was found during this study to support a small population of the Pecos River pupfish. This species was formerly among the species recognized as endangered by the State of New Mexico. The spring, now called Pupfish Spring, is about 11 miles west-southwest of the WIPP site.

The Pecos River is the nearest permanent water course. It ultimately receives any surface-runoff drainage from the WIPP site via Laguna Grande de la

Sal. Natural brine springs, representing outfalls of the brine aquifers in the Rustler Formation, feed the Pecos at Malaga Bend, 14 miles southwest of the site.

This natural saline inflow adds approximately 340 tons of salt per day to the Pecos. Return flow from irrigated areas above Malaga Bend makes a further contribution to the salinity. The concentrations of potassium, mercury, nickel, silver, selenium, zinc, lead, manganese, cadmium, and barium also show significant elevations at Malaga Bend but tend to decrease downstream. The heavy metals presumably are rapidly adsorbed onto the river sediments. Natural levels of certain heavy metals in the Pecos below Malaga Bend exceed the water-quality standards of the World Health Organization, the U.S. Environmental Protection Agency (EPA), and the State of New Mexico. For example, the maximum level for lead is 50 parts per billion and levels of up to 400 parts per billion have been measured during WIPP-related studies.

Several marine organisms are present in the lower Pecos and in the Red Bluff Reservoir. They include small, shelled protozoans (Foraminifera), a Gulf Coast shrimp, an estuarine oligochaete and dragonfly, and several species of marine algae. These species have presumably been introduced. A depauperate fauna--consisting mainly of salt-tolerant species of insects, oligochaetes, and nematodes--and unusual algal assemblages characterize this stretch of the river.

The combination of high salinity, elevated concentrations of heavy metals, and salt-tolerant and marine fauna makes the lower Pecos a unique river system.

Two species of fish in the Pecos below Carlsbad are recognized by the State of New Mexico as being endangered: the gray redhorse and the blue sucker. Since 1979, two other species, the rainwater killifish and the Pecos pupfish, are no longer recognized by the State as endangered, because several thriving populations were discovered in the lower Pecos.

Three additional State-listed endangered species of fish are found in the Black River, a perennial stream that flows from the west and enters the Pecos north of Malaga Bend. One of these, the Pecos gambusia (Gambusia nobilis), also appears on the Federal list. Moderate populations of the gray redhorse and the blue sucker are also found in the Black River.

7.2 SOCIOCULTURAL ENVIRONMENT

The analyses carried out for this environmental impact statement have required the collection of voluminous data describing the social and cultural resources of the region around the WIPP site. Because detailed summaries of the data are too long to be included in their entirety in this text, they are presented in Appendix H. This section discusses the major data in general terms intended to serve as background material for the predictions of environmental impacts in Chapter 9. The details of the impact analyses rest heavily on the data in Appendix H, which should be consulted by readers who wish to investigate the impacts fully or to find references to detailed source material.

7.2.1 History and Archaeology

The aboriginal inhabitants of the region around the WIPP site were American Indians; wandering bands of hunters or foragers probably crossed the area. Spanish explorers passed through during the sixteenth century, but the area was used almost entirely by Indians until cattlemen began coming to the area around 1866, about 20 years after the United States acquired the land. Trading posts appeared in the late nineteenth century; the town now called Carlsbad was founded in 1889. The twentieth century brought the developments--mainly the production of potash, oil, and gas--that have increased the population eightfold in the last 50 years.

The region has not been considered a fruitful area for archaeological research, because the wandering aboriginal inhabitants left few traces that have remained for study today. Archaeologists studying the Southwest have concentrated on the major prehistoric cultural centers far from the WIPP site. The basic studies of the region are summarized in Appendix H.1, which also presents a summary of the intensive archaeological surveys made during the investigations of the WIPP site.

The first of these surveys of the WIPP land found about eight archaeological sites per square mile in the central 4 square miles; a site was defined as a place used and occupied by prehistoric people. The evidence found at the sites was usually stone tools, fragments of pottery, or dark stains in soil or rock that had once served as a hearth. The survey found no pit houses or permanent structures. Later surveys of the rights-of-way outside the central 4 square miles have, however, found what appear to be the remains of two prehistoric structures. None of the surveys have found that the prehistory of the WIPP site is different from that of its surroundings.

The results of these surveys support the conclusion that prehistoric people used the area lightly but pervasively. Although the archaeological resources around the WIPP site are few and widely scattered, they may shed light on the ways in which people have lived in marginal environments. To find and preserve these resources, careful archaeological surveys are made in all the areas that the WIPP project will disturb.

7.2.2 Land Ownership and Use

Figures 7-6 and 7-7 show land ownership and use within 30 miles of the WIPP site. These maps show that there is little private land in the area. Most of the land is owned by the Federal Government or the State of New Mexico.

The dominant use of the land around the site is grazing; the areas marked for oil and gas production in Figure 7-7 also support grazing. The average number of cattle that can graze in each section is approximately six to nine. There are numerous active oil and gas wells. The only agricultural land within 30 miles is irrigated farmland along the Pecos River, near the municipalities of Carlsbad and Loving; little, if any, dry-land farming takes place within the area.

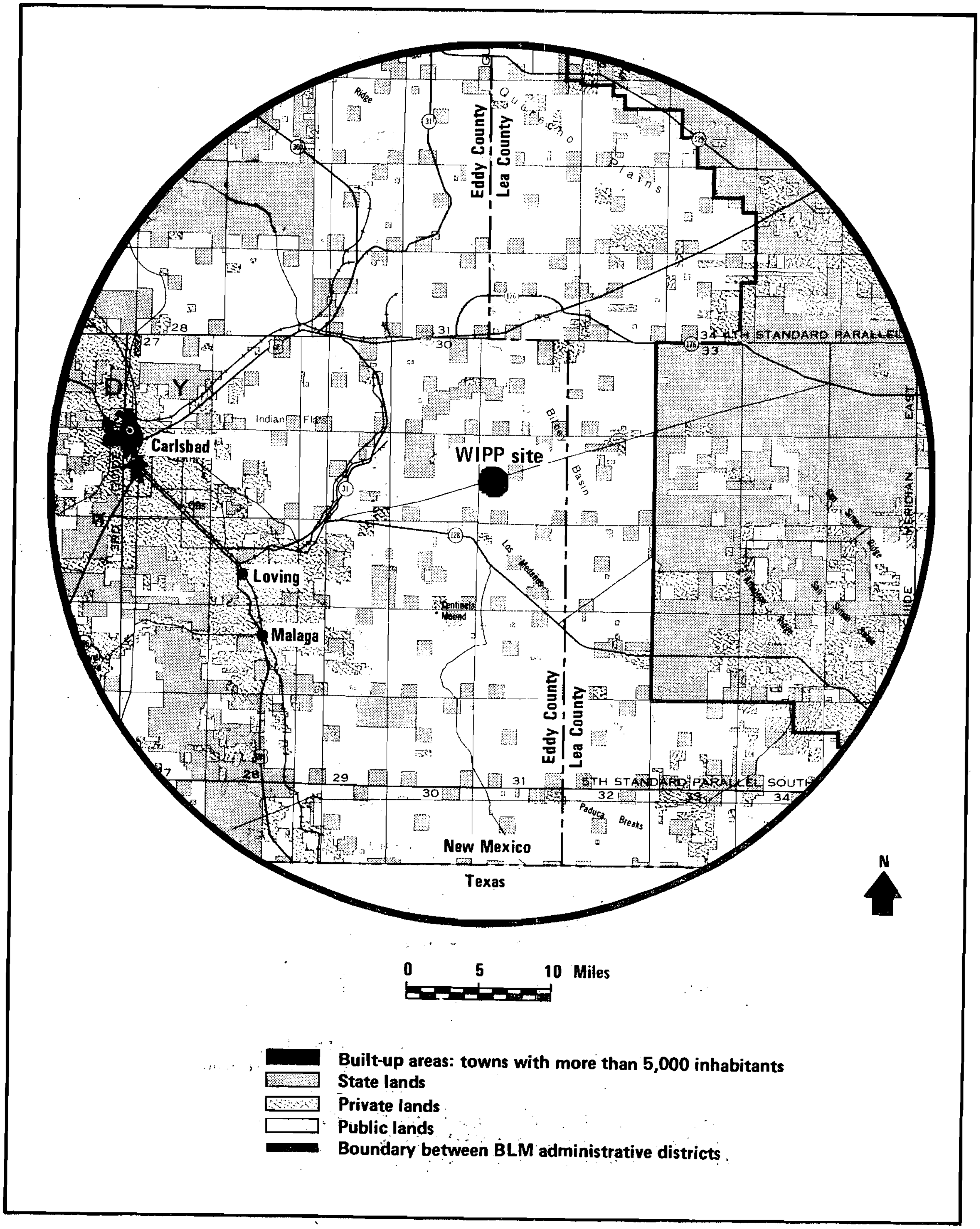
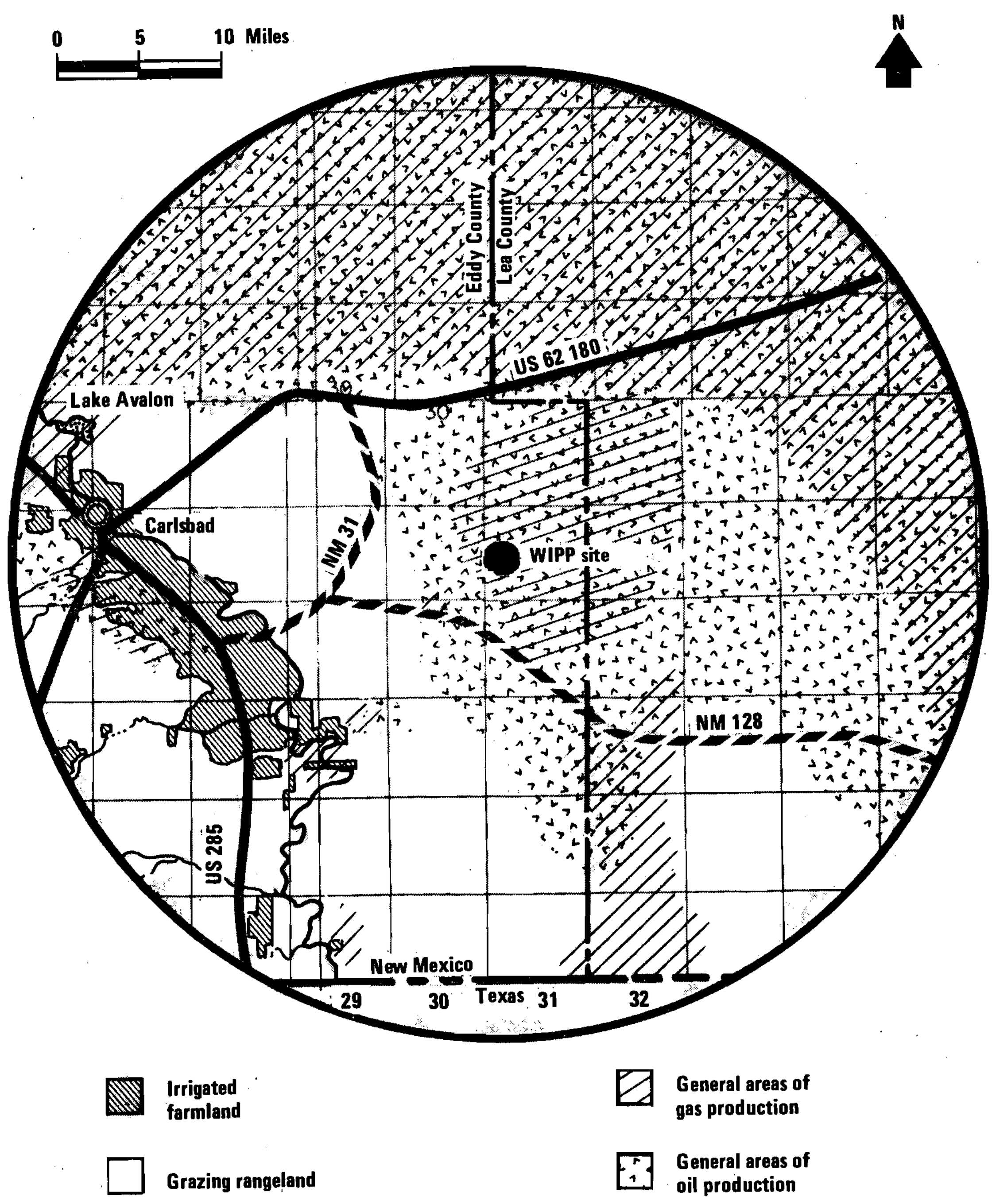


Figure 7-6. Land ownership within 30 miles of the WIPP site.



Sources: Bureau of Reclamation Land Use Map, 1968; New Mexico Bureau of Mines and Mineral Resources, New Mexico Energy Resources Map, 1974; Adcock and Associates, field surveys, 1978.

Figure 7-7. Land use within 30 miles of the WIPP site.

At present, land within 10 miles of the site is used for potash-mining operations, active oil and gas wells, and grazing. With or without the WIPP, this pattern is expected to change little in the future.

7.2.3 Population

The immediate area around the WIPP site is sparsely settled: only 16 people live within 10 miles. Within 50 miles, however, reside approximately 102,245 persons, most of them in seven principal municipalities: Artesia, Carlsbad, and Loving in Eddy County and Eunice, Hobbs, Jal, and Lovington in Lea County. The nearest of these municipalities is Loving, 18 miles away, with a population of 1600. The two largest are Hobbs, with 32,600 inhabitants, and Carlsbad, with 28,600 inhabitants.

The populations of Eddy and Lea Counties are predominantly urban. In Eddy County, 76.9% of the people live in urban areas, 18.1% in rural nonfarm areas, and 5% in rural farm areas. In Lea County, the corresponding figures are 81.1%, 15.1%, and 3.8%.

Extensive data on population are given in Appendix H (Section H.2.1).

7.2.4 Housing

Housing is available but not abundant in the three communities--Carlsbad, Hobbs, and Loving--that are the most likely to be affected by the WIPP.

Through annexation, Carlsbad has recently expanded greatly the vacant land within the city limits. Because much of the city is now being rezoned, however, the amount of land that will be available for future housing is difficult to predict. For several years the vacancy rate has been about 1%, somewhat lower than the 3% generally felt to be desirable for orderly population growth and community development. About 10,000 housing units exist in Carlsbad; mobile homes are about 9% of this total.

Hobbs has no zoning ordinance. The vacancy rate there has been about 1% to 2% for the last 2 or 3 years. Of more than 11,000 housing units, about 12% are mobile homes.

Although the 4% vacancy rate in Loving is higher, the number of units there is much smaller--about 500. About 10% of these units are mobile homes.

Discussions of housing, including tables of data, for all three municipalities are in Appendix H (Section H.3.3).

7.2.5 Industries, Employment, and Income

The basic industries of the two-county area are mining, manufacturing, and agriculture. The major industry is mining; it accounts for 24.6% of the total personal income in Eddy County and 31.2% in Lea County. Potash mining and processing in Eddy County and oil and natural-gas production in Lea County are the principal mining activities. Within 10 miles of the site are three potash mines and two potash-processing plants.

In the two counties are 94 manufacturing companies. Manufacturing, which accounted for 5.2% of all personal income there in 1977, includes food processing, meat packing, the production of chemicals, and the fabrication of metal parts. Within 5 miles of the site, there are no manufacturing establishments.

In 1977 agriculture accounted for less than 4% of the total personal income in the two-county area. Agriculture there primarily produces cotton and livestock. Because of the arid climate, farming operations rely on irrigation for water resources; most of the irrigated lands are located along the Pecos River (Figure 7-7). Within 10 miles of the site, there is no irrigation or farming activity. Cattle graze on the site and the surrounding land.

There are no commercial establishments within 5 miles of the site. Within 10 miles there is only one, a general store.

Tourism, particularly in Eddy County, contributes substantially to the economy of the two-county area. The Carlsbad Caverns National Park, approximately 40 miles west-southwest of the site, is the major tourist attraction of the area; in 1978 the attendance totaled 867,276 persons. Other parks, such as the Guadalupe Mountains National Park in Texas, the Living Desert State Park, and the Presidents' Park in Carlsbad, also attract local residents and tourists.

Between 1974 and 1978 the expanding economy of the two counties was accompanied by a growth in the labor force of about 4% per year. The unemployment rate in 1979 was about 4%.

The per-capita income in the two counties is higher than the statewide average: $6811 in Eddy County and $6089 in Lea County. These incomes are also higher than the national average for counties that are not in Standard Metropolitan Statistical Areas.

Full discussions of industries, employment, and income are in Appendix H (Sections H.2.2, H.3.1, and H.3.2).

7.2.6 Transportation

As shown in Figure 7-1, several U.S. and New Mexico highways are within 30 miles of the site. Within 10 miles of the site are portions of New Mexico Highways 31 and 128; both are two-lane roads with a bituminous surface. New Mexico 128 connects the community of Jal with New Mexico 31, which provides access to Loving and Carlsbad. Near the WIPP site, New Mexico 128 is used primarily by ranchers, potash miners, and employees of gas companies. New Mexico 31 connects U.S. Highway 62-180 (the main artery between Carlsbad and Hobbs) with U.S. Highway 285. Since this highway provides access to several mining operations, Route 31 is used primarily by potash miners.

Numerous dirt roads in the area are maintained for ranching, pipeline maintenance, and access to oil- and gas-drilling sites. The better roads are surfaced with caliche, while others are little more than tracks in the sand.

Rail transportation in Eddy and Lea Counties is provided by the Atchison, Topeka and Santa Fe Railroad and the Texas-New Mexico Railroad. There are no railroad tracks within 5 miles of the WIPP site. Railroad tracks reach the Duval Corporation's Nash Draw mine, the facilities of the International Minerals and Chemical Corporation, and the Kerr-McGee plant, all potash-mining operations between 5 and 10 miles from the site.

The two chief commercial airports in the two-county area are the Cavern City Airport near Carlsbad and the Lea County Municipal Field near Hobbs. There are no airports within 5 miles of the WIPP site. The nearest air strip, 12 miles north of the site, is privately operated.

Appendix H (Section H.3.4) provides further information on transportation, including discussions of the local systems in Carlsbad, Hobbs, and Loving and an analysis of traffic patterns and road conditions. Section 8.3 describes the new roads that will lead from the major highways to the WIPP.

7.2.7 Community Services

A wide range of educational opportunities is available in the two-county area. Carlsbad and Hobbs offer full primary and secondary education; each city has 14 public schools. Students in Loving attend schools there through junior high school and then attend high school in Carlsbad. In all three communities, enrollments are less than the capacities of the school systems. Vocational training is offered in Eddy County by the Carlsbad and Artesia Public Schools and in Lea County by the Hobbs School District and the New Mexico Junior College. Three institutions offer higher education. In Carlsbad there is a branch campus of New Mexico State University. In Hobbs two institutions offer college credit: New Mexico Junior College, a rapidly expanding 2-year State-supported institution, and the College of the Southwest, a small private school that offers 4-year degree programs.

Short-term hospitalization is available in four communities in the two-county ara. In Eddy County there are two hospitals--the Artesia General Hospital in Artesia and the Guadalupe Medical Center in Carlsbad. Lea County also has two hospitals--a small one in Jal and the Lea Regional Medical Center in Hobbs. In 1980 a new hospital will be opened in Lovington. Eddy County has about 3.5 hospital beds for each 1000 people; Lea County has about 3.6. Physicians provide family-practice medical services in most of the communities in the two counties. Ambulance and emergency services are available in both counties.

Carlsbad, Hobbs, and Loving all offer community services typical of other U.S. cities of their sizes. Because the full discussion of these services is voluminous, it appears in Appendix H, which examines the structure of these communities in detail: social services, fire and police protection, water and sewage systems, communications, electricity and natural-gas services, recreational opportunities, and solid-waste management. Appendix H also contains detailed information on the local governments, including detailed tables of revenues and expenditures.

7.3 GEOLOGY

The geologic studies at and around the WIPP site are aimed at collecting detailed geologic information for use in evaluating the site's suitability for a radioactive-waste repository. This section summarizes the large amount of geologic information currently available; most has been drawn from the WIPP Geological Characterization Report (Powers et al., 1978), which should be consulted for more detailed information and for references to primary sources. The Safety Analysis Report (DOE, 1980) also contains detailed discussions of this material.

The geologic characterization of the site started with surveys of literature and existing data and has continued with the collection of new data. In the process, many standard petroleum- and mineral-industry techniques have been used. Special emphasis has been placed on correlating data obtained by geophysical techniques and borehole drilling. The geophysical techniques most widely used have been seismic reflection and resistivity. By June 1980, new seismic-reflection data for about 152 line-miles had been obtained, and over 9000 resistivity measurements had been made and analyzed. Twenty-one boreholes had been drilled to evaluate potash resources. Sixteen boreholes had been drilled primarily for stratigraphic information on or near the site, and fifteen other holes had been drilled at the edge of, or away from, the site to study salt dissolution. Three of these holes, located outside the boundaries of the site, were drilled through the salt to test deep aquifers and to acquire geologic data on the deeper strata.

Geologic studies continue in order to permit a better quantification of the rates of geologic processes in and near the site and to develop a more thorough understanding of the geologic phenomena of interest. More detailed descriptions of the geologic, hydrologic, and geophysical methods of investigation are given in Appendix J and in the Geological Characterization Report (Powers et al., 1978).

7.3.1 Summary

The site is a topographically monotonous, slightly hummocky plain covered with caliche and sand. It is near a drainage divide that is almost free of drainage patterns but separates two major and actively developing solution-erosion features.

The waste-emplacement areas of the WIPP are to be about 2150 feet deep, near the middle of a thick sequence (from 500 to 4100 feet beneath the surface) of relatively pure evaporite strata containing primarily rock salt and anhydrite. The Salado Formation, richest in rock salt and nearly 2000 feet thick, contains the salt layers in which the wastes are to be emplaced. The disposal horizon is hydrologically isolated by at least 1300 feet of evaporites, mainly rock salt, from the overlying nonevaporite formations, and by nearly 2000 feet of anhydrite and rock salt from the underlying nonevaporite formations.

The Delaware basin, in which the site is located, has long been, and is considered still to be, tectonically stable. Major tectonic activity and basin subsidence ended about 225 million years ago; since then regional eastward tilting has been the main geologic movement near the site. No surface faulting is known at the site.

Tectonic faulting and warping of pre-Permian rocks near the site seem to have predated Permian evaporite deposition. Deformation of the evaporites has occurred primarily in the Castile Formation beneath the Salado and is most intense in a belt on the inner edge of the buried Capitan reef 8 miles north of the site. Penetration into highly thickened salt sections and salt structures in the Castile has occasionally been accompanied by artesian brine flows. An anticline (of lesser magnitude than those commonly associated with brine flows) on the upper Castile is located at the northern edge of control zone II (see Figure 7-8). Control zones I and II appear to be in a slight structural trough.

Bedded-salt dissolution near the site is restricted to the Rustler Formation and the top of the Salado Formation. There is no evidence that the resulting adjustment has produced any significant structural irregularities or collapse features in overlying strata. The closest surficial effects from dissolution are at Nash Draw, whose edge is 4 miles northwest of the center of the site. The rocks exposed there are strongly jointed, cavernous, and locally brecciated. No "breccia pipes" or domes are known at the site, even though they have been the subject of intensive investigations.

Minor igneous activity, in the form of dikes and possible sills, has occurred in the Delaware basin, but the closest such feature is about 9 miles northwest of the center of the site and is 35 million years old.

The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have only been in place in the State since 1961. Historical records before 1962 indicate that no earthquakes with a modified Mercalli (MM) intensity of V or greater have occurred within 120 miles of the site. The closest were two MM IV events at Carlsbad in 1923 and 1949. The strongest within 180 miles was the 1931 MM VIII event at Valentine, Texas, about 125 miles away. The closest shock reported since 1961 (when more and improved instruments were introduced in New Mexico) was a magnitude 2.3 event on January 19, 1978, about 10 miles northeast of the site; the largest two were a magnitude 4.6 earthquake centered almost 180 miles to the southwest in August 1966 and a magnitude 4.7 earthquake 190 miles east of the site in June 1978.

The earthquake data show two distinct clusters. Many small events are scattered on the Central Basin platform, just across the New Mexico-Texas border to the east; these are probably caused by the injection of water for oil recovery. A second cluster is southwest of the site in the Rio Grande rift zone, also outside the Delaware basin in Texas. The remaining recorded earthquakes within 180 miles are scattered sparsely in the Great Plains and the Basin and Range provinces to the north and west.

Analysis of risk from vibratory ground motion at the surface shows that the greatest ground accelerations expected to occur once in 1000 and 10,000 years are less than or equal to 0.06g and 0.1g, respectively. The probabilities of higher values depend mainly on assumptions about the seismic potential of the area near the site.

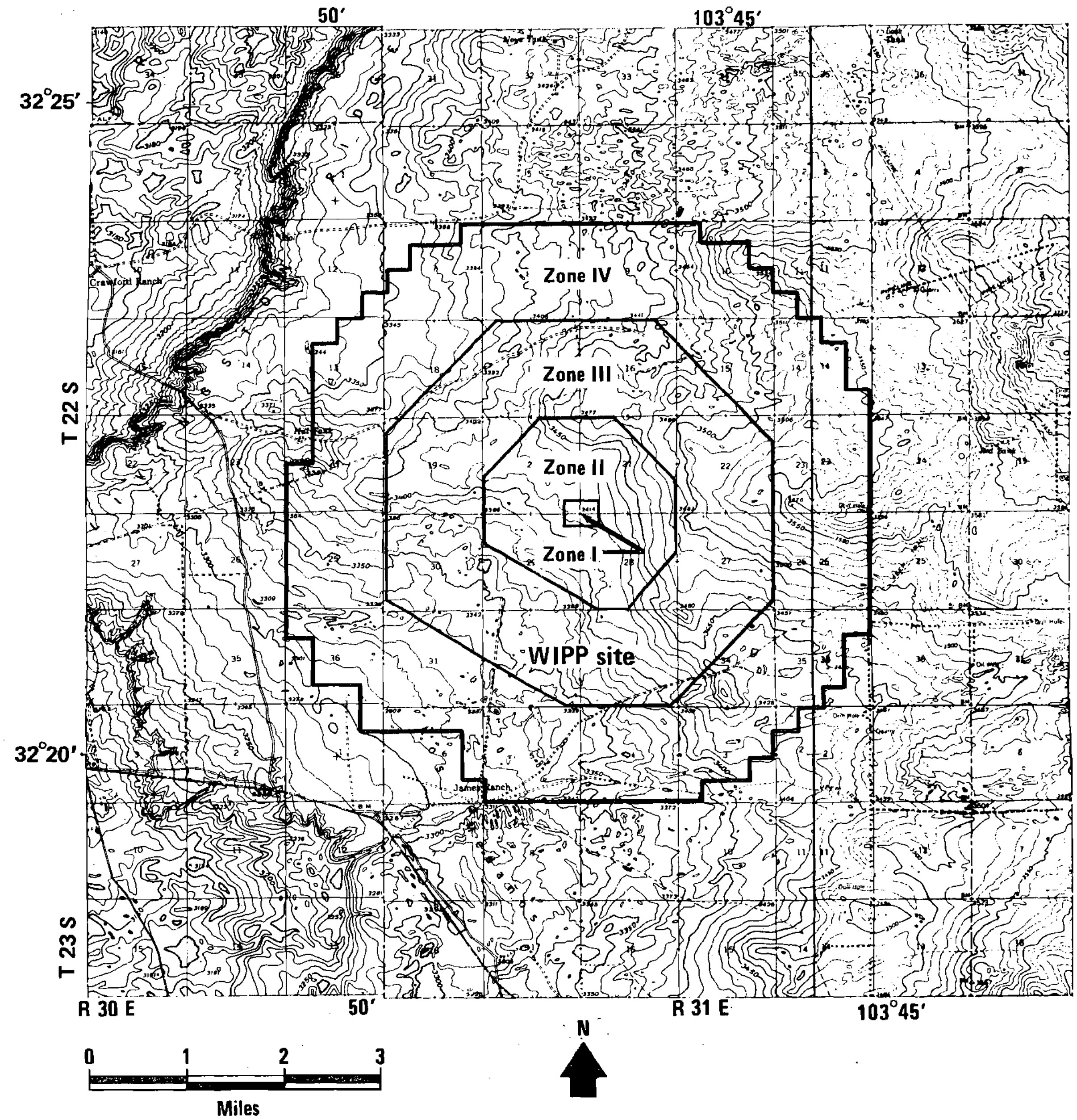


Figure 7-8. Site topographic map.

Mineral resources at the site include caliche, gypsum, salt, sylvite, langbeinite, oil, gas, and distillate. Only potassium salts (sylvite and langbeinite), which occur in strata above the repository, and hydrocarbons (oil, gas, and distillate), which occur in strata below the repository, are of present economic concern. Enormous deposits of caliche, salt, and gypsum elsewhere in the region are more than adequate for future requirements. To a large extent the potash and hydrocarbon resources lie in control zone IV, in which mining and drilling can be allowed. Langbeinite, gas, and distillate are the only known or probable economic resources under control zones I, II, and III.

The site soils are all from the Kermit-Berino Association--sandy, deep soils from wind-worked mixed sand deposits. The Berino and the Kermit are the only series in control zones I and II; both are deep, noncalcareous, yellow-red, red, or light-colored sands. They occur on gently sloping terrain and have a slight water-erosion potential and a very high wind-erosion potential.

7.3.2 Regional Geology

This section discusses the surface and subsurface geology of the region within 200 miles of the WIPP site in southeastern New Mexico, focusing on the Delaware basin.

Geologic history

The geologic history of the region (Figure 7-9) falls into three phases after the formation of a basement crystalline complex 1 to 1.5 billion years ago. The first phase, lasting at least 500 million years, was the uplift and erosion of Precambrian sedimentary and metamorphic rocks. The deep igneous rocks were exposed, and the area was reduced to a nearly level plain (Powers et al., 1978, pp. 3-38ff).

The second phase, corresponding to the Paleozoic Era, was an almost continuous marine submergence with slow accumulations of shelf and shallow basin sediments. The early to middle Paleozoic Era was characterized by generally mild epeirogenic movements (vertical movements on a continental scale) and the deposition of marine carbonates and clastics (sand, silts, and clays). During the Early Ordovician, a broad sag, the Tobosa basin, formed and began deepening. The deposition of shelf clastics continued, and carbonates were deposited in shallow waters. Mild tectonic activity continued until the middle Mississippian with occasional minor folding and perhaps faulting. As the basin subsided, the Pedernal landmass to the north emerged and there was some regional erosion (Powers et al., 1978, pp. 3-89ff).

From Late Mississippian through Pennsylvanian time, tectonic activity increased; the Central Basin platform, the Matador arch, and the ancestral Rockies formed, with massive depositions of clastics next to the uplifted areas. The Tobosa basin was split into the rapidly subsiding Delaware, Midland, and Val Verde basins. During Pennsylvanian time, repeated marginal faulting caused periodic uplift of bordering platforms and some warping in the Delaware basin. By Early Permian time, this tectonic activity apparently died out as basin subsidence and sedimentation accelerated. Reefs developed during the mid-Permian; eventually the Permian sea became briny, forming thick Late Permian evaporite deposits (Castile, Salado, and Rustler Formations) in deep water and on brine flats. The Late Pennsylvanian and Permian clastic and evaporite sequence is the result of the accumulation of over 13,000 feet of sediments in a relatively brief period (50 to 75 million years). The final event of this long, nearly continuous accumulation of marine sediments was the deposition of marine or brackish tidal-flat red beds over the evaporite strata (Powers et al., 1978, pp. 3-93ff).

In the third and present phase, which began about 225 million years ago, the region has had mainly continental or nonmarine environments and relatively stable tectonic conditions. During the Triassic, a broad flood-plain surface

ERA	PERIOD	EPOCH	YEARS* DURATION	YEARS* BEFORE THE PRESENT	MAJOR GEOLOGIC EVENTS–SOUTHEAST NEW MEXICO REGION
CENOZOIC	Quaternary	Holocene	10,000		Eolian and erosional/solution activity. Development of present landscape.
		Pleistocene	1,800,000	1,800,000	
	Tertiary	Pliocene	3,400,000		Deposition of Ogallala fan sediments. Formation of caliche caprock.
		Miocene	18,800,000		Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe-Delaware Mountains.
		Oligocene	13,000,000		
		Eocene	16,500,000		Erosion dominant. No Early to Mid-Tertiary rocks present.
		Paleocene	11,500,000	65,000,000	Laramide "revolution." Uplift of Rocky Mountains. Mild tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		70,000,000	135,000,000	Submergence. Intermittent shallow seas. Thin limestone and clastics deposited.
	Jurassic		46,000,000	181,000,000	Emergent conditions. Erosion, formation of rolling terrain. Deposition of fluvial clastics.
	Triassic		49,000,000	230,000,000	Erosion. Broad flood plain develops.
PALEOZOIC	Permian		50,000,000	280,000,000	Deposition of evaporite sequence followed by continental red beds. Sedimentation continous in Delaware, Midland, Val Verde basins and shelf areas.
	Pennsylvanian		30,000,000	310,000,000	Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
	Mississippian		35,000,000	345,000,000	Regional tectonic activity accelerates, folding up Central Basin platform, Matador arch, ancestral Rockies. Regional erosion. Deep, broad basins to east and west of platform develop.
	Devonian		60,000,000	405,000,000	Renewed submergence. Shallow sea retreats from New Mexico; erosion.
	Silurian		20,000,000	425,000,000	Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Peninsula emergent, until Middle Mississippian.
	Ordovician		75,000,000	500,000,000	Marathon–Ouachita geosyncline, to south, begins subsiding. Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform, and carbonates.
	Cambrian		100,000,000	600,000,000	Clastic sedimentation – Bliss sandstone.
	PRECAMBRIAN				Erosion to a nearly level plain. Mountain building, igneous activity, metamorphism, erosional cycles.

*There is no consensus on times and durations. See Cohee et al. (1978) for a further review of this subject.

Figure 7-9. Major geologic events affecting southeastern New Mexico and western Texas.

developed with the deposition of clastics. No Jurassic deposits are known; the rolling terrain on Triassic rocks is presumed to have formed during the Jurassic. During the Jurassic, and perhaps as early as the Triassic, subsurface dissolution of the Upper Permian evaporites began. During the Cretaceous, the area was submerged, and thin limestone and clastics collected in intermittent shallow seas. At the close of the Mesozoic, the Rocky Mountains were uplifted, with mild tectonic and igneous activity to the west and north of the site. Throughout most of the Tertiary, erosion dominated. The mid to late Tertiary Basin and Range uplift of the Sacramento and the Guadalupe-Delaware Mountains was accompanied by regional uplift and east-southeastward tilting. Miocene-Pliocene Ogallala fan deposits accumulated on this gently sloping surface, and a resistant caliche caprock formed. During Quaternary time, the present landscape developed through surface erosion and the dissolution of the Upper Permian evaporites, the formation of an additional caliche layer (Mescalero), terrace and stream-valley deposition, and the deposition of windblown material (Powers et al., 1978, pp. 3-89ff).

During the third phase, periods of continental deposition have alternated with erosional episodes marked by shallow angular unconformities. These unconformities represent intervals during which the salt beds at the site were tilted and subjected to potential dissolution. At least four erosional episodes are recognized:

1. Early Triassic time, in which the Dewey Lake Red Beds were eroded to a slight angular unconformity before the deposition of the Upper Triassic Santa Rosa and Chinle Sandstones.

2. Jurassic-Early Cretaceous time, in which the Santa Rosa was tilted and eroded to a wedge before marine inundation in Washitan time (latest Early Cretaceous).

3. A Late Cretaceous through mid-Tertiary interval when the region was again tilted and the Triassic Santa Rosa Sandstones were beveled for a second time.

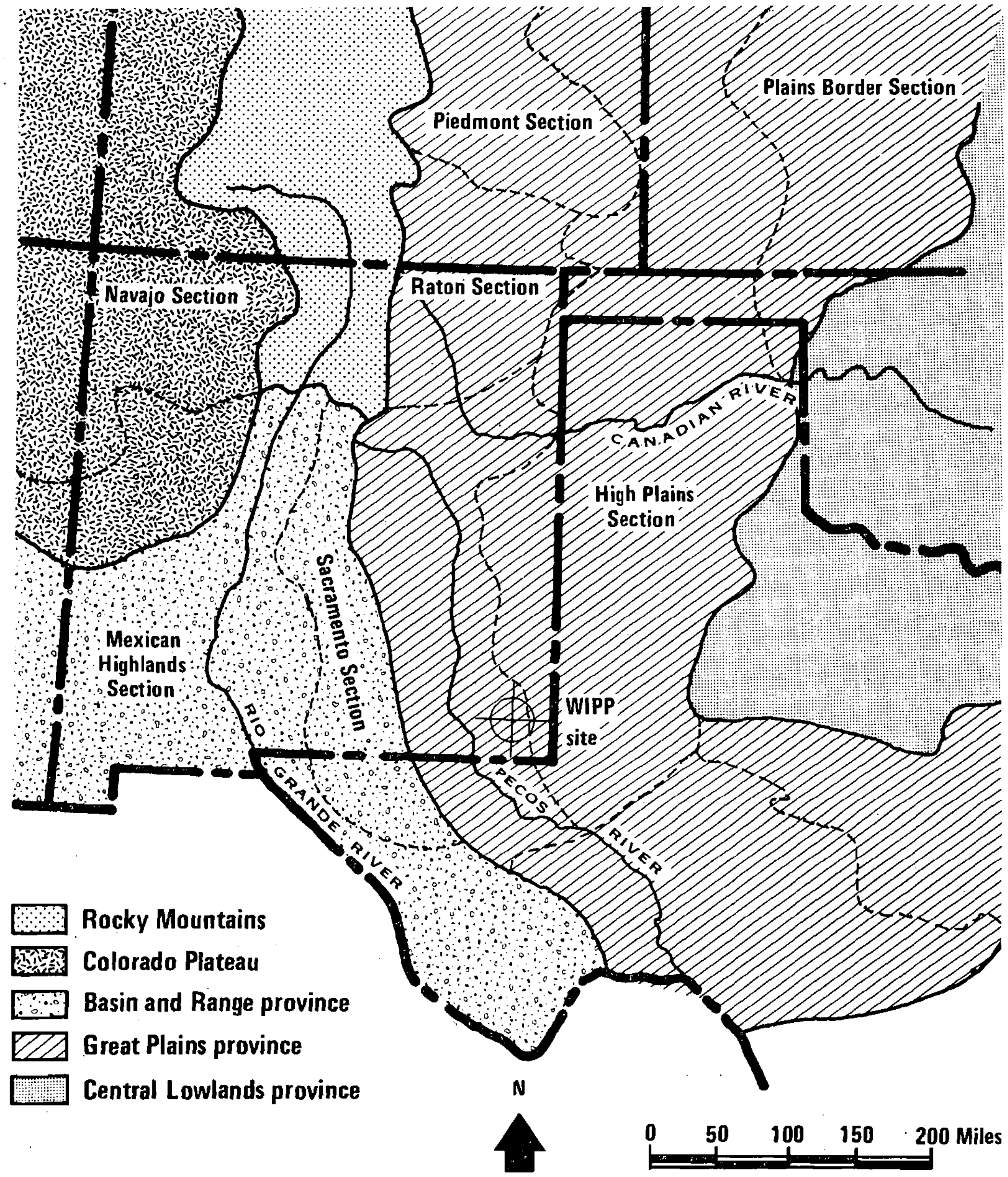
4. A post-Ogallala uplift and erosion in early Pleistocene time, before the deposition of the (Kansan?) Gatuna Formation took place.

After the deposition of the Gatuna Formation, there probably were wetter intervals during the later Illinoian and Wisconsin glaciations, during which there was renewed erosion. During later glaciations, climatic conditions did not change and the local climate remained semiarid, as indicated by the development of the Mescalero caliche beginning about 500,000 years ago (Bachman, in preparation).

Each period of tilting and erosion caused gradual salt migration down the resultant slope. The salt deformed as it impinged on reef abutments or responded to uneven sediment loading or erosional unloading. There may have been several such episodes. Furthermore, each erosional period subjected buried salt to potential dissolution. Any present "deep-dissolution" features in the basin could have started as soon as Early Triassic time, but more probably episodes of active dissolution occurred during the Jurassic and Late Cretaceous-middle Tertiary and the several pluvial periods corresponding to Pleistocene glacial stages. Episodic dissolution and the evidence from detailed mapping studies (Bachman, in preparation) are discussed further in Section 7.4.4.

Physiography and geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province, a broad highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range province to the Central Lowlands province (Figure 7-10). The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough 5 to 30 miles wide and as much as 1000 feet deep in the north. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, including such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations range from more than 6000 feet in the northwest to about 2000 feet in the south (Powers et al., 1978, pp. 3-3ff).



Adapted from Fenneman (1931).

Figure 7-10. Physiographic provinces and sections.

The Pecos Valley section is bordered on the east by the Llano Estacado, a virtually uneroded plain formed by river action. The Llano Estacado is part of the High Plains section of the Great Plains physiographic province. Few and minor topographic features are present in the High Plains section, formed when more than 500 feet of Tertiary silts, gravels, and sands were laid down in alluvial fans by streams draining the Rocky Mountains. In many areas the nearly flat surface is cemented by a hard caliche layer.

To the west of the Pecos Valley section are the Sacramento and the Guadalupe Mountains, part of the Sacramento section of the Basin and Range province. The Capitan escarpment along the southeastern side of the Guadalupe Mountains marks the boundary between the Basin and Range and the Great Plains provinces. The Sacramento section has large basinal areas and a series of intervening mountain ranges.

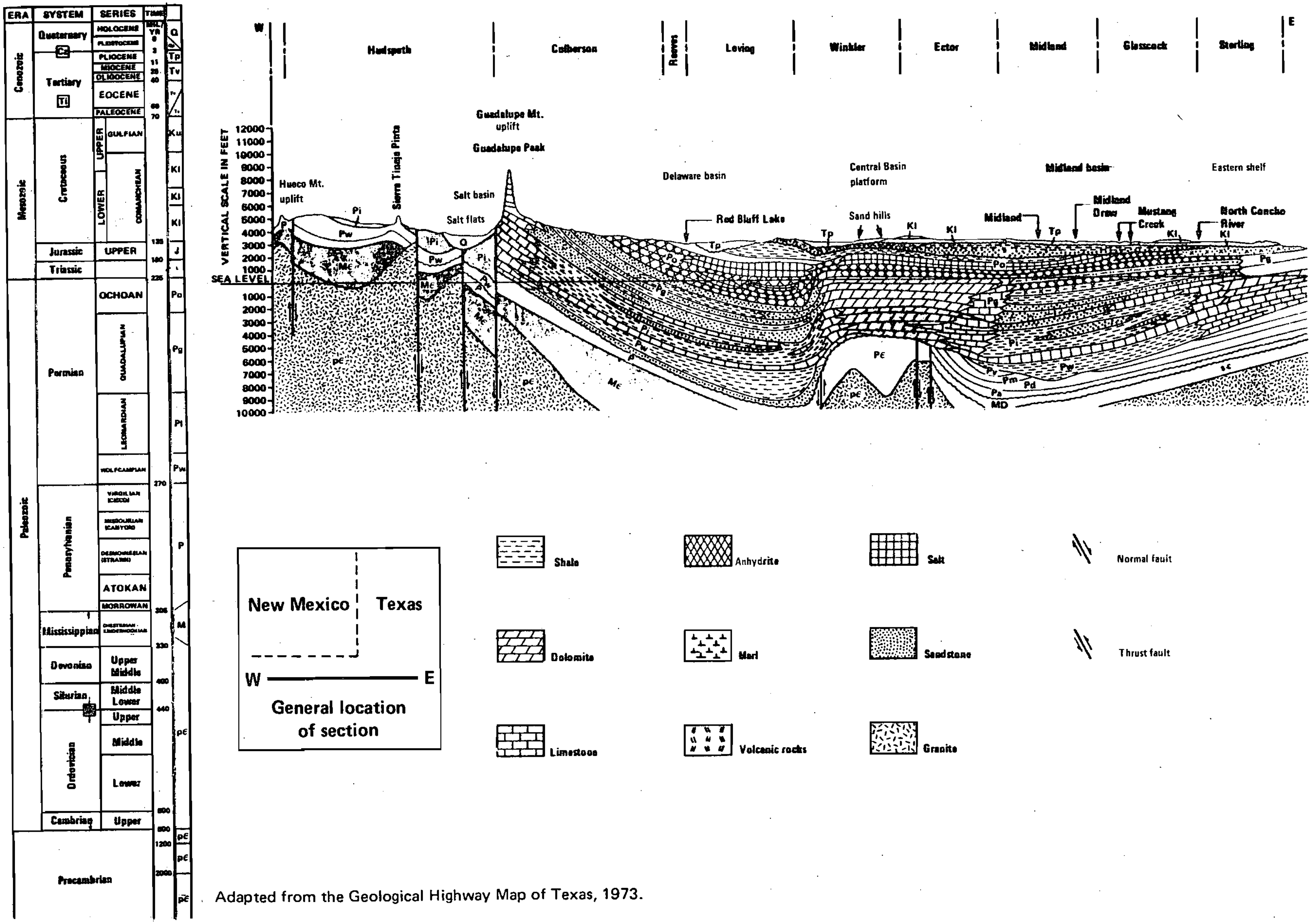
The main geomorphic features bearing on the region are the Pecos River drainage system, the Mescalero plain, a karst terrain, and wind-erosion "blowouts." The Pecos River system has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched sometime after the middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. Most of the ground surface east of the Pecos River Valley lies in the Llano Estacado, a poorly drained eastward-sloping surface covered by gravels, wind-blown sand, and caliche that has developed since early to middle Pleistocene time. The surface locally has a karst terrain containing superficial sinkholes, dolines, and solution-subsidence troughs, from both surface erosion and subsurface dissolution. The site lies near a caliche- and sand-covered drainage divide separating two major and actively developing solution-erosion features: Nash Draw to the west and San Simon Swale to the east.

Stratigraphy and lithology

A regional geologic section is shown in Figure 7-11. The stratigraphic section at the site region includes Precambrian through Triassic rocks, overlain by outliers of possible Cretaceous age and widespread sediments of late Tertiary through Quaternary age.

Metasediments and granitic-volcanic igneous materials constitute most of the regional basement, cropping out in isolated areas to the west and north. The granitic rocks range in age from about 1400 million years in the north to about 1000 million years in the south and are overlain in places by younger volcanic materials. The surface of the Precambrian reflects the late Paleozoic platform-and-basin structural configuration of the area (Powers et al., 1978, pp. 3-24ff).

The Paleozoic section consists of up to 20,000 feet of Upper Cambrian sandstones through Upper Permian evaporites and red beds. The Ordovician, Silurian, and Devonian rocks are mainly carbonates with sands, shales, and cherts. They were deposited in the shallow, calm shelves of the broadly subsiding Tobosa basin, with minor perturbations in uplifted areas such as the ancestral Central Basin platform. The Mississippian sequence consists of locally cherty limestones overlain by silty and sandy shales, truncated against adjacent emerging uplands. Post Mississippian mountain building caused uplift, tilting, and erosion, producing a massive section of Lower Pennsylvanian continental sediments interbedded with dark limestones, particularly toward the top of the section. From late in the Pennsylvanian through the Permian, a basin, basin-margin, and shelf configuration developed; it resulted in the deposition of dark shales, clastics, and some limestones and bioclastics. During the Permian a series of reefs formed along the basin margins, and shallow-water limestones and clastics were deposited on the adjacent shelves. In the Late Permian, evaporites were deposited in shallow seas restricted by the encircling Permian reefs (Powers et al., 1978, pp. 3-27ff). The evaporites are overlain by Permian red beds.



Adapted from the Geological Highway Map of Texas, 1973.

Figure 7-11. Geologic column and cross section of the New Mexico-Texas region.

The Mesozoic sequence is represented only by the Upper Triassic terrigenous Santa Rosa Sandstone, which in many places is truncated or removed by erosion, and by scattered patches of Cretaceous limestone and sandstones (Powers et al., 1978, pp. 3-53ff).

The early Cenozoic section is missing from the region because it has been eroded or was never deposited. The widespread late Miocene-Pliocene Ogallala Formation to the east of the site represents the earliest preserved Cenozoic deposit known in the region. The Ogallala is capped by a dense, resistant layer of caliche, probably formed during the late Pliocene. Quaternary deposits occur only locally and consist of the middle Pleistocene Gatuna Formation and later terrace, channel, and playa deposits, Mescalero caliche, and Holocene wind-blown sands (Powers et al., 1978, pp. 3-56ff).

Structure and tectonics

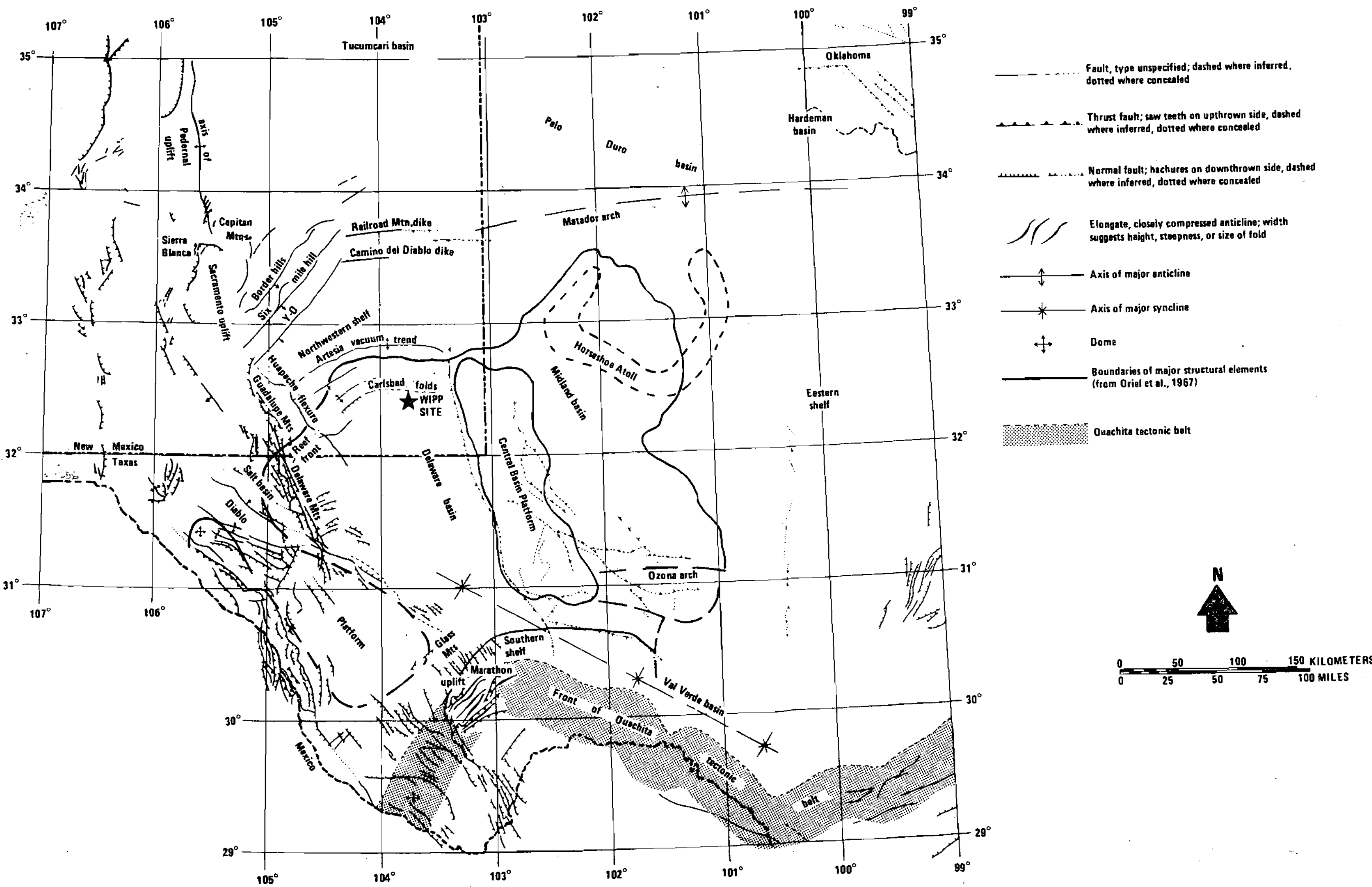
The major structural framework of the region is provided by the large-scale basins and platforms of late Paleozoic age and by Cenozoic features primarily associated with Basin and Range tectonics (Figure 7-12). The principal late Paleozoic features of the area were the Tobosa basin, later the Permian basin and its border lands. These elements include the Delaware basin, the Central Basin platform, the Midland basin, the Northwestern shelf, the Pedernal uplift, the Matador arch, the Val Verde basin, the Ouachita tectonic belt, and the Diablo platform.

The Delaware basin is a broad, oval, asymmetrical trough with a northerly trend and southward plunge and a structural relief of more than 20,000 feet on top of the Precambrian. Deformation of the basin rocks is minor, with formations older than Late Permian mainly gently downwarped. Deep-seated faults, some reflecting Precambrian faults, occur--as do folds, joint sets, and a number of smaller, probably solution-related, structures originating in the Upper Permian evaporites. The basin was defined by Early Pennsylvanian time, with major structural adjustments during Late Pennsylvanian to Early Permian time. Since the Late Permian, tectonic activity has lessened and is expressed in regional eastward tilting, relative uplift resulting in some erosion, and major faulting along the west face of the Guadalupe Mountains (Powers et al., 1978, pp. 3-60ff).

The Central Basin platform, a northward-trending subsurface feature separated from the Delaware basin to its west by a zone of major normal faulting, is a broad uplift of Precambrian to Pennsylvanian rocks, within which movement took place periodically, probably from the Precambrian until the late Paleozoic, when the basin became structurally stable. (Present seismic activity, probably related to the use of water injection for oil recovery, is discussed in Section 7.3.6.)

North and northwest of the Delaware basin lies the Northwestern shelf, which was well developed before Permian time and which may have originated in the early Paleozoic as the margin of the Tobosa basin. There are various flexures, arches, and faults on the shelf, but tectonic activity probably ceased in Tertiary time.

The Diablo platform, which forms the southwestern border of the Delaware basin, experienced uplift, folding, and faulting in the late Paleozoic. Deformation also occurred in late Tertiary time through block faulting and



Sources: Cohee, 1962; Kelley, 1971; Claiborne and Gera, 1974; Oriel et al., 1967.

Figure 7-12. Major regional structures.

buckling. Holocene uplift along the eastern side suggests continuing tectonic activity in the area. The other late Paleozoic structural elements of the area are only remotely related to the site.

Late Tertiary Basin and Range tectonics produced the Sacramento, the Guadalupe, and the Delaware Mountains to the west. They are generally eastward-tilted fault blocks bordered on the west by complex normal fault systems forming short, steep, westward slopes and backslopes dipping gently eastward. Small fault scarps in recent alluvium at the western edge of these ranges, some seismic activity, and changes in level lines suggest that structural development is continuing (Powers et al., 1978, pp. 3-73ff).

Igneous activity

The igneous activity that occurred in the region since Precambrian time is represented by Tertiary intrusives and Tertiary to Quaternary volcanic terranes located north, west, and south of the site area outside the Delaware basin. Only minor igneous activity, now represented by dikes and possibly sills, is known to have occurred within the Delaware basin.

The igneous feature of this type that is closest to the WIPP site is a nearly vertical trachyte or lamprophyre dike or set of en-echelon dikes. It trends about N 50° E. It extends for perhaps 75 miles into New Mexico from near the Texas-New Mexico border and passes about 9 miles northwest of the center of the site (Figure 7-13). The dike is exposed in two mines. It is also shown by cuttings or logs from drill holes and by aeromagnetic indications, and at the surface in the Yeso Hills 42 miles southwest of the site. Dated as middle Tertiary (about 35 million years old), it intrudes only into the Late Permian Salado and underlying formations.

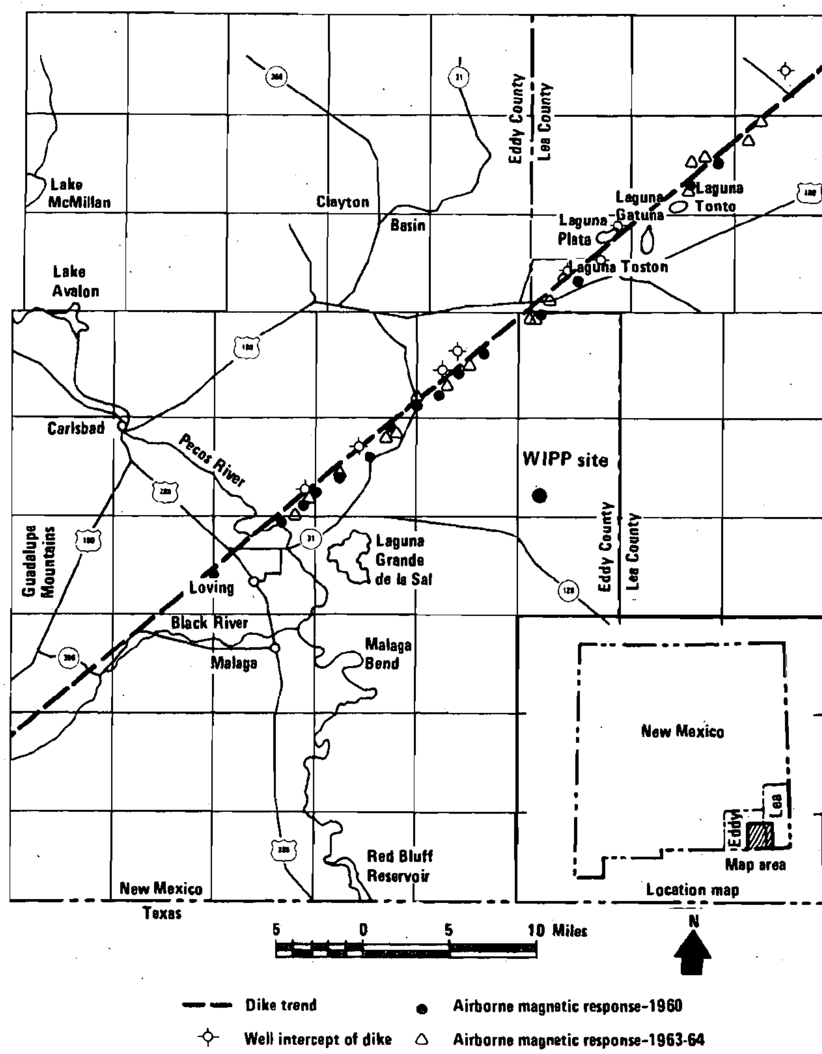
The principal Tertiary igneous features outside the Delaware basin are possible intrusive bodies within the Delaware Mountains, widespread intrusives farther south and west in the Trans-Pecos region of Texas, and several features well to the north of the basin: the eastward-trending El Camino del Diablo and the Railroad Mountain dikes and the stocks of the Capitan and the Sierra Blanca Mountains. Quaternary volcanic and related extrusive terrains are present far west of the site region in the Basin and Range province and the Rio Grande rift.

7.3.3 Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest, hummocky with sand ridges and dunes. A hard caliche layer (Mescalero caliche) is typically present beneath the sand blanket and on the surface of the underlying Pleistocene Gatuna Formation. Figure 7-8 is a topographic map of the area. Elevations at the site range from 3570 feet in the east to 3250 feet in the west. The average east-to-west slope is 50 feet per mile (Griswold, 1977).

Livingston Ridge is the most prominent physiographic feature near the site. It is a west-facing escarpment that is about 75 feet high and marks the eastern edge of Nash Draw, the drainage course nearest to the site. Nash Draw is a shallow 5-mile-wide basin, 200 to 300 feet deep and open to the southwest. It is at least partly caused by subsurface dissolution and the accompanying subsidence of overlying sediments (see Section 7.4.4). Livingston Ridge is the approximate boundary between terrain that has undergone erosion and/or solution collapse and terrain that has been affected very little (Powers et al., 1978, pp. 4-5ff).

About 15 miles east of the site is the southeast-trending San Simon Swale, a depression due at least in part to subsurface dissolution. Between San Simon Swale and the site is a broad, low mesa named "the Divide." Lying about 6 miles east of the site and about 100 feet above the surrounding terrain, it is a boundary between southwest drainage toward Nash Draw and southeast drainage toward San Simon Swale. The Divide is capped by the Ogallala Formation and the overlying caliche, upon which have formed small, elongated depressions similar to those in the adjacent High Plains section to the east.



Source: Elliot (1976a)

Figure 7-13. Igneous dike in the vicinity of the WIPP site.

Surface drainage is intermittent; the nearest perennial stream is the Pecos River, about 15 miles southwest of the center of the site. Surface runoff from heavy rains at the site may enter the Pecos River via Nash Draw; the discharge of shallow groundwater seems also to be controlled by the Pecos River (see Section 7.4). The site's location near a natural divide protects it from flooding and serious erosion by heavy runoff. Should the climate become more humid, any perennial streams should follow the present basins, and Nash Draw and San Simon Swale would be the most eroded, leaving the area of the Divide relatively intact (Bachman, 1974).

Dissolution-caused subsidence in Nash Draw and elsewhere in the Delaware basin has caused a search for geomorphic indications of subsidence near the site. One feature that has attracted some attention (Griswold, 1977) is a very shallow sink about 2 miles north of the center of the site in the southeast part of Section 9, T 22 S, R 31 E. It is very subdued, about 1000 feet in diameter and about 30 feet deep. Resistivity studies (Elliot, 1976b) indicate a very shallow surficial fill within this sink and no disturbance of underlying beds, implying a surface, rather than subsurface, origin. Recent resistivity surveys in the site area (Elliot, 1977) showed an anomaly in Section 17, T 22 S, R 31 E, within control zone II. It resembles the pattern over a known sink, a so-called breccia pipe, but drilling showed a normal subsurface structure without breccia, and the geophysical anomaly has been accounted for by low-resistivity rock in the Dewey Lake Red Beds. The process of salt dissolution is discussed in Section 7.4.4.

7.3.4 Site Stratigraphy and Lithology

This section provides stratigraphic (chronologic sequence, age, depth, thickness, and extent) and lithologic (rock type) descriptions of the total rock column at the site. More detail is given in the Geological Characterization Report (Powers et al., 1978, pp. 4-9ff). The site geologic column, Figure 7-14, indicates the major rock units beneath the site. Table 7-1 provides similar information in tabular form. The systems not discussed in the text are not present at the site because they were not deposited or have been eroded away.

The rock column at the site consists of a Precambrian crystalline basement 1400 to 1000 million years old, mostly metasediments and igneous rocks; carbonates of Ordovician to Mississippian age deposited in shallow-water or shelf conditions; basinal sediments of Late Mississippian to mid-Permian age, mostly sandstone deposited after the Delaware basin had formed; Permian evaporites; and Late and post-Permian clastic rocks. The surface is covered by a thin persistent veneer of Holocene sand.

The total thickness of the rock column above the Precambrian basement at the site is about 18,000 feet. Of this, pre-Permian rocks make up about 5000 feet, Permian rocks over 12,000 feet, and post-Permian rocks less than 100 feet. The Permian system constitutes over two-thirds of the sedimentary pile, but the portion of interest for the WIPP is the upper 4000 feet of evaporite and evaporite-related rocks of the Ochoan Series of Late Permian age.

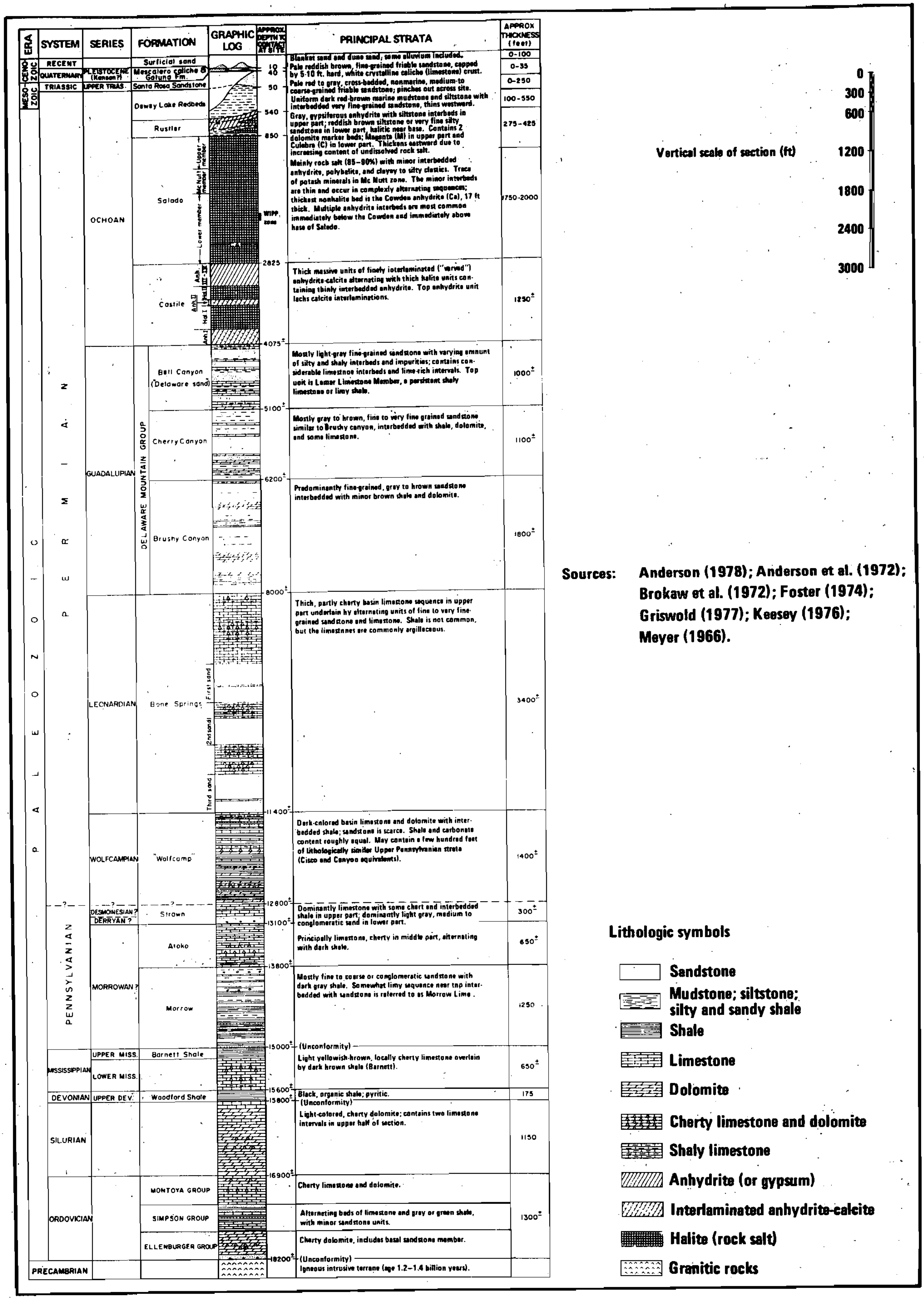


Figure 7-14. Site geologic column.

Table 7-1. Summary of WIPP-Site Stratigraphy

Era	System	Series	Formation	Million years before present	Approximate depth to lower contact at site center (ft)	Approximate thickness (ft)
Cenozoic	Holocene		Surficial sand		10	0-100
	Quaternary	Pleistocene	Mescalero caliche	0.01		
			Gatuna		40	0-35
	Tertiary[a]					
Mesozoic	Cretaceous[a]					
	Jurassic[a]					
	Triassic	Upper Triassic	Santa Rosa Sandstone	181	50	0-250
Paleozoic	Permian	Ochoan	Dewey Lake Red Beds	230	540	100-550
			Rustler		850	275-425
			Salado		2,825	1750-2000
			Castile		4,075	1250
		Guadalupian	Bell Canyon		5,100	1000
			Cherry Canyon		6,200	1100
			Brushy Canyon		8,000	1800
		Leonardian	Bone Springs		11,400	3400
		Wolfcampian	"Wolfcamp"		12,800	1400
	Pennsylvanian	Desmoinesian?	280			
		Derryan?	Strawn		13,100	300
		Morrowan?	Atoka		13,800	650
			Morrow		15,000	1250
	Mississippian	Upper Mississippian	Barnett Shale	310		
		Lower Mississippian	--		15,600	650
	Devonian	Upper Devonian	Woodford Shale	345	15,800	175
	Silurian	--	--	405	16,900	1150
	Ordovician	--	Montoya Group	425		
			Simpson Group			
			Ellenburger Group		18,200	1300
	Cambrian[a]		500			
Precambrian			600			

[a]System not present at the site.

Precambrian

Crystalline basement rocks near the site are believed to be granitic igneous rock or metamorphosed granites and rhyolites. The surface of the basement is about 17,900 to 18,200 feet deep. Radiometric ages are 1140 to 1350 million years (Powers et al., 1978, p. 4-12).

Pre-Permian rocks

Ordovician system. In the area of the site, the Paleozoic section begins with an estimated 1290 feet of Ordovician rocks beneath the center of the site (Foster, 1974). These rocks consist mostly of carbonates alternating with minor amounts of shale, sandstone, and conglomerate.

Silurian system. Lying above the Ordovician dolomites is carbonate rock of Silurian or Siluro-Devonian age. Near the site it is entirely light-colored dolomite with appreciable chert, except for two prominent intervals of limestone (Foster, 1974). The basal contact is apparently disconformable in this area. The total thickness of Silurian or Siluro-Devonian carbonates is about 1140 feet (Foster, 1974). They thin westward relatively uniformly. The top of the Silurian is about 15,850 feet beneath the surface (Netherland, Sewell, 1974).

Devonian system. The Devonian system is represented by a distinctive unit of organic, pyritic black shale that unconformably overlies the Silurian carbonates. Beneath the center of the site, it is about 175 feet thick and thickens gradually southeastward (Foster, 1974).

Mississippian system. Rocks of the Mississippian system at the site include a series of limestones and overlying shale. The top of the Mississippian is about 15,150 feet below the surface (Netherland, Sewell, 1974). The carbonates are about 480 feet thick at the site, gradually thickening northward. The overlying black shale is about 175 feet thick.

Pennsylvanian system. The Pennsylvanian strata at the site are approximately 2200 feet thick (Foster, 1974). The section consists of alternating members of sandstone, shale, and limestone and rests unconformably on the underlying Mississippian shale. The Morrow, the Atoka, and the Strawn Formations, at the base of the Pennsylvanian sequence, are the major prospect horizons for gas production at and near the WIPP site.

Unlike most of the earlier Paleozoic strata, the Pennsylvanian strata and some of the Lower Permian strata in the Delaware basin show many changes in vertical lithology and many lateral facies changes along time-equivalent horizons.

Permian system

The Permian strata in the Delaware basin, as much as 13,000 feet thick, are the most complete Permian succession in North America. The Permian section at the site is about 12,800 feet thick; it comprises over two-thirds of the entire sedimentary column and is more than twice as thick as all earlier Paleozoic formations combined (about 5200 feet). Of this total, about 3500 feet of thick, relatively pure evaporites (mainly halite and anhydrite) are in the upper part of the sequence, where the repository is to be constructed (Powers et al., 1978, pp. 4-19ff).

The Lower Permian rocks are interbedded limestone, shale, dolomite, and sandstones. During the Late Permian, the Capitan reef and the overlying massive evaporites were deposited. These evaporites consist of, in ascending order, the Castile, the Salado, and the Rustler Formations, which are overlain by the clastics of the Dewey Lake Red Beds. The four formations at the site have a total thickness of about 4000 feet, of which about 3500 feet are evaporites--largely anhydrite and halite, with some fine-grained clastics and evaporitic salts, including carbonates and potassium and magnesium minerals. The Castile and the Rustler are richer in anhydrite and carbonate rock than is the Salado, and they form barriers that over geologic time have retarded the movement of groundwater into the Salado Formation.

Castile Formation. The Castile rests in apparent conformity on underlying sandstones and limestones. At the site its top is about 2800 feet deep, and it is about 1300 feet thick. It consists mainly of massive beds of laminated calcite-anhydrite and halite. In the basin, the Castile has several massive anhydrite members separated by moderately thick salt beds merging to the north into a wedge of anhydrite that thins toward the Capitan reef.

Salado Formation. The principal salt formation of the area, the Salado lies with probable unconformity on the Castile. At the center of the site, its top is 860 feet deep, and its thickness is 1975 feet. It is divided informally into three main members. The individual beds are very persistent and are the basis of a numbering system used by mining companies. The three members are an unnamed lower, the McNutt Potash Zone, and an unnamed upper. The three members are similar except that the McNutt Potash Zone is locally rich in potassium- and magnesium-bearing minerals and supports extensive potash mining to the west and north of the site. The upper member contains relatively larger amounts of clay minerals and sulfate minerals, including anhydrite and polyhalite (Powers et al., 1978, pp. 4-29ff).

The lower member of the Salado Formation is the proposed location of the WIPP repository. Rock core from a drill hole at the center of the site shows the purest and thickest halite beds to be in this lower member. The lower member consists primarily of halite, though interbeds of anhydrite and polyhalite are fairly common. Thin zones with a clay mineral content of up to a few percent are present in the lower member as well as in the rest of the Salado. Many of these zones are associated with anhydrite or polyhalite beds. A significant marker bed in the lower member is a 22-foot seam of anhydrite called the Cowden anhydrite. Within the lower member, the halite below the Cowden is the purest and most uniform, as inferred from drilling logs and the core taken from a drill hole at the center of the site (ERDA-9). Next in quality is a halite zone above the Cowden. The proposed mine level for the WIPP is about 2150 feet below the surface.

During the drilling of two holes near the site (AEC-7 and AEC-8) and occasionally in potash mines, pockets of nitrogen-rich gas have been encountered in the evaporite sequence. Lambert (1978) suggests that this gas was originally dissolved in seawater trapped as fluid inclusions. The evaporites underwent some postdepositional recrystallization about 204 million years ago; during this process some fluid inclusions coalesced, forming pockets of brine and air. The free oxygen is readily scavenged by reducing chemical species, leaving accumulations of nitrogen-enriched gas.

Rustler Formation. Outcrops of the Rustler in Nash Draw are often disrupted near the surface by the solution of salt and gypsum to form a jumbled mass of gypsum with some dolomite, sandstone, and clays. Eastward, at greater depths, the gypsum in the Rustler gives way to the original anhydrite and minor polyhalite, and the sandstone and claystone give way to sandy and clayey salt. At the center of the site, where its top is 550 feet deep and the formation is 310 feet thick, the Rustler consists primarily of thick seams of anhydrite (up to 50 feet thick) and siltstones containing halite near the base. It contains two dolomite beds, the Culebra and the Magenta, 720 and 610 feet deep, respectively. Each is about 25 feet thick. The Culebra contains water of varying quality and quantity (see Section 7.4) (Powers et al., 1978, pp. 4-39ff). (The Rustler Formation might possibly contain vertebrate fossils in this area. If significant vertebrate fossils are found in the Rustler or in other formations during construction, paleontologists from State or regional institutions will be promptly invited for salvage operations.)

<u>Dewey Lake Red Beds</u>. Resting unconformably on the Rustler Formation, the Dewey Lake Red Beds are the uppermost of the Late Permian and Paleozoic rocks in the Delaware basin. They are reddish-orange to reddish-brown siltstones and fine-grained sandstones. Some beds are structureless, others are horizontally laminated or cross-laminated. According to Vine (1963), they represent the beginning of a continuous deposition of detrital sediment after the long period of evaporite deposition in the Delaware basin and in the adjacent shelf areas of southeastern New Mexico. At the site, they are 63 feet deep and 490 feet thick.

<u>Post-Permian rocks</u>

<u>Triassic system</u>. The Santa Rosa Sandstone of Late Triassic age rests unconformably with sharp lithologic contact on the Dewey Lake Red Beds. This unconformity indicates a break in deposition between Permian and Late Triassic time, perhaps longer than any previous in the region since Mississippian time or even earlier. At the site the Santa Rosa Sandstone is a 9-foot-thick erosional wedge that pinches out just to the west of the center of the site. It is mostly cross-stratified, medium- to coarse-grained, gray to yellow-brown sandstone, but it includes conglomerate and reddish-brown mudstone (Powers et al., 1978, pp. 4-44ff).

<u>Quaternary system</u>. The Gatuna Formation of Pleistocene age forms a thin blanket, locally absent, up to 30 feet thick. In spite of its nearness to the surface, however, the Gatuna crops out only rarely, being mostly obscured by a thin but persistent veneer of caliche and surficial sand. The nearest mapped outcrops occur along the west-facing slope of Livingston Ridge at the edge of Nash Draw, about 4 miles northwest of the center of the site (Figure 7-15). Though the Gatuna is mainly a fine-grained, reddish or brownish friable sandstone, conglomerate lenses and blankets are common regionally. Gatuna time, which occurred about 600,000 years ago, was the most humid Pleistocene stage in southeastern New Mexico (Bachman, 1974 and in preparation; Powers et al., 1978, pp. 4-47ff).

Beneath an obscuring cover of wind-blown sand, most of the site is covered by a hard caliche (a near-surface layer of calcium carbonate) called the Mescalero caliche. It is 3 to 5 feet thick, light gray to white, and sandy and is said to be the remnant of an extensive soil profile. It began forming about 600,000 years ago through successive cycles of solution and reprecipitation of soil carbonates during the dry period after the moist climate of Gatuna time.

Holocene deposits near the site include wind-blown sand, alluvium, and playa deposits (Figure 7-15). The main deposit is the wind-blown sand, locally known as the Mescalero sand (Vine, 1963), that covers nearly all of the site, occurring either as a sheet deposit resting on caliche or as conspicuous dune fields. The sheets are probably no more than 10 to 15 feet thick on the average; the sand dunes may be as high as 100 feet. At many places the sand consists of a compacted, slightly clayey moderate-brown sand that is up to 1.5 feet thick and is overlain by loose, light-brown to light-yellowish-gray sand. The dunes appear to be relatively inactive at present, partly stabilized by a sparse plant cover. The widespread deposits of wind-blown sand are indicative of a large source of fine sand as well as of the extreme fluctuations of climate during Pleistocene time. During humid intervals in Pleistocene time, the sand was eroded from nearby outcrops of the Ogallala Formation, and during arid intervals the wind has moved this sand across the Mescalero plain (Bachman, 1974).

Description of the emplacement horizon

The Geological Characterization Report (Powers et al., 1978), particularly Chapters 7 and 9, details studies of horizons at depths of about 2100 and 2700 feet and related rocks in the Salado Formation. At the time two levels were planned for the WIPP, the lower one for the demonstration of spent-fuel disposal, which has since been deleted from the WIPP mission. A horizon at a depth of about 2150 feet has been selected for the WIPP TRU-waste repository. Thus the studies at 2100 feet remain applicable. They include studies of the mineral composition, chemical and thermophysical properties, deformation, volatile-matter content, and fluid inclusions of the beds.

In its physical properties and mechanical behavior, rock salt differs from other geologic materials. It shows nonlinear inelastic response under practically all loading conditions. It behaves in a ductile fashion even at temperatures and pressures often encountered in mining. It can undergo large strains before failure, and openings even at very shallow depths have completely closed over long periods (Baar, 1977). It is therefore important to distinguish salt from other rocks, particularly in analyzing deformations.

The rock salt of southeastern New Mexico has been studied through petrography, which gives indirect information on physical and mechanical properties, through direct measurements of physical properties, and through direct measurements of thermal-mechanical properties.

The basic mineral of the emplacement horizon is halite. Also present are anhydrite, polyhalite, quartz, and a suite of clay minerals (illite, chlorite, talc, serpentine, and expandable clays). Halite beds within the emplacement horizon are about 97% halite. Most of the remainder is anhydrite (Bodine and MacMillan, 1978).

The grain size of all salt studied varies, in order of decreasing abundance, from coarse (larger than 0.45 inch) to medium (0.05 to 0.45 inch) and fine-grained (smaller than 0.05 inch). The grain geometry of many coarse samples suggests some secondary recrystallization (Bodine and MacMillan, 1978).

Grain boundaries are moderately tight; halite grains touch locally, with few mineral constituents in the interstices. Individual grains show no elongation or preferred orientation.

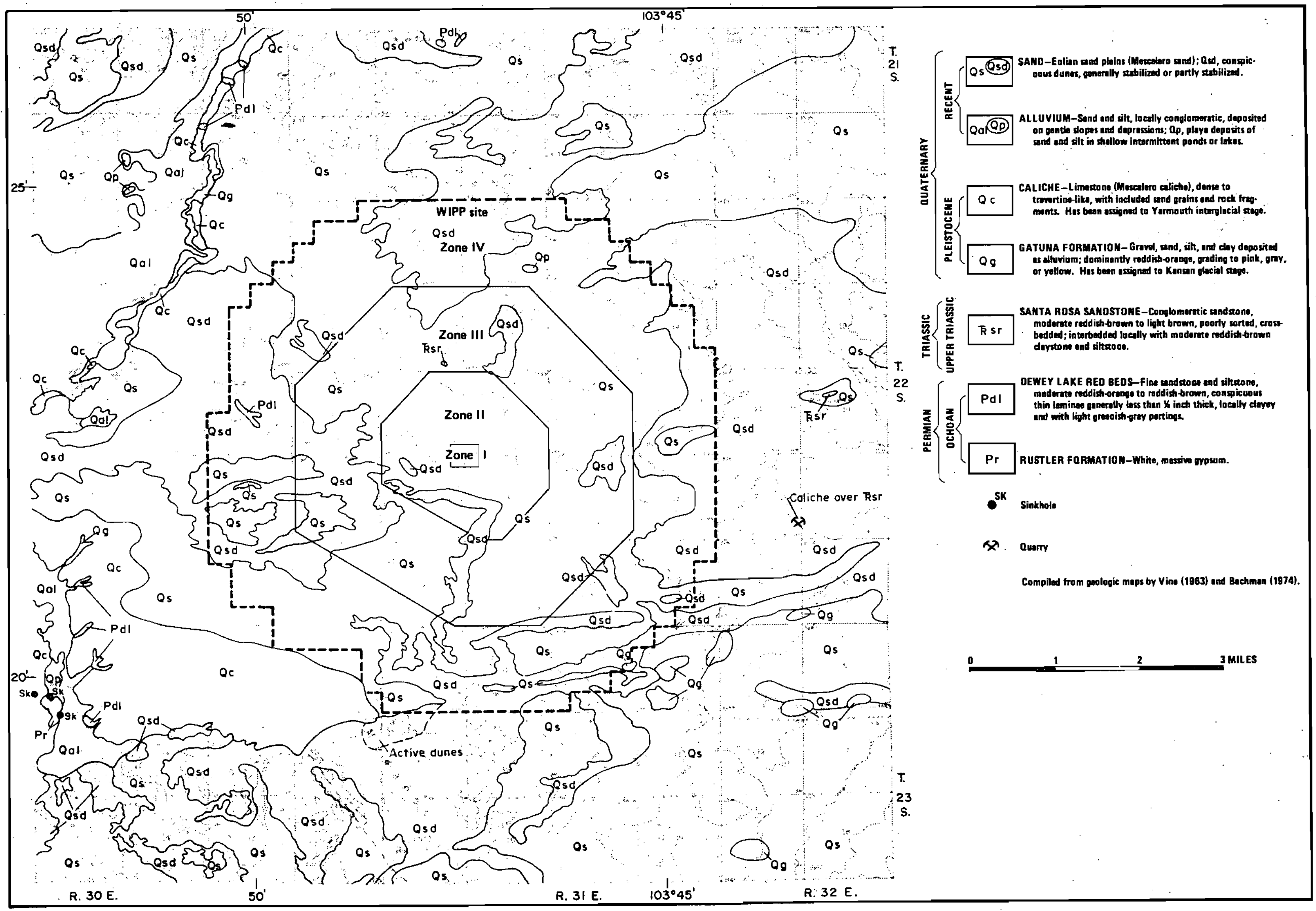


Figure 7-15. Surficial geology map.

Powdered samples were heated in nitrogen and their weight loss measured. The loss includes water loss, gas loss, and loss from decomposition. The median weight loss was 0.36%, but one sample of polyhalite (theoretically 6 weight percent water) from below the proposed emplacement levels had a 5.4% weight loss (Powers et al., 1978, pp. 7-32ff and Table 7.12). Roedder and Belkin's (1978) samples showed an average of 0.36 weight percent fluid throughout the evaporites. The range of fluid content was from about 0.1 to 1.7 weight percent, consistent with results obtained by static heating and thermogravimetric analysis. Roedder and Belkin (1978) also indicate that the fluids are not simply sodium and potassium chloride solutions, but include other ions, such as magnesium. The amount of gas in the fluid inclusions is generally very low, implying that the inclusion would probably move up a thermal gradient toward a heat source. The inclusions seem not to have migrated significantly since they were formed during Permian time.

The physical properties measured include density, moisture content, porosity, air permeability, electrical resistivity, ultrasonic velocity, and thermal conductivity. Mechanical properties measured include uniaxial compressive strength, unconfined tensile strength, stress-strain behavior and ultimate stress in quasistatic triaxial compression, elastic moduli, principal strain ratios, yield stress (elastic limit), and creep rates. Other tests addressed the effects of specimen preparation on the results obtained in the laboratory. Representative mechanical properties are listed in Table 7-2.

Salt from the site can undergo transient and steady-state creep. Both are being considered in design calculations, with steady-state creep being particularly important at high temperatures. Preliminary steady-state creep rates are in the range of 10^{-10} to 10^{-7} per second. Transient creep depends on pressure, principal stress difference, and temperature. The test results indicate that these three are interdependent. Of these three, temperature appears to have the most dramatic effect on the creep rate.

7.3.5 Site Structure and Tectonics

Rock structures record past rock deformations. This record allows the reconstruction of the tectonic history (large-scale events involving the earth's crust) of the site and the region and the evaluation of the general stability. This section summarizes information on tectonic and nontectonic mechanisms, deep structures, salt deformation, shallow structures, and man-induced subsidence structures. More detailed descriptions are given elsewhere (Powers et al., 1978, Section 4.4).

Tectonic and nontectonic mechanisms at the site

In the development of the Delaware basin preexisting rocks were deformed by the weight of rapidly deposited sediments and by tectonic stress from within the crust. The presence of thick salt beds strongly affects the deformations. The deformation of thick salt is plastic, very different from the deformation of most other geologic materials under similar conditions. Therefore, when tectonic forces act on a structure with a thick salt bed sandwiched between two layers of brittle rock, there need be no similarity between the deformations of the upper and the lower rock layers. Differences in deformation above

Table 7-2. Properties of Salt at the WIPP Site[a]

Property	Average value (range)
PHYSICAL PROPERTIES	
Density (g/cm^3)	2.18
Porosity (%)	0.5 (0.1-0.8)
Moisture loss (% by weight to 300°C)	0.4 (0-1.0)
Resistivity (ohm-m)	58,100 (4900-230,000)
Air permeability (darcys)	10^{-7}
P-wave velocity (km/sec)	4.5 (4.42-4.62)
Thermal conductivity (W/m-K)	5.75
MECHANICAL PROPERTIES	
Quasistatic properties at 23°C	
Unconfined strength (psi)	2450-3300
Secant modulus (psi)	2×10^6
Principal strain (Poisson's) ratio	0.25-0.35
Strain at failure (%) for a confining pressure σ_3 of	
0 psi	2.5-6.0
500 psi	17-20
3000 psi	20
Tensile strength (psi)	220
Initial yield stress ($\sigma_1 - \sigma_3$)(psi)	100
Preliminary creep properties	
Steady-state creep rate ϵ (sec^{-1}):	
At 23°C and $\sigma_1 - \sigma_3$ = 1000 psi	10^{-10}
At 130°C and $\sigma_1 - \sigma_3$ = 2000 psi	10^{-7}

[a]Data from Powers et al. (1978, pp. 1-34ff).

and below a salt layer can also result from the collapse and deformation of rock units overlying zones of salt dissolution.

Clearly, then, structural features in the rocks that occur in the area are related to the position of these rocks in the geologic column. Accordingly, the following description of geologic structure at the site is organized into separate discussions of structures below the salt, the salt beds, and structures above the salt; also discussed is subsidence in the Potash Mining District close to the site to the north and west (Powers et al., 1978, pp. 4-54ff).

Deep structures

The Middle and Early Permian rocks beneath the salt beds slope east-southeast at about 50 feet per mile. The Paleozoic rocks beneath the Permian slope in the same direction but more steeply, at about 100 to 150 feet per mile. The nearest substantial fault is a north-trending fault about 15 to 20 miles east and southeast of the site, described by Foster (1974) and referred to as the "Bell Lake fault." It has a length of about 15 miles and a displacement of about 500 feet. Foster's analysis of borehole data indicates that Upper Permian strata are not offset by the fault, but the deeper Permian strata are distorted near the fault (Powers et al., 1978, pp. 4-56ff).

Contour maps based on seismic-reflection data from the Paleozoic strata below the salt show small faults running generally north-northeast and small, shallow domes and saddles several miles apart and several hundred feet from crest to trough (Griswold, 1977; Powers et al., 1978).

Figures 7-16 and 7-17 (Griswold, 1977) show general southwest-northeast and northwest-southeast sections, respectively, across the site. Faults arising in the basement rocks cut through the Pennsylvanian strata and fade out in the Permian. Faults indicated in the lower portion of the Castile are believed to be depositional-growth faults or due to massive salt flow. They are not found in the Delaware Mountain Group. There is much less warping in the Delaware Mountain Group, and it is apparently unrelated to the deeper trends. The Delaware Mountain Group locally forms a northwest-trending saddle, with about 100 feet of structural relief, near the center of the site.

Structural differences between Delaware and pre-Permian strata suggest different origins and two periods of faulting. Below the Pennsylvanian all strata are deformed together, the intensity increasing with depth. Tectonic deformation apparently occurred in Late Pennsylvanian or Early Permian time and established the local structure of all pre-Permian rocks. Faults arising in the basement rocks cut into, but not through, the Pennsylvanian strata (Powers et al., 1978, p. 4-59).

<u>Salt deformation in the Castile and Salado Formations</u>

In the northern Delaware basin, a structural feature common to all levels of the evaporite section is the uniformity in the direction and the slope of the gentle, southeastward dip (Figure 7-17) (Jones, 1973). Superimposed on the regional dip pattern are localized salt-flow structures; some may be Permian in age, others appear related to Delaware basin tilting of mid-Tertiary age (Powers et al., 1978, pp. 4-60ff).

The greatest deformation in the evaporite sequence at or near the site seems to be related to a deformation belt inside the Capitan reef front. This belt is irregular in geometry but is generally about 5 miles in width, and it is reflected in the folding, particularly in the Castile Formation, of the interbedded halite and anhydrite. The belt of deformation sometimes includes salt-flow structures from the Castile (Anderson, 1978; Anderson and Powers, 1978). Some of this structure seems to have been formed when regional tilting caused plastic flow of salt against the Capitan reef. Data from the site area indicate only that tilting occurred after Late Triassic time and before late Miocene time. Other salt structures do not appear to involve overlying Permian and post-Permian rocks, implying that in those instances deformation may have occurred at about the same time as deposition (Powers et al., 1978, pp. 4-61ff). About 5 miles northeast of the center of the WIPP site is an anticlinal or domelike structure with a core of mobilized Castile salt within the belt of salt deformation flanking the Capitan reef. An anticlinal

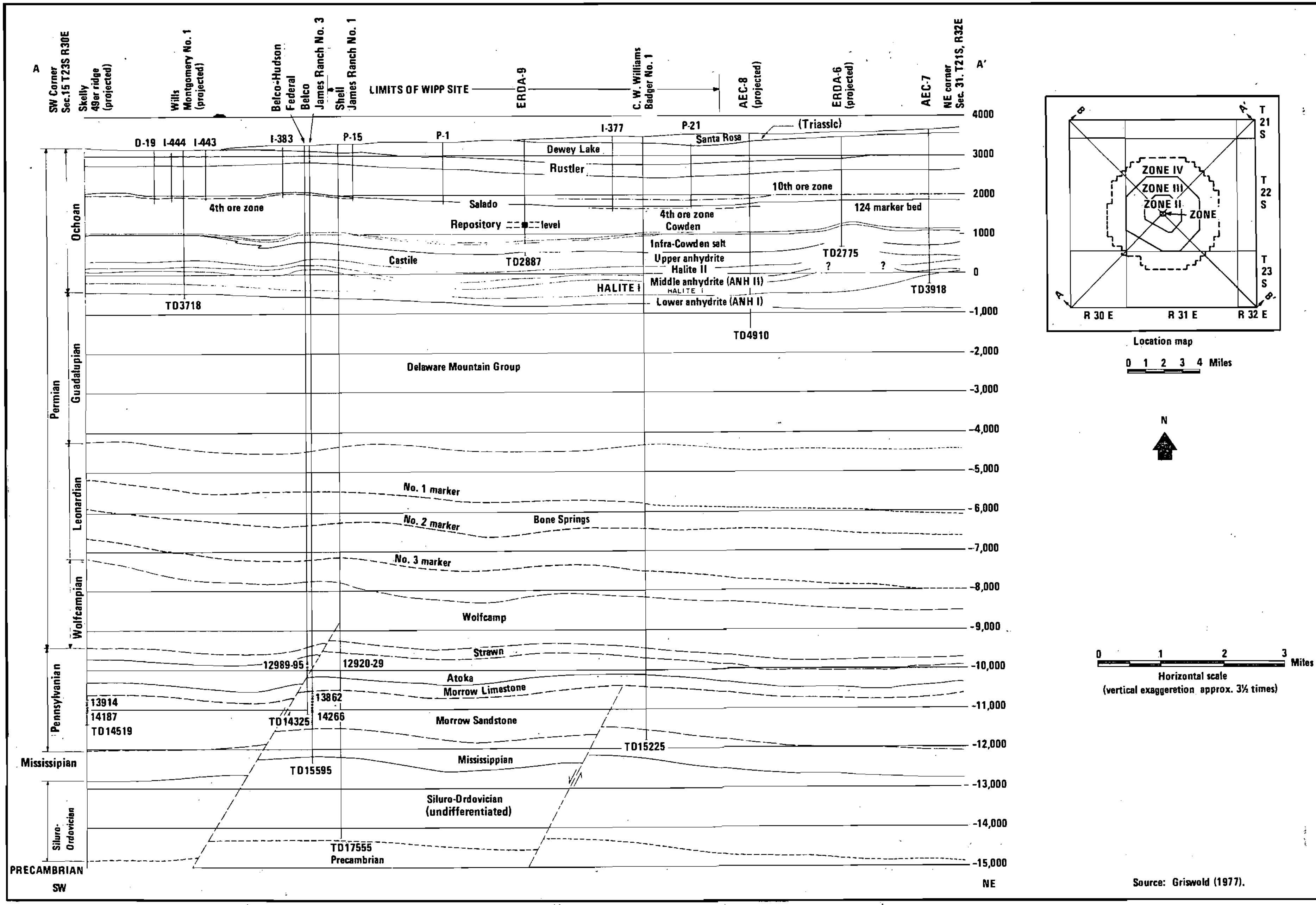


Figure 7-16. Site geologic section A-A'.

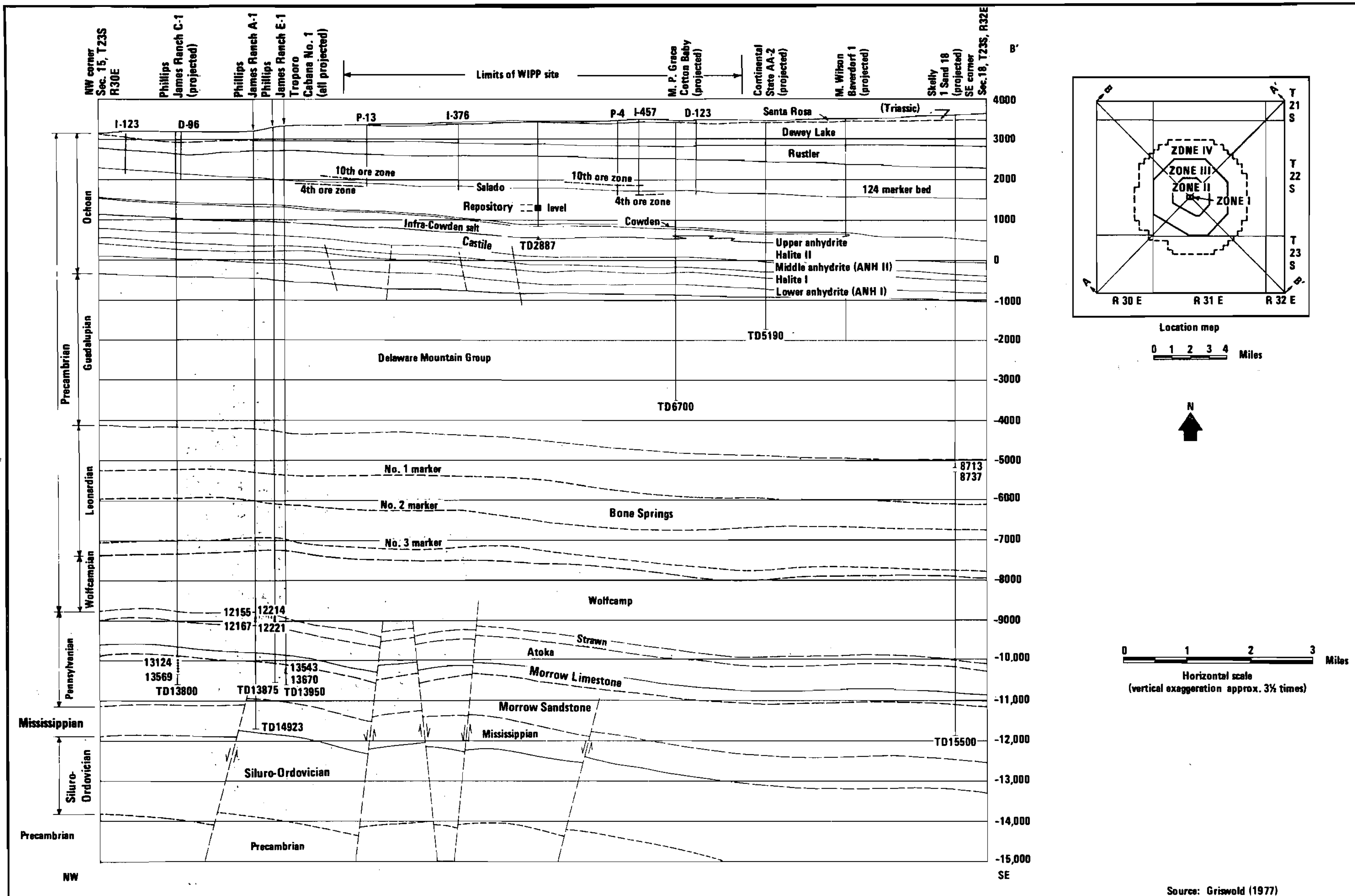


Figure 7-17. Site geologic section B-B'.

structure of less vertical size is 3 to 4 miles southwest of the center of the WIPP site.

A ridge-and-saddle configuration trending northwest, with a crest-to-trough separation of 2 to 3 miles and a total structural relief of up to 400 feet, is indicated by the contours of the top surface of the Castile Formation as determined from seismic-reflection data.

The structure contours presented in the Geological Characterization Report (Powers et al., 1978, Figure 4.4-6) also indicated an inferred fault with a displacement of about 300 feet at the edge of control zone II. Since that time about 77 line-miles of additional seismic data (Bell and Murphy, 1979) have been obtained, and WIPP-12 (see Figure 7-23) has been drilled. The borehole data confirm an elevation change of about 130 feet between ERDA-9 and WIPP-12 on the top of the Castile Formation. The inference is that there is an anticlinal structure on the top of the Castile. In their analysis of seismic-reflection data from ERDA-9 and WIPP-12, Bell and Murphy (1979) point out that the apparently continuous reflecting layers from the top of the Castile are not consistent with the depth of the top of the Castile and the seismic velocities measured in ERDA-9 and WIPP-12. This may be explained by a relatively tight folding or a discontinuity in the upper Castile. Boreholes indicate no evidence of this structure at the top of the Salado. Four boreholes (WIPP 18, 19, 21, 22) were previously drilled between ERDA-9 and WIPP-12 to determine whether the previously inferred faulting extended upward through the Salado and into or through the Rustler. No evidence of a fault was obtained from these holes, and the small differences in stratigraphic thicknesses are well within the normal range for the area. The detailed north-south and northwest-southeast cross sections through the site shown in Figures 7-18 and 7-19 are based on the latest available (November 1979) borehole and seismic reflection data.

The seismic reflection data available (Powers et al., 1978; Bell and Murphy, 1979) all confirm the existence of an area in the northern part of the site with significant differences in the seismic character of the Castile and the Salado. This area has been called the "disturbed zone." The salient features of this area (Figure 7-18) are an anticlinal structure at its southern margin, interruptions and discontinuities in the seismic returns from the lower evaporites, thinning and thickening of evaporite beds, and seismic reflections from the upper Salado that are extremely difficult to interpret. Preliminary examination of cores from boreholes WIPP 11, 12, and 13 confirms thinning and thickening of evaporite beds in the Castile and the lower Salado. The principal hypotheses of the origin of the disturbed zone are dissolution, mechanical halite flow, and deposition. None of these is preferred at this time, and a combination of processes may have occurred. The core does not contain residues from regional deep dissolution, and it does not indicate a massive mechanical flow of halite. The deformation of sediment before lithification accounts for some, but not all, features. Shallow-borehole data do not indicate anomalous geologic conditions in the upper Salado except that marker bed 124 appears low in an industry potash hole 2 miles north of ERDA-9. Examination of core and other data is continuing to provide additional assessment of the disturbed zone.

Additional seismic-reflection data (Bell and Murphy, 1979) have made it apparent that the fault trend on the Castile inferred earlier (Powers et al., 1978, Figure 4.4-6) is not correct. The fault or fold near WIPP-12 and to the

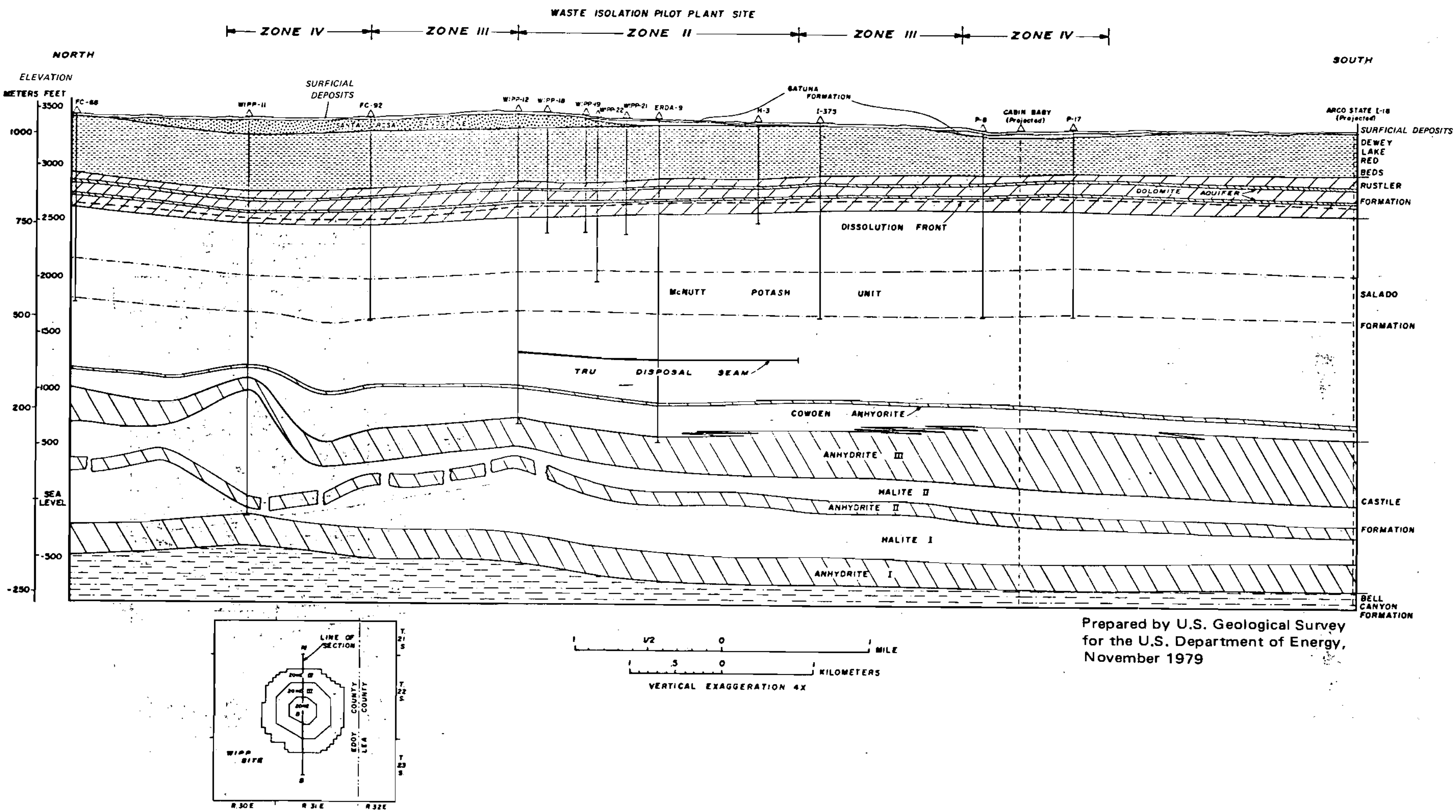


Figure 7-18. Geologic section through the WIPP site: north-south.

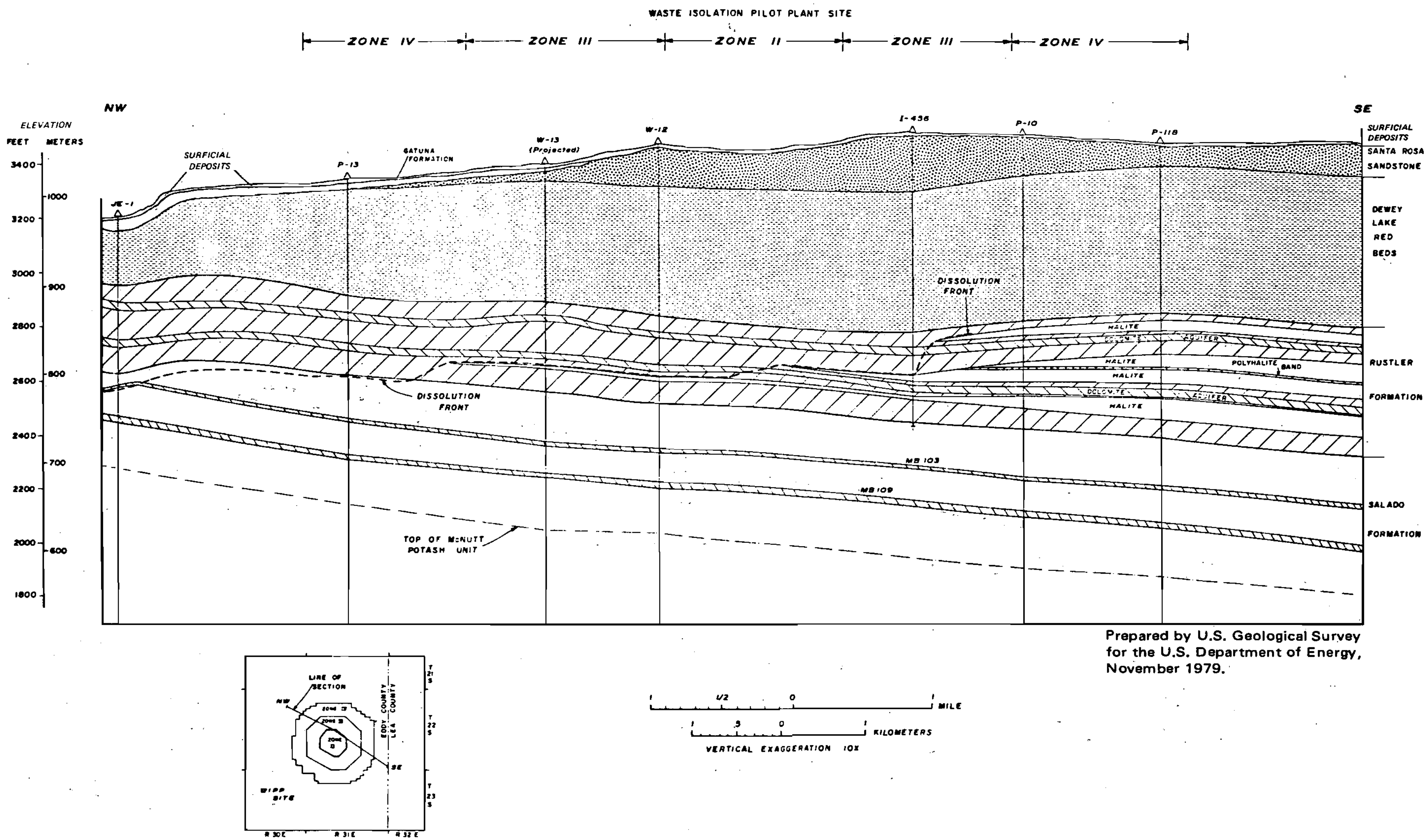


Figure 7-19. Geologic section through the WIPP site: northwest-southeast

northwest is arcuate and bounds the disturbed zone. The evidence near the southeast edge of the site is part of an old fault or discontinuity, trending northeast, not northwest, in and below the lower evaporites. The inference of a northwest-trending fault through the center of the site, though reasonable from the data available in 1978, is not supported by the additional data.

Anderson (1978) has attributed some localized depressions within the evaporite units to "deep dissolution." In the central part of the basin, to the south of the site, these "deep-seated sinks" may not show at the surface and are not clearly related to the shallower dissolution features described below. These midbasin "deep sinks" may not be of recent origin. If they are, they may well be related to other collapse features in the Delaware basin region as different stages of a general process of erosion (Anderson, 1978, pp. 58-59). Bachman (in preparation), however, attributes these latter exposed features in the Delaware basin to processes other than deep dissolution (Section 7.4.4).

Two depressions in the Salado occur near the site. One, identified by Anderson (1978, Figure 7) as a possible "deep sink," is nearly 5 miles east-southeast of the center of the site and is based on one borehole. The isopach of the infra-Cowden salt exhibits severe thinning or absence at this borehole. Neither Castile nor Salado isopachs indicate any similar features. The top of marker bed 124 is a low at this borehole (Anderson, 1978). A second depression is centered about 2 miles north of the center of the site and is also based on a single borehole. This feature appears not to be a sink or breccia pipe, as horizons other than marker bed 124 are not affected and there is no resistivity anomaly. There is no basis for postulating a northwest-trending fault or dissolution zone on the basis of these features. For site structures see the Geological Characterization Report (Powers et al., 1978).

The interception of a brine reservoir in ERDA-6 at a now-abandoned site (Section 2.2.3) has caused concern over the possible existence of such reservoirs at the present site and the consequences to a repository. The occurrences of brine reservoirs have previously been summarized (Griswold, 1977; Powers et al., 1978). The nearest is immediately southwest of the site at the Hudson-Belco well. The next closest is ERDA-6, about 2 miles northeast of the outer site boundary. Five wells, present in two clusters about 10 to 12 miles east of the site, are also known to have produced brine. All of these occurrences, except for the Hudson-Belco well, are within a general deformation belt inside the Capitan reef. The Hudson-Belco well is on an anticlinal structure about 3 miles southwest of the center of the site. All of the brine appears to come from the Castile Formation, and it is associated with the middle, or possibly upper, anhydrite of the Castile. However, the Castile has been penetrated many times without producing brine, and WIPP-11 in particular penetrated through an anticlinal structure in the Castile without detecting any brine or fluids. With this background, the broad anticlinal structure in the Castile at the northern edge of control zone II is the closest area to the site that might be suspected of containing a brine reservoir. ERDA-9 (to the south), WIPP-12 (on the crest of the structure), and WIPP-13 (immediately northwest of the structure) have penetrated into the upper Castile anhydrite (WIPP-13 to the base of the Castile) without revealing any brine reservoir.

The repository level (about 2150 feet) at ERDA-9 is nearly 700 feet above the upper Castile anhydrite and perhaps 1300 feet or more above the middle anhydrite of the Castile. Since the mining will follow stratigraphic horizons, at least several hundred feet of evaporites will be between the repository in the Salado Formation and the uppermost beds presumed to have produced brine. Because of the 700-foot layer of evaporites between the repository level and the Castile Formation, a deep Castile brine pocket would pose no hazard to the repository even if one should be present in the Castile--an unlikely probability for an area of gentle structure.

In addition, the very existence of brine reservoirs, such as at ERDA-6, and the time that has elapsed since fluid movement (at least 500,000 years ago, Powers et al., 1978, p. 7-99) give reasonable assurance that such reservoirs are not connected either to aquifers above the Salado or to the surface.

In summary, the Salado Formation has a relatively uniform easterly dip of about 80 to 100 feet per mile across the site, and there is little evidence of any significant structural anomalies (Figures 7-18 and 7-19). No plastic deformation or buckling associated with salt flow seems to have occurred in the Salado as has been inferred for the lower levels of the Castile. Artesian brine reservoirs are sometimes associated with much-thickened salt sections and salt-flow structures in the Castile. The apparently thickened section of Castile within the site is mainly at the northern edge of control zone II. The effects appear to be much less than at ERDA-6, where the buckling was so severe as to make mining in a single bed nearly impossible.

Shallow structures

"Shallow" is here defined to include all depths down through the Rustler Formation, or to a depth of about 850 feet beneath the center of the site (Powers et al., 1978, pp. 4-73ff).

At the site, the surface sand makes it hard to observe the surface geologic structure. Rocks above the Salado Formation have been weathered and sometimes have secondary structures resulting from surficial dissolution and subsidence (see also Section 7.4). Shallow structures near the site therefore have greater irregularity and complexity than do deeper rocks. In nearby Nash Draw the original structures are masked by widespread slumping from salt dissolution. This surface jumbling is in Nash Draw, and not between Livingston Ridge and the site. Livingston Ridge, 4 miles northwest of the site, marks the edge of Nash Draw. The rocks exposed here are strongly jointed, cavernous, and locally brecciated; stratification is generally obliterated (Jones, 1973).

The Rustler Formation in the southwestern part of the site has a dip of about 80 feet per mile to the southeast. Eastward thickening of the Rustler is related to the increasing amount of halite preserved. Subsurface data show that the dissolution of 100 to 200 feet of salt has modified the surface and shallow subsurface structure, but has not been accompanied by highly irregular subsidence structures in the overlying strata at the site.

The top of the Dewey Lake Red Beds does not slope eastward as do all lower Delaware basin horizons; it slopes generally northeastward (Jones, 1973).

No surface faults have been mapped within 5 miles of the center of the site. The faults that have been mapped in the area are more distant and are plainly related to collapse features rather than to tectonic origins. On the basis of aerial photographs and limited field work, Griswold (1977) suggested a fault on the west edge of Livingston Ridge. Since then, reexamination in the field has led him to change his mind (personal communication, February 20, 1978). Recent mapping by Bachman (in preparation) confirms the lack of surface faulting at this location or elsewhere within 5 miles of the center of the site.

Kelley (1971) suggests two faults that he calls the Barrera and the Carlsbad faults at the foot of the Guadalupe Mountains west of the Pecos River. Others (e.g., P. T. Hayes, 1964, personal communication cited by Kelley) do not believe a fault is present. Reinvestigation (Hayes and Bachman, 1979) has revealed that stratigraphic relationships are normal and that these suggested faults do not exist.

Man-induced subsidence features

In the Carlsbad mining district (BLM, 1975), there has been subsidence during and after underground mining. Areas where subsidence effects have occurred (14 square miles) or are expected (40 square miles) are shown in Figure 7-20. These areas are north, northwest, and west of the site at distances from 3.5 to 26 miles. The maximum subsidence observed is about two-thirds of the height of the ore zone mined. Current ore zones are 4 to 8 feet thick; maximum subsidences are 2 feet 8 inches to 5 feet 4 inches.

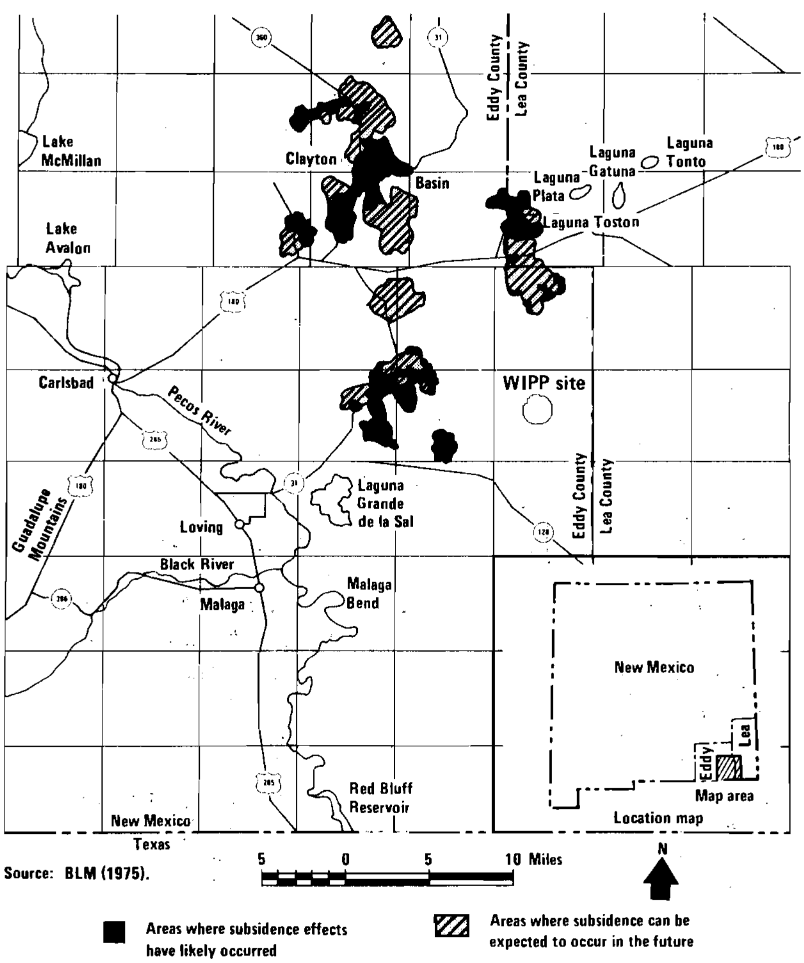


Figure 7-20. Generalized map of the Carlsbad mining district showing likely subsidence areas and expected future subsidence areas.

7.3.6 Seismology

The purpose of the seismic studies is to build a basis from which to predict the ground motions that the WIPP repository might be subjected to both in the near and in the distant future. The concern about seismic effects in the near future, during the operational period, pertains mainly to the design requirements for surface and underground structures to withstand levels of ground motion much greater than those expected during this period. The concern about effects occurring over the long term, after the repository has been decommissioned and sealed, pertains more to relative motions (faulting) within the repository and possible effects on the integrity of the salt beds and/or shaft seals.

In this discussion, all intensities are based on the modified Mercalli intensity scale (Wood and Neuman, 1931). Most of the magnitudes were determined by the New Mexico Institute of Mining and Technology or described in the Geological Characterization Report (Powers et al., 1978, pp. 5-10ff).

Seismic history

Seismic data are presented here in two time frames, before and after the time when seismograph data for the region became available.

The earthquake record in southern New Mexico dates back only to 1923, and seismic instruments have been in place in the State only since 1961. Sanford and Toppozada (1974) have examined various records to determine the seismic history of the area within 180 miles of the site. Their results for the period before 1961 are given in Table 7-3. With the exception of the weak shock in 1926 at Hope, New Mexico, and the shocks in 1936 and 1949 felt at Carlsbad, all known shocks before 1961 occurred to the west and southwest of the site and more than 100 miles away.

Since 1961, instrumental coverage has become comprehensive enough to locate most of the moderately strong earthquakes (local magnitude >3.5) in the region. Instrumentally determined shocks that occurred within 180 miles of the site since 1961 are listed in Table 7-4 and shown in Figure 7-21. Their distribution may be biased by the fact that seismic stations were more numerous and were in operation for longer periods north and west of the site.

Except for the activity southeast of the site, the distribution of epicenters since 1961 differs little from that of shocks before that time. There are two clusters, one associated with the Rio Grande Rift on the Texas-Chihuahua border and another associated with the Central Basin platform in Texas near the southeastern corner of New Mexico. This latter activity was not reported before 1964. It is not clear from the record whether earthquakes were occurring in the Central Basin platform before 1964, although local historical societies and newspapers tend to confirm their absence before that time.

A station operated for 10 months at Fort Stockton, Texas, indicated many small shocks from the Central Basin platform. Activity was observed at the

Table 7-3. Reports of Felt Earthquakes Within 180 Miles of the WIPP Site Before 1961

Date	Time (GMT)	Location of maximum reported intensity	Distance (km) and direction from site	Maximum reported intensity[a]	References[b]	Remarks
1923 Mar 7	04:03	El Paso, Tex.	260, S75W	V	1-3	Felt in Sierra Blanca (166 km to SE), Columbus (130 km to W), Alamogordo (135 km to N). Newspaper accounts suggest epicenter in northern Chihuahua.
1926 July 7	22:00	Hope and Lake Arthur, N.M.	90, N54W	III	4	Earth sounds heard in NE direction at Hope; windows rattled at Lake Arthur.
1930 Oct 4	03:25	Duran, N.M.	280, N32W	(IV)	5	Moderate shock felt by many. Rolling motion, rumbling sound, rattled windows. No damage.
1931 Aug 16	11:40	Valentine, Tex.	210, S20W	VIII	5-7	Strong damaging earthquake. Felt over 1,250,000 km^2. See text.
1931 Aug 16	19:33	Valentine, Tex.	210, S20W	(V)	5	Strong aftershock.
1931 Aug 18	19:36	Valentine, Tex.	210, S20W	V	5	Strong aftershock.
1931 Aug 19	01:36	Valentine, Tex.	210, S20W	(V)	5	Strong aftershock.
1931 Oct 2	?	El Paso, Tex.	260, S75W	(III)	5	Feeble shock.
1931 Nov 3	14:50	Valentine, Tex.	210, S20W	(V)	5	Strong aftershock of August 16, 1931, earthquake.
1935 Dec 20	05:10	Clovis, N.M.	230, N13E	III-IV	8	Two shocks. Tile wall in creamery cracked.
1936 Jan 8	06:46	Carlsbad, N.M.	40, N89W	(IV)	3, 5	Newspaper account indicates this event was probably centered near Ruidoso, N.M.
1936 Aug 8	01:40	El Paso, Tex.	260, S75W	(III)	3, 5	Weak shock not felt elsewhere.
1936 Oct 15	18:	El Paso, Tex.	260, S75W	(III)	5	Slight shock.

Table 7-3. Reports of Felt Earthquakes Within 180 Miles of the WIPP Site Before 1961 (continued)

Date	Time (GMT)	Location of maximum reported intensity	Distance (km) and direction from site	Maximum reported intensity[a]	References[b]	Remarks
1937 Mar 31	22:45	El Paso, Tex.	260, S75W	(IV)	3,5	Felt by many.
1937 Sept 30	06:15	Ft. Stanton, N.M.	200, N53W	(V)	5	Awakened many.
1943 Dec 27	04:00	Tularosa, N.M.	220, N70W	IV	9	Rattled windows.
1949 Feb 2	23:00	Carlsbad, N.M.	40, N89W	(IV)	5,9	Two distinct shocks felt by several, and a few frightened. Windows, doors, dishes rattled.
1949 May 23	07:22	East Vaughn, N.M.	280, N28W	VI	5,9	Felt area 33-km strip connecting East Vaughn and Pastura. At East Vaughn few things fell from shelves, loose objects rattled.
1952 May 22	04:20	Dog Canyon, N.M.	158, N79W	IV	5,9	Felt by two in ranch house. Windows, doors, dishes rattled.
1955 Jan 27	00:37	Valentine, Tex.	210, S20W	IV	5,9	Felt by many. Houses shaken.

[a]Based on the modified Mercalli intensity scale of 1931. Intensities given in parentheses were assigned by the authors.

[b]The numbers in this column are for the references listed below.

1. Woollard (1968).
2. Bulletin of the Seismological Society of America (1923).
3. Newspaper account.
4. S.A. Northrop, personal communication.
5. U.S. Earthquakes (NOAA and USGS, published annually).
6. Sellards (1933).
7. Byerly (1934).
8. Northrop and Sanford (1972).
9. Abstracts of Earthquake Reports for the Pacific Coast and Western Mountain Region (NOAA).

Table 7-4. Instrumentally Located Earthquakes That Have Occurred Within 180 Miles of the WIPP Site Since 1961[a]

Date (yr/mo/day)	Origin time	Location Lat. N	Location Long. W	Magnitude[b] M (NMT)	Distance from CLN[c] (miles)
62/3/3	18:16:47	33.8	106.4	1.2	
62/3/6	09:59:10	31.1	104.6	3.0	
64/2/11	09:24:10	34.4	103.7	2.5	
64/3/3	01:26:27	35.0	103.6	2.2	
64/6/18	20:20:18	33.1	106.1	1.2	
64/6/19	05:28:39	33.1	106.0	1.7	
64/11/8	09:26:00	31.9	103.0	2.7	
64/11/21	11:21:24	31.9	103.0	2.5	
65/2/3	19:59:32	31.9	103.0	3.0	
65/4/13	09:35:46	30.3	105.0	2.5	
65/8/30	05:17:30	31.9	103.0	2.6	
66/8/14	15:25:47	31.9	103.0	2.8	
66/8/16	18:47:21	30.7	105.5	2.9	
66/8/19	04:15:44	30.3	105.6	4.6	
66/8/19	08:38:21	30.3	105.6	3.6	
66/9/17	21:30:13	34.9	103.7	2.2	
66/11/26	20:05:41	30.9	105.4	2.6	
66/11/28	02:20:57	30.4	105.4	3.3	
66/12/5	10:10:37	30.4	105.4	3.3	
67/9/29	03:52:41	32.3	106.9	2.0	
68/3/9	21:54:26	32.7	106.0	2.9	
68/3/23	11:53:39	32.7	106.0	2.3	
68/5/2	02:56:44	33.0	105.3	2.6	
68/8/22	02:22:26	34.3	105.8	2.1	
69/5/12	08:26:18	32.0	106.4	3.0	
69/5/12	08:49:16	32.0	106.4	2.6	
69/6/1	17:18:24	34.2	105.2	2.0	
69/6/8	11:36:02	34.2	105.2	2.4	
69/10/19	11:51:34	30.8	105.7	2.8	
71/7/30	01:45:50	31.7	103.1	3.1	
71/7/31	14:53:48	31.6	103.1	3.2	
71/9/24	01:01:54	31.6	103.2	3.0	
72/2/27	15:50:04	32.9	106.0	2.3	
72/7/26	04:35:44	32.6	104.1	2.8	
72/12/9	05:58:39	31.7	106.4	2.2	
72/12/10	14:37:50	31.7	106.5	2.2	
72/12/10	14:58:02	31.7	106.5	1.8	
74/7/31	17:34:48	33.1	104.2	2.1	59
74/8/17[d]	07:35:17	30.3	105.8	3.3	194
74/8/26	07:33:22	34.4	105.8	2.6	191
74/9/26	23:44:09	32.8	106.2	2.5	148
74/10/2	02:40:24	32.1	101.0	2.7	163
74/10/15	10:07:58	33.9	106.5	2.5	198
74/10/27	16:18:53	30.5	104.8	2.8	149
74/11/1	10:45:50	33.8	106.6	2.2	134
74/11/1	15:06:08	31.7	106.9	2.8	197
74/11/12	02:32:06	32.1	101.3	2.8	147
74/11/12	02:35:34	32.1	102.7	1.6	66
74/11/12	07:14:29	31.9	100.8	2.6	178

Table 7-4. Instrumentally Located Earthquakes That Have Occurred Within 180 Miles of the WIPP Site Since 1961[a] (continued)

Date (yr/mo/day)	Origin time	Location Lat. N	Location Long. W	Magnitude[b] M (NMT)	Distance from CLN[c] (miles)
74/11/21	16:22:59	32.5	106.3	2.5	150
74/11/21	18:59:06	32.1	102.7	2.4	66
74/11/22	08:54:05	32.8	101.5	2.2	134
74/11/22	14:11:13	33.8	105.1	2.2	133
74/11/28	03:35:21	32.6	104.1	3.8	27
75/1/30	16:00:38	31.0	103.1	2.5	107
75/2/2	01:59:44	31.6	106.8	2.6	196
75/2/2	20:39:23	35.1	103.1	3.0	198
75/4/8	15:29:42	32.2	101.7	2.1	123
75/4/20	16:59:56	31.3	102.6	2.1	105
75/7/25	08:11:40	29.9	102.5	3.3	194
75/8/1	07:27:47	30.4	104.6	4.1	149
75/8/3	03:26:53	31.0	104.0	2.3	99
75/10/10	11:16:56	33.3	105.0	2.3	100
76/1/10	01:49:57	31.7	102.8	2.3	77
76/1/15	20:43:57	31.0	102.2	2.2	134
76/1/19	04:03:30	31.9	103.0	2.6	59
76/1/21	23:11:17	30.9	102.3	2.1	138
76/1/22	07:21:58	31.9	103.0	2.7	56
76/1/25	04:48:28	32.0	103.1	3.3	50
76/1/28	07:37:49	32.0	101.0	2.7	164
76/2/4	16:15:28	31.6	103.7	1.8	58
76/2/14	05:35:21	31.6	102.5	1.9	94
76/3/5	02:58:18	31.9	102.6	2.6	76
76/3/9	06:49:42	29.6	104.5	4.2	204
76/3/12	12:39:56	29.8	104.5	3.7	191
76/3/15	12:30:48	32.2	103.0	1.9	49
76/3/18	23:07:05	32.2	102.9	1.9	49
76/3/20	12:42:20	31.2	105.0	2.1	115
76/3/20	16:15:58	32.2	103.1	2.0	40
76/3/27	22:25:22	32.2	103.1	2.2	40
76/4/1	14:40:28	33.8	105.9	2.7	166
76/4/1	14:46:58	33.9	106.0	2.8	173
76/4/1	14:51:17	33.9	105.9	1.6	168
76/4/3	20:40:51	31.3	103.0	3.1	89
76/4/6	18:09:00	33.9	105.0	3.1	172
76/4/12	08:02:34	32.3	103.0	1.8	43
76/4/18	03:48:19	33.9	106.0	2.3	169
76/4/19	05:03:40	34.0	106.8	2.4	214
76/4/21	08:40:06	32.3	102.9	2.4	51
76/4/30	19:28:35	32.0	103.3	1.8	41
76/4/30	19:51:12	32.0	103.2	1.8	44
76/5/1	11:13:40	32.4	103.1	2.6	38
76/5/3	06:52:59	32.4	105.6	2.6	114
76/5/3	08:00:39	32.0	103.2	1.8	43
76/5/3	11:27:40	32.0	103.1	1.6	47
76/5/4	15:05:39	31.9	103.2	1.9	44
76/5/6	17:18:24	32.0	103.2	2.2	45
76/5/6	17:28:46	31.9	103.2	1.6	47

Table 7-4. Instrumentally Located Earthquakes That Have Occurred Within 180 Miles of the WIPP Site Since 1961[a] (continued)

Date (yr/mo/day)	Origin time	Location Lat. N	Location Long. W	Magnitude[b] M (NMT)	Distance from CLN[c] (miles)
76/5/8	11:46:41	32.0	103.2	1.4	41
76/5/11	23:04:40	32.3	102.9	2.2	50
76/5/21	13:17:35	32.3	105.3	2.5	93
76/5/24	23:40:31	34.7	104.9	2.4	182
76/5/26[d]	11:52:26	32.4	102.6	2.0	69
76/6/13[d]	22:05:06	30.9	103.0	2.0	113
76/6/14	23:29:59	31.6	102.6	1.9	89
76/6/15	02:19:58	31.6	102.4	2.1	99
76/6/15	08:50:20	31.5	102.4	2.5	103
76/6/16[d]	14:05:14	31.6	102.1	2.0	113
76/7/28	12:21:50	33.1	102.3	2.2	96
76/8/5[d]	22:23:29	30.8	101.8	2.1	163
76/8/10	09:03:12	31.8	102.2	1.9	99
76/8/10	10:15:14	31.8	102.2	2.1	104
76/8/15	19:12:04	30.1	105.2	2.7	185
76/8/25[d]	01:21:11	31.5	102.0	2.4	119
76/8/25	01:27:49	31.5	102.5	2.5	98
76/8/26	15:22:13	31.8	102.2	2.1	101
76/8/29	19:49:27	30.2	105.0	2.6	173
76/8/30	11:51:25	31.5	102.6	2.0	91
76/8/30	13:07:48	33.9	106.3	2.5	186
76/8/31	12:46:22	31.5	102.8	2.4	82
76/9/5	10:39:46	32.2	102.8	1.6	59
76/9/17	02:47:47	32.2	103.1	2.8	39
76/9/17	03:56:30	31.5	102.6	2.5	98
76/9/19	10:23:21	32.3	102.9	1.3	50
76/9/19	10:40:46	30.6	104.5	3.4	139
76/10/14	11:02:60	32.3	103.1	1.4	40
76/10/22	05:06:12	31.5	102.2	2.4	110
76/10/23	12:51:37	31.6	102.4	2.0	101
76/10/25	00:27:03	31.8	102.5	2.5	88
76/11/3	23:24:15	31.0	102.5	2.1	124
76/11/17[d]	23:16:07	30.8	101.8	2.4	163
76/12/12[e]	23:00:14	31.5	102.5		98
76/12/12[e]	23:25:57	31.6	102.6		93
76/12/15[e]	08:51:43	31.6	102.7		87
76/12/19[e]	21:26:14	31.8	102.5		89
76/12/19[e]	23:54:22	32.2	103.0		43
76/12/19[e]	23:56:47	32.2	103.1		42
77/1/29	09:40:44	30.6	104.6	2.4	138
77/2/4	07:48:18	30.7	104.6	2.2	131
77/2/10	01:22:49	32.3	103.1	1.4	38
77/2/18	14:10:36	32.2	103.1	1.7	41
77/3/1	23:47:15	34.8	104.8	2.7	189
77/3/5	22:56:09	31.2	102.6	1.9	111
77/3/14	10:10:26	33.0	101.1	2.9	163
77/3/15[d]	23:21:08	30.9	101.9	2.5	156
77/3/19[d]	21:27:47	31.3	102.6	2.2	106
77/3/20	07:54:09	32.2	103.1	2.3	41

Table 7-4. Instrumentally Located Earthquakes That Have Occurred Within 180 Miles of the WIPP Site Since 1961[a] (continued)

Date (yr/mo/day)	Origin time	Location Lat. N	Location Long. W	Magnitude[b] M (NMT)	Distance from CLN[c] (miles)
77/3/29	00:35:35:	31.6	103.3	1.6	64
77/4/3	14:24:06	31.3	103.3	1.8	81
77/4/4	04:47:29	31.3	103.2	1.8	83
77/4/7	05:45:40	32.2	103.1	2.2	43
77/4/7	18:56:51	31.6	102.9	1.9	76
77/4/7	22:32:25	31.6	102.9	2.2	74
77/4/12	23:18:27	31.2	102.6	2.5	109
77/4/16	06:44:23	31.6	103.3	1.3	63
77/4/17	21:47:13	31.5	102.5	1.8	94
77/4/18	18:08:24	31.6	102.2	2.0	106
77/4/22	22:56:37	32.2	103.1	1.5	42
77/4/25	10:12:52	32.0	102.8	1.9	61
77/4/26	09:03:08	32.0	103.1	2.4	51
77/4/28	12:54:39	31.8	102.6	1.4	82
77/4/28	12:55:39	31.8	102.5	2.7	86
77/4/26	09:03:08	32.0	103.1	2.4	51
77/4/28	15:22:37	31.8	102.5	1.8	85
77/4/29	03:09:42	31.8	102.7	1.8	78
77/6/7	23:01:24	32.9	101.2	3.7	154
77/6/8	00:51:29	32.8	100.9	3.0	171
77/6/8	13:29:09	32.8	100.8	3.6	175
77/6/8	13:39:37	32.8	101.6	3.1	132
77/6/17	03:37:04	32.8	101.0	3.1	167
77/7/11	12:31:55	31.8	102.6	2.0	80
77/7/11	13:29:49	31.8	102.7	1.6	79
77/7/12	17:06:05	31.7	102.6	1.8	83
77/7/18	12:37:31	31.8	102.7	1.9	77
77/7/22	04:01:10	31.8	102.7	1.7	76
77/7/22	04:18:10	31.8	102.7	1.8	79
77/7/22	04:36:51	31.7	102.7	1.4	77
77/7/24	09:23:00	31.8	102.7	1.7	77
77/7/26	02:01:08	31.8	102.7	1.2	79
77/8/21	03:01:11	30.5	104.9	3.1	151
77/11/14	07:26:26	31.6	104.9	2.4	93
77/11/27	20:48:21	32.9	101.3	3.0	149
77/12/16	11:56:40	31.5	102.4	1.9	102
77/12/21	01:36:22	31.5	102.4	1.9	101
78/1/12	14:55:06	31.5	102.4	2.4	102
78/1/15	23:17:58	31.3	102.1	2.1	123
78/1/18	08:53:19	31.6	103.3	1.7	64
78/1/19	03:42:36	32.5	103.7	2.3	10
78/2/5	10:46:23	31.6	103.1	1.6	67
78/2/5	14:19:52	31.4	104.6	2.3	88
78/3/2[e]	08:57:50	32.3	103.1		39
78/3/19[e]	10:48:49	31.5	102.5		97
78/4/7	00:57:39	32.0	106.0	2.3	138
78/7/5	02:45:05	31.8	102.5	1.4	88
78/7/15	10:40:27	31.6	102.1	1.7	113
78/7/18	12:07:31	30.2	104.1	2.6	156

Table 7-4. Instrumentally Located Earthquakes That Have Occurred Within 180 Miles of the WIPP Site Since 1961[a] (continued)

Date (yr/mo/day)	Origin time	Location Lat. N	Location Long. W	Magnitude[b] M (NMT)	Distance from CLN[c] (miles)
78/7/21	05:02:35	34.5	105.1	3.1	174
78/7/21	20:35:43	31.2	102.6	1.7	108
78/9/29	20:07:41	31.5	102.4	2.3	103
78/9/30	23:31:48	31.6	102.7	2.4	82
78/10/2	09:35:06	31.5	102.5	1.7	99
78/10/2	09:58:32	31.6	102.5	2.0	93
78/10/2	11:25:07	31.5	102.3	2.0	107
78/10/3	06:12:16	31.9	102.9	1.8	61
78/10/6	15:23:47	31.6	102.4	2.2	98

[a]Data before 1974 from Sanford and Toppozada (1974); data since 1974 from A. R. Sanford (personal communication, 1979). Events with a magnitude of less than 1.0 not included. Events not recorded at station CLN also not included.

[b]Magnitudes revised from those published in the draft EIS.

[c]Station CLN, 4 miles northeast of the center of the WIPP site, has been operated for the DOE by the New Mexico Institute of Mining and Technology since 1972.

[d]Tentative epicenters.

[e]Events recorded while station CLN was not in operation by an array on the Central Basin platform operated for the DOE by the USGS since late 1975.

time the station opened on June 21, 1964. Shurbet (1969) suggested that this activity is related to the injection of water underground for oil recovery. The suggestion has merit in that the Central Basin platform is an old structure (Early Permian), with no surface indication of having been rejuvenated, and in that enormous quantities of water have been injected. In one of the oil fields, the Ward-Estes North operated by the Gulf Oil Corporation, the cumulative total of water injected up to 1970 was over 1 billion barrels. Accounting for 42% of the water injected in Ward and Winkler Counties, Texas, the quantity is three times the total injected in all the oil fields of southeastern New Mexico in the same period. The known hydrocarbon resources nearest the site are two gas wells approximately 3 miles to the southwest of the center of the site. Water injection has not been used in this region to stimulate gas production. The nearest oil fields in the Delaware basin, where secondary recovery might be attempted, are 7 miles from the site. Water-injection operations would be prohibited within the site during the period of administrative control. After the closing of the repository, seismicity induced by water injection would not produce enough ground displacement to jeopardize the repository.

The strongest earthquake on record within 180 miles of the site was the Valentine, Texas, earthquake of August 16, 1931 (event 4 in Table 7-3). Coffman and von Hake (1973) estimate it to have been of magnitude 6.4 (modified Mercalli intensity of VIII). The Valentine earthquake was 130 miles south-

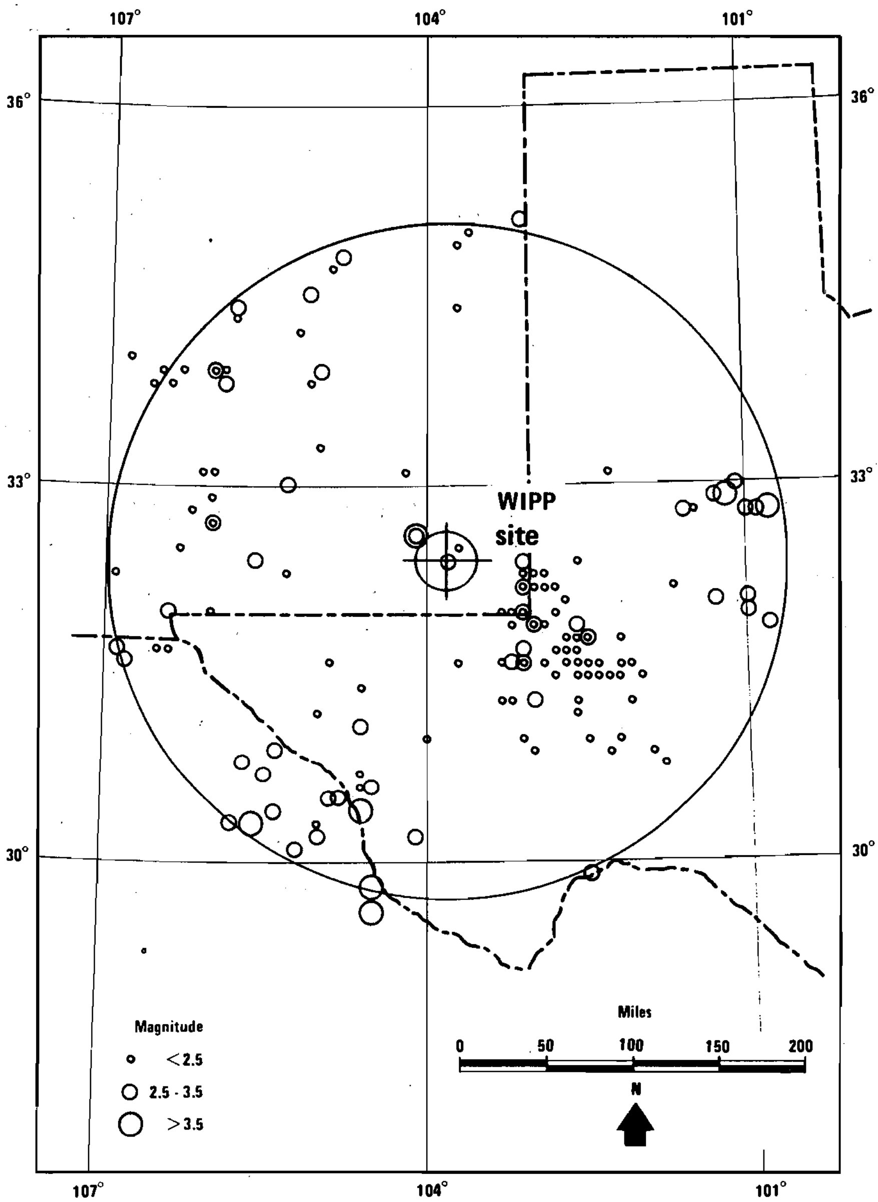


Figure 7-21. Regional earthquake epicenters.

southwest of the site. Its modified Mercalli intensity at the site is estimated to have been V; this is believed to be the highest intensity felt at the site in this century.

In 1887, a major earthquake occurred in northeast Sonora, Mexico. Although about 335 miles west-southwest of the site, it is indicative of the size of earthquakes possible in the eastern portion of the Basin and Range province, west of the province containing the site. Sanford and Toppozada (1974) estimate its magnitude to have been 7.8, and Coffman and von Hake (1973) list it as VIII-IX in modified Mercalli intensity. It was felt over an area of 0.5 million square miles (as far as Santa Fe to the north and Mexico City to the south); fault displacements near the epicenter were as large as 26 feet (Aguilera, 1920).

Local observations

From April 1974 to October 1978, 420 events identifiable as local and regional earthquakes (within about 210 miles) were recorded by a station (CLN) 4 miles from the center of the site (see Appendix J). For 159 of the 420 events, the epicenters were identified and magnitudes determined (Table 7-4). Nine tentative locations were also determined. These seismic patterns are similar to those of the preinstrumental data.

Local earthquakes. Any seismic activity at or near the site is of great interest. Three events (July 26, 1972; November 28, 1974; and January 19, 1978) have been instrumentally recorded within 35 miles of the WIPP site. Seismic events become more numerous with distance.

The nearest event to the WIPP site occurred on January 19, 1978, about 10 miles northeast of station CLN. Its magnitude was 2.3, and the event does not appear to have been related to human activity.

The other two nearby events (July 26, 1972, and November 28, 1974) had magnitudes of 2.8 and 3.6, respectively, and both were about 25 miles to the northwest. At both times, rockfalls and ground cracking were reported at an active potash mine. To determine whether collapse at this mine was responsible for both events, an analysis was made of whether the two epicenters coincided. They were about 6 miles apart. Thus the two events cannot both have been caused by the mine. Moreover, the earthquake had too much energy to have been caused by the rockfall. In the absence of additional seismic data on these events, seismic risk at the site should be estimated on the assumption that both were natural (Caravella and Sanford, 1977).

Seismic risk

Maps of the position and intensity of recorded earthquakes are useful in evaluating the probability of an earthquake at a given site. To increase their usefulness, the historical data have been supplemented with field geologic data.

Several researchers have divided the United States into zones of earthquake risk. The standard estimate is that of Algermissen (1969). According to this estimate, the site is located in seismic risk zone 1, where only minor damage to structures is to be expected, corresponding to a modified Mercalli intensity of V to VI. Earlier, Richter (1959) had placed the region within a seismic zone where the probable maximum intensity would be VIII. Sanford and Toppozada (1974) considered the site to be either on the boundary of zones 2 and 3 or within zone 2, depending on whether earthquakes in the Central Basin platform are found to be natural or induced by human activity.

One desires not only an estimate of the largest seismic motions possible at a site but also an estimate of their probability. Such an estimate has been made for the WIPP site, starting with an analysis of the recurrence rates of earthquakes in nearby active areas.

Earthquakes in the Central Basin platform. The Central Basin platform is a structural feature less than 30 miles east of the site, adjacent to the Delaware basin. Instrumental studies have shown the Central Basin platform to be much more active than would be expected from its stable tectonic setting.

Primarily for this reason, a seismographic station array was established in Kermit, Texas, in late 1975. During the period from November 1975 to July 1977, 407 local events were detected and 135 located with array data.

The Central Basin platform has been active since at least mid-1964. It has been the most active seismic area within 180 miles of the site in the number of events, but not in magnitude of events. The data imply that seismic activity is equally likely to occur anywhere along the Central Basin platform, without any clear relationship to small-scale structural details such as pre-Permian buried faults. Attempts have been made to relate this seismicity to the injection of water for the recovery of oil. Such a relationship has not been unequivocally established, but the lack of evidence for a tectonic origin suggests this correlation.

Sanford et al. (1978) calculated the apparent recurrence rates for earthquakes on the Central Basin platform. The distribution of minor shocks implied a recurrence rate of every 10,000 years for earthquakes of the size of the 1887 Sonoran event. There is no evidence that such earthquakes have occurred (fault scarps 25 miles long would be expected from shallow quakes such as these, with displacements of perhaps 10 feet; they are not found). To explain this discrepancy, three possible explanations have been advanced:

1. Crustal movement has only recently resumed on the Central Basin platform.

2. The structure of the Central Basin platform imposes a limit on the possible magnitude of earthquakes.

3. The minor shocks observed were caused by human activity.

The first explanation may not be absolutely discarded. However, it is extremely unlikely that a structure such as the Central Basin platform, which has exhibited no tectonic movement for about 200 million years, should be tectonically reactivated so recently that no surface manifestations are observed. The calculated recurrence rates previously discussed indicate a large event every 10,000 years; no surficial evidence has been found to confirm such events. The first explanation is not reasonable given the information now available. The third explanation, which seems best supported by the evidence, means that the seismic activity in the Central Basin platform is not natural and should be not be used for assessing tectonic stability over the long term. The second explanation is used in the analysis presented here. It is more conservative in that it assumes natural causes (which is probably not the case), but with an upper limit to the magnitude of an earthquake on the Central Basin platform. This assumption would be consistent with natural earthquakes in a region where the geology does not indicate large recent events.

The method of Cornell (1968) was used to estimate seismic risk at the site (Powers et al., 1978, pp. 5-32ff). Three source regions suggested by Algermissen and Perkins (1976) were used: the Rio Grande rift, the Central Basin platform, and the remainder of the area within 180 miles of the WIPP site (site source zone). The analysis used Sanford's recurrence relationships (Sanford et al., 1976, 1978). On the basis of the earthquake of 1887, an upper limit of 7.5 was set on the magnitude of earthquakes in the Rio Grande

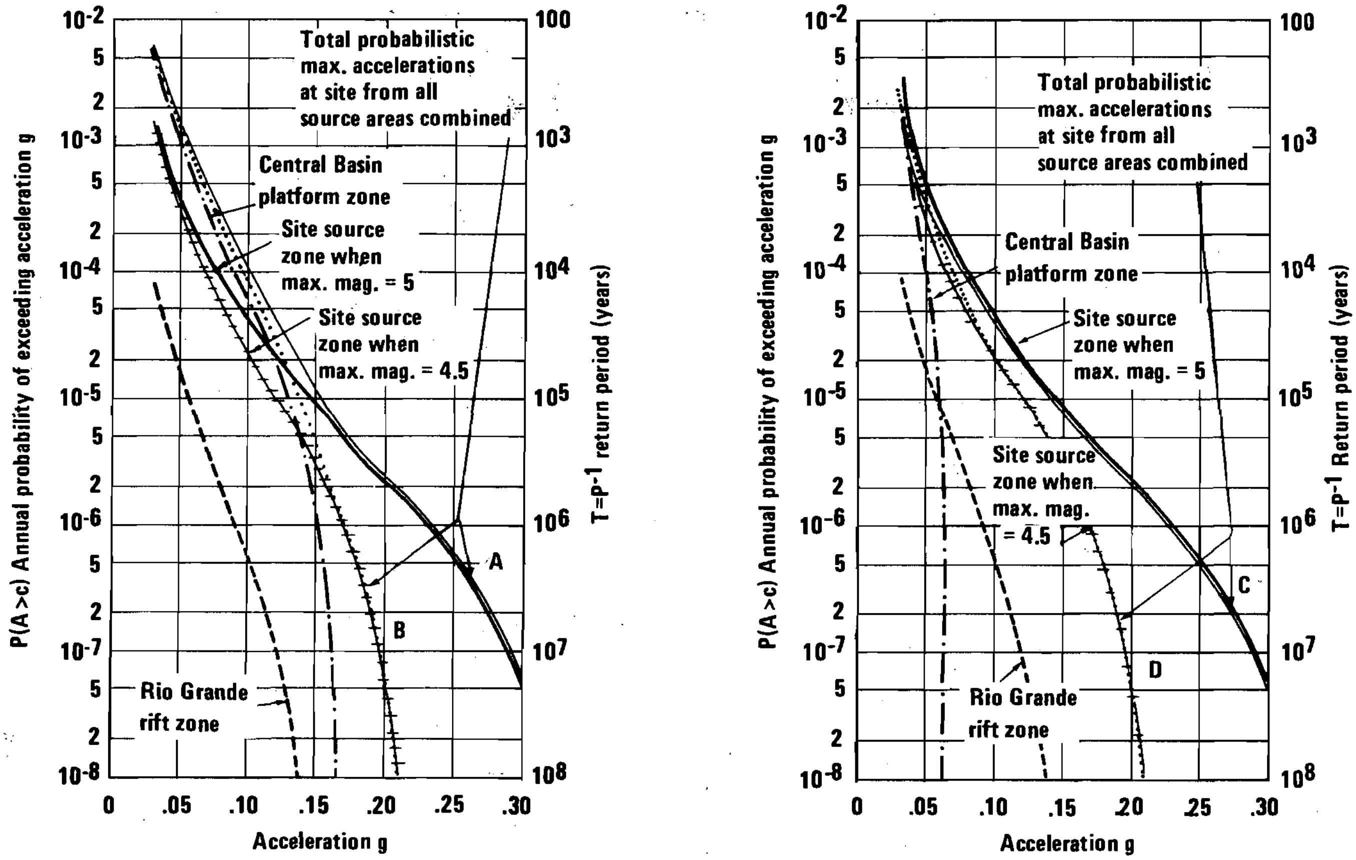


Figure 7-22. Seismic risk when the maximum magnitude event is assumed to be 6.0 (left) and 5.0 (right). The following maximum magnitudes are assumed for the site and the Central Basin platform source zones, respectively: curve A, 5 and 6; curve B, 4.5 and 6; curve C, 5 and 5; curve D, 4.5 and 5. Complete descriptions of the assumptions underlying these and the remaining curves may be found in the Geological Characterization Report (Powers, et al., 1978).

rift.* On the basis of the largest earthquake observed so far (magnitude 3.2) and considering the uncertainties in causative mechanisms, the upper magnitude limit for the Central Basin platform was set at 5 and 6 in separate calculations. The largest earthquake so far observed in the remaining region (the site source zone) was of magnitude 3.6; from this, and from the absence of any indication of Holocene local faulting, the upper magnitude limit for the site region was set at 4.5 and 5 in separate calculations. The depth of earthquakes in the site source zone was assumed to be 3 miles.

The Cornell method expresses seismic risk as the probability per year that a specific acceleration will be reached or exceeded. The probabilities calculated for the WIPP site are shown in Figure 7-22.

Figure 7-22 shows the separate contributions to these totals of each of the three source regions with each of the assumed upper magnitude limits. The

*The fact that this magnitude is less than Sanford and Toppozada's (1974) estimate of 7.8 does not affect the conclusions of the analysis.

contribution of the Rio Grande rift source zone to the total seismic risk at the site is small at all acceleration levels. Curves A and B and curves C and D indicate the total combined acceleration for the various combinations of upper magnitude limits indicated above.

From Figure 7-22 the accelerations that would be experienced at the site from earthquakes in the three source zones separately are as follows for two levels of probability:

Source zone	Upper limit magnitude	Acceleration g for probability (per year) 10^{-8}	10^{-6}
Rio Grande rift	7.5	0.14	0.09
Central Basin platform	6.0	0.17	0.15
Central Basin platform	5.0	0.07	0.07
Site source zone	5.0	>0.3	0.23
Site source zone	4.5	0.21	0.17

The total seismic risk is controlled by earthquake probabilities in one of these source zones, depending on the acceleration level considered. The relationships are shown below.

Upper limit magnitude			Controlling zone	
Rio Grande rift	Central Basin platform (CBP)	Site source zone (SSZ)	High acceleration	Low acceleration
7.5	5	4.5	SSZ	SSZ
7.5	6	4.5	SSZ	CBP
7.5	5	5.0	SSZ	SSZ
7.5	6	5.0	SSZ	CBP

Thus assumptions about the seismic properties of the area around and beneath the site (site source zone) are important in estimating seismic accelerations at the WIPP site and the potential for faulting through the repository after its closure. The possibility of faulting at the site of a magnitude that could significantly affect its integrity is extremely low.

7.3.7 Energy and Mineral Resources*

The geologic studies of the WIPP site have included the investigation of potential mineral resources. The objective was to evaluate the impact of denying access to these resources and other consequences of their occurrence. These consequences are discussed in detail in Section 9.2.3. Of the mineral resources expected to occur beneath the site, five are of practical concern:

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*A more comprehensive description of the energy and mineral resources of the site is presented in the Geological Characterization Report (Powers et al., 1978, Chapter 8).

the potassium salts sylvite and langbeinite, which occur in strata above the repository salt horizon, and the hydrocarbons crude oil, natural gas, and distillate (liquids associated with natural gas), which occur in strata below the repository horizon. Other mineral resources beneath the site are caliche, salt, and gypsum (Table 7-5); enormous deposits of these minerals near the site and elsewhere in the country are more than adequate (and more economically attractive) to meet future requirements for these materials (Powers et al., 1978, pp. 8-2ff).

The shape, thickness, depth, and grade of the potassium salts and hydrocarbons under the site were established. These data formed the basis for calculating the total amount of resources. The term "resources" means concentrations of materials in a form that makes their economic extraction currently or potentially feasible. The next step was to determine to what extent these resources could be classified as reserves; the latter term is restricted to resources that can be extracted profitably by existing techniques and under present economic conditions. It is appropriate to compare the relative quantities of a mineral in terms of either resources or reserves; it is not appropriate to compare the resources at a site with reserves elsewhere, or vice versa (Powers et al., 1978, pp. 8-5ff).

Methods used to determine potash resources at the WIPP site

The site is adjacent to the Carlsbad Potash Mining District, which provides 80% of the U.S. domestic supply of potassic chemical fertilizers. Throughout the Carlsbad Potash Mining District, commercial quantities of potassium salts are restricted to the middle portion, called the McNutt Potash Member, of the Salado Formation. A total of 12 horizons, or ore beds, have been recognized in the McNutt Potash Member. Number 1 is at the base, and Number 12 is at the top.

Table 7-5. Total Mineral Resources at the WIPP Site

Resource	Quantity	Depth (ft)	Richness
Caliche[a]	185 million tons	At surface	21-69% insoluble
Gypsum[a]	1.3 billion tons	300-1500	Pure to mixed
Salt[a]	198 billion tons	500-4000	Pure to mixed
Sylvite ore[b]	133.2 million tons	1600	8% K_2O, 4-ft thickness
Langbeinite ore[b]	351.0 million tons	1800	3% K_2O, 4-ft thickness
Crude oil[c]	37.50 million bbl	4000-20,000	31-46° API[d]
Natural gas[c]	490.12 billion ft^3	4000-20,000	1100 Btu/ft^3
Distillate[c]	5.72 million bbl	4000-20,000	53° API[d]

[a]Data from Siemers et al. (1978).
[b]Low-grade resource and better. Data from John et al. (1978).
[c]Data from Foster (1974).
[d]The degrees API unit has been adopted by the American Petroleum Institute as a measure of the specific gravity of hydrocarbons.

Exploratory drilling for potash has been done near the site by private companies. The results of that drilling were supplemented by 21 exploratory holes drilled in the area of the site by the DOE to evaluate potash deposits. In all, data were available from 61 holes drilled by industry, the 21 holes drilled by the DOE, and 2 site-characterization exploratory holes--a total of 84 holes. The locations of these holes are shown in Figure 7-23. While the spacing of the holes is variable, in no case are they more than 1 mile apart within the boundaries of the site.

Three studies were performed to establish and/or evaluate the potash resources of the site. The basic determination of potash resources at the site was the responsibility of the U.S. Geological Survey (USGS). The other two studies were economic evaluations whose purpose was to establish which portions of the identified resources qualified as reserves; these are discussed in Section 9.2.3. Descriptive data, including sample analysis, for the 21 exploratory holes drilled by the DOE have been reported by Jones (1978). An estimate of the total potash resources has been reported by John et al. (1978). The USGS used established procedures for determining the volume, thickness, and grade (richness) of bedded mineral deposits. The essential steps were to (a) determine the thickness and grade for each mineralized layer discovered in each hole, (b) assign the mineralized layer to the appropriate ore bed, (c) determine the probable continuity of mineralized ore beds to adjacent holes, and (d) then determine the volume and average grade for a bed enclosed by adjacent mineralized holes. Reasonable extrapolation was permitted outward from a mineralized hole toward barren areas, but the distance never exceeded 0.5 mile.

The USGS established three standard grades--low, lease, and high--to quantify the potash resources at the site. These are listed in Table 7-6. The USGS assumes that the "lease" and "high" grades comprise reserves because some lease-grade ore is mined in the Carlsbad district. Most of the potash that is mined, however, is better typified by the high grade. Even the high-grade resources may not be reserves, however, if their properties make processing uneconomic. This document restricts the designation "reserves" only to those resources that have the proper processing properties and grade of ore for an operator to realize a profit from their exploitation.

Table 7-6. USGS Standard Grades for Classifying Potash Resources and Reserves

Grade[a]	Type of ore	K_2O content (%)
Low	Langbeinite	3
	Sylvite	8
Lease	Langbeinite	4
	Sylvite	10
High	Langbeinite	8
	Sylvite	14

[a]All three grades must have a minimum thickness of 4 feet.

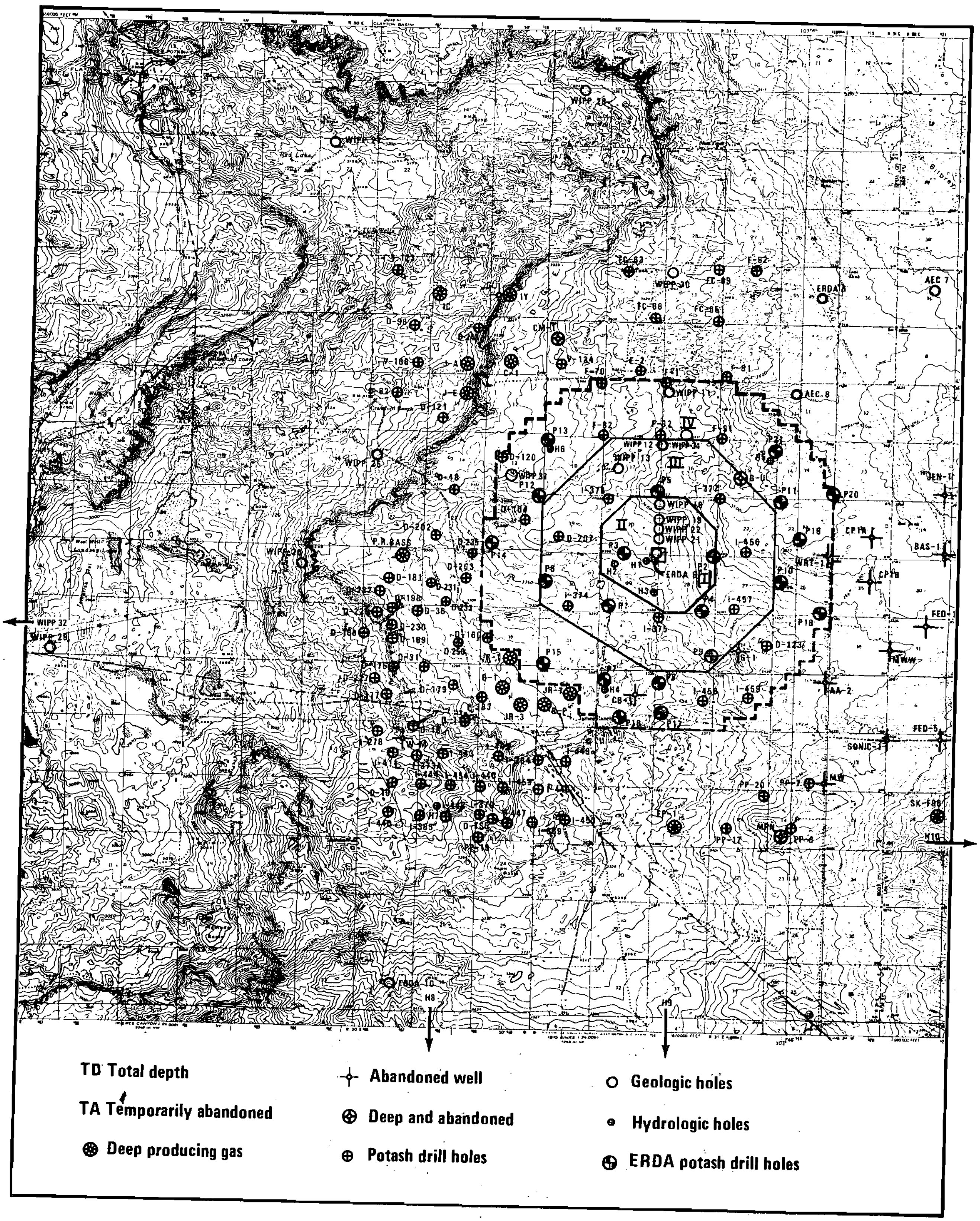


Figure 7-23. Location of all exploration drill holes within a square, 10 miles on a side, centered at the WIPP site. The figure also shows several exploration holes drilled by the ERDA and the DOE outside this square.

Potash salts, whether sylvite (KCl, marketed under the name muriate of potash), langbeinite ($K_2SO_4 \cdot 2MgSO_4$), or potassium sulfate (K_2SO_4), are marketed according to the equivalent content of potassium oxide (K_2O) determined by chemical analysis. The K_2O content is the industry-accepted measure of quality, even though the potash salts do not in themselves contain potassium oxide. Pure sylvite contains the equivalent of 63.17% K_2O, whereas pure langbeinite contains 22.7%, and potassium sulfate contains 50% K_2O equivalent. Raw ores contain a mixture of minerals--mostly halite (salt), clays, and insoluble evaporites--in addition to either sylvite or langbeinite. Potassium sulfate is a manufactured product, not occurring as ore. Hence, raw ore always contains much less equivalent K_2O than do the pure minerals. All potash ores are upgraded into marketable products by re- fining. The accepted standard for refined products is 60% K_2O for sylvite and 22% for langbeinite.

At present, the average grades of ores being mined in the Carlsbad district are 14% K_2O as sylvite and 8% K_2O as langbeinite. Therefore, the USGS high grade is equivalent to current mining costs and market prices. The median grade, termed "lease" grade in Table 7-6, represents the lowest grades of sylvite (10% K_2O) and langbeinite (4% K_2O) ores treated by Carlsbad refineries. The low grade, 8% K_2O as sylvite or 3% K_2O as langbeinite, is presently uneconomic for mining at Carlsbad.

All three grades must have a minimum thickness of 4 feet, the minimum seam thickness for efficient mining. If an ore bed is thinner than 4 feet, it must have an offsetting increase in the K_2O content of potassium salts such that if diluted with barren material it still meets the established grade criteria.

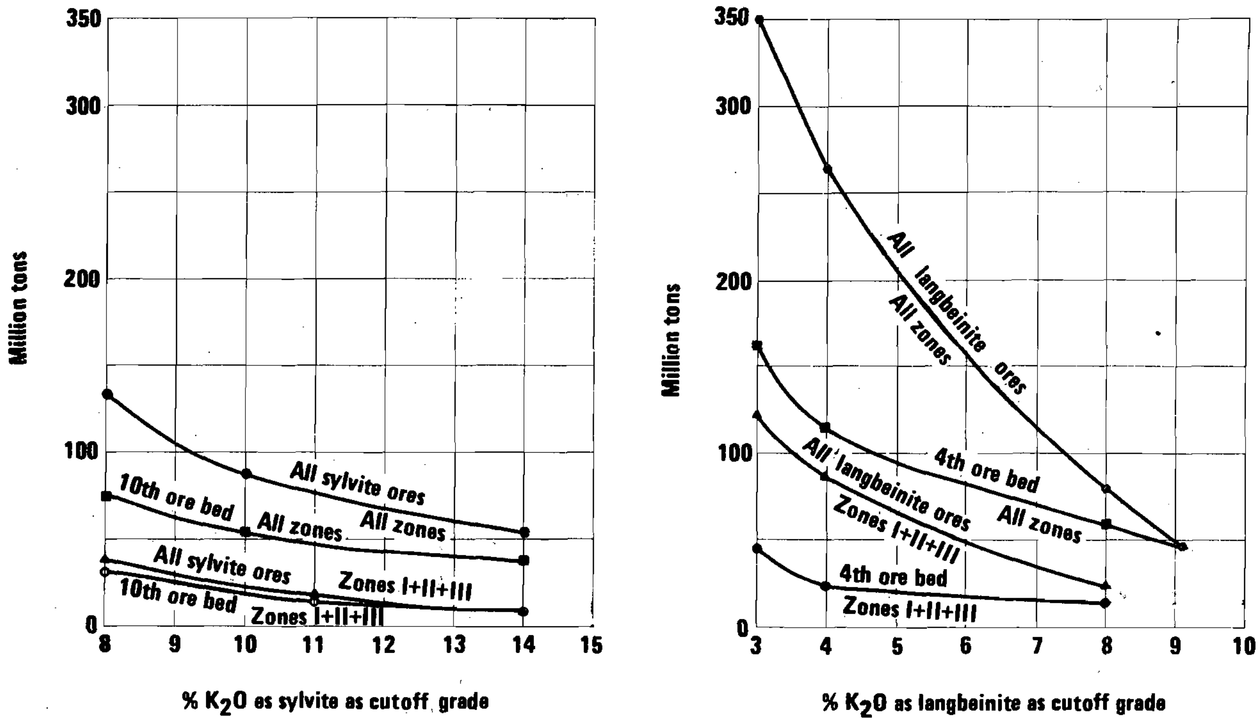
Results of the potash-resource evaluation

The results of the USGS evaluation have been released and are summarized in Table 7-7 (see John et al., 1978, for full details). Figure 7-24 shows how the amounts of these resources depend on the grade criteria used.

The estimates of total resources are considered to be sufficiently accurate because of the density of exploratory drilling in and near the site. The data base exceeds both in quality and in quantity the data available to investigators who have estimated national or worldwide resources.

Methods used to determine potash reserves at the WIPP site

Two separate studies were conducted for the DOE by the U.S. Bureau of Mines (USBM, 1977) and Agricultural and Industrial Minerals, Inc. (AIM, 1979) to determine what portion of the potash resources at the WIPP site is economic and may be considered to be reserves. Both studies started with the basic grade and thickness data provided by the USGS, and the USBM study was available for use by AIM. However, the two studies used different concepts for the development of the potash reserves and evaluated processing difficulties independently. The AIM approach, which may more nearly resemble the perspective of a potash operator, results in lower reserve estimates. However, because estimates of reserves and the associated economics are subject to uncertainty and because the USBM report gives a higher estimate of reserves, most tables presented here will use USBM reserve estimates. The AIM report also estimated potash resources in the Carlsbad district and in the United States to allow



Data from John et al. (1978).

Figure 7-24. Sylvite and langbeinite resources and reserves at the site.

comparison with the WIPP-site resources, and their values will be used in these comparisons. It should also be noted that local potash operators question the economic feasibility of mining the WIPP reserves.*

The USBM method of determining to what extent the deposits could be profitably mined and thus considered reserves consisted of designing conceptual models for exploiting the deposits. Models ranged from new mines and refineries to mines that merely send the new ore to existing refineries. Shaft locations were selected to minimize underground development and allow the richest ore beds to be mined first. The latter is important to the quick recovery of invested capital.

Costs were either estimated or, when available, matched to known cost experience at nearby mines. All costs, including construction, were used in discounted cash-flow analysis to determine the market price for refined products guaranteeing a 15% rate of return on invested capital. Federal, State, and local taxes and royalties were taken into account.

In all, the USBM prepared 12 different conceptual plans (which it has termed mining units) for exploiting the potash deposits in the WIPP site. Of these, eight were fully evaluated and four discarded because of complex problems related to the enrichment of raw ore.

*Public hearing on the WIPP draft environmental impact statement, Carlsbad, New Mexico, June 9, 1979, Volume VI, p. 974.

Table 7-7. Potash Resources (Millions of Tons)[a]

Ore bed[b]	Low grade	Lease grade	High grade
		SYLVITE ORES	
10	74.8	53.7	38.7
9	10.3	6.0	0.7
8	48.1	28.8	13.7
Total	133.2	88.5	53.1
		LANGBEINITE ORES	
10	55.6	49.4	8.8
5	26.2	24.2	1.6
4	161.0	115.4	59.0
3	34.5	25.6	--
2	73.7	50.2	9.8
Total	351.0	264.8	79.2
		ALL ORES	
10	130.4	103.1	47.5
9	10.3	6.0	0.7
8	48.1	28.8	13.7
5	26.2	24.2	1.6
4	161.0	115.4	59.0
3	34.5	25.6	--
2	73.7	50.2	9.8
Total	484.2	353.3	132.3

[a]Data from John et al. (1978), Table 4.

[b]The ore-bed numbers refer to the 12 horizons of the McNutt Potash Member, the middle portion of the Salado Formation. Ore bed 1 is at the base, and ore bed 12 is at the top. The mineralization in ore beds 1, 6, 7, 11, and 12 is insufficient to be classified as a resource.

Results of the potash-reserve determination

The full findings of the reserve evaluation have been reported (USBM, 1977; AIM, 1979), and the USBM estimates are summarized in Table 7-8. The eight mining units that were conceived and then costed are listed in the approximate order in which they would rank as potentially minable. Only the 48.46 million tons in mining unit B-1 (Figure 7-25) within the site were classified as reserves by the USBM study. This is much less than would be classified as reserves by the USGS. The USGS used the potash grade and thickness parameters of the most efficient producers in the district. These minimum ore standards, excluding all other minability parameters, include all material in the WIPP site with a minimum cutoff grade of 4% K_2O as langbeinite or 10% K_2O as sylvite in a thickness of 4 feet.

Table 7-8. Review of USBM Potash Evaluation

Mining unit	Product	Recoverable ore (10^6 tons) In mining unit	At site
B-1	Langbeinite	79.78	48.46
A-1	Muriate	57.60	27.41
D-2	Langbeinite	87.93	23.57
A-2	Muriate	98.32	51.80
C-2	Muriate	57.19	36.49
D-3	Langbeinite	140.27	42.45
C-3	Muriate	70.64	52.87
A-3	Muriate	135.02	73.77

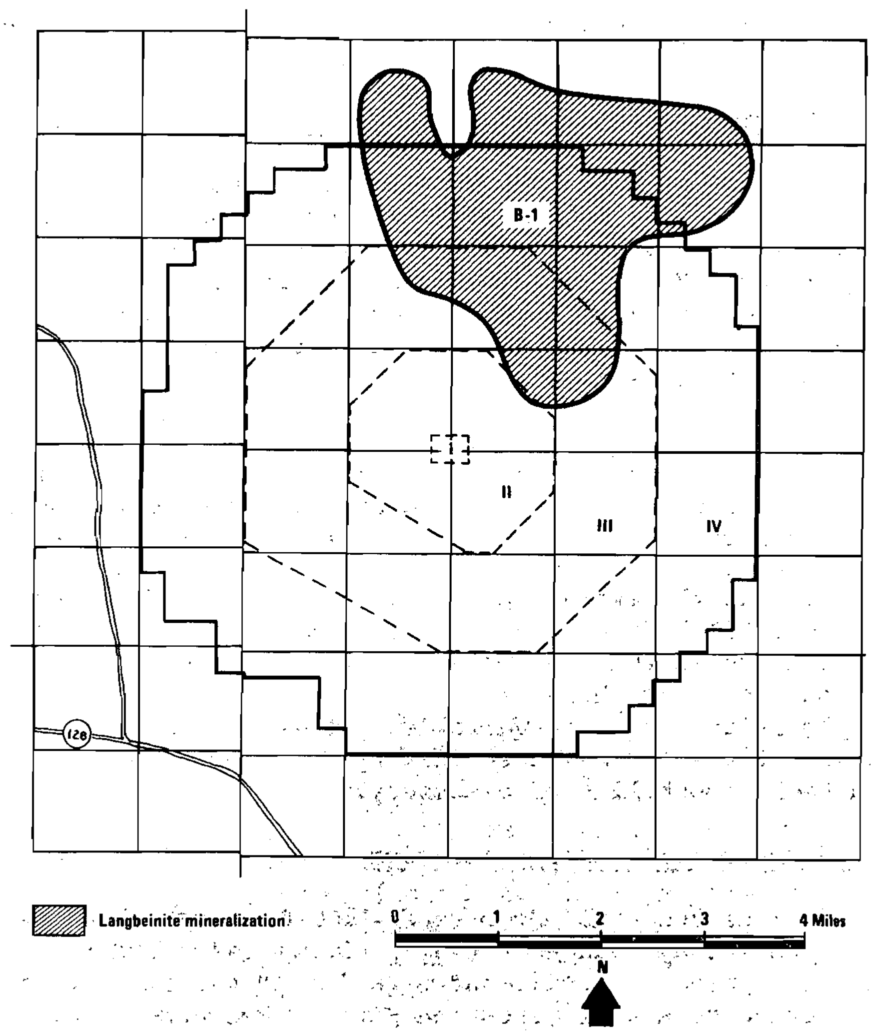


Figure 7-25. Economic langbeinite mineralization in mining unit B-1. (After USBM, 1977).

The USBM used criteria consistent with industry practice in preparing economic-feasibility studies. In calculating potash-ore reserves, it used a method based on engineering design and economic-analysis procedures, including discounted cash flow, to determine the tonnage of minable potash ore that will yield a 15% rate of return on the total capital investment. Only economically recoverable ore is included in the USBM reserve estimates.

Under the USBM criteria, only mining unit B-1 meets the 1977 market prices current at the time of the study: $42 per ton of muriate, $84 per ton of "sulfate" (K_2SO_4), and $48 per ton of langbeinite. This particular reserve consists of langbeinite, mostly in ore bed 4 in the northern portion of the site. (Restriction of mining within the WIPP site would not render uneconomic the remainder of mining unit B-1 outside the site.)

Unit A-1 does not meet the market-price requirements; however, the market price of muriate has exceeded $52 per ton in the recent past, at which point the A-1 deposit would be considered a marginal, or "nearly economic," deposit. (Average market prices for October 1979 were $58.37 per ton of muriate, $42-44 per ton of langbeinite, and $56.14 per ton of all sulfate products: USGS Conservation Division, Monthly Mining Report, Roswell, New Mexico.) The A-1 deposit consists of sylvite contained in ore bed 10 and located on the west side of the site.

Methods used to determine the hydrocarbon resources at the WIPP site

The New Mexico Bureau of Mines and Mineral Resources (NMBM&MR) conducted a hydrocarbon-resource study in southeastern New Mexico under contract to the Oak Ridge National Laboratory (Foster, 1974). The study included an area of 1512 square miles (Figure 7-26). At the time of that study, the proposed repository site was about 5 miles northeast of the current site. The NMBM&MR evaluation included a more detailed study of a four-township area centered on the old site; the present site is in the southwest quadrant of that area (Figure 7-26).

The resource evaluation was based both on the known reserves of crude oil and natural gas in the region and on the probability of discovering new reservoirs in areas where past unsuccessful wildcat drilling was either too widely spread or too shallow to have allowed discovery. All potentially productive zones were considered in the evaluation; therefore, the findings may be used for determining the total hydrocarbon resources at the site. A fundamental assumption in this study is that the WIPP area has the same potential for containing hydrocarbons as the much larger region in which the study was conducted and for which exploration data are available. Whether such resources actually exist can be satisfactorily established only by drilling at spacings close enough to give a high probability of discovery.

Results of the hydrocarbon-resource evaluation

Table 7-9 summarizes the findings of the NMBM&MR hydrocarbon evaluation as the potential resource of hydrocarbons that probably exist under a square mile (640 acres) with the typical geologic and stratigraphic section of that region. The New Mexico Bureau of Mines and Mineral Resources examined an area of 967,680 acres (1512 square miles). The hydrocarbon resources under the site are then estimated as the proportion of the total in the 29.625 square miles of the site (Table 7-10).

Table 7-9. Potential Hydrocarbon Resources Expected in Various Formations in the Delaware Basin[a]

Formation	Adjusted production estimate per section (640 acres)		
	Oil (10^6 bbl)	Gas (10^9 ft^3)	Distillate (10^6 bbl)
Ramsey	0.472	0.756	--
Delaware Mountain Group	0.026	0.010	--
Bone Springs	0.145	0.285	--
Wolfcamp	0.016	0.647	0.024
Pennsylvanian	0.265	10.438	0.132
Mississippian	--	--	--
Silurian/Devonian	0.342	4.408	0.037
Ordovician	--	--	--
Total	1.266	16.544	0.193

[a]Data from Foster (1974). In the original, Foster distinguished between "dry" and "associated" gas. The two types have been summed for simplicity. The estimates for each stratigraphic unit were derived by dividing the total reserves for that unit by the number of acres that have been fully explored, both producing and found dry. Foster also calculated expected resources by another method, based on the success ratio of "wildcat" wells. The wildcat method resulted in lower expected resources; hence, the resources reported here are the larger of the two estimates.

The hydrocarbon-resource quantities given in Table 7-10 are equivalent to potash-resource-quantity estimates in that both relate to the quantity of what is present, and not to its economic value or recoverability. Because the

Table 7-10. In-Place Hydrocarbon Resources at the Site[a]

Formation	Oil (10^6 bbl)	Gas (10^9 ft^3)	Distillate (10^6 bbl)
Ramsey	13.98	22.40	--
Delaware Mountain Group	0.77	0.30	--
Bone Spring	4.30	8.44	--
Wolfcamp	0.47	19.17	0.71
Pennsylvanian	7.85	309.22	3.91
Mississippian	--	--	--
Silurian/Devonian	10.13	130.59	1.10
Ordovician	--	--	--
Total	37.50	490.12	5.72

[a]Product of the estimates given in Table 7-9 and the number of sections in the WIPP site (29.625).

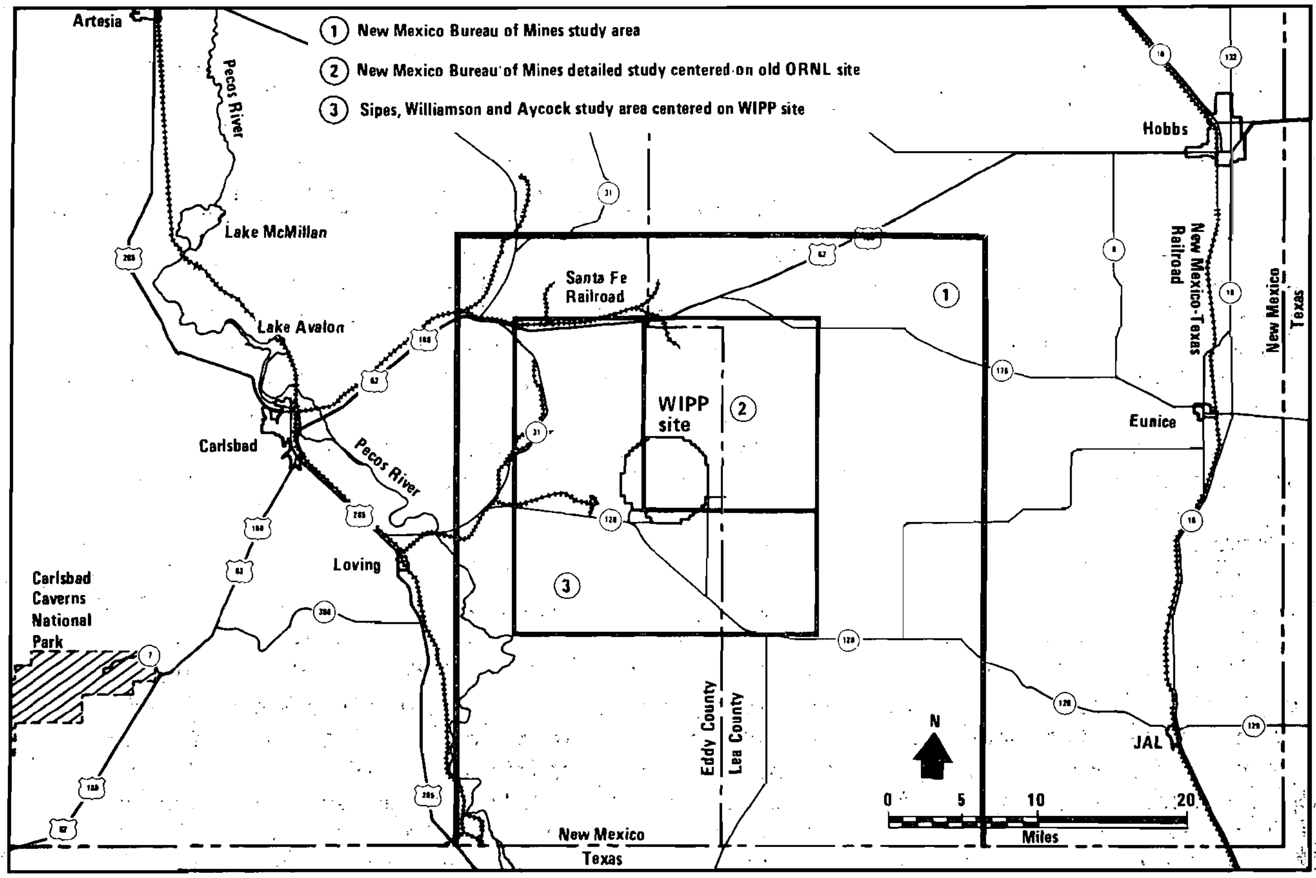


Figure 7-26. Location of hydrocarbon resource study areas.

hydrocarbon-resource evaluation relies on statistical probability, it is not as accurate as the potash-resource evaluation. The potash resources were actually drilled and assayed, while the hydrocarbon resources were estimated by projecting historical drilling success into an untested area. Site-selection requirements dictated that the inner zones be free of deep holes (i.e., oil and gas test holes).

Methods used to determine hydrocarbon reserves

The consulting petroleum engineering firm of Sipes, Williamson, and Aycock, Inc. (SW&A) performed the study of economic hydrocarbon reserves under contract to Sandia National Laboratories (Keesey, 1976). Because there has been no hydrocarbon-exploration drilling in WIPP control zones I, II, and III, the study relied on information gained from nearby exploration. To this extent the reserve evaluation followed that for resources. SW&A engineers studied a 400-square-mile area centered on the site (Figure 7-26). Unlike the resource study, the reserve evaluation considered economic factors. Drilling and completion costs and risk factors were balanced against expected recoverable reservoir volumes and delivery rates to determine profitability. Potential exploratory drill sites were selected with the benefit of seismic surveys that had been completed at the site during the course of site evaluation (G. J. Long and Associates, 1976). Price forecasts for hydrocarbons were based on information available at the time of the study. A more recent update (Keesey,

1979) has been based on the current and anticipated pricing structure and is incorporated into this report.

Results of the hydrocarbon-reserve estimate

The study of resources by NMBM&MR indicates that there are as many as 15 potential productive horizons ("pay zones") within the eight major stratigraphic divisions that underlie the evaporite deposits. Economic analysis revealed that only a single zone, the Morrow Formation of Pennsylvanian age, is worthy of exploration risk. This is true despite the large gas production from the Atoka Formation by a single well just outside the southwest corner of the site. Wells offset slightly from the productive well have not been productive in the Atoka. Gas production from the Atoka in the surrounding region is not large enough to justify exploration of the Atoka, although some production ancillary to Morrow production may be possible. The Morrow is a fairly consistent natural-gas producer over much of this area. Twenty hypothetical drilling sites were selected to develop the gas expected in the Morrow (Figure 7-27). Locations were selected on the basis of geologic structure as established by interpretation of seismic reflection surveys available from both service-company files and DOE surveys. Estimated reserves that ranged from 1.45 billion to 7.26 billion cubic feet were allocated to each well in the assigned reserves based on reserves indicated in the surrounding SW&A study area. The 1976 evaluation (Keesey, 1976) has been updated (Keesey, 1979) to reflect the actual performance of previously drilled wells and wells added in the study area since the 1977. Data available through May 1979 were used. From this information and the indicated seismic structure, 20 drill locations were identified within the WIPP site where a potential for hydrocarbons could be assigned to the following classes: proved but undeveloped, probable, and possible reserves. In addition, the 1979 study has considered a category of unassigned reserves for which there is no basis other than a purely statistical assumption that every hole, drilled in the remaining WIPP area at a density of two per section, would produce gas in the quantities statistically indicated by other producing wells in the area. These quantities might more properly be considered as possible resources rather than reserves; they are therefore not indicated in Table 7-11 but are indicated in Table 7-12. The summary resource tables indicate the values from the NMBM&MR report because that study indicates greater resources, having included all possible pay zones. The following is a description of the three reserve categories present at the WIPP site.

Proved but undeveloped reserves

These are proved reserves that can be expected to be recovered from new wells on undrilled acreage or from existing wells where a relatively major expenditure is required to establish production. Reserves on undrilled acreage are limited to drilling locations that offset productive wells and are therefore virtually certain of production when drilled. Proved reserves for other undrilled locations are included only when it can be demonstrated with certainty that there is a continuity of production from the existing productive formations.

Probable reserves

Reserves assigned under this category are those that are supported by favorable engineering or geologic data, but since they are subject to certain

Table 7-11. Expected Hydrocarbon Reserves at the WIPP Site

	Gross reserves	
	Condensate (bbl)	Gas (10^6 ft^3)
Potential hydrocarbon reserves underlying the WIPP site area		
Proved but undeveloped	81,758	11,610
Probable	21,462	19,144
Possible	15,304	13,868
Total reserves	118,524	44,622
Unassigned reserves	272,319	39,352
Total	390,843	83,974
Percentage of reserves recoverable with straight drilling or directional drilling	100	100
Gross wellhead value (future revenue) of oil and gas reserves		
Undiscounted	$287,502,346	
Discounted 16.25%	$168,774,143	
Cost of recovery, undiscounted		
Cost to drill and complete 54 wells		
Case A[a]	$182,306,000	
Case B[b]	152,419,000	
Case C[c]	117,631,000	
Operating costs	10,146,324	
Loss of revenue to the State, undiscounted		
With no drilling allowed	$ 19,107,546	
With drilling	0	

Source: Keesey (1979).

[a]All locations drilled from outside control zone IV.

[b]Eleven interior locations drilled from inside control zone IV (all directional holes).

[c]All locations drilled from inside control zone IV (23 directional holes).

unknowns and risks, their inclusion in the proved-reserve classification cannot be justified.

Possible reserves

Reserves assigned to this category are those for which limited engineering or geologic data are available but which, by analogy with offsetting or similar production-performance and engineering and geologic data, are considered to have recoverable potential. Such reserves would include second- or third-row

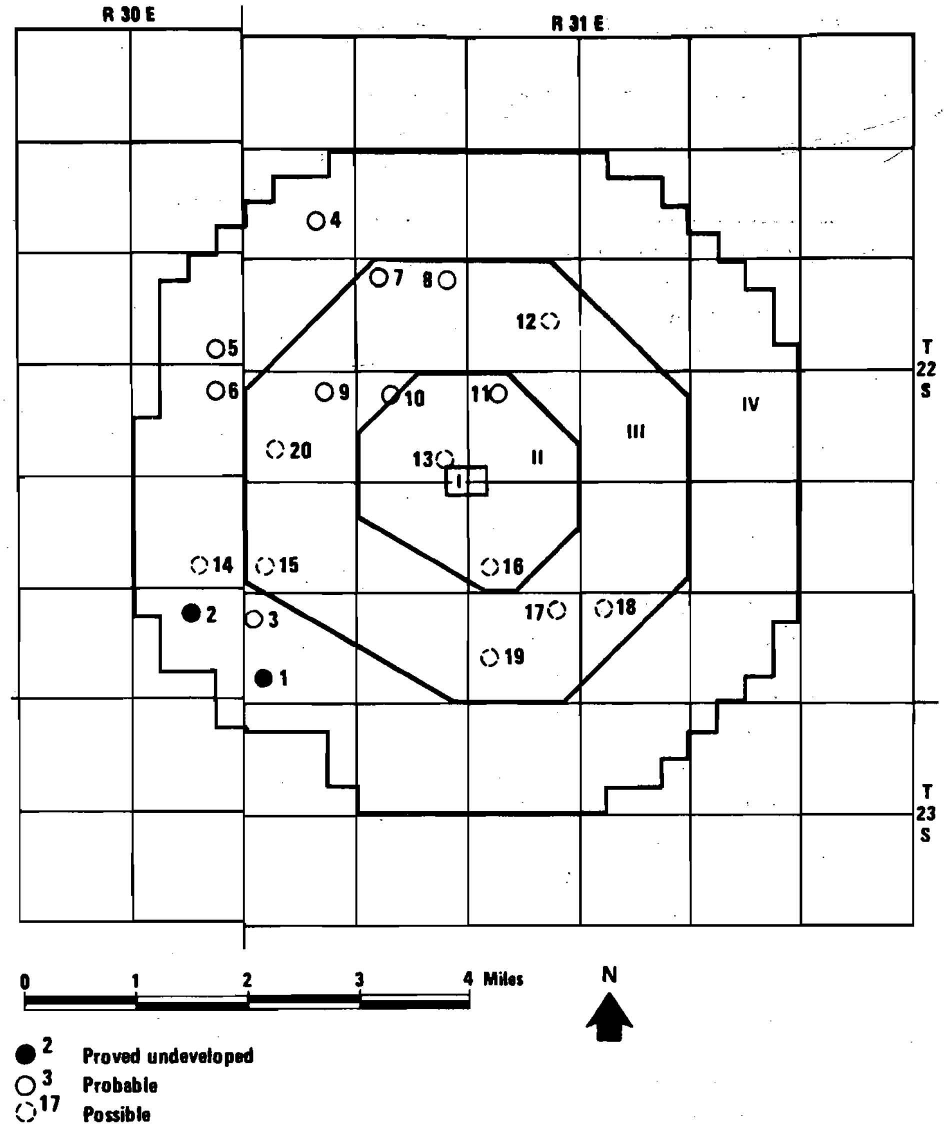


Figure 7-27. Hypothetical drilling sites to develop potential Morrow gas reservoirs.

stepouts to existing production. Accordingly, possible reserves are subject to an exceptionally high risk.

The highest reserves were assigned to wells that either were direct offsets to known Morrow gas producers or contained a combination of favorable geologic structure with chances of encountering shallower pay zones on drilling down to the Morrow. Reserves expected under the site are summarized in Table 7-11. The total natural-gas reserve is 44.62 billion cubic feet. Some natural-gas liquids (distillate) can be expected to be associated with the gas. The recent SW&A report (Keesey, 1979) states that 118,524 barrels of distillate would be associated with the production of these reserves.

Table 7-11 summarizes the data from the 1979 hydrocarbon-reserves study, and Table 7-12 breaks down the study by WIPP control zone.

Table 7-12. Hydrocarbon Reserves and Resources at the WIPP Site

Category	Condensate (bbl) Zones I,II,III	Zone IV	Category total	Gas (10^6 ft^3) Zones I,II,III	Zone IV	Total
Proved but undeveloped reserves	0	81,758	81,758	0	11,610	11,610
Probable reserves	11,640	9,822	21,462	9,050	10,094	19,144
Possible reserves	14,169	1,135	15,304	12,002	1,866	13,868
Total reserves	25,809	92,715	118,524	21,052	23,570	44,622
Unassigned reserves and resources			272,319			39,352
Grand total			390,843			83,974

Source: Keesey (1979).

7.3.8 Soils

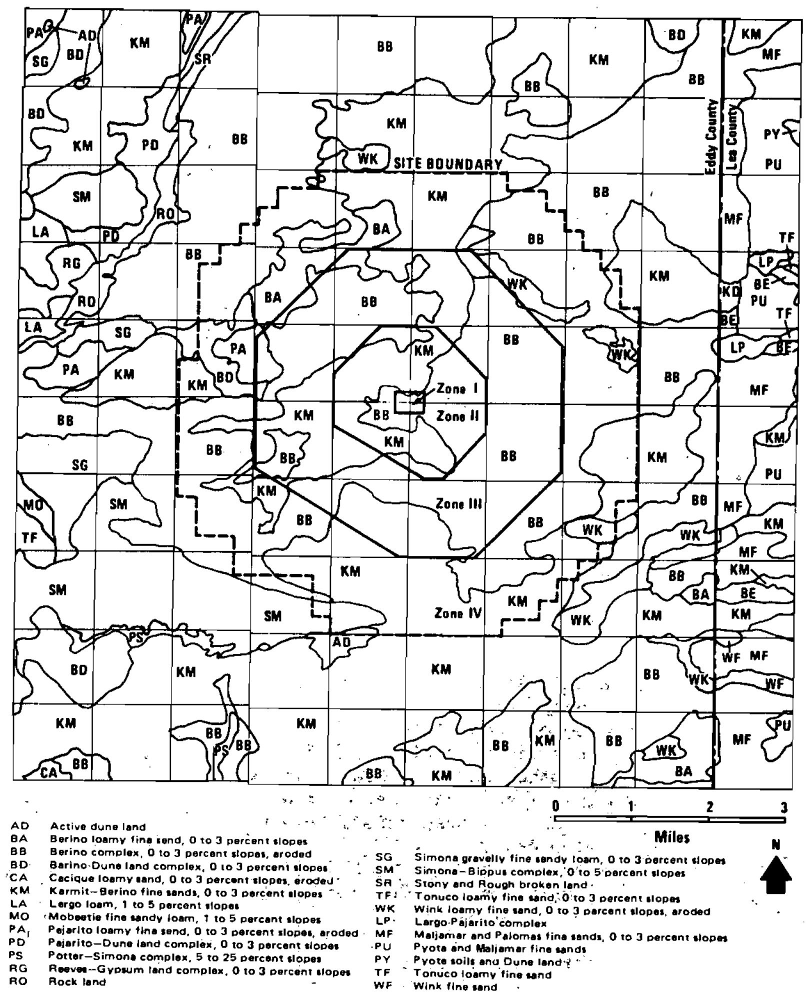
This section briefly discusses the characteristics and distribution of soil types in the region of the WIPP site. The biological aspects of soils, such as fertility and productivity, are described in Appendix H. Details of the soil associations and properties may be found in reports published by the U.S. Soil Conservation Service (1971) and Wolfe et al. (1977).

The soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary system is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian system is represented by limestone, dolomite, and gypsum bedrock.

Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. The prevailing climate and vegetation have caused many soils of the region to develop a light-colored surface. Subsoil colors normally are light brown to reddish brown, but are often mixed with lime accumulations (caliche), which result from limited, erratic rainfall and insufficient leaching.

A soil association is a landscape that has a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 5 miles of the site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit; they are described on the next page. Of these three associations, only the Kermit-Berino occurs at the site (Figure 7-28), in control zones I and II. It consists of two soil series, the Berino and the Kermit. Their properties are summarized in Table 7-13.

Association	Description	Occurrence (%)
1	Kermit-Berino: sandy, deep soils from wind-worked mixed sand deposits	82
2	Simona-Pajarito: sandy, deep soils and soils that are shallow to caliche; from wind-worked deposits	14
3	Pyote-Maljamar-Kermit: gently undulating and rolling deep, sandy soils	4



Source: SCS, 1971.

Figure 7-28. Soil-series map.

Table 7-13. Estimated Properties, Characteristics, and Engineering Suitability of Soils at the Site[a]

Property	Soil sample depth (cm) Berino 0-17	Berino 17-50	Kermit 0-60
	ESTIMATED PROPERTIES AND CHARACTERISTICS		
Depth to bedrock or hard caliche (in.)	More than 60		More than 60
Classification			
USDA (texture)	Fine sand and fine sandy loam		Fine sand
Unified	SM	SC	SP-SM
AASHO	A-2	A-6	A-3
Percentage passing sieve:			
No. 4 (4.7 mm)	100	100	100
No. 10 (2.0 mm)	100	100	100
No. 200 (0.074 mm)	10-20	35-45	5-10
Permeability (in./hr)	5.0-10.0	0.2-0.8	10.0
Available water capacity (in./in. soil)	0.06-0.08	0.14-0.16	0.06-0.08
Reaction (pH)	6.6-7.3	6.6-7.3	6.6-7.3
Electrical conductivity (10^3 mmhos/cm at 25°C)	0-1.0	0-4.0	0-1.0
Corrosivity (untreated steel pipe)	Low	Moderate	Low
Shrink-swell potential	Low	Moderate	Low
Erodibility			
Water erosion (K factor)	0.17 (slight potential)		0.15 (slight potential)
Wind erosion (I factor)	134-220 (very high potential)		220 (very high potential)
	ESTIMATES OF THE SUITABILITY OF THE SOILS FOR SPECIFIED USES		
Suitability as a source of			
Topsoil	Poor		Poor: drifting sand
Road fill	Poor to fair		Good if soil binder is added
Degree of limitation for disposal fields for septic tanks and tile systems	Severe: moderately slow permeability; soft caliche at a depth of 50 in.		Slight: drifting sand
Highway location	Features favorable		Loose sand hinders hauling; drifting highly erodible
Dikes and levees	Sandiness of surface material necessitates mixing with subsoil material		Not applicable
Farm ponds and embankments	Susceptible to piping; moderate seepage; sandy, porous surface		Not applicable
Irrigation	Rapid intake rate; smoothing necessary; susceptible to wind erosion		Not applicable
Leveling and benching	Soft caliche at a depth of 50 in.; highly susceptible to wind erosion		Not applicable
Foundations for low buildings	Good bearing capacity		Good suitability if soil is confined
Pipelines	Features favorable		Subject to blowouts
Hydrologic group	A		A

[a]Data from the Soil Conservation Service (1971).

Generally, the Berino series, which covers about 50% of the site, consists of deep, noncalcareous, yellow-red to red sandy soils that developed in wind-worked material of mixed origin. These soils occur as gently sloping (0% to 3% slopes) undulating to hummocky areas and are the most extensive of the deep, sandy soils in the Eddy County area. Berino soils are subject to continuing wind and water erosion. If the vegetative cover is seriously depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest.

Generally, the Kermit series, which covers about 50% of the site, consists of deep, light-colored, noncalcareous, excessively drained loose sands, typically yellowish-red fine sand. The surface is undulating to billowy (0% to 3% slopes) and consists mostly of stabilized sand dunes. Kermit soils are slightly to moderately eroded. Permeability is very high, and if vegetative cover is removed, the water-erosion potential is slight but the wind-erosion potential is very high.

7.4 HYDROLOGY

The WIPP site is in the southwestern portion of the Permian basin, within the surface-water basin of the Rio Grande Water Resources Region and the Great Plains groundwater region (Figure 7-29). The site and surrounding land drain into the Pecos River. The WIPP site lies within the Delaware basin, a portion of the Unglaciated Central region that includes some of the least productive aquifers in the United States. The low productivity and the general aridity of the area give even poor aquifers unusual significance.

There are no perennial streams or surface-water impoundments on the site, nor are there any wells yielding more than a few gallons per minute. The climate is semiarid, with a mean annual precipitation of about 12 inches, a mean annual runoff of 0.1 to 0.2 inch, and a mean annual pan evaporation of more than 100 inches. Brackish water with total-dissolved-solids (TDS) concentrations of more than 3000 parts per million (ppm) is common in the shallow wells used for watering livestock. Surface waters typically have high TDS concentrations, particularly chloride, sulfate, sodium, magnesium, and calcium.

At the site, hydrologic data have been and are being obtained from conventional and special-purpose test configurations in 38 drilled holes. Geophysical logging of the open boreholes has provided hydrologic information on the rock strata intercepted. Pressure measurements, fluid samples, and ranges of rock permeability have been obtained for selected formations through the use of standard and modified drill-stem tests. Slug injection or withdrawal tests have provided additional data to aid in the estimation of transmissivity and storage. Also, potentiometric surfaces of major aquifer systems have been contoured from measured depths to water in boreholes.

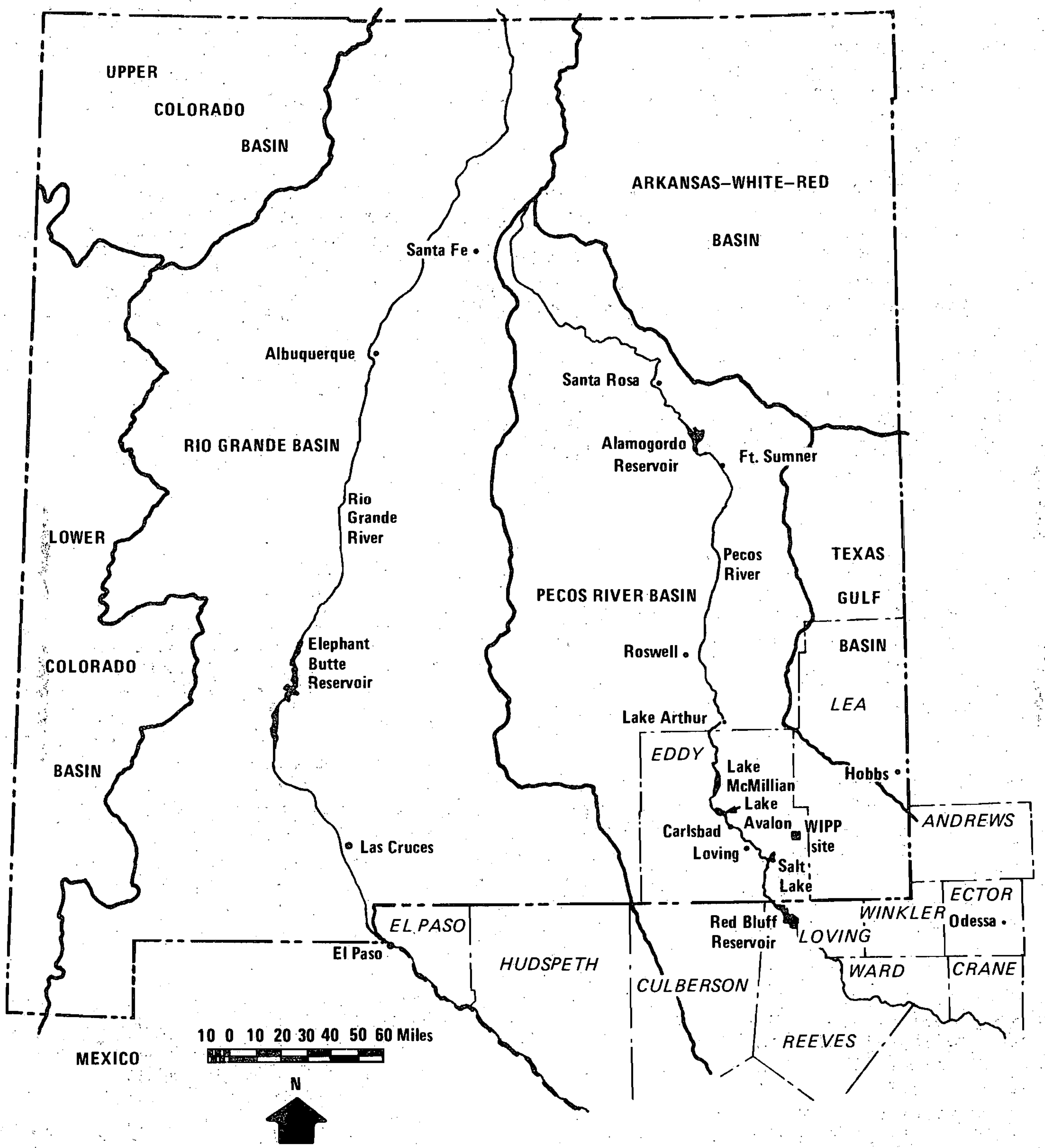


Figure 7-29. Location of the WIPP site and principal river basins and reservoirs.

7.4.1 Surface-Water Hydrology

The WIPP site is in the Pecos River basin, which contains about 50% of the drainage area of the Rio Grande Water Resources Region. The Pecos River headwaters are northeast of Santa Fe, and the river flows to the south through eastern New Mexico and western Texas to the Rio Grande. The Pecos River has an overall length of about 500 miles, a maximum basin width of about 130 miles, and a total drainage area of about 44,535 square miles (about 20,500 square miles are noncontributing).

The Pecos River is generally perennial, except in the reach below Anton Chico and between Fort Sumner and Roswell, where the low flows percolate into the stream bed. The main stem of the Pecos River and its major tributaries have low flows (Table 7-14), and the streams are frequently dry. About 75% of the total annual precipitation and 60% of the annual flow result from intense local thunderstorms between April and September. The principal tributaries of the Pecos River, in downstream order, are the Gallinas River, Salt Creek, Rio Hondo, Rio Felix, Eagle Creek, Rio Penasco, the Black River, and the Delaware River.

Table 7-14. Discharge in the Pecos River Basin Within or Adjacent to the Permian Basin[a]

River	Location	Drainage area (miles^2)	Period of record	Discharge (cfs)		
				Average	Minimum	Maximum
Pecos	Santa Rosa, N.M.	2,650	1912-75	138	0.3	55,200
Pecos	Acme, N.M.	11,380	1937-75[b]	194	0	45,000
Pecos	Artesia, N.M.	15,300	1936-75[b]	265	0	51,500
Pecos	Malaga, N.M.	19,190	1936-75[b]	196	5	120,000
Pecos	Orla, Texas	21,210	1937-75[b]	181	0	23,700
Pecos	Girvin, Texas	29,560	1939-75[b]	96	2.2	20,000
Rio Hondo	Roswell, N.M.	963	1963-75	9	0	659
Rio Felix	Hagerman, N.M.	932	1939-75	16	0	74,000
Rio Penasco	Dayton, N.M.	1,060	1951-75	6	0	29,000
Black	Malaga, N.M.	343	1947-75	14	0.7	74,600
Delaware	Red Bluff, Texas	689	1937-75	14	0	81,400

[a]Data from USGS (1976).
[b]Flow regulated.

The mean annual precipitation in the region is about 12 inches, and the mean annual runoff is 0.1 to 0.2 inch. The maximum recorded 24-hour precipitation at Carlsbad was 5.12 inches, in August 1916. The 6-hour, 100-year precipitation event for the site is 3.6 inches and is most likely to occur during the summer. The maximum daily snowfall at Carlsbad was 10 inches, in December 1923.

The maximum recorded flood on the Pecos River near Malaga occurred on August 23, 1966, with a discharge of 120,000 cubic feet per second (cfs) and a stage elevation of about 2938 feet above mean sea level (USGS Station No. 08406500). The minimum surface elevation of the WIPP site is approximately 300 feet above the elevation of this maximum historical flood elevation.

More than 90% of the mean annual precipitation at the site is lost by evapotranspiration. Table 7-15 shows the mean monthly temperature at Artesia, the mean monthly pan evaporation at Lake Avalon, and the mean monthly rainfall at Carlsbad. On a mean monthly basis, evapotranspiration at the site greatly exceeds the available rainfall; however, intense local thunderstorms may produce runoff and percolation. Water-infiltration rates in the local sand dunes are probably similar to the 1.6-inch-per-hour intake rate of Harkey sandy loam (75% sand) near Carlsbad (Blaney and Hanson, 1965).

Four major reservoirs are located in the Pecos River basin: the Alamogordo Reservoir, Lake McMillan, Lake Avalon, and the Red Bluff Reservoir, the last just over the border in Texas (Figure 7-29). The storage capacities of these reservoirs and other Pecos River reservoirs adjacent to the Pecos River basin are shown in Table 7-16.

Table 7-15. Mean Monthly Temperature, Pan Evaporation, and Rainfall[a]

Month	Mean monthly temperature, Artesia (°F)	Mean monthly pan evaporation, Lake Avalon (inches)	Mean monthly precipitation, Carlsbad (inches)
January	40.9	4.20	0.42
February	44.9	5.76	0.37
March	51.8	9.23	0.46
April	60.9	11.8	0.54
May	69.4	14.0	1.82
June	78.4	14.6	1.33
July	80.0	13.1	1.54
August	79.4	12.4	1.67
September	72.7	9.72	2.00
October	62.1	7.00	1.69
November	48.8	4.51	0.35
December	41.8	5.44	0.47

[a]Data from Blaney and Hanson (1965).

Regional water quality

Water quality in the Pecos River basin is affected by mineral pollution from natural sources and from irrigation return flows. At Santa Rosa, New Mexico, the average suspended-sediment discharge of the river is about 1650 tons per day. Large amounts of chlorides from Salt Creek and Bitter Creek enter the river near Roswell. River inflow in the Hagerman area contributes increased amounts of calcium, magnesium, and sulfate; and waters entering the river near Lake Arthur are high in chloride. Below Lake McMillan, springs flowing into the river are usually submerged and difficult to sample; springs that could be sampled had TDS concentrations of 3350 to 4000 ppm. Concentrated brine entering at Malaga Bend adds an estimated 70 tons per day of chloride to

Table 7-16. Major Reservoirs in the Pecos River Basin[a]

Reservoir	River	Total storage capacity[b] (acre-feet)	Use[c]
Los Esteros Lake	Pecos	282,000	FC
Alamogordo Reservoir	Pecos	122,100	IR, R
Lake McMillan	Pecos	33,600	IR, R
Lake Avalon	Pecos	5,000	IR
Red Bluff Reservoir	Pecos	310,000	IR, P
Two River Reservoir	Rio Hondo	167,900	FC

[a]Data from New Mexico State Engineer's Office (1967) and the U.S. Army Corps of Engineers (1977).

[b]Capacity below the lowest uncontrolled outlet or spillway.

[c]Key: FC, flood control; IR, irrigation; R, recreation; P, hydroelectric.

the Pecos River (FWPCA, 1967). Time-weighted averages of water-quality parameters for three sampling stations on the Pecos River between Carlsbad and Malaga Bend are shown in Table 7-17.

The potash industry uses 19,800 acre-feet of "fresh water" annually, which is pumped from groundwater wells drilled into the Capitan aquifer. The industry discharges about 19,100 acre-feet of brine effluent annually into the surface sediments, contaminating shallow brackish aquifers and recharging existing brackish ponds and lakes (BLM, 1978). The potash industry also discards more than 3 parts of solid sodium chloride for each part of potassium chloride product. This has resulted in about 200 million tons of sodium chloride in waste piles, which contribute to brine contamination through runoff from thunderstorms. Most of this brine also discharges into ponds and lakes in Nash Draw. The land-surface slope and shallow-aquifer gradient around Nash Draw are toward the Pecos River.

Table 7-17. Water-Quality Parameters (Time-Weighted Averages) for Sampling Stations on the Pecos River, October 1975 to September 1976[a]

Station No.	Discharge (cfs)	pH	Dissolved-solids concentration (ppm)				
			Total	Chloride	Sulfate	Sodium	Calcium
08405000 (Carlsbad)	12	7.7	2,290	531	1100	322	334
08406500 (near Malaga)	26	7.7	5,060	1690	1820	1030	524
08407000 (Pierce Canyon Crossing)	28	7.5	13,350	6500	2280	4020	551

[a]Data from the U.S. Geological Survey (1977), Water Year October 1975 to September 1976.

Regional water use

The total water-withdrawal rate for the Permian basin in 1975 was about 30,000 million gallons per day (mgd), with about 19,000 mgd coming from groundwater. The total withdrawal for the Upper Pecos and the Rio Grande-Pecos Water Resource Subregions in 1975 was 1771 mgd, of which 1079 mgd, or 61%, came from groundwater. Agriculture, with a withdrawal of 1546 mgd, or 87% of the total, is the most significant user (Table 7-18). Agricultural acreage between Carlsbad and the Red Bluff Reservoir used less than 7% of the total irrigation requirements of the Pecos River basin and less than 1% of the total surface-water and groundwater withdrawals for the Permian basin.

The Pecos River, as it flows into Texas south of Carlsbad, is a major source of dissolved salt in the west Texas portion of the Rio Grande basin. Natural discharge of highly saline groundwater into the Pecos River in New Mexico keeps TDS levels in the water in and above the Red Bluff Reservoir very high. Total-dissolved-solids levels in this interval exceed 7500 milligrams per liter 50% of the time and during low flows can exceed 15,000 milligrams per liter. Additional inflow from saline-water-bearing aquifers below the Red Bluff Reservoir, irrigation return flows, and runoff from oil fields continue to degrade water quality between the reservoir and northern Pecos County in Texas. Annual discharge-weighted average TDS concentrations exceed 15,000 milligrams per liter. Water use is varied in the southwest Texas portion of the Pecos River drainage basin. For the most part, water use is restricted to irrigation, mineral production and refining, and livestock. In many instances, surface-water supplies are supplemented by groundwaters that are being depleted and are increasing in salinity.

Local surface-water hydrology

There are no perennial streams or surface-water impoundments at the WIPP site. At its nearest point, the Pecos River is about 14 miles southwest of the center of the site.

Table 7-18. Water Use in the Upper Pecos and Rio Grande-Pecos Subregions[a]

Use category	Surface-water and groundwater withdrawals (mgd) 1975[b]	1985	2000
Agriculture	1546	1239	1689
Steam-electricity	12	3	2
Manufacturing	0	0	0
Domestic	47	47	47
Commercial	8	8	8
Mining	151	155	161
Public lands	4	4	4
Fish hatcheries	3	5	7
Total	1771	1461	1918

[a]Data from the U.S. Water Resources Council (1979).
[b]The total groundwater withdrawal for 1975 was 1079 mgd.

The drainage area of the Pecos River at this location is 19,000 square miles (Figure 7-29). A few small creeks and draws are the only westward-flowing tributaries of the Pecos River within 20 miles north or south of the site. (A low-flow investigation has been initiated by the USGS within the Hill Tank Draw drainage area, the most prominent drainage feature near the WIPP site. The drainage area is about 4 square miles, with an average channel slope of 1 to 100, and the drainage is westward into Nash Draw. Two years of observations showed only four flow events. The USGS estimates that the flow rate for these events was under 2 cubic feet per second.) The Black River (drainage area 400 square miles) joins the Pecos from the west about 16 miles southwest of the site. The Delaware River (drainage area 700 square miles) and a number of small creeks and draws also join the Pecos along this reach. The flow in the Pecos River below Fort Sumner is regulated by storage in Lake Sumner, Lake McMillan, Lake Avalon, and several other smaller irrigation dams.

There are no major lakes or ponds within 10 miles of the center of the site. Laguna Gatuna, Laguna Tonto, Laguna Plata, and Laguna Toston are more than 10 miles north of the site and are at elevations of 3450 feet or higher. Thus surface runoff from the site would not flow toward any of them. To the west and northwest, Red Lake, Lindsey Lake, Laguna Grande de la Sal, and a few unnamed ponds are more than 10 miles from the site, at elevations of 3000 to 3300 feet.

7.4.2 Regional Groundwater Hydrology

The WIPP site lies in the Delaware basin, which contains some of the least productive aquifers in the United States. The only large quantities of potable groundwater are in localized shallow aquifers. The Delaware basin is bounded by a limestone reef of Permian age known as the Capitan Formation (Figure 7-30), which is one of the eight rock units important to the hydrology of the WIPP site in the Delaware basin; the others are the Delaware Mountain Group, the Castile Formation, the Salado Formation, the Rustler Formation, the Dewey Lake Red Beds, the Santa Rosa Sandstone, and the Chinle Formation. Of these eight rock units the Castile and Salado Formations are defined as aquicludes (non-water-transmitting layers of rock that bound an aquifer); the rest contain aquifers of low yield and nonpotable water.

Capitan Limestone

The Capitan Limestone crops out in the southern end of the Guadalupe Mountains and is a massive limestone unit that grades basinward into recemented, partly dolomitized reef breccia and shelfward into bedded carbonates and evaporites. In Eddy and Lea Counties, it has an average thickness of about 1600 feet. Its hydraulic conductivity ranges from 1 to 25 feet per day and in southern Lea County and east of the Pecos River at Carlsbad is 5 feet per day. Average transmissivities around the northern and eastern margins of the Delaware basin are 10,000 square feet per day in thick sections and 500 square feet per day in incised submarine canyons (Figure 7-31; Hiss, 1976). In the aquifer, water-table conditions are found southwest of the Pecos River at Carlsbad; however, artesian conditions exist to the north and east. A deeply incised submarine canyon near the Eddy-Lea County line has been identified, and the hydraulic gradient to the southeast of this restriction has been affected by large oil-field withdrawals. The Capitan Limestone is recharged by

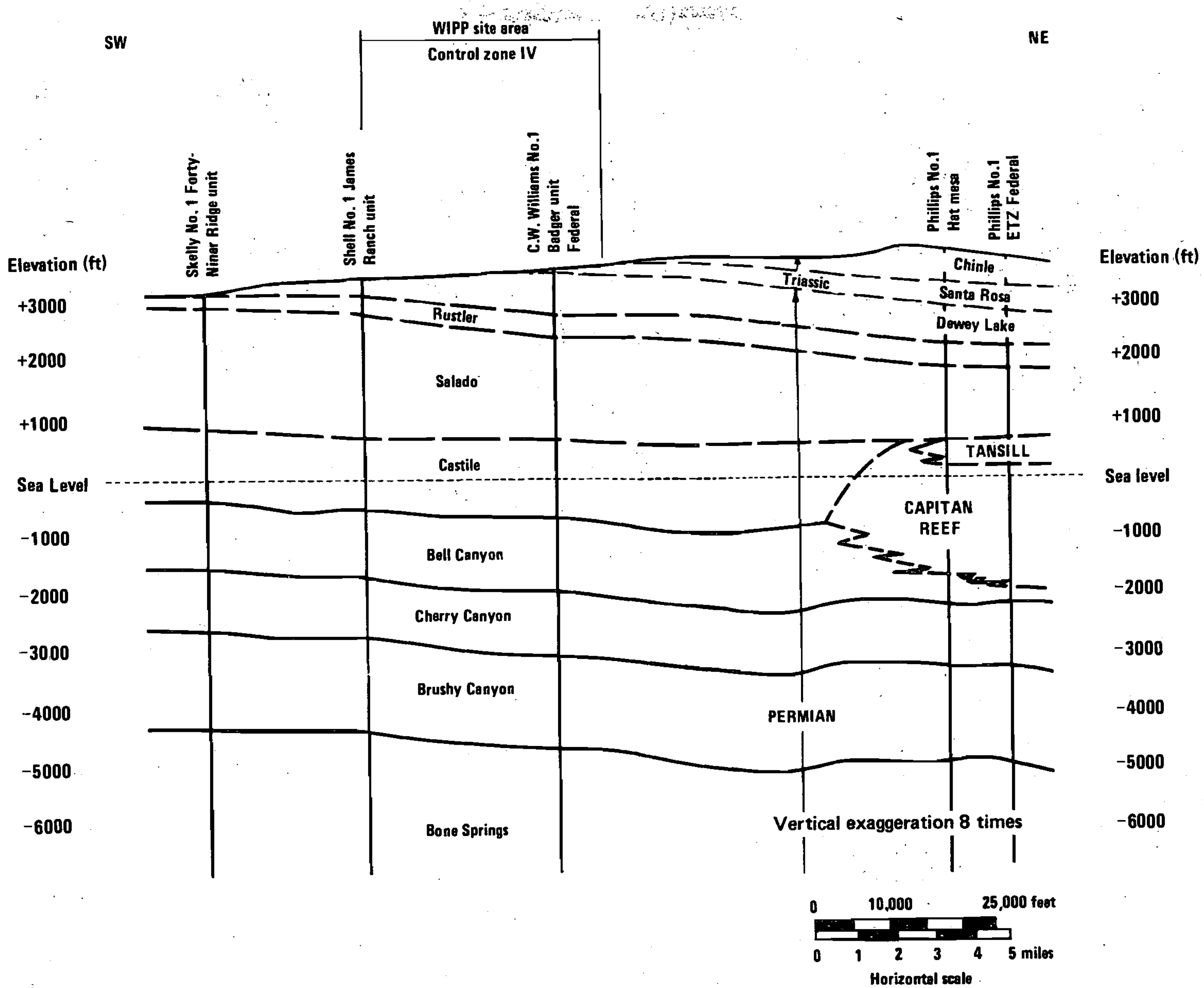


Figure 7-30. Generalized site stratigraphic section.

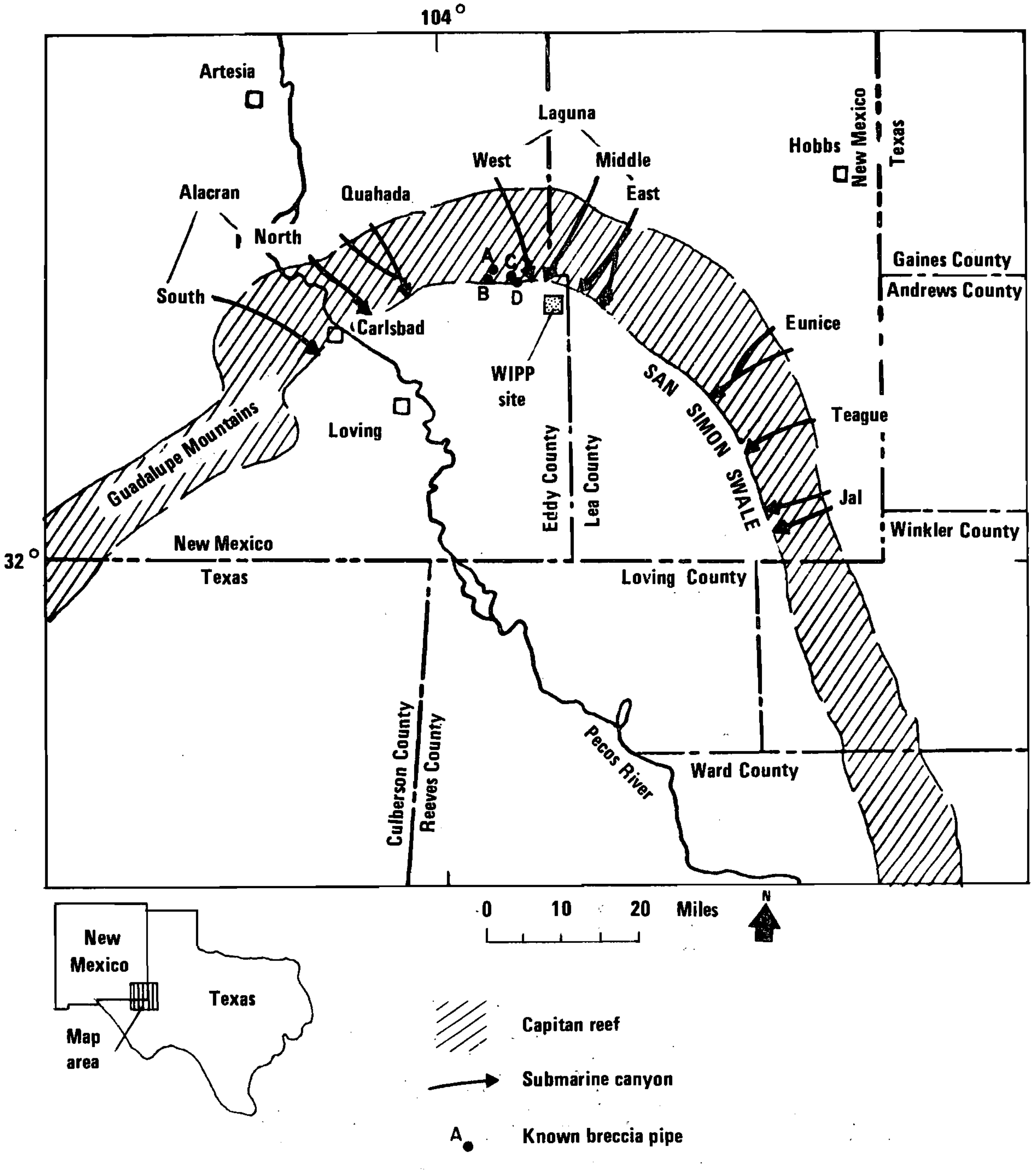


Figure 7-31. Location of breccia pipes and submarine canyons in the Capitan reef. (Generalized from Hiss, 1975, Figure 11.)

percolation through the Northern shelf aquifers, by flow from underlying basin aquifers to the south and west, and by direct infiltration at its outcrop in the Guadalupe Mountains.

Delaware Mountain Group

Formations of the Delaware Mountain Group underlie the Capitan reef and form the floor of the Delaware basin evaporite sequence. Three separate formations, each about 1000 feet thick, are assumed to form a single aquifer system with an average hydraulic conductivity of 0.02 foot per day, an average porosity of 16%, and a calculated transmissivity of about 50 square feet per day (Powers et al., 1978, p. 6-14). A potentiometric map (Figure 7-32) representing a composite surface for the Delaware Mountain Group and the Capitan aquifer has been constructed by Hiss (1976). The data were adjusted for the

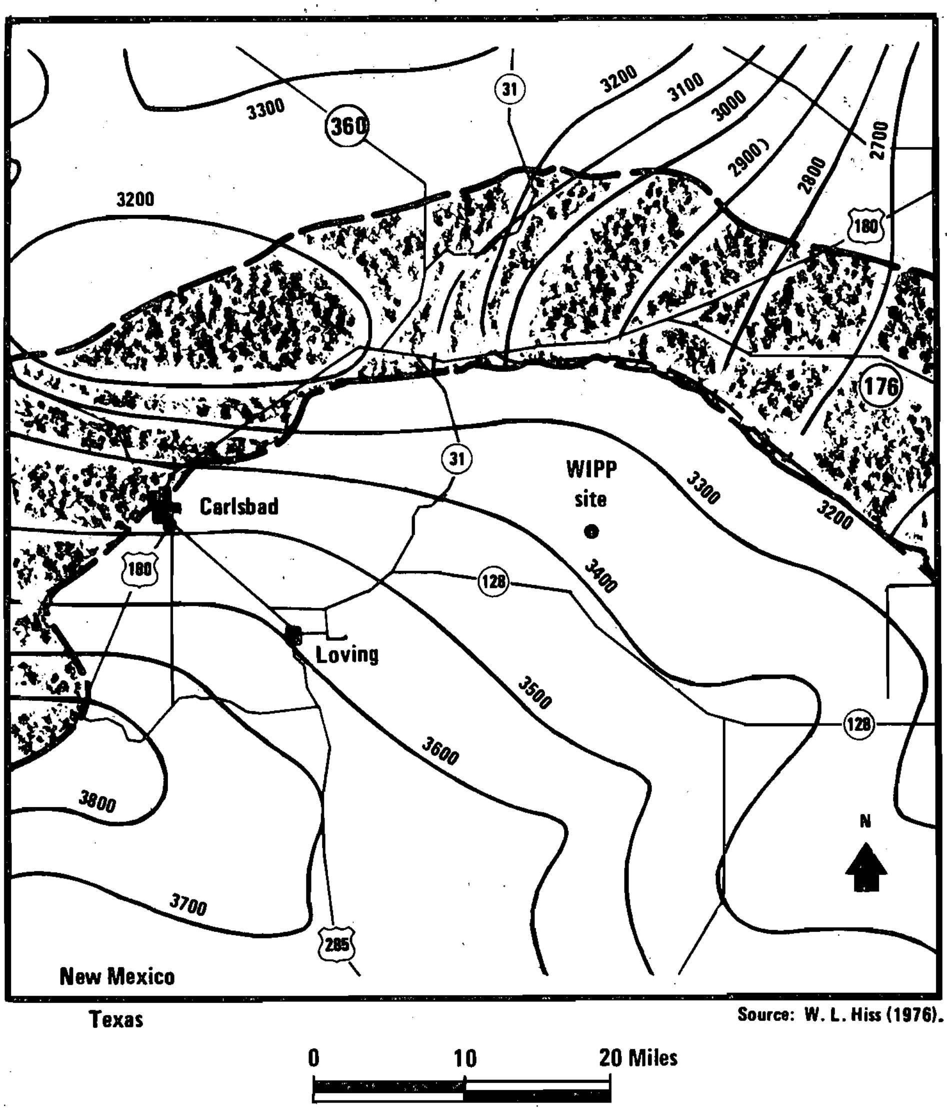


Figure 7-32. Potentiometric surface map (composite) of the Delaware Mountain Group.

saline density and expressed as freshwater equivalent. The brines in the Delaware Mountain Group flow northeasterly under a hydraulic gradient of 25 to 40 feet per mile and discharge into the Capitan aquifer. Velocities range from 0.2 to 0.3 feet per year, and groundwater yields from wells in the Delaware Mountain Group are 0.6 to 1.5 gallons per minute.

Castile Formation

The Castile Formation separates the Delaware Mountain Group from the Salado Formation. The Castile anhydrite unit is 1300 to 2000 feet thick; it is a confining bed (Lohman et al., 1972) without circulating groundwater. Groundwater flow from the Capitan aquifer and the Delaware Mountain Group into the Salado is prohibited by the very low hydraulic conductivity of the Castile. On the western side of the Delaware basin, local cavernous zones near the outcrop of the Castile hold groundwater for stock and domestic use; the water is high in dissolved solids (Bjorklund and Motts, 1959). Drilling has encountered pockets of brine in the middle to lower Castile anhydrites (see Section 7.3.5). These brines may have high concentrations of dissolved gases such as carbon dioxide, methane, hydrogen sulfide, and nitrogen. Brine pockets have been found to occur throughout the Delaware basin, but "artesian" pockets of brine have been found only in conjunction with anticline structures.

Salado Formation

The Salado Formation laps extensively over the back reef of the Capitan Limestone and includes three divisions: the lower salt member, the McNutt Potash Zone, and the upper salt member. It is 1400 to 2100 feet thick and yields no quantities of water to wells. The Salado acts hydrologically as a confining bed and does not contain circulating groundwater. Small pockets of saturated brine and nitrogen gas have been observed in the Salado (Jones et al., 1973).

Rustler Formation

The Rustler Formation ranges from 200 to 600 feet in thickness and contains the principal water-bearing units of the area. These are, in descending order, the Magenta Dolomite member, the Culebra Dolomite member, and the Rustler-Salado interface. For all practical purposes the Magenta and the Culebra members, each about 25 feet thick, are confined aquifers separated by 100 to 150 feet of interbedded halite, polyhalite, and anhydrite. The Rustler-Salado interface (brine) aquifer varies in thickness and is the least productive of these water-bearing rock members at the WIPP site. To the west in Nash Draw, it provides high flows of brine. At the WIPP site, the Culebra aquifer is the most productive, with groundwater yields varying from tenths of a gallon to a few gallons per minute. To the west in Nash Draw, the Magenta and the Culebra members are in contact because of the extensive dissolution of intervening rock members. It is in Nash Draw that groundwater yields are the greatest for all water-bearing units.

Hydrologic studies are being continued to get more and better data on (a) the potentiometric heads for each aquifer to determine their potential gradients and directions of groundwater flow and (b) hydraulic parameters such as transmissivity, hydraulic conductivity, yield, and effective porosity to quantify groundwater migration. Hydraulic testing to date near the site indicates that the average groundwater gradient of the Magenta Dolomite and

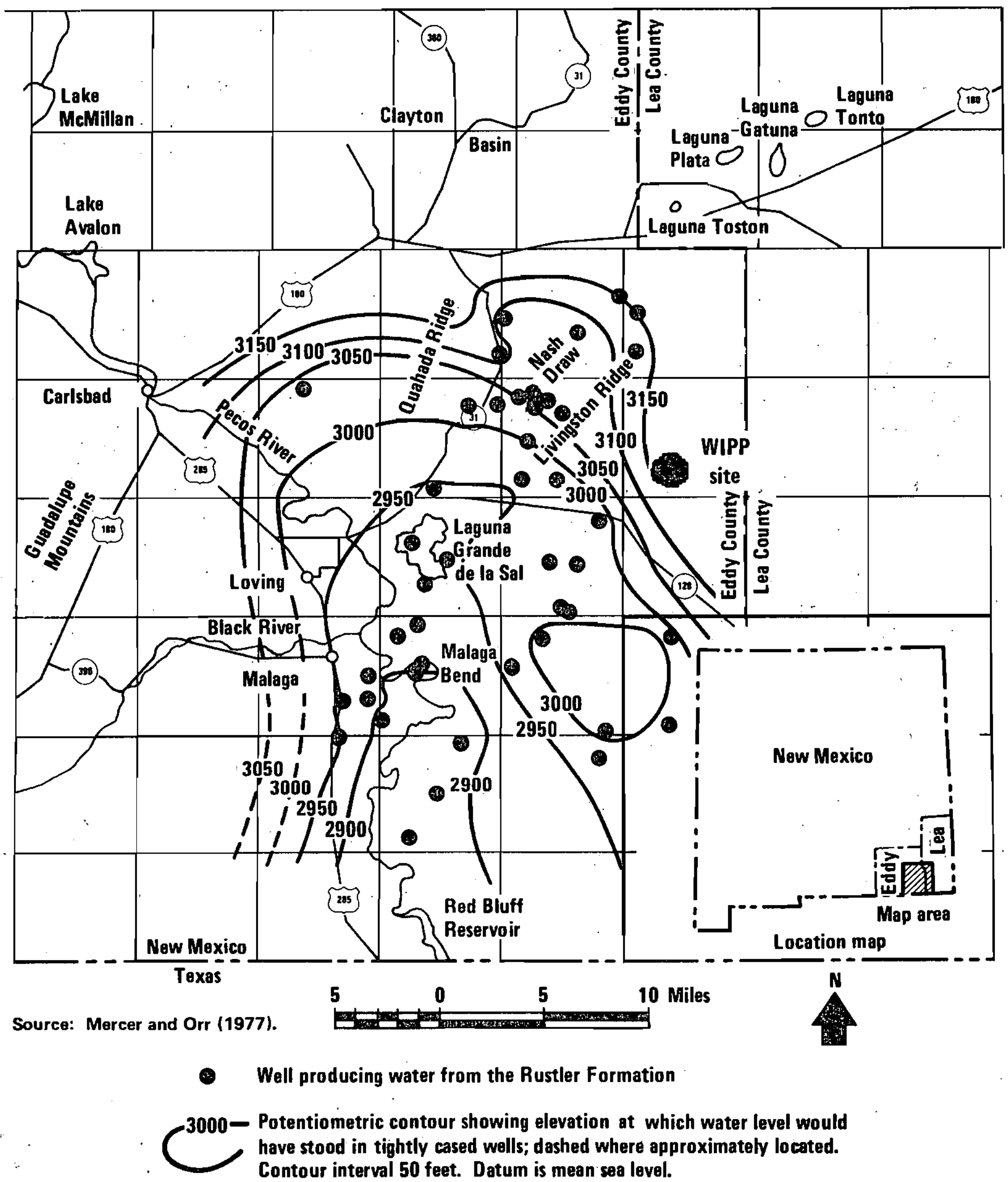


Figure 7-33. Potentiometric surface map of the Rustler Formation.

the Rustler-Salado contact is to the southwest and that of the Culebra Dolomite is to the southeast and then to the southwest. The potentiometric head data from which these gradients were determined are from within the site area itself. Data from testing being conducted in 38 holes within and outside the WIPP site will soon be available. At each of nine sites, three holes were drilled specifically to determine the hydraulic character of the Magenta and Culebra Dolomites and the Rustler-Salado interface. Other holes penetrate to specific horizons and are completed in one or more water-bearing zones. As these data are obtained, they will be included in the hydrologic model to improve its predictive accuracy.

Figure 7-33 is a composite potentiometric-surface map of the Rustler Formation. The average porosity is about 10%, and the calculated transmissivity ranges from 10^{-4} to 140 square feet per day, the former at the east edge of the site (Powers et al., 1978, p. 6-36). Groundwater gradients range from 7 to 120 feet per mile. Total dissolved solids in well water sampled from the Rustler Formation are at levels of 3000 to 60,000 ppm (Lambert, 1978). Groundwater movement in the Rustler near the site is westward toward Nash Draw and then southward toward the Pecos River.

Dewey Lake Formation

The Dewey Lake Formation is a siltstone deposit that is 200 to 600 feet thick (Jones, 1954). Because of its low hydraulic conductivity, the Dewey Lake Formation functions as a confining bed. Groundwater probably occurs only in sandstone lenses of small capacity.

Santa Rosa Sandstone

The Santa Rosa Sandstone is about 140 to 300 feet thick and is present over the eastern half of the WIPP site. It dips gently westward, except in local areas of collapse, and crops out northeast of Nash Draw. As a water-bearing unit, the Santa Rosa near the WIPP site has a saturated thickness of only 1 to 2 feet and occurs in lenses that are very limited in extent. It has a porosity of about 13% and a specific capacity of 0.14 to 0.2 gallon per minute per foot of drawdown (Nicholson and Clebsch, 1961). Figure 7-34 is a map indicating where groundwater occurs in the Santa Rosa. Lows in the potentiometric surface near the Eddy-Lea County line and in San Simon Swale suggest recharge into underlying rocks, possibly through collapse zones, and a possibility of a groundwater divide (at a surface ridge) between the site and San Simon Swale. In general, groundwater flows south and is of better quality than that found in the Rustler Formation.

It is not known at this time what quantities of water from the Santa Rosa recharge the shallow aquifers along the Pecos River, if any. The groundwater gradient in adjacent Texas along the Pecos River is influenced by a large-scale withdrawal of groundwater resulting in a net loss of groundwater storage. The water-level declines have created sizable cones of depression along the river and gradients toward the river. The Santa Rosa aquifer in southwest Texas adjacent to the New Mexico border is not downgradient from the WIPP site. There are several reasons for believing that Santa Rosa waters at the WIPP site will flow into the Pecos River rather than to the south into Texas: the configuration of the potentiometric head map, the influence of extensive pumping, and a topographic groundwater divide east of the WIPP site. Groundwaters pumped from the Santa Rosa and alluvium deposits are used extensively for irrigation and livestock.

Chinle Formation

The Chinle Formation is a mudstone deposit above the Santa Rosa Sandstone to the east of the site. It ranges in thickness from about zero near the Eddy-Lea County line to as much as 800 feet north of San Simon Swale (Mercer and Orr, 1977). Because of the low hydraulic conductivity of mudstone, the Chinle Formation is hydrologically a confining bed.

Groundwater flow

Groundwater in porous formations west of the Pecos River flows eastward from the Guadalupe Mountains. The alluvium and shallow aquifers contribute

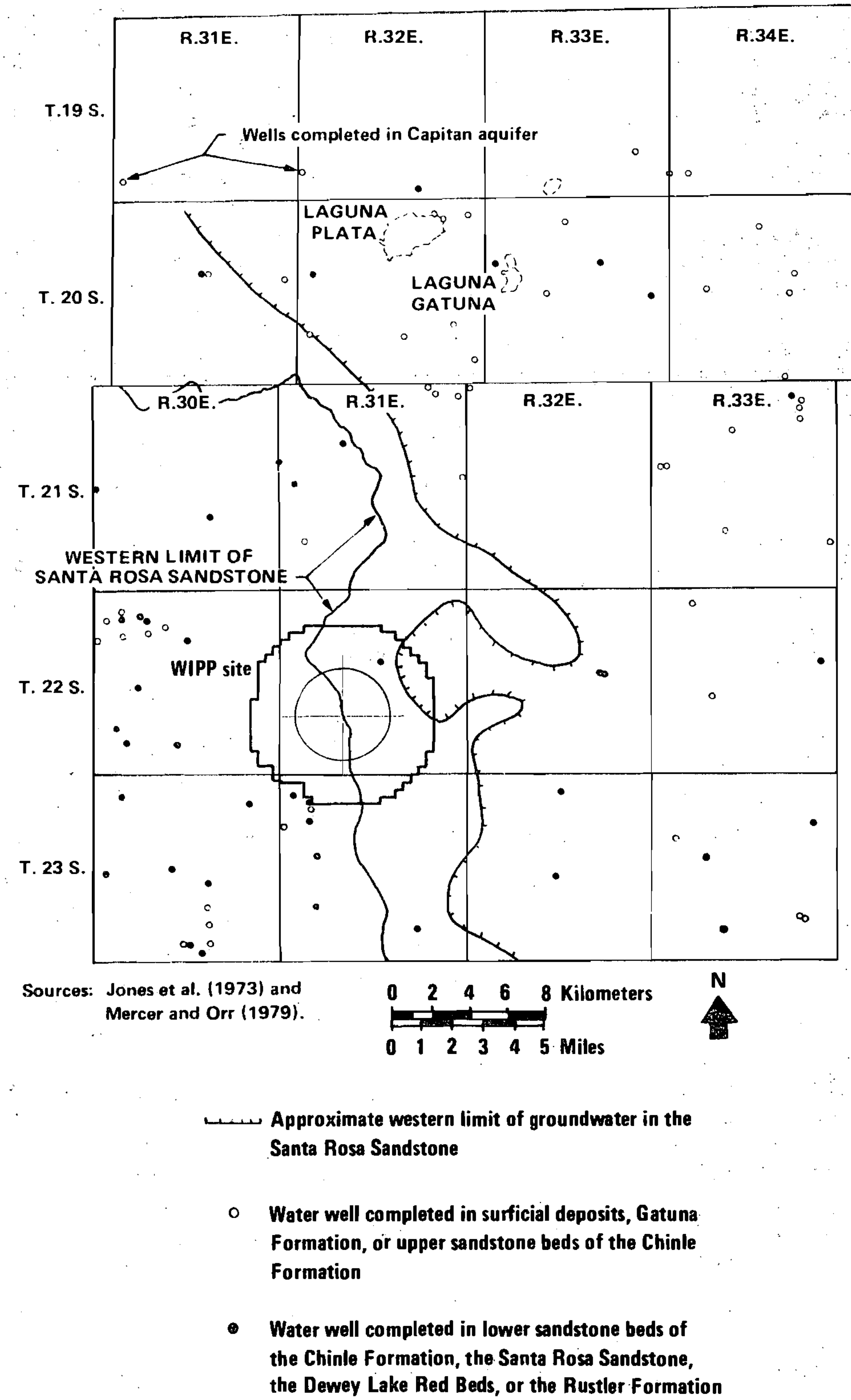


Figure 7-34. Occurrence of shallow groundwater in the region of the WIPP site.

groundwater to the base flow of the Pecos and provide a potable-water source for Carlsbad (Hendrickson and Jones, 1952). Brine solutions under a hydraulic head established presumably by fresher groundwaters of outcrop zones in the Guadalupe Mountains flow northeasterly in the Delaware Mountain Group under the Delaware basin to discharge slowly into the base of the Capitan aquifer.

Groundwater in the Capitan aquifer east of the Pecos River but west of a hydrologic barrier (Figure 7-31) near the Eddy-Lea County line either moves very slowly or is static. The hydrologic barrier is formed by a broken or eroded section in the reef; it isolates the groundwater users in the west from the larger oil-company withdrawals (for oil recovery through water injection) in the east. There is little or no coupling between wells on opposite sides of the barrier (Hiss, 1975). A water sample collected from a borehole into the Capitan reef (Hackberry) and west of the hydrologic barrier yielded the oldest water taken from the reef and was estimated to be 1,000,000 ± 300,000 years old (Barr, Lambert, and Carter, 1978).

Groundwater in the Capitan aquifer to the east of the Eddy-Lea County line has been heavily pumped for oil-field flooding. These withdrawals have lowered the potentiometric surface and significantly reduced the artesian head in the eastern portions of the reef, producing a groundwater gradient clockwise to the east and southeast. The sources of Capitan recharge are the brines in the Delaware Mountain Group and various back-reef formations.

Groundwater in the Rustler Formation east of the Pecos River generally flows to the south and southwest along formational gradients intersecting shallow and alluvium aquifers before discharging into the Pecos River. Those aquifers with a high TDS and salt content contribute much to the saline contamination of the Pecos River and adjoining shallow aquifers in and around Malaga Bend. The portions of the Magenta and the Culebra members of the Rustler that lie beneath the Dewey Lake Red Beds are more isolated from percolating rainfall and less productive than comparable portions near Nash Draw with no siltstone cover. The Santa Rosa Sandstone and the Rustler Formation provide a limited supply of groundwater for livestock and for mineral refining.

To refine the data that are the present basis for estimating the direction of groundwater flow and groundwater migration in the aquifers of principal concern to the WIPP, four additional hydrologic complexes have been drilled around the southern area between the WIPP site and the Pecos River (Figure 7-35). The data obtained at these locations will be used to determine the location of dissolution fronts, the potentiometric surface near Nash Draw and the Pecos River, the effect of the surface ridge between the WIPP site and San Simon Swale as a groundwater divide, and the hydraulic parameters necessary for the establishment of groundwater migration.

Groundwater quality

Analyses of groundwater from the Delaware basin are shown in Table 7-19. Stable-isotope measurements indicate that the groundwater in the Santa Rosa, the Rustler, and the Capitan Formations comes from rainwater. None of the saline groundwaters were found to be original evaporite mother liquors or products of partial evaporation (Lambert, 1978).

There is a shallow-dissolution area in the residuum of the Salado-Rustler contact underlying Nash Draw. Extending from northwest of Nash Draw south-

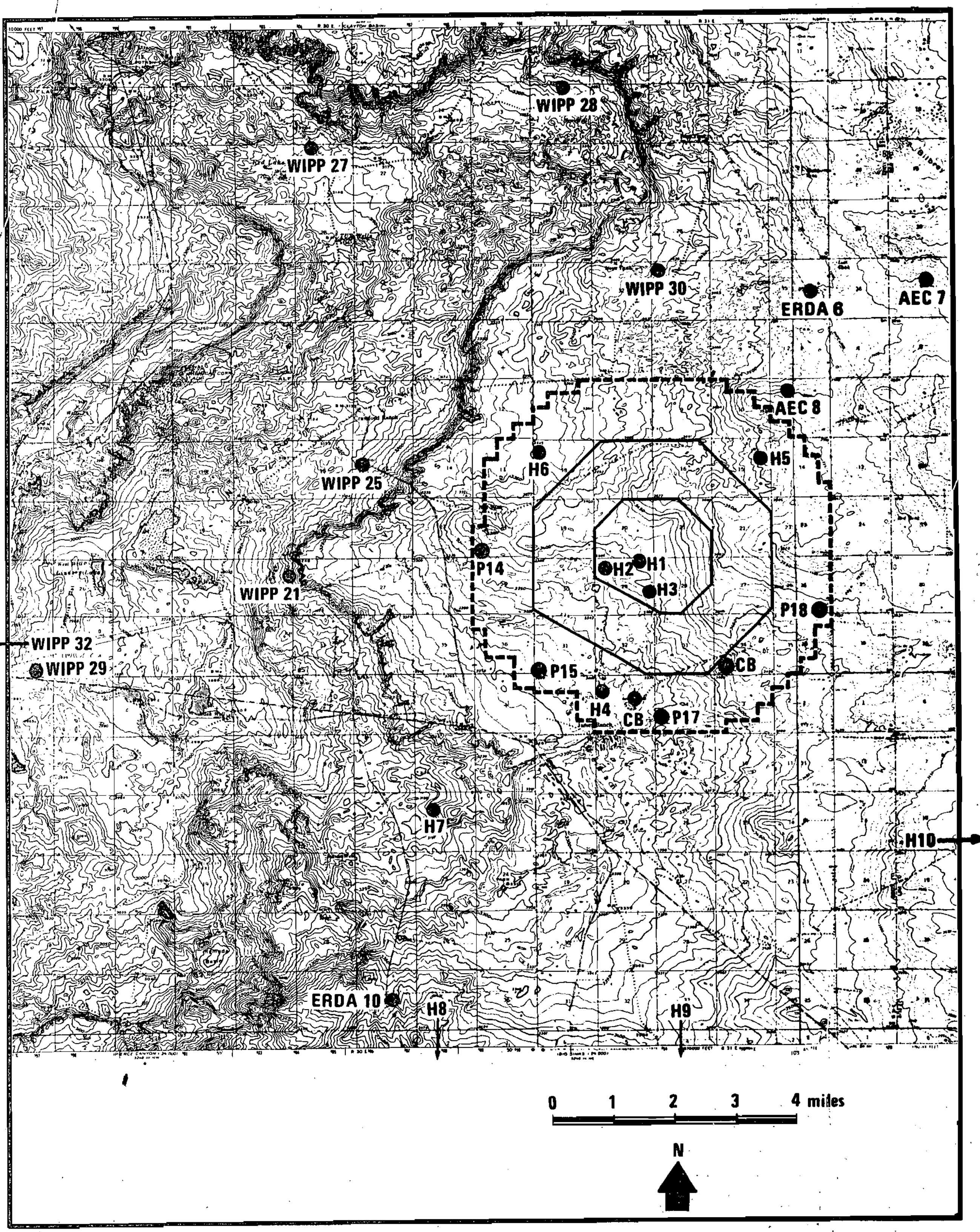


Figure 7-35. Location of drill holes used for hydrologic testing.

Table 7-19. Chemical Analysis of Groundwater in the Delaware Basin[a]

Sample name	Formation sampled	pH	Dissolved-solids concentration (mg/l) Total	Chloride	Sulfate	Sodium	Calcium
Carlsbad Well 7	Capitan	7.2	474	10	72	8	74
Hackberry	Capitan	6.0	192,000	110,800	5,150	68,700	2200
Middleton	Capitan	7.4	33,800	17,050	3,720	10,600	1100
Shell No. 28	Capitan	7.1	11,300	3,900	2,400	2,280	940
James Ranch	Rustler	7.6	3,240	400	1,570	68	590
Duval mine/ collector ring	Rustler	7.4	14,380	6,400	2,500	3,600	1100
H-3, Magenta	Rustler	7.4	14,800	5,800	2,600	4,200	760
H-3, Culebra	Rustler	7.4	60,000	33,000	5,200	19,000	1500
Duval mine/ seep-BT58	Salado	5.5	395,000	250,000	3,100	46,300	520
ERDA-6	Castile	7.3	321,000	186,100	16,000	112,000	130

[a]Data from Lambert (1978).

westward beyond the Pecos River, it is about 30 miles long and 2 to 10 miles wide (Figure 7-36). Water presumably escapes from the strata above the Salado through fractures and solution zones and moves southward along the upper salt surface to discharge as brine into the Pecos River at Malaga Bend. Recharge is augmented by potash-refinery effluents discharged into Nash Draw.

Hydraulic testing in boreholes between Malaga Bend and Laguna Grande de la Sal shows that the brine aquifer at the Salado-Rustler contact has a transmissivity of 8000 square feet per day. Assuming (from drill-hole information) an average thickness of 50 feet, a hydraulic gradient of 1.4 feet per mile, and an effective porosity of 20%, the rate of brine movement is estimated to be about 0.2 foot per day. Estimates of brine discharge into the Pecos River are 200 gallons per minute (Theis and Sayre, 1942) and 300 gallons per minute (Hale et al., 1954).

7.4.3 Local Groundwater Hydrology

As of June 1980, hydrologic tests had been made at 16 locations near the WIPP site. Of these, ten locations were specifically drilled for hydrologic testing: H-1 through H-10 (Figure 7-35). The hydrologic complexes consist of three holes drilled in a triangular array. Each hole is drilled and completed to a specific depth to penetrate a specific aquifer: the upper Magenta Dolomite, the lower Culebra Dolomite, or the Rustler-Salado interface. The depths to these water-bearing zones within the WIPP site are about 525, 630, and 750 feet, respectively. Hydraulic tests to date at these 16 locations indicate that the hydraulic conductivity ranges from 0.0001 to 0.008 foot per day, with 0.7 foot per day only at hole H-3 in the Culebra (Mercer and Orr, 1979). Observations of potentiometric head are being made at least monthly at all locations. In some instances heads have not yet reached equilibrium; they are continuing to change. Tracer tests are being conducted at the H-2 complex

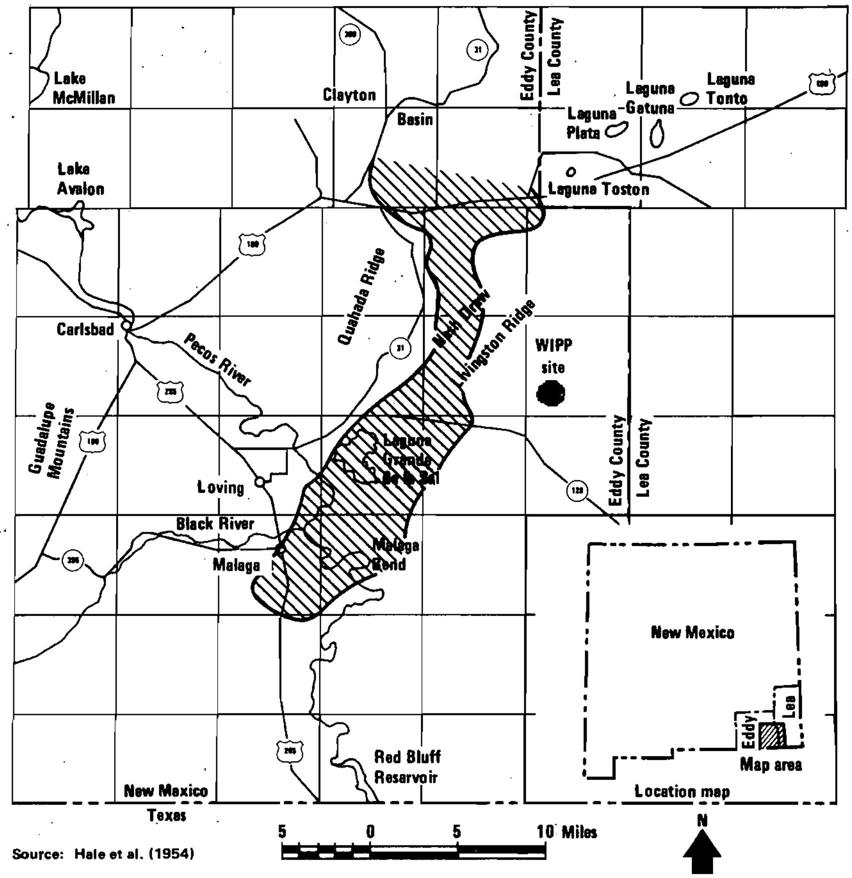


Figure 7-36. Location of the shallow-dissolution zone (shaded area).

with the primary objective of determining effective porosity and dispersivity. Similar tests are slated for three, and possibly five, other locations within and near the WIPP site.

In general, the hydrologic testing program has been directed at determining the potential head and hydraulic character of the water-bearing rock strata and the chemistry of formation water beneath the site. Data analysis has been aimed at evaluating geologic stability and groundwater-transport characteristics. A site geologic column is shown in Figure 7-11.

Hydraulic testing in drill holes at the site (Figure 7-35) shows little groundwater above the Salado. To date, testing by the U.S. Geological Survey has concentrated on the fluid-bearing zones of the Rustler Formation and the Rustler-Salado contact (Mercer and Orr, 1978). These zones, if the repository should be breached, are the most probable route for radionuclide transport through the geosphere to people, and data on their hydraulic characteristics are needed for estimating potential health hazards. Groundwater in the Rustler Formation and in the Rustler-Salado contact is considered a valuable resource when it can be used for livestock (Rustler) or potash refining (Rustler-

Salado contact); however, these waters usually contain TDS concentrations of more than 3000 ppm.

The Bell Canyon Formation of the Delaware Mountain Group yields unsaturated brines that have a sufficient "freshwater" head to reach the Rustler Formation but are blocked by the Castile Formation. The hydraulic conductivities of the Castile and the Salado have been measured at the ERDA-9 exploratory hole. Test results (Table 7-20) show the hydraulic conductivities measured in ERDA-9. The formations effectively separate the aquifers above the evaporites from those below, thus forming a hydrologic barrier between these aquifers.

Table 7-20. Calculated Hydraulic Conductivity from Drill-Stem Tests in ERDA-9[a]

Formation	Test depth (ft)	Hydraulic conductivity (ft/day)
Salado	1440-1496	
Salado	2026-2106	15.8×10^{-6}
Salado	2524-2630	5.25×10^{-6}
Salado/Castile	2635-2886	15.8×10^{-6}

[a]Derived from Lambert and Mercer (1977).

Conclusions on the occurrence of fluids in the rock units under the site can be summarized as follows (Mercer and Orr, 1978, 1979):

1. Water levels of fluid-bearing zones in the Rustler Formation show that the hydraulic potential decreases with depth, indicating downward fluid movement in rocks above the salt should there be any openings. However, the potential-head differences between fluid-bearing units indicate no vertical hydraulic connection.

2. The distribution of head in the Culebra Dolomite indicates groundwater flow southeast across the site and then south-southwest, with the gradient varying from 7 to 120 feet per mile. Transmissivity varies from 140 square feet per day on the flanks of Nash Draw to 10^{-1} square foot per day near the center of the site and 10^{-4} square foot per day on the east side. This variation is attributed to the dissolution of salt in the Rustler, which decreases from the complete removal of salt in the west to little or no removal in the east.

3. Potential head in the Magenta Dolomite has been measured in three holes at the site and indicates fluid movement to the southwest. The hydraulic gradient is 50 feet per mile, and transmissivities range from 0.01 to 2.0 square feet per day.

4. Fluids in the Culebra and Magenta Dolomites apparently move primarily along fracture systems and through low-yielding fractured rocks.

5. Very low yields of brines were found along the Rustler-Salado contact, with transmissivities ranging from 10^{-1} to 10^{-5} square foot per day.

6. Preliminary evaluation of tests on Bell Canyon sands at AEC-8 shows that the potentiometric surface, corrected to freshwater density, is higher than similarly corrected levels of fluid zones in the Rustler.

7. Preliminary data from drill holes outside the WIPP site indicate a groundwater boundary at a surface ridge between the site and San Simon Swale.

8. The groundwater gradient for the Santa Rose Sandstone appears to be determined by a hydrologic divide west of San Simon Swale and by local pumping practices near the Pecos. Flow is to the south into Texas.

Further hydrologic studies are planned:

1. The location of recharge areas for WIPP-related aquifers will be attempted by age dating and by geochemical analysis of groundwaters and head configurations beyond and within the Delaware basin.

2. Continued regional-hydrology studies will include portions of southwest Texas that might be affected and/or influenced by WIPP-related hydrologic systems.

3. Groundwater-migration studies will use tracers injected into aquifer systems to determine effective porosity and dispersivity.

7.4.4 Dissolution of Salts in the Permian Evaporites

Dissolution of salt in the evaporite beds of southeastern New Mexico is recognized to have produced dissolution residues and so-called breccia pipes. Other features possibly related to salt dissolution are sinks or depressions of varying size. Blowouts and surface depressions caused by the dissolution of caliche may be confused with salt-dissolution features. Dissolution residues are of two main types: the insoluble residue or leached zone (Vine, 1963) at the top of the Salado and layers of dissolution breccia zones (Anderson, 1978) within the deeper evaporite beds.

Anderson (1978) estimated that up to 50% of the original salt of the Delaware basin has been removed by erosion or groundwater. These processes have intermittently removed salt for more than 100 million years (Bachman, 1974 and in preparation) during wetter climates (Pleistocene) and probable marine inundation (Cretaceous). The effects are pronounced in the portion of the Delaware basin west of the Pecos River, where major areas have had all their salt removed; this accounts for a large portion of the original salt removed. The following discussion therefore focuses on the processes that are believed to be active at present and their possible effects on the WIPP.

Shallow dissolution

The shallow-dissolution features either involve the upper evaporites or are very near-surface features (e.g., sinks) that do not involve evaporites. The shallow-dissolution feature most relevant to the WIPP is the dissolution within the Rustler Formation and at the top of the Salado that produces a dissolution residue or leached zone (Vine, 1963). The depth of shallow dissolution in the evaporites (base of leached zone) is very irregular but usually less than 300 feet in Nash Draw near the site. It is well developed in the western part of the Delaware basin, where the evaporites are exposed or near the surface. In Nash Draw, where the Rustler Formation is exposed, dissolution extends into the upper Salado and produces an insoluble residue. East of Nash Draw, down-dip into the Delaware basin, the evaporite formations become progressively deeper, and the present-day top of the salt is found progressively higher in the stratigraphic section (Figure 7-19). The top of the salt is at the top of the Salado Formation about 2 miles west of the center of the site and occurs progressively higher in the Rustler Formation across the site. Where halite remains on the eastern side of the site, the Rustler is thicker. The presence of halite in the Rustler is partial evidence that the upper Salado has not yet been attacked by dissolution in that area.

The "dissolution front" within any formation is the leading edge of dissolution. The dissolution front of the Salado Formation is where dissolution is beginning to affect the top of the Salado.

Jones (1973) reported the solution front at the top of the Salado Formation to be between 2 and 3 miles west of the site center. Drilling at the WIPP site indicates that the front, at its closest point, is in control zone III due west of the site center. It is very unlikely that the Salado solution front has reached control zone II, as boreholes P-3 and H-2c (Figure 7-35) show halite in the lower Rustler Formation. West of the front in Nash Draw, there is an almost fourfold reduction in the thickness of the Rustler, to as little as 150 to 170 feet in some places. This is the residue of a 500-foot section after leaching by circulating groundwater.

As dissolution progresses, voids may develop, and the residue may be weakened until it is no longer able to support the overburden. The slumping of the residue and the collapse of the overlying rock can extend to the ground surface, resulting in a topographic sink. The resulting distinctive pitted terrain, called "karst," has poorly developed surface drainage and is extensive in southeastern New Mexico, although it is not present in the area of the site.

Bachman (in preparation) considers Nash Draw to have formed as a result of dissolution and erosion that began before or during Gatuna time and is continuing today. Bachman ascribes the origin of Nash Draw to the following process: (a) initial dissolution occurs along surficial joints and fractures in gypsum to form tunnels and caves in dendritic patterns, (b) sediments are then carried into these dissolution cavities by erosion, then (c) continued dissolution within the central drainage system increases the stream gradient and results in headward cutting by erosion, and, finally (d) Nash Draw widens further as a result of the dissolution of gypsum. These processes have combined to produce a topographic feature that has a greater width-to-length ratio than the more usual erosional valleys. The processes that form Nash Draw are active mostly in the Rustler Formation.

Another large depression cited by Bachman (1974) is San Simon Swale, 22 miles east of the site. Shallow dissolution is a factor in its development, which apparently still continues. The last recorded collapse occurred about 40 years ago (Nicholson and Clebsch, 1961). Many sinks along the Pecos River Valley have collapsed in historical times (Bachman, 1974). As recently as 1973, a small collapse sink formed at Lake Arthur, about 50 miles north of Carlsbad.

To evaluate the potential hazard to the site of continued dissolution in nearby places such as Nash Draw, the rates of dissolution have been estimated. Since Mescalero time, Nash Draw appears to have subsided between the Livingston and Quahada Ridges as much as 180 feet. At one place its surface is 180 feet below the projected elevation of the Mescalero caliche. However, the interval between the top of the Salado Formation and the top of marker bed 124 in the middle of the Salado at the same location is 420 feet, or 330 feet less than at Livingston Ridge, where relatively little of the Salado salt has been removed. It is concluded that about 150 feet of the Salado salt was removed before Mescalero time and about 180 feet since. With this in mind, Bachman (1974) analyzed the dissolution in Nash Draw as having occurred since the development of the Mescalero caliche, 600,000 years ago, and found that the average vertical-dissolution rate was about 0.33 foot per 1000 years.

Clearly, this rate is neither constant nor the same throughout the region. At least two other factors must be considered, but no geologic information is available for their evaluation:

1. Dissolution and subsidence rates have probably not been constant in Nash Draw during the past 600,000 years. Much of the subsidence may have occurred during periods of higher rainfall in the late Pleistocene (Wisconsin time). Bachman (in preparation) limits the annual rainfall to 25 to 30 inches during this time, the conditions necessary for the formation of the Mescalero caliche.

2. The subsidence in Nash Draw, whenever it occurred in the Pleistocene, is not an average rate applicable to the whole region. From the western part of the WIPP site to the area of "the Divide," the Mescalero caliche is relatively undisturbed, suggesting no dissolution there since Mescalero time.

An alternative approach to the estimation of dissolution rates was used by F. A. Swenson (Bachman and Johnson, 1973), who estimated that the maximum amount of salt being dissolved and discharged by springs and streams along the east flank of the basin is 955 tons per square mile each year. This gives a present vertical-dissolution rate of about 0.5 foot of salt in 1000 years.

The estimated rate of horizontal shallow dissolution in the western part of the Delaware basin is about 6 to 8 miles per million years (Bachman and Johnson, 1973), based on the assumption that at the end of Ogallala time the Salado Formation extended to the Capitan reef escarpment on the western edge of the basin. Bachman (in preparation), recognizing that salt dissolution also occurred earlier than Ogallala time, concludes that this estimated average rate of salt removal by shallow dissolution is a conservative overestimate.

Bachman (in preparation) has determined that semiarid climates must have prevailed in southeastern New Mexico for the last 500,000 years. This conclusion is based on the climatic conditions under which the Mescalero caliche, which began to be deposited about 600,000 years ago, could be formed and preserved as it is over the WIPP site. This indicates a relatively stable environment over that period. Thus, although there were significant climate-caused geologic changes elsewhere in the United States during that time, there were no significant geologic effects at the WIPP site. The normal pluvial cycle has a 10,000- to 20,000-year period; thus several of these would be included in any determination of past dissolution rates and would therefore be factored into future expectations as well.

These estimates of horizontal- and vertical-dissolution rates suggest that the waste in the repository could be expected to remain isolated from dissolution for 2 to 3 million years.

Deep dissolution

Deep-dissolution phenomena are those that occur within the evaporite section or that may be initiated from below the evaporites. The major features of concern for the WIPP are layers of dissolution breccia and so-called breccia pipes. Deep-dissolution phenomena in the evaporites may also have developed larger collapse features within the basin (Maley and Huffington, 1953; Anderson, 1978).

The most prominent small-scale (less than 1 mile across) dissolution features near the Delaware basin have been described by Vine (1960) as "domal karst features." One such dome (dome C, 14 miles northwest of the WIPP site; see Figure 7-31) has a collapsed center at the surface. Its subsurface projection, intercepted at the level of the McNutt Potash Zone in the Mississippi Chemical Corporation mine, is a cylindrical chimney filled with clay and halite-cemented brecciated rock belonging to higher strata. A similar dome (dome A), northwest of dome C, was drilled in borehole WIPP-31 to a depth of about 810 feet. This exploratory borehole encountered rubble or breccia similar to that in the mine below dome C. Anderson (1978) showed several other domal karst features similar in surface characteristics to breccia pipes. The closest of these is in Section 33, T 22 S, R 29 E, 11 miles west of the center of the site. It was tested in borehole WIPP-32, which reveals a normal upper Salado sequence for that location, with no sign of breccia or rubble within the borehole. A chimney containing cemented-rubble was encountered in exploratory drilling near the Weaver Mine 20 miles northwest, but it was not associated with a breached dome at the surface. The subsurface expression of other domes in the vicinity of Nash Draw and Malaga Bend (Reddy, 1961; Anderson, 1978) is poorly known. A recent study (Bachman, in preparation) of many of these domes distinguishes those formed by deep dissolution (cemented-rubble chimneys, or "breccia pipes") from those caused by nondissolution processes. It appears that domes known to have breccia or rubble at depth, inferred to have a dissolution origin, are restricted to the Capitan reef or back-reef area, at least in the vicinity of the WIPP site.

Geophysical surveys reveal a distinct resistivity low over the features (domes A and C and "Weaver pipe") known to be underlain by breccia or rubble. The electrical-resistivity technique has been used as a screening device over the WIPP site. Two localized resistivity lows, with signatures somewhat similar to those of the domes, occurred within the WIPP site (Section 20-21, Section 17). Both locations have subsequently been drilled into the upper Salado or deeper and have normal stratigraphy. Thus, present screening techniques, drilling, and mapping at the WIPP site are consistent with the conclusion that domes or "breccia pipes" are restricted to the Capitan reef or back-reef areas and are not present within the WIPP site. Observation of similar features elsewhere in this and other salt basins has indicated that these breccia pipes occur only where deep-dissolution effects are known to be present (Bachman, in preparation).

Exploration by drill holes and seismic reflections indicate variations in the thickness of Castile salt in the area, particularly in the "disturbed zone" in the northern part of the WIPP site. WIPP-13 has recently been deepened to the basal anhydrite of the Castile; preliminary examination of the core and logs reveals no layers of dissolution residues or breccias, as would be expected from regional dissolution. Detailed examination of core and comparison with other deep cores in the area of the WIPP site will continue in order to better understand the nature of the variations in the thickness of the Castile.

Bachman (in preparation) has determined that domes A and C, known breccia pipes, were formed more than 500,000 years ago during Gatuna time and before Mescalero time. Bachman reports only minor near-surface readjustment of these features during and after the formation of the Mescalero caliche and concludes that no known breccia pipe has formed since Gatuna time. Bachman also reports that domes near Malaga Bend were formed before Mescalero time.

The known breccia pipes (domes A and C) in New Mexico overlie the buried Capitan reef aquifer; some may be present north of the reef (e.g., "Weaver pipe"). Bachman (in preparation) attributes these pipes to the dissolution of salt by unsaturated water from the aquifer in a process like that described by Anderson (1978). The flow of water in the Capitan aquifer was to the east at Gatuna time; retardation of the flow by fine-grained sediments in the Laguna submarine canyon complex (see Hiss, 1975) near domes A and C produced hydraulic heads high enough to cause the upward percolation of water and dissolution (Figure 7-31). The Pecos River has dissected the Capitan aquifer system since Gatuna time, and the aquifer system is now nearly horizontal. Bachman concludes that, as long as the present hydrologic system is maintained, it is improbable that other breccia pipes will form over the reef aquifers.

Most authorities believe that there are no active deep dissolution processes that would affect the WIPP repository. Anderson (1978), who has studied deep dissolution in the Delaware basin, believes that deep dissolution is a continuing process. In reporting the results of his studies, he states that estimates of deep-dissolution rates were difficult to make from the evidence available to him, but suggested that deep dissolution would not affect the WIPP site for the next million years. Bachman (in preparation) has indicated that Cretaceous rocks lap across Castile to Triassic rocks regionally. The implication is that these rocks were exposed during Triassic and Jurassic time; from this Bachman assumes that much of the "deep dissolution" occurred during these times when the evaporites were not deeply buried. Estimated rates may therefore be conservatively high, because of the assumption of dissolution due only to more geologically recent processes. It is also believed by some observers that missing evaporite members may be ascribed to depositional facies changes, and not to dissolution. The ERDA-10 hole, drilled south of the WIPP site to check an area of potential deep dissolution, found no evidence of blanket dissolution, leading to the conclusion that the missing Castile halite member was never deposited.

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8 The WIPP and Its Operation

This chapter describes the plans for the WIPP facility, in which alternative 2, the authorized alternative, would be carried out. It begins by describing the particular site in Los Medanos* where, according to these plans, the WIPP will be built (Section 8.1). After a general description of the plant in Section 8.2, the discussion treats in more detail the design of the buildings and equipment and the plans for operations; Section 8.3 gives this information for the aboveground parts of the WIPP, and Section 8.4 gives it for the underground parts. Because small amounts of radioactive waste will be produced during the operations, the design includes systems for handling this waste; they are described in Section 8.5. Small amounts of radioactive material will be released during the operations; Section 8.6 describes the releases. Section 8.7 discusses the nonradioactive waste produced at the plant and the methods planned for its disposal. Section 8.8 discusses water and power systems, roads, railroads, and communications. The research and development that is part of the authorized WIPP mission is described in Section 8.9, which outlines the plans for the experiments to be performed. Because the methods used for disposal make it possible for the waste to be removed from its burial in the future, Section 8.10 reviews the plans for waste retrieval. Section 8.11 reviews the plans for decommissioning the WIPP at the end of the project. Section 8.12 describes the plans for dealing with emergencies at the plant and for guarding it.

8.1 DESCRIPTION AND USE OF THE SITE

8.1.1 Location and Description

The Los Medanos site is in Eddy County in southeastern New Mexico, about 25 miles east of Carlsbad (Figure 8-1). The land area committed to the project will be approximately 6 miles in diameter. It will contain 18,960 acres (29.6 square miles) in four townships: T 22 S, R 31 E; T 23 S, R 31 E; T 22 S, R 30 E; and T 23 S, R 30 E. The actual area under the control of the U.S. Department of Energy (DOE) will not be a true circle because the boundaries conform to existing land parcels (Figure 8-2).

Sections 7.1 and 7.2 describe the prominent natural and man-made features in the region around the site. The site itself is a hummocky, nearly flat plain that supports the desert vegetation described in Section 7.1 and Appendix H. There are no industrial, commercial, institutional, recreational, or residential structures within the boundaries of the site; no highways, railways, or waterways cross it. Three natural-gas pipelines traverse the site; an El Paso Natural Gas Company pipeline oriented northeast-southwest is about 1 mile north of the center of the site at its closest point.

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*In this chapter, the terms "Los Medanos site" and "WIPP site" are synonymous.

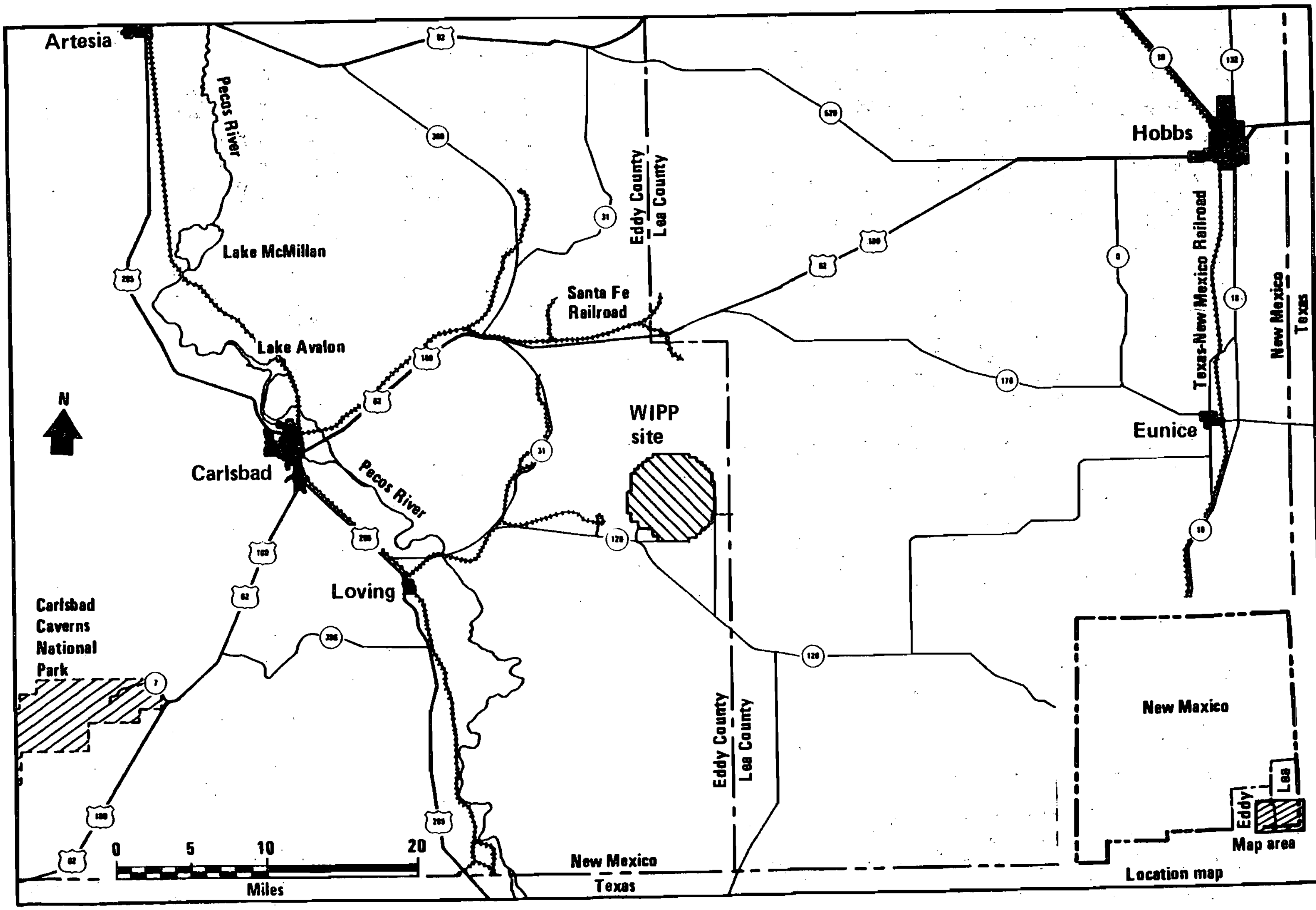

Figure 8-1. General location of the WIPP site.

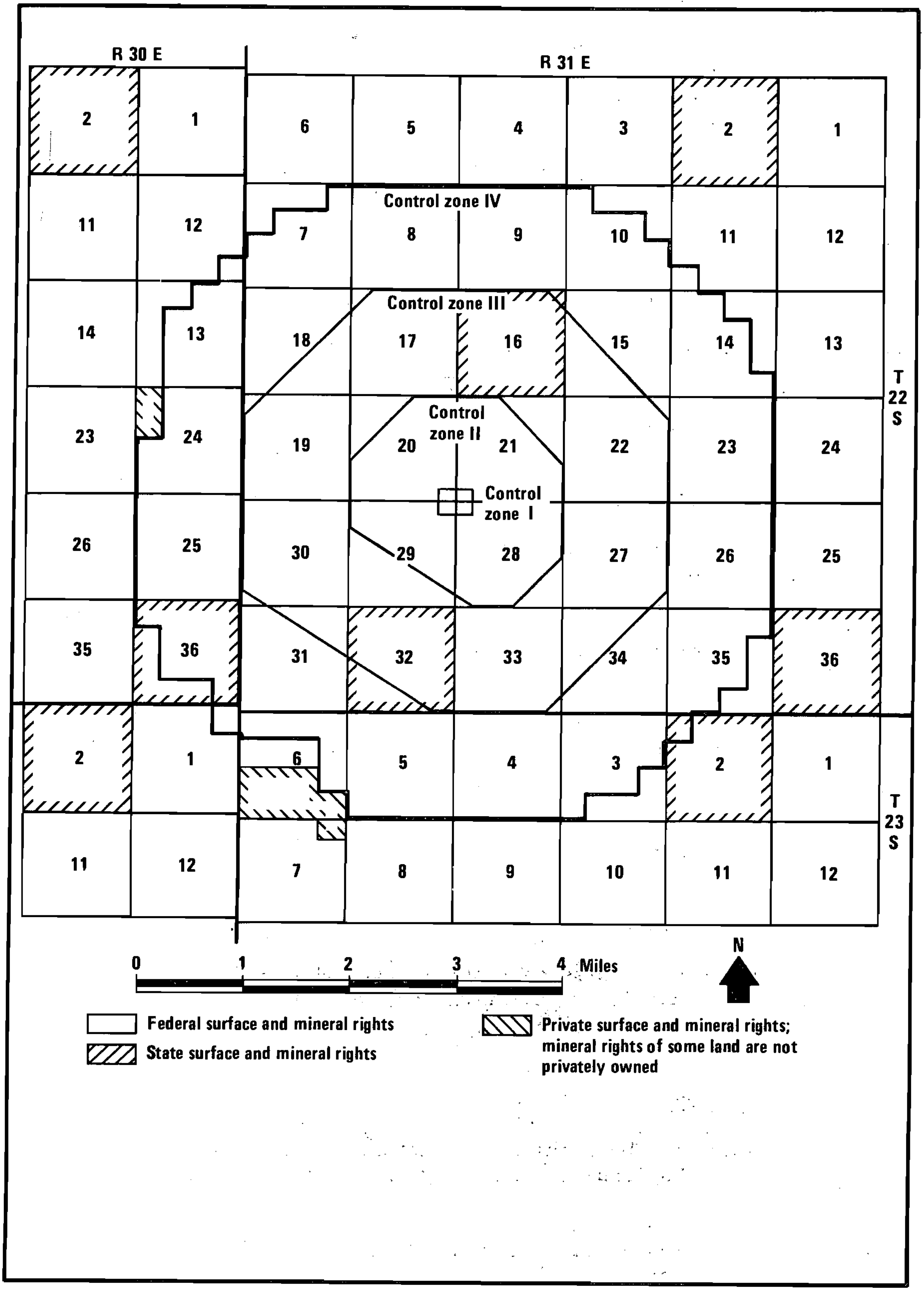

Figure 8-2. Control zones and ownership of mineral rights at the WIPP site.

8.1.2 Control Zones

The four control zones at the site, shown in Figure 8-2, will be under the full control of the DOE. The DOE's intent is to exercise successively fewer restraints on surface and underground use at increasing distances from the center of the site.

Control zone I, covering about 100 acres in Sections 20, 21, 28, and 29 of T 22 S, R 31 E, will contain most of the surface facilities. It will be surrounded by a security fence, with provisions for additional security measures.

Control zone II, an area of about 1800 acres, will overlie the maximum potential extent of underground development. For the authorized mission, all radioactive waste will be emplaced within an underground area of about 100 acres beneath control zone II. This zone will not be fenced except for the areas set aside as long-term biological study plots. Livestock grazing will be permitted in this zone under controls like those of the Bureau of Land Management (BLM) and State agencies on the surrounding land. Only drilling and mining carried out by the DOE will be permitted within this control zone.

Control zone III, surrounding control zone II, will have an outside diameter of 4 miles and an area of about 6200 acres. It will not be fenced, and grazing will be permitted. With permission from the DOE, shallow wells may be drilled for stock water, but no other drilling or mining will be permitted unless evaluations now in progress show that such activities will not increase the risk of breaching the repository or providing a route for the potential movement of radioactive materials into the biosphere.

Control zone IV, surrounding control zone III, will have an outside diameter of 6 miles and an area of about 11,000 acres. Grazing and shallow wells for water will be permitted. Continuous or drill-and-blast mining for potash may be permitted under DOE restrictions, but no solution mining will be permitted. Existing producing oil or gas holes in this zone will be permitted to continue through their useful lives; to protect the repository, they will be sealed as prescribed by the DOE when they are abandoned. New wells for oil and gas production may be drilled in conformance with DOE standards to facilitate eventual plugging; recovery methods such as flooding or hydrofracturing will not be permitted.

The DOE will not exercise any control over the land outside control zone IV and will not impose any restrictions on its use.

8.1.3 Rights-of-Way

Rights-of-way will be acquired for access to the site. The proposed rights-of-way for the completed facility are shown in Figure 8-3 and listed in Table 8-1.

Present access to the site from New Mexico Highway 128 is provided by caliche-surfaced roads built during exploration for oil and gas or for potash, some ranch roads, and extensions of these roads to site-exploration drill holes. Eventually, access to the site will be from the north and south by new paved highways. Rail access will be provided by extending a railspur that now reaches the Duval Corporation's Nash Draw mine west-southwest of the site.

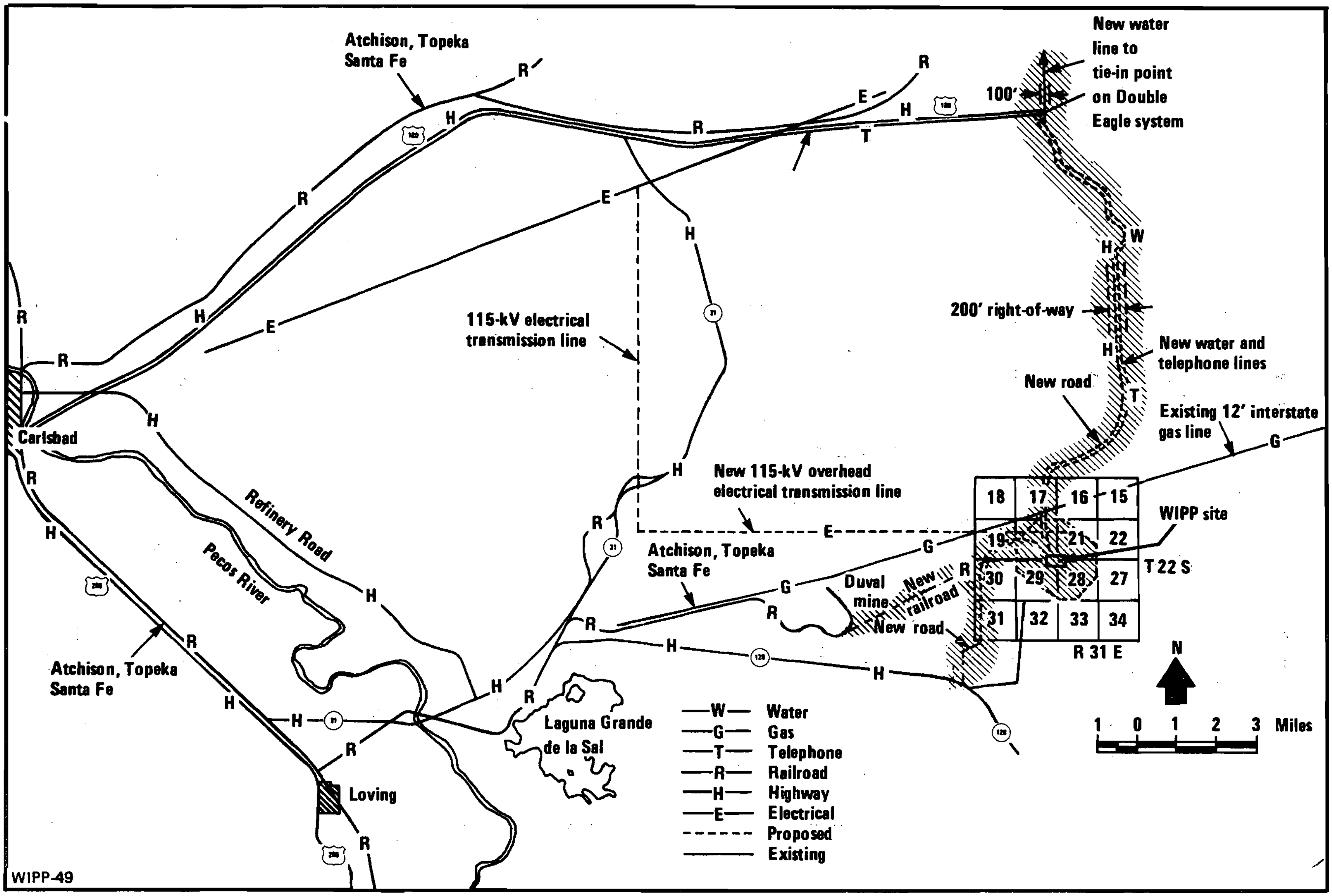

Figure 8-3. Rights-of-way for the WIPP.

Table 8-1. Rights-of-Way for the WIPP

Right-of-way	Length (miles) Total	Off-site[a]	Width (feet)	Area (acres) Total	Off-site[a]
North access road	13	10	200	315	245
South access road	4	1	200	100	25
Access railroad	6	3	100	75	35
Electricity	14	11	100	170	135
Water line (extension)	18	18	100	220	220
Telephone	(b)	(b)	(b)	(b)	(b)
Total				880	660

[a]Outside control zone IV.
[b]Telephone lines will be in the right-of-way of the north access road.

Electrical power will be brought to the site from the northwest over a separate right-of-way. A telephone line will be brought from the north on the right-of-way for the new access road. Water will be purchased from the Double Eagle Water System owned by the City of Carlsbad. It will be carried over an 18-mile right-of-way that reaches from a tie-in point on the existing system; it then will move to the site on the right-of-way of the north road.

8.1.4 Land Ownership and Leaseholds

All of the land required for the WIPP is Federal or State land (Figure 8-2): 17,200 acres (26.9 square miles) of Federal land and 1760 acres (2.75 square miles) of State land.

There is no private land within the boundaries of the proposed withdrawal area; there are, however, two parcels of private land immediately outside the site: 80 acres in the northwest corner of Section 24 (T 22 S, R 30 E) and about 300 acres in the southern half of Section 6 (T 23 S, R 31 E). The headquarters of the James Ranch is on the latter parcel.

The proposed withdrawal area is currently encumbered by the long-term leases summarized in Table 8-2 and discussed in the paragraphs that follow.

Grazing rights

All of the land within the WIPP withdrawal area has been leased for grazing. Kenneth Smith of Carlsbad, New Mexico, owns the Crawford Ranch, which has lease rights to 6680 acres in the northern portion of the proposed withdrawal area. J. C. Mills of Abernathy, Texas, owner of the James Ranch, has lease rights to 12,280 acres in the southern portion of the proposed withdrawal area (Figure 8-4).

There are no water wells at the WIPP site, although there are a number nearby, especially near the headquarters of the James Ranch outside the southwest border of the site. The nearest well, the only one within the site boundary, is about 2 miles northeast of the center of the site near the border between control zones III and IV in Section 15 (T 22 S, R 31 E).

According to BLM records, a grazing density of nine cattle per section (i.e., 70 acres per head of cattle) is permitted on this leased land, and a decrease to six cattle per section has been proposed.

Potash leases

About one-quarter of the land within the WIPP withdrawal area is leased or has applications pending for potash exploration. As shown in Figure 8-5 and Table 8-2, 4800 acres are now leased by four companies, three of which are already operating mines in the Carlsbad Potash Area. These leases are not

Table 8-2. Summary of Leases at the Site in March 1979

Land status	Whole area		Excluding zone IV	
	Acres	Percent	Acres	Percent
	TOTAL AREA INVOLVED			
Federal land	17,200		7,063	
State land	1,760		1,076	
Total	18,960		8,139	
	SUBJECT TO GRAZING LEASES			
Federal land	17,200	100	7,063	100
State land	1,760	100	1,076	100
Total	18,960	100	8,139	100
	SUBJECT TO POTASH LEASES			
Federal land	3,040	17.7	1,459	20.7
State land	1,760	100	1,076	100
Total	4,800	25.3	2,535	31.1
	SUBJECT TO OIL AND GAS LEASES			
Federal land	6,400	37.2	3,186	45.1
State land	200	11.4	40	3.7
Total	6,600	34.8	3,226	39.6
	SUBJECT TO BOTH POTASH AND OIL AND GAS LEASES			
Federal land	1,280	7.4	640	9.1
State land	200	11.4	40	3.7
Total	1,480	7.8	680	8.3

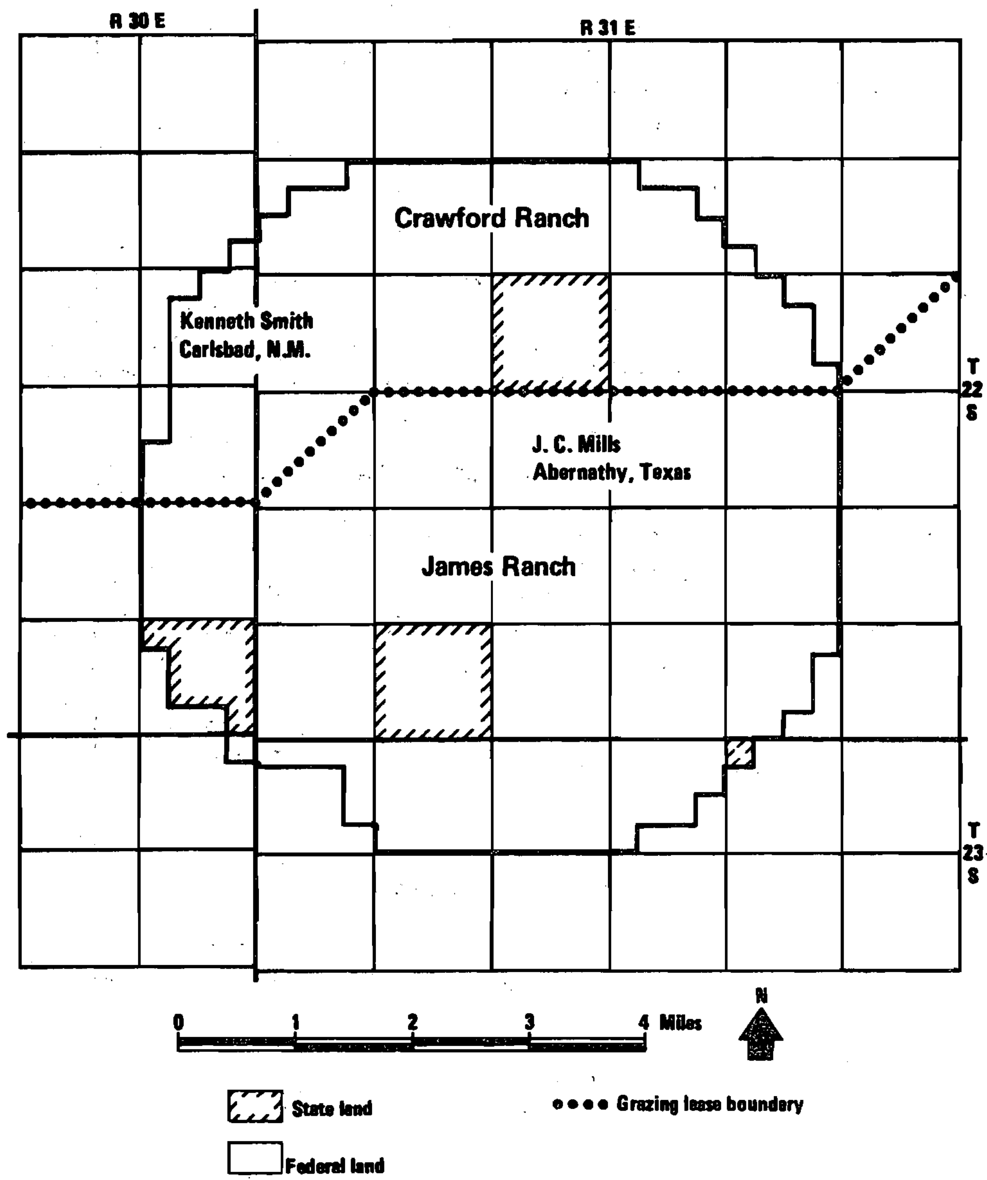

Figure 8-4. Grazing leases within the WIPP site.

being developed currently. If a lessee files an application to develop a lease within the three inner zones, the DOE will take action to obtain the rights to the lease. All the potash leases will be purchased by the DOE before the beginning of any construction except for work involving site and preliminary-design validation. No potash mining will be permitted within the three inner zones for a number of years and perhaps forever. The amount of potash mineralization in the withdrawal area is discussed in Section 7.3.7.

Oil and gas leases

In March 1979 ten companies held leases for oil and gas exploration on about 6600 acres of the withdrawal area (Figure 8-6 and Table 8-2). Since

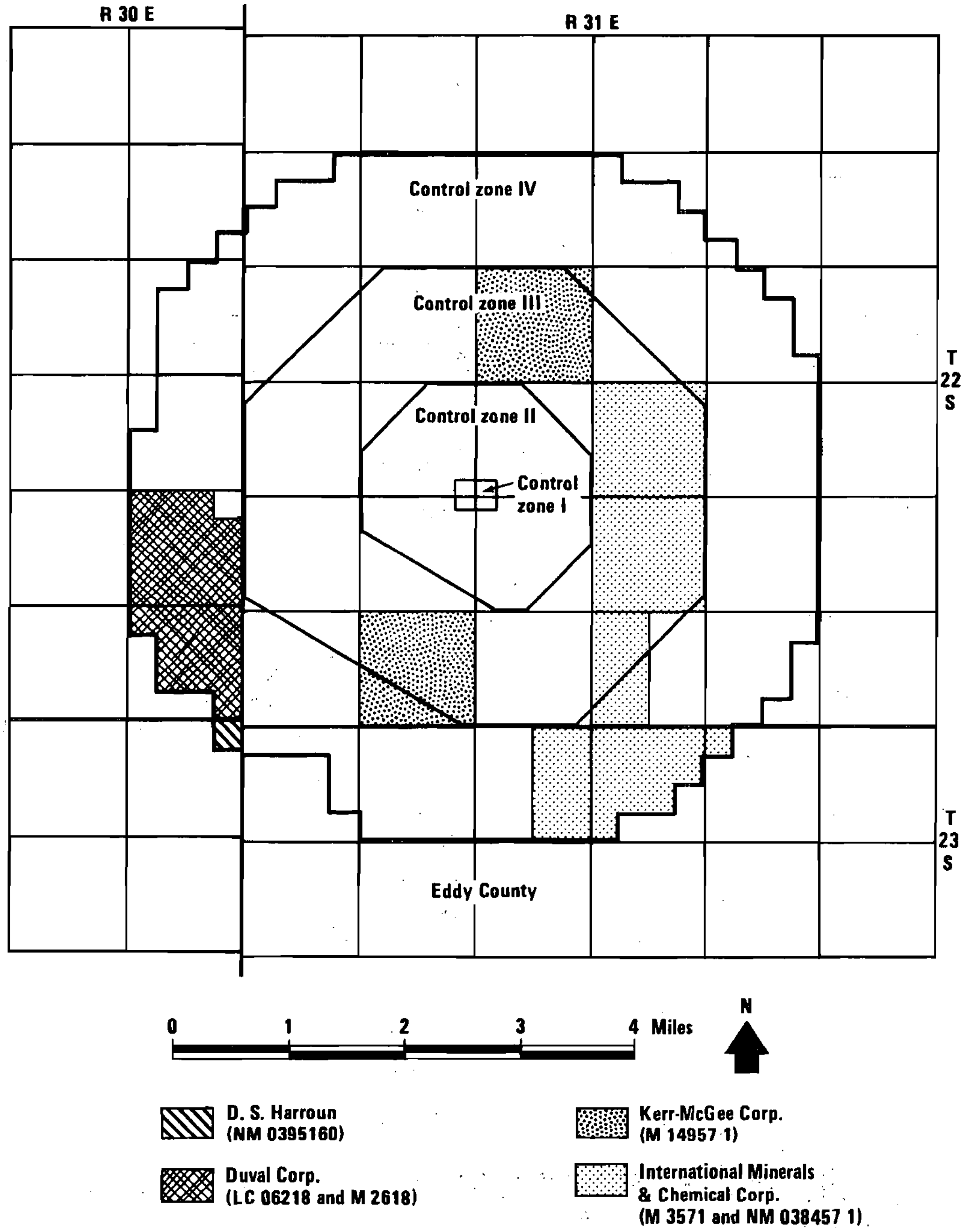

Figure 8-5. Potash leases within the WIPP site.

the beginning of exploratory studies at the site, the DOE has acquired oil and gas leases on an additional 7100 acres inside the area. These acquisitions have been necessary to keep the salt beds intact; exploratory drill holes might have penetrated the volume of salt that the WIPP will occupy. Section 7.3.7 discusses the amounts of oil and gas that may lie beneath the site.

Figure 8-6 shows the four abandoned oil and gas exploration holes within the withdrawal area; all are in control zone IV.

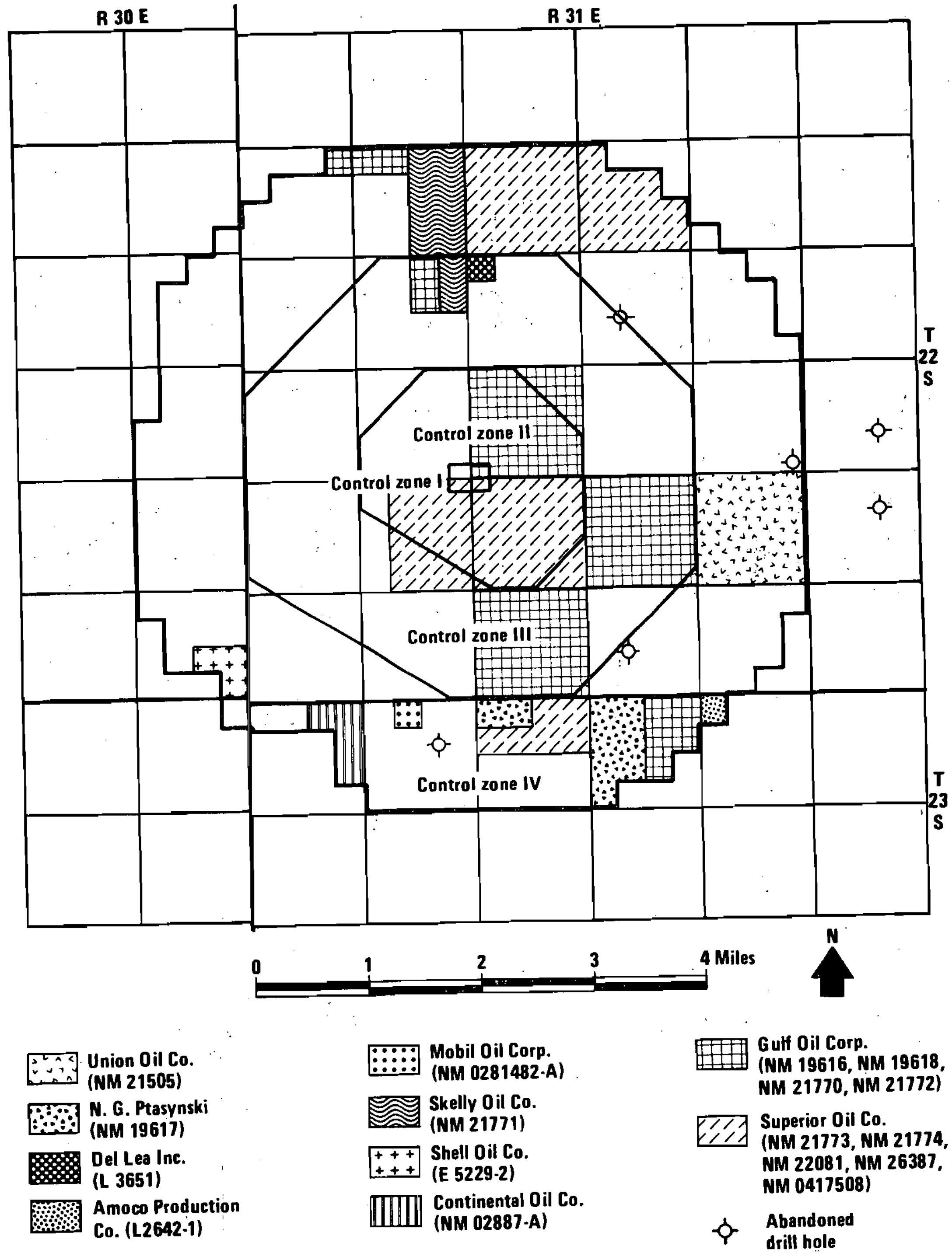

Figure 8-6. Oil and gas leases within the WIPP site.

8.2 GENERAL DESCRIPTION OF THE WIPP

The authorized WIPP facility (Figure 8-7) is designed to receive, inspect, overpack when necessary, and dispose of radioactive wastes in bedded salt. It is designed to be a repository for demonstrating the disposal of defense TRU waste and a facility for research and development with in-situ tests of techniques proposed for the disposal of defense wastes.

Figure 8-8 shows the layout of the surface structures at the plant. They include a waste-handling building for receiving and preparing radioactive waste for transfer underground, an underground-personnel building to support underground operations, a disposal-exhaust-filtration building, an administration building, and various support structures: a warehouse and workshop building, an emergency-power plant, a vehicle-maintenance building, a sewage-treatment plant, and a water-supply system. In addition, there will be a mined-rock (salt) pile, an evaporation pond for runoff from the mined-rock pile, and a sewage-treatment plant. A construction-spoils disposal area and a sanitary landfill are also included in the design.

The underground facilities consist of four shafts to the underground area, a mined underground horizon containing an area for the disposal of contact-handled (CH) and remotely handled (RH) TRU wastes and two areas for research and development with defense wastes.

The plans for the WIPP call for its development to occur in two distinct phases: (1) site and preliminary-design validation (SPDV), in which two deep shafts and an underground experimental area are constructed (Brausch et al., 1980); and (2) full construction, in which the required surface and underground facilities and the remaining shafts are built. The operation of the WIPP will begin after the surface and underground facilities have been completed, although mining of the salt will continue throughout much of the operational period.

8.2.1 SPDV Phase

Two shafts will be constructed at the WIPP site for the SPDV program; the shafts will be drilled with "blind-boring" methods using large-scale drilling equipment similar to oil-field equipment, but larger. A drilling fluid composed of brine, bentonite, and caustic soda will be used to keep the drilling head cooled, lubricate the hole, minimize inflow from the water-bearing strata encountered, and remove cuttings from the hole. Blind boring was selected rather than conventional shaft sinking (i.e., blast and rock removal) because of cost and time savings (see Sections 9.6.1 and 9.6.2).

To provide primary access to the underground experimental area a 12-foot-diameter shaft will be bored near the center of control zone I to a depth of 2300 feet. The shaft will be lined with 10-foot-diameter steel casing to a depth of about 850 feet. The remaining 1450 feet, the portion of the shaft in the Salado salt, will be unlined. A sand-and-concrete grout, injected along the outside of the liner over its entire length, will seal off inflow from water-bearing strata.

The 12-foot-diameter shaft will be equipped with a temporary hoist and headframe. This hoisting system will transport excavated salt to the surface

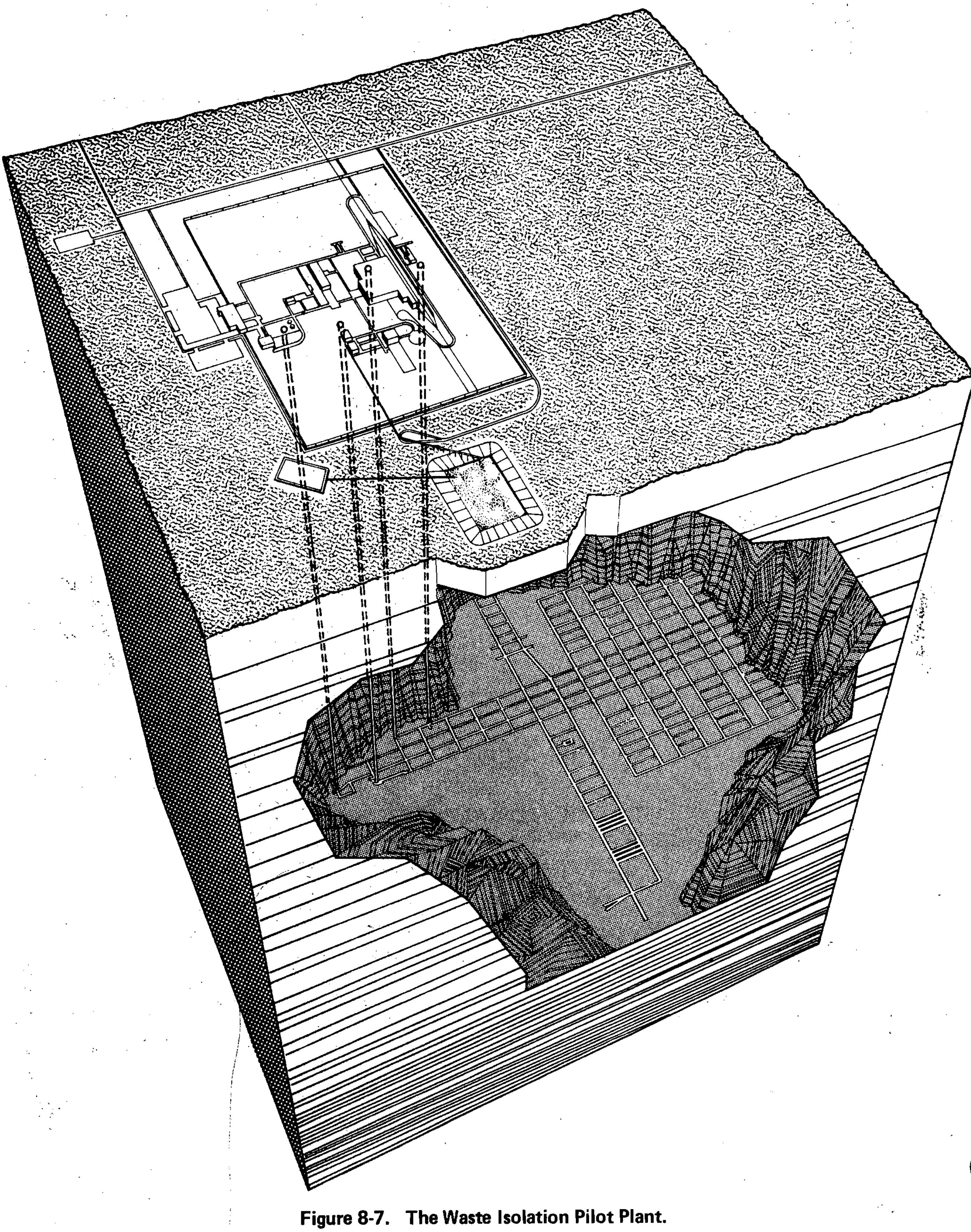

Figure 8-7. The Waste Isolation Pilot Plant.

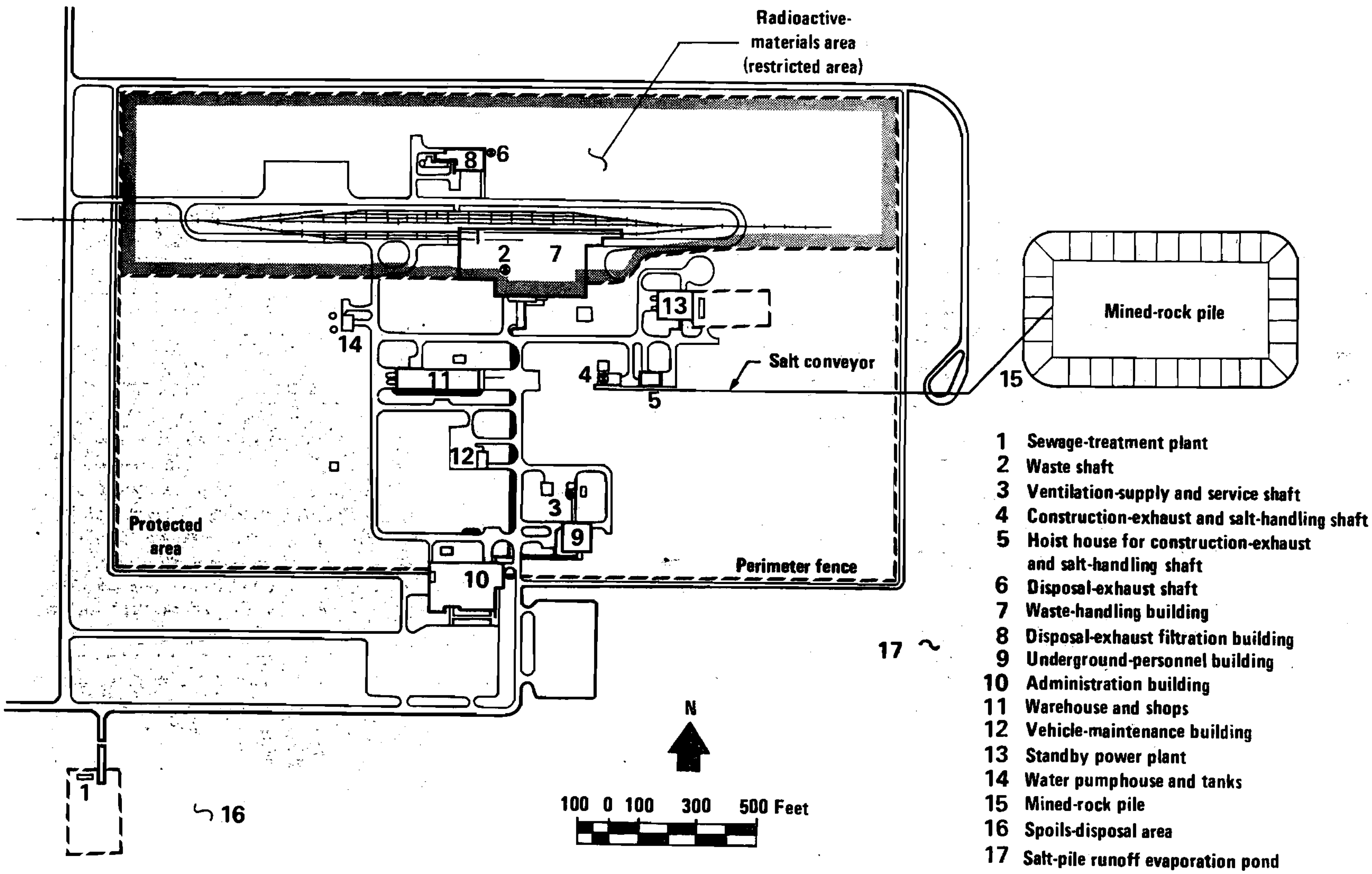

Figure 8-8. Surface structures and plant layout.

and personnel, materials, and equipment to and from the underground experimental area.

A 6-foot-diameter ventilation shaft, bored about 600 feet south of the larger shaft, will be equipped with a temporary emergency hoisting system for removing personnel from the underground facility. This shaft will be unlined throughout its depth, although some rock support in the form of wire mesh and rock bolts may be provided. The water-bearing strata penetrated by the shaft will be sealed if any significant inflows are noted.

After the area around the bottom of the shaft has been developed by drilling and blasting methods, an electrically powered continuous-mining machine will excavate the underground area for the SPDV program. Starting at the bottom of the 12-foot-diameter shaft, horizontal excavation in the Salado salt will produce a network of underground cavities about 10 acres in area. The excavation will advance northward from the shafts by the cutting of two main drifts about 1500 feet long and 12 feet high through the shaft pillar (the volume around the shafts that is disturbed as little as practicable to minimize surface subsidence and to provide adequate structural support to the shaft). Outside the shaft pillar, experimental rooms will be constructed on each side of the main drifts. About 8 acres of underground experimental rooms will be provided during the SPDV phase.

Salt will be removed from the advancing working face on underground diesel-powered transporters and an electrically powered conveyor, which will carry the salt to the 12-foot-diameter shaft. There the salt will be loaded onto a salt-handling skip (a hoisting car) for transport to the surface, where a front-end loader will put it into a large dump truck for transport to the salt-storage pile. During the underground development, 340,000 tons of salt will be removed.

The experiments to be conducted are discussed in Section 8.9.1. No radioactive wastes will be used in the experimental studies during the SPDV phase.

The SPDV program is strictly for data collection and experiments; therefore, the supporting surface facilities at the site are designed, to the extent practical, for only temporary duty at a minimum cost. To accommodate the construction, technical, and mining personnel at the site, trailers parked at the site near the shaft will provide temporary offices, laboratories, and other facilities for underground workers.

Two types of waste rock will be brought to the surface during the construction: (a) a mixture of drilling fluid and overburden rock (primarily claystone, anhydrite, and salt) developed during shaft sinking and (b) salt excavated during the construction of the underground experimental area.

During shaft sinking, a brine drilling fluid will be continuously circulated to facilitate the drilling. This fluid will carry the waste rock to the surface, where it will be pumped to one of two holding ponds at the site. In these ponds (one for each shaft) the larger pieces of waste rock will settle to the bottom, and the clarified drilling fluid will be skimmed from the surface and recirculated to the advancing shaft. It is expected that about 2.4 million gallons of drilling fluid will be continuously circulated in drilling the 12-foot-diameter shaft; about 600,000 gallons of drilling fluid will be used in drilling the 6-foot-diameter shaft. After drilling has been completed, the fluid will be pumped to the spoils-disposal area south of the site and the waste rock will be retained in the holding ponds.

Salt from the underground experimental area will be transported from the larger shaft to the salt-storage pile located immediately east of the central area. The 340,000 tons of salt removed from the underground area during the SPDV program will form a pile 540 feet wide, 540 feet long, and 40 feet high. A ditch will be constructed around the periphery of the salt pile to collect rainwater runoff from the pile. A dike along the north side of the pile will divert upland runoff away from the pile.

Solid waste (general construction trash) generated during construction will be collected in bins and hauled to the Carlsbad or Hobbs sanitary landfill for disposal.

The utilities required for the SPDV program will be supplied as follows:

1. Electrical power will be supplied at the site by a power line following the right-of-way shown in Figure 8-3.

2. Water for construction, dust control, and fire protection will be supplied by water-tank trucks located at the site. Bottled water will be used for drinking.

3. Portable toilets will be supplied by a commercial sanitation service.

Access to the site will be provided by an existing caliche-surfaced road originally constructed as part of the development of the ERDA-9 borehole. No additional access roads need to be constructed for the SPDV program. An additional right-of-way will be obtained for the electrical-power line.

8.2.2 Full-Construction Phase

The plant will be constructed in accordance with the general design criteria of ERDA Manual Appendix 6301, Part 1, with modifications approved by the DOE, and the WIPP design criteria. To protect public health and safety and the environment, the surface buildings that will contain radioactive materials, the central monitor-and-control room, the system for ventilating the underground disposal area, the waste-hoist system, and the diesel generators are designed to withstand the effects of credible earthquakes, tornadoes, and accidents. Other measures to avoid, minimize, or mitigate adverse environmental effects are discussed in Section 9.6.

The surface structures consist of eight major buildings. The underground structures consist of four shafts and a waste-disposal area about 2150 feet below the surface. Approximately 100 acres will be used for the underground disposal area.

8.2.2.1 Surface Structures

The principal surface structure is the waste-handling building (Figure 8-8). It is about 230 feet wide, 575 feet long, and 50 feet high (except for a 125-foot-high bay area). The building has separate areas for the receipt, inventory, inspection, and transfer of CH and RH TRU wastes through separate airlocks to a common waste shaft. It also contains offices, change rooms, a health-physics laboratory, and equipment for ventilation and filtration. Safety equipment and measures for controlling radiation exposures are included in the design of the waste-handling building.

The underground-personnel building contains support facilities for personnel working underground in construction and waste-handling operations (Figure 8-8). This building is about 100 feet wide, 150 feet long, and 14 feet high.

Other surface structures (Figure 8-8) include the administration building (about 36,000 square feet), the disposal-exhaust-filtration building (about 10,000 square feet), the vehicle-maintenance building (about 2300 square feet), a building containing a warehouse and shops (about 18,000 square feet), the emergency-power plant (about 10,000 square feet), the water pumphouse, and the sewage-treatment plant.

A 30-acre area east of the plant (Figure 8-8) contains the mined-rock pile, which will store the rock, principally salt, excavated from the repository. The maximum height of the pile is approximately 60 feet.

8.2.2.2 Underground Structures

The four shafts to the underground area will be developed as follows:

1. The SPDV exploratory shaft will be used for the disposal-area exhaust shaft.

2. The SPDV ventilation and salt-handling shaft will be enlarged to form the waste-handling shaft.

3. The construction-exhaust and salt-handling shaft and the ventilation-supply and service shaft will be sunk conventionally by blasting and removing the loose rock with a crane.

With the exception of the disposal-exhaust shaft (which will be lined with steel) each of these shafts will be lined with concrete down to the top of the Salado salt.

The underground structures are on one mined level about 2150 feet below the surface, laid out in a conventional "room-and-pillar" arrangement (Figure 8-9). They include three separate mined areas: approximately 100 acres for the disposal of CH and RH TRU wastes, approximately 7.5 acres dedicated to research and development with high-level wastes, and approximately 12 acres for research and development in rock mechanics and mine design. The tunnels that connect these three areas to one another and to the shafts will occupy about 30 acres. The underground areas will be developed using continuous mining machines, rather than by blasting. The mined salt will then be transported via underground hauling machines and conveyors to the salt-handling shaft for removal from the mine.

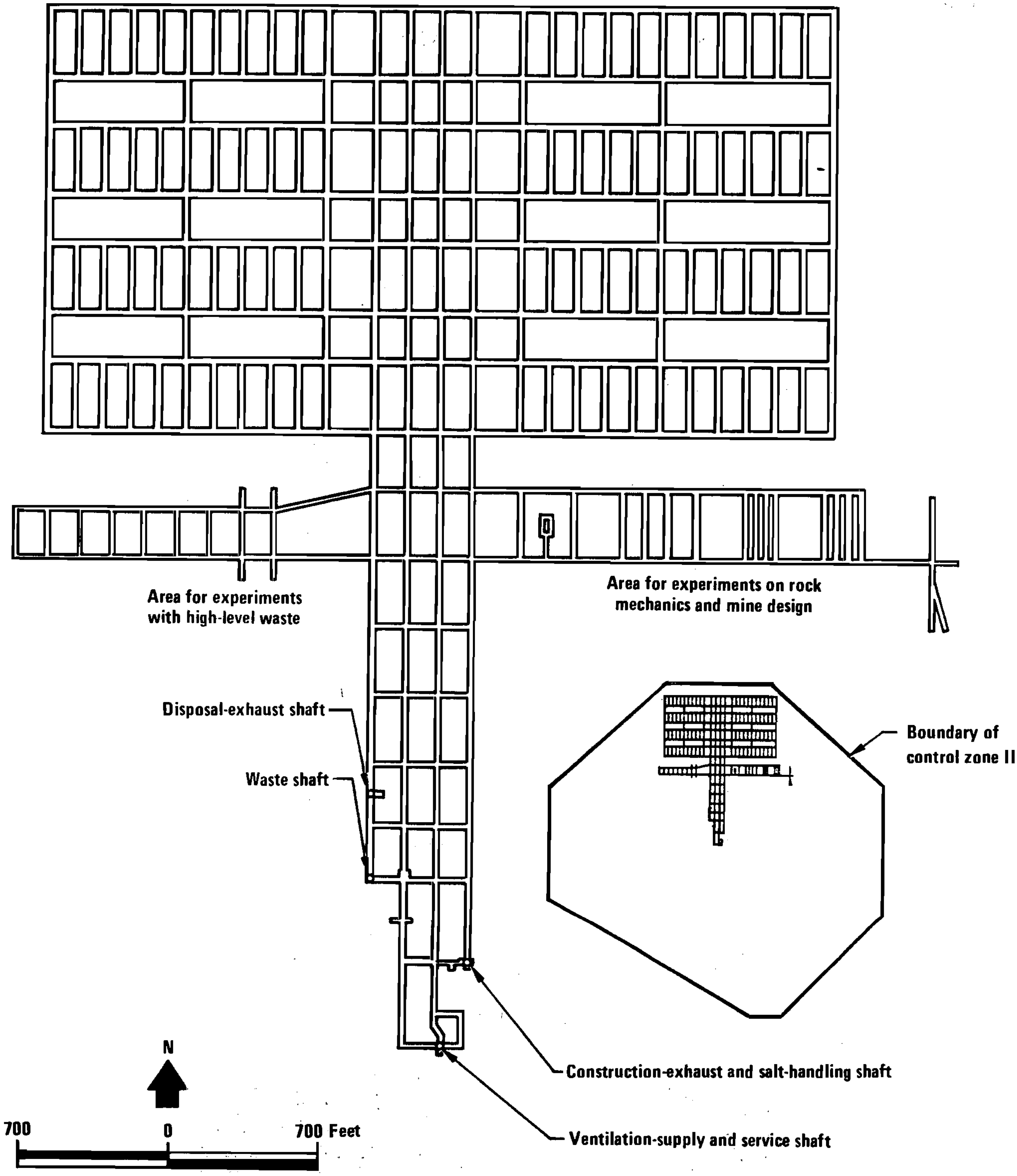

Figure 8-9. The underground layout of the WIPP.

Both CH and RH TRU wastes will be moved underground through the waste shaft in the waste-handling building. The other accessways to the underground disposal areas are the ventilation-supply and service shaft for ventilation and the movement of personnel and equipment, a construction-exhaust and salt handling shaft to remove mined salt and to exhaust air from mining operations, and a disposal-exhaust shaft to exhaust air from the waste-disposal area.

Underground workshops, warehouses, and equipment-storage areas are provided for the various pieces of mining and salt-transport equipment used in underground construction. An underground ventilation system supplies air to both the construction and the waste-disposal areas; separate exhausts are installed for each area. Safety equipment and measures for the control of radiation exposures are included in the design of the underground facilities.

8.3 SURFACE FACILITIES AND OPERATIONS

8.3.1 Waste-Handling Building and Operations

The waste-handling building (Figure 8-10) is equipped to deal with both CH-and RH TRU waste from the time the waste is unloaded until it is lowered through the waste shaft for placement underground. Separate areas are provided for handling CH and RH TRU wastes. The areas for CH waste include a shipping-and-receiving area for railroad cars and trucks, a receiving-and inspection area, an inventory-and-preparation area, and an overpack-and-repair room for damaged containers. The areas for RH waste include a separate shipping-and-receiving area, an area for shipping-cask preparation and decontamination, an area for loading and unloading casks, and a hot cell above the loading area for waste-canister storage, overpacking, or decontamination. Two independent airlocks at the shaft entrance allow wastes to enter from the CH-waste and RH-waste areas. Filtration equipment for the waste-handling area, a laboratory, change rooms, and offices are also in the waste-handling building.

Liquid radioactive waste generated at the site from decontamination operations will be collected from holding tanks for solidification. The solidified waste will be packaged and taken underground for disposal as CH waste if it meets the waste-acceptance criteria.

Handling of CH TRU waste

Contact-handled waste will be shipped to the plant by rail or truck in shipping containers approved by the U.S. Department of Transportation. The shipping containers will be unloaded in the waste-handling building, after entering through airlocks that control the movement of air during the waste-handling operations. The air in the waste-handling building will be maintained below atmospheric pressure to prevent contaminants from leaking to the outside air, even though no contaminants are expected to become airborne in significant amounts.

The CH TRU waste will be received in 55-gallon drums, special boxes, or bins that have been transported inside Type B packagings (Section 6.3.1). Once the packagings have been surveyed for contamination, they will be

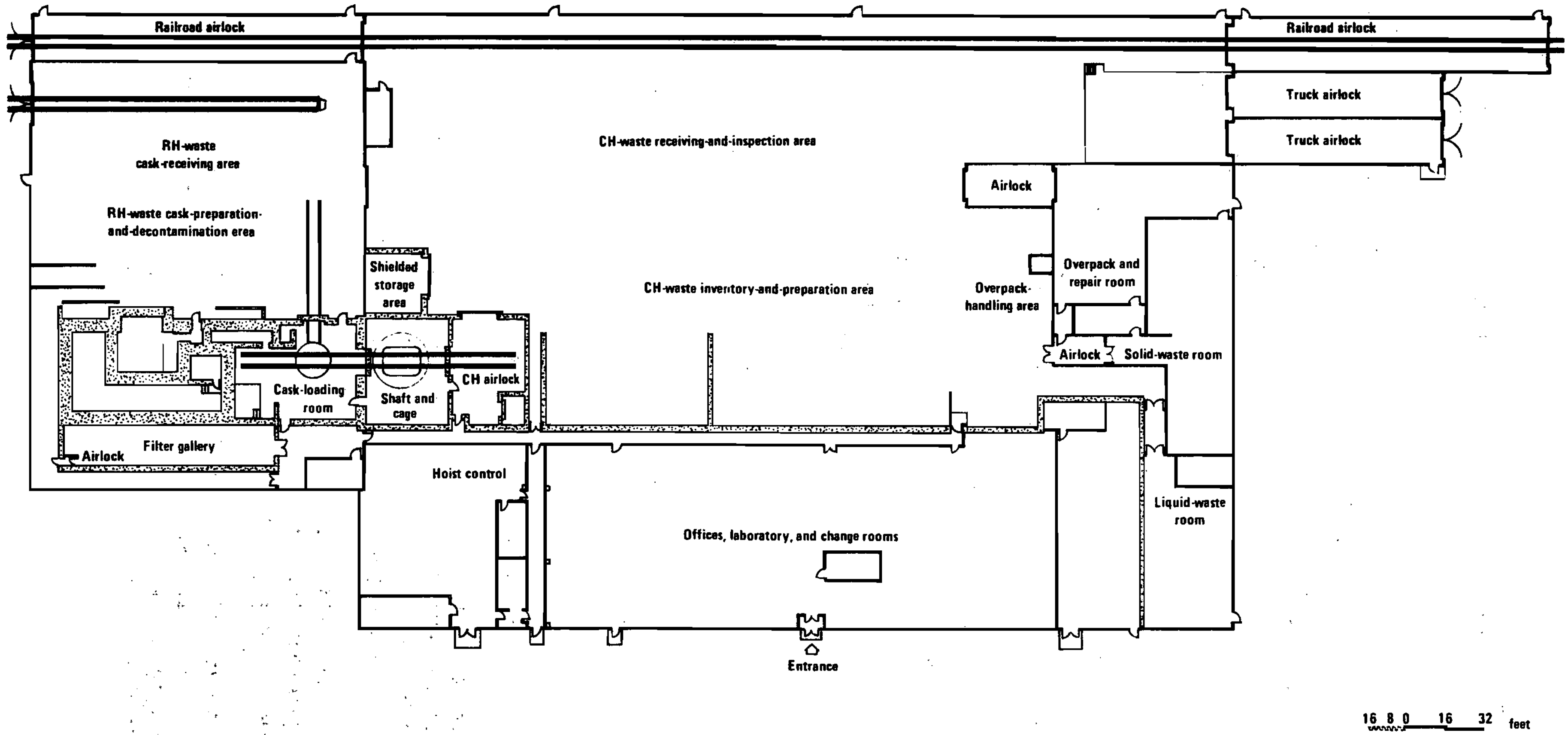

Figure 8-10. Waste-handling building.

unloaded in the receiving-and-inspection area if found to be acceptable. If found to be contaminated, a packaging will be moved into the overpack-and-repair room for the unloading of the waste containers. If inspection shows that the waste containers are not contaminated or damaged and if the accompanying documentation shows that they meet the waste-acceptance criteria (Chapter 5), they will be moved to the CH-waste inventory-and-preparation area, stacked on pallets for uniform handling, and transported underground. If a waste container is found to be externally contaminated or damaged, it will be sent to the overpack-and-repair room (Figure 8-10), where it will be decontaminated, overpacked or repaired, and returned to the CH-waste inventory-and-preparation area for transfer underground. The empty shipping containers will be decontaminated, if necessary, and reloaded onto transport vehicles leaving the plant.

Handling of RH TRU waste

Remotely handled TRU waste will arrive by rail or truck in special shielded shipping casks approved by the Department of Transportation. On arrival, each shipping cask, which may contain one or more canisters of waste, will be inspected and unloaded from the railcar or truck in the cask-unloading-and-receiving area of the waste-handling building. If the railcar or truck is found to be contaminated, it will be decontaminated. From the receiving area the cask will be moved to the cask-preparation-and-decontamination area, where operations such as the attachment of handling equipment can be performed; the RH-waste will be handled from behind shielding with remote-handling equipment. The cask will then be moved into the cask-unloading room. There the RH-waste canisters will be unloaded from the shipping casks into the hot cell, where they will be inspected, surveyed for contamination, and identified. Any contaminated or damaged canisters will be inserted into an overpack. The canisters will be removed from the hot cell into a transfer cell and loaded into the facility cask, a cask specially designed to transfer RH waste to the WIPP underground disposal area. After appropriate treatment, the shipping cask will be checked for external contamination, decontaminated if necessary, and returned to the shipper for reuse.

8.3.2 Facilities Supporting Underground Operations

The underground-personnel building provides change rooms, showers, areas for equipment-storage, and offices for personnel working underground. About 100 feet from the building is the ventilation-supply and service shaft containing the hoist by which personnel and equipment will be moved underground.

The disposal-exhaust-filtration building adjacent to the disposal-exhaust shaft contains equipment for exhausting and filtering the air from the underground-disposal areas.

Mined rock (mostly salt) will be brought to the surface through the construction-exhaust and salt-handling shaft. Once at the surface, the mined rock will be moved by conveyor to the mined-rock pile outside the security fence. It is estimated that the pile will reach a maximum height of about 60 feet and cover about 30 acres.

8.3.3 Facilities Supporting Surface Operations

The administration building provides space for contractor personnel, visitors, and services; the center of security operations, it also contains a control room for monitoring all activities at the site.

The emergency-power building contains standby diesel generators and the necessary power switchgear.

The warehouse and shops, the water pumphouses, the vehicle-maintenance building, and the sewage-treatment facility are buildings of standard design.

8.3.4 Environmental Control System

The environmental control system maintains a controlled environment for plant personnel and limits the discharge of radioactivity to the atmosphere. It includes heating, ventilating, and air-conditioning systems; air-cleaning and final discharge systems; and all related subsystems.

Access to areas with higher potential for contamination will be restricted. Pressure differences, maintained between separated areas in the plant and between these areas and the outside air, will insure air flow in the proper direction. To confine radioactive material, the air-cleaning system will pass the air through banks of high-efficiency particulate air (HEPA) filters. Monitors will warn of the presence of radioactivity in the air stream by triggering alarm systems.

8.4 UNDERGROUND FACILITIES AND OPERATIONS

8.4.1 Waste Facilities

The underground waste facilities described in this section consist of the waste-shaft, the waste-shaft hoist-cage system, and all facilities in the waste-disposal area.

Waste shaft

The waste shaft will be constructed by enlarging the SPDV ventilation shaft. This waste shaft, which will be about 19 feet in diameter and 2300 feet deep, will be used to transfer CH and RH TRU waste from the waste-handling building to the underground disposal areas. The waste-shaft hoist cage accommodates the RH-waste facility casks and the CH-waste containers to be handled at the plant. The hoist cage will be designed to handle a payload of 35 tons.

Disposal of CH TRU waste

The top of the waste shaft is in the waste-handling building (Figure 8-10). After a pallet has been loaded with containers of CH TRU waste, it will be transferred to the hoist cage, which will be lowered through the waste

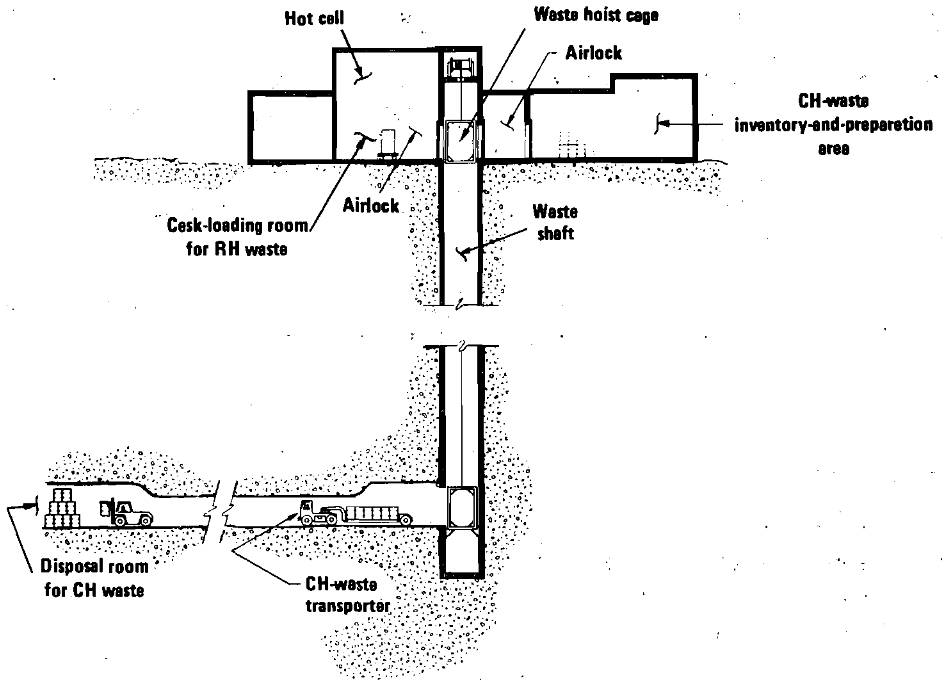

Figure 8-11. The waste shaft, connecting rooms in the waste-handling building, and the underground disposal horizon. The two pieces of equipment shown underground carry and stack contact-handled waste. A specially designed forklift, not shown, carries remotely handled waste through the underground facility.

shaft to the underground waste-receiving station (Figure 8-11). The hoist cage will be a steel cage guided by wire ropes in its descent and ascent. The strength of these ropes is about five times the maximum load to be carried in the cage.

In the waste-receiving station, an opening about 13 feet high by 33 feet wide allows access to the shaft. The pallet and the waste containers will be unloaded from the hoist cage and transported by a diesel-powered transporter to the waste-disposal areas. A decontamination and radiation-safety-check station is near the waste shaft on the disposal horizon.

Parallel entries will provide access to each waste-disposal room (Figure 8-9). The rooms are planned to be approximately 33 feet wide, 13 feet high, and 300 feet long. These rooms are separated by 100-foot-wide pillars and blocked into areas between 200-foot-wide barrier pillars. Immediately after the emplacement of CH TRU waste, the disposal rooms will be backfilled with salt to reduce any potential fire hazard.

<u>Disposal of RH TRU waste</u>

The facility cask, holding one RH-waste canister, will be lowered in the hoist cage to the waste-receiving station at the lower end of the waste shaft (Figure 8-11). Here it will be removed from the hoist cage and picked up and transported to the waste-disposal area by a forklift. Decontamination and radiation-safety-check stations will be close to the waste shaft. The RH-waste canisters will be horizontally emplaced in steel-lined holes in walls of the barrier pillars along major tunnels. Each lined hole will then be capped with a shielded steel plug. In order to make retrieval easy, should it become necessary or desirable, these major tunnels will not be backfilled until definite decisions on retrieval have been made.

8.4.2 Support Facilities Underground

The ventilation-supply and service shaft is used to move personnel, materials, and equipment between the surface and underground areas. In addition, the shaft supplies fresh air for the underground ventilation system. Underground workshops and warehouses will be located near this shaft. Underground offices, decontamination showers, and sanitary facilities (packaged chemical toilets) will also be near this shaft.

The construction-exhaust and salt-handling shaft will be used to bring mined rock to the surface and to exhaust air from the mining-operations area. The disposal-exhaust shaft carries air from the underground disposal areas to the disposal-exhaust-filtration building.

8.4.3 Underground Environmental Control System

The environmental control system includes the ventilation and final discharge systems and all the associated subsystems. The general requirements for the underground system are similar to those discussed for the surface system in Section 8.3.4.

A schematic outline of the underground ventilation system is shown in Figure 8-12. The air supply for the underground areas will enter through the ventilation-supply-and-service shaft and then be divided into two separate air streams: one that supports the construction (mining) activities, where there will be no possibility for the release of radioactivity from waste, and one that supports the waste-disposal operations, where there will be a potential for the release of radioactivity. The air that flows down the waste shaft immediately flows back up through the disposal-exhaust shaft.

The separated air streams will allow waste-disposal and construction activities to proceed simultaneously. Double bulkheads will maintain the independence of the two air streams. Pressure differences across the bulkheads will insure that all leakage through them flows to the areas that support waste disposal. The bulkheads, made of fire-resistant materials, will be designed to accommodate displacements caused by salt creep or seismic motion.

The construction air stream ventilates the construction areas as well as the experiments that do not use radioactive waste and the shops and warehouses at the disposal horizon. The air is exhausted through the construction-exhaust and salt-handling shaft to the atmosphere.

The disposal-area air stream ventilates the waste-disposal and experimental waste areas and is exhausted through the disposal-exhaust shaft to the disposal-exhaust-filtration building.

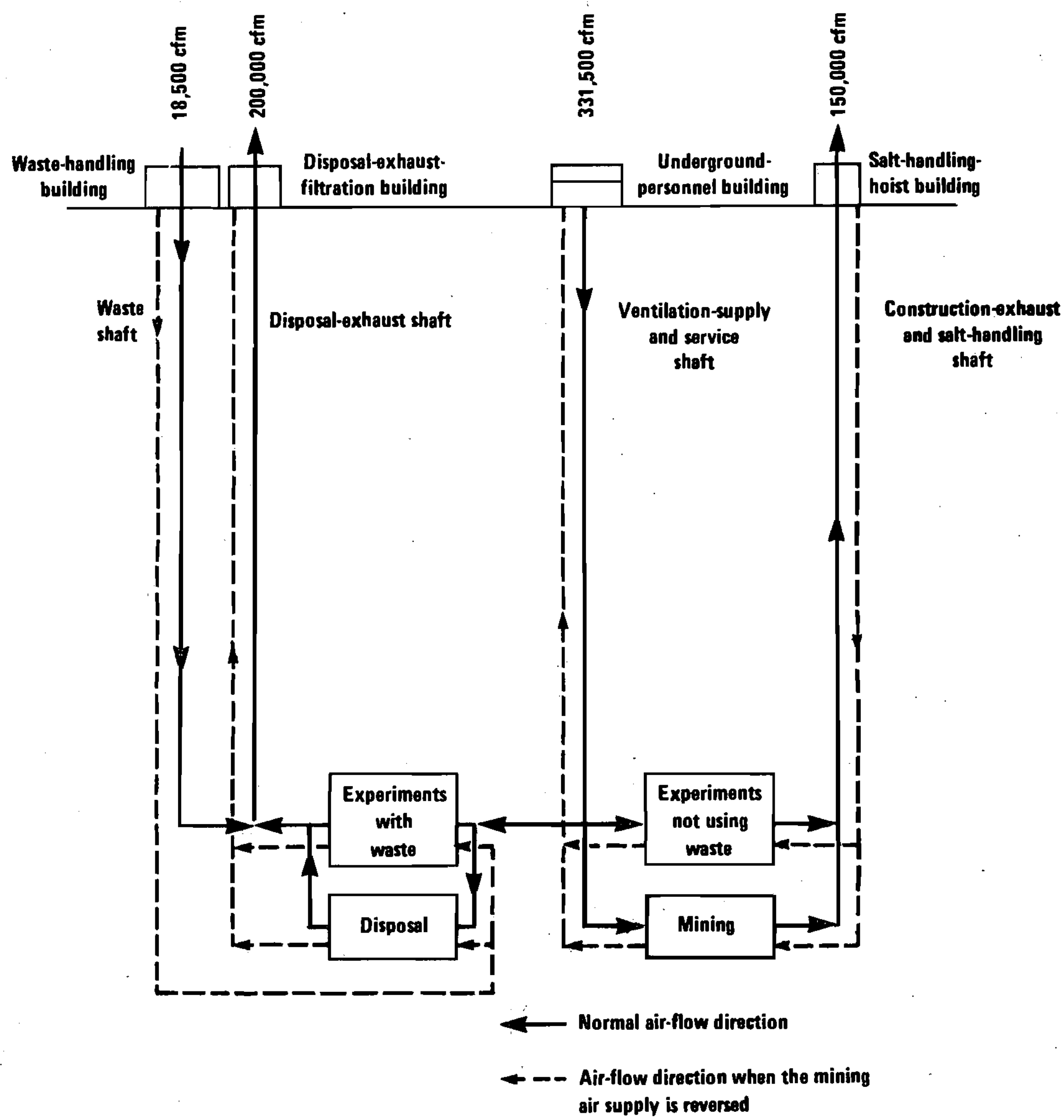

Figure 8-12. Underground ventilation flow.

After an accident activates signals from radiation monitors, the air-flow volumes become roughly half of those for normal operations, but their flow directions do not change except that the disposal-exhaust air is diverted through HEPA filters.

In the event of a fire emergency the direction of the air flow through the construction area can be reversed. During reversal the total air volume through both the construction and the disposal areas remains unchanged, but two major changes do occur:

1. The construction-exhaust and salt-handling shaft becomes the intake shaft for construction operations (at 150,000 cubic feet per

minute), and the ventilation-supply and service shaft becomes the exhaust shaft.

2. The waste shaft becomes the intake shaft for disposal operations (at 200,000 cubic feet per minute), and the disposal-exhaust shaft remains the exhaust shaft.

8.5 SYSTEMS FOR HANDLING RADIOACTIVE WASTE GENERATED AT THE SITE

The radioactive-waste systems are designed to collect, transfer, and package radioactive waste produced by the plant. These systems have sufficient surge capacity to handle waste produced during postulated accidents (Section 9.5.1) as well as during normal operations.

The radioactive wastes generated at the site will be liquids, such as decontamination solutions, which will be solidified before packaging for disposal; solids, like gloves, clothing, and filters; or gases, including airborne particulates. Appropriate systems are provided to handle each of these types of waste.

8.5.1 Liquid Radioactive Waste

Sources and quantities

Small quantities of liquid radioactive waste (radwaste) will be produced both daily and intermittently at several locations in the plant. These liquids will consist of both nondetergent radwaste and detergent radwaste; a maximum of 12,500 gallons per year of both will be produced.

In the waste-handling building, liquid radwaste will be produced routinely during the decontamination of shipping or facility casks. Small quantities will be produced in the laboratory. Additional small quantities will be intermittently produced by the decontamination of radwaste-processing equipment. If decontamination of facilities handling radioactive waste is needed, it will produce liquid radwaste. In the event of a fire, large volumes of potentially contaminated water could result from fire-fighting efforts, but they will be handled separately by a process described below. In the underground operations, liquid radwaste will be produced mainly by equipment decontamination.

Liquid-radwaste processing

Small quantities of liquid radwaste will be produced in normal operations. These wastes will be solidified, perhaps by mixing with cement, and emplaced in the repository as CH waste if they meet the waste-acceptance criteria.

In the unlikely event of a fire, a large volume of possibly contaminated water will collect in floor trenches specifically designed for the collection of water from the fire sprinkler system. This water, if it is contaminated, will then be processed by a portable liquid-radwaste-processing system brought onto the site after the fire.

8.5.2 Solid Radioactive Waste

Sources and quantities

Solid radioactive waste will be produced in the waste-handling building, the disposal-exhaust-filtration building, and the underground disposal and experimental areas. Table 8-3 gives estimates of the production of solid waste, which consists of general process trash and used ventilation (HEPA) filters.

Normal operations and plant maintenance will generate general process waste, the largest volume of solid wastes, including discarded protective clothing, cleaning rags, plastic bags, swipes used to check containers, and contaminated equipment parts. Dry solid waste will be segregated at its source into compressible and noncompressible waste. The compressible material will be transferred to a compaction station and compacted into steel containers, which will then be sealed. All noncompressible waste will also be sealed into steel containers.

The largest source of solid radioactive waste resulting from normal operation will be contaminated ventilation (HEPA) filters. Filters from low-contamination areas will be handled by direct contact; protective clothing and respirators will keep personnel exposure as low as reasonably achievable. Remote-handling equipment will be used in the replacement of hot-cell filters. For disposal, filters will be compacted and packaged in steel boxes.

Table 8-3. Estimated Annual Production of Solid Waste

Type of waste	Volume[a] (cubic feet)	Number of 55-gallon drums	Number of DOT-7A boxes[b]
Compressible waste	800	133	--
Ventilation filters	620	--	8
Total	1420	133	8

[a]Compacted volume.
[b]A steel box 6 by 5 by 4 feet.

Disposal of solid radioactive waste

Boxes and drums of the solid waste generated at the site may be disposed of in the repository. However, the form of this waste may not meet the chemical and physical criteria for acceptance at the repository, and the installation of a processing facility to handle the small quantities of site-generated waste may not be practical. If this waste cannot meet the criteria for disposal, it may be shipped to another facility for processing and then returned to the WIPP for disposal in a form that meets the acceptance criteria.

8.5.3 Gaseous Radioactive Material

Gaseous and airborne radioactive material may appear in the ventilation system and the experimental-area gaseous-radioactive-waste system.

Ventilation air from the waste-handling building that might contain radioactive particulates will pass through the filtration system before it is exhausted to the atmosphere. Consisting of prefilters and two stages of HEPA filters in series, the filtration system has an estimated combined decontamination factor of 10^6 (American Association for Contamination Control, 1968). The exhaust will be monitored continuously for radioactivity.

A separate filtration system will remove particulates from gaseous waste produced in the underground experimental area. Gaseous waste from this system will pass through appropriate air-cleaning devices before being exhausted to the disposal-exhaust system. This gaseous-waste stream will be monitored continuously for radioactivity. The composition of the gaseous effluent released to the general ventilation system will depend on the experiments being conducted.

Mining operations will release radon isotopes that exist naturally in the mined rock. These gases will enter the underground-ventilation system and will be released to the atmosphere as in normal mining practice.

8.6 SOURCES OF THE POTENTIAL RELEASE OF RADIOACTIVE MATERIALS

During normal handling and storage operations at the plant, small amounts of radioactivity may be released. This section discusses the sources of these releases and predicts the amounts of radioactivity that may reach the biosphere. The predictions are the source terms for the analyses in Sections 9.3.2 and 9.5, which evaluate the radiological impacts of WIPP operation.

The discussion in this section characterizes the pathways for release according to five parameters:

1. Type of waste in a package.
2. Location inside the plant where the release occurs.
3. Origin of the released material: inside the package or on its surface.
4. Process by which the release occurs.
5. Filtration of the release.

Estimating the amount of released material requires, in addition to pathway descriptions, such details as container design, quality control, handling and transfer procedures, and storage methods. This analysis attempts to make realistic assumptions about these details. When data necessary for precise estimates are lacking, the analysis makes conservative engineering judgments; that is, it attempts to overestimate the potential releases. The release sources and pathways are presented in Table 8-4. The potential consequences of these releases are discussed in Section 9.3.2.

Table 8-4. Pathways for the Release of Radioactivity During Normal Operation[a]

Area	Release source	Release mechanism
	CONTACT-HANDLED WASTE (AT SURFACE)	
Unloading and loading; inventory and preparation	Surface contamination of undamaged drums and boxes	Particulates become airborne during unloading or loading
Overpack-and-repair room	Surface contamination and contents leaking from damaged drums and boxes	Particulates become airborne during unloading, loading, and temporary storage
	CONTACT-HANDLED WASTE (UNDERGROUND)	
Disposal-exhaust-filtration building	Surface contamination of CH-waste drums and boxes	Surface contaminants are released to exhaust air during disposal operations
	REMOTELY HANDLED WASTE (AT SURFACE)	
Cask receiving and unloading	Surface contamination of casks	Particulates become airborne during unloading, loading, and transfer
Cask preparation and decontamination	Surface contamination of casks	Particulates become airborne during handling
		Particulates are released through leaks in the gaseous-waste-handling system
Hot cell	Surface contamination of undamaged canisters	Particulates become airborne during unloading, transfer, and temporary storage
	Surface contamination and contents leaking from damaged canisters	Particulates become airborne during unloading, transfer, repair, and temporary storage
	REMOTELY HANDLED WASTE (UNDERGROUND)	
Disposal-exhaust-filtration building	Surface contamination of RH-waste containers	Surface contaminants are released to exhaust air during disposal operations

[a]Except for underground operations, effluent treatment is provided by filters in the ventilation system (decontamination factor = 10^6).

8.6.1 Release from the Aboveground Handling of CH TRU Waste

Calculations of radioactivity-release rates from the normal handling of CH TRU waste were based on operation at three shifts per day and 5 days per week. At this rate the WIPP could handle approximately 1.2 million cubic feet of CH waste per year. The numbers of waste packages would be 160,000 drums (55-gallon) and 2400 boxes per year.

The level of surface contamination on each container (drum or box) may vary significantly: some containers will be clean while others may be at the maximum allowable level of contamination. In order to obtain an upper (conservative) estimate of the radioactivity releases, it is assumed that all containers holding radioactive materials will have the maximum surface-contamination level permitted by the Department of Transportation under Title 49 of the Code of Federal Regulations (CFR), Section 173.397(a). This contamination level is 20 times that allowed by the WIPP waste-acceptance criteria. The handling of containers inside the waste-handling building will cause some of the removable (nonfixed) surface radioactive contaminants to become airborne. It is conservatively assumed that 10% of the surface contaminants (i.e., all of the radioactivity that could be removed by a wipe test as described in 49 CFR 173.397) on all containers will be released into the building atmosphere as a result of handling.

Normally, drums and boxes will be inspected for damage before shipment to the site. Only undamaged containers will be shipped to the site for disposal. Operating experience at the Idaho National Engineering Laboratory suggests that the number of containers that suffer some sort of damage or have some undetected defects will be very small; of the damaged containers, many will be dented, but not pierced. To derive a conservative estimate of releases from damaged containers, 30 drums and 5 boxes each year are assumed to be damaged (or defective) and to release radioactivity.

Radioactivity contained inside a damaged container may be released through cracks caused by rough handling. The cracks generated by dropping a 55-gallon drum during handling are assumed to be less than 1% of the total drum surface area. Because the waste is in solid form with less than 10% in small particles (Section 5.1), the amount of material released through cracks is assumed to be proportional to the ratio of the area of the cracks to the total area of the drum. Releases from damaged boxes are treated the same way.

Only a fraction of the material released from the damaged drum or box will become airborne. According to experiments with various waste forms (Mishima and Schwendiman, 1973), the fraction of the released waste (including particles of respirable and nonrespirable size) that becomes airborne is 0.00023 per hour. Under the assumption that 4 hours pass before the damaged waste package is brought to the repair area and the spilled waste is cleaned up, 0.1% (0.00023 x 4 x 100) of the released activity may become airborne.

Particulates airborne in the building will be vented through the filtration system in the waste-handling building, which has a decontamination factor of 10^6 (American Association for Contamination Control, 1968). The radioactivity released to the environment will therefore be 1 million times lower than the amount assumed to be airborne in the waste area.

The calculated annual release from the CH waste via the ventilation exhaust is given in Table 8-5.

8.6.2 Release from the Aboveground Handling of RH Waste

Two types of defense waste will be handled remotely in the waste-handling building: defense RH TRU waste for disposal and high-level waste for experiments.

According to the WIPP design, 10,000 cubic feet of RH TRU waste (about 370 canisters) per year could be handled in the building; about 75% by volume of the RH waste will be delivered to the plant by rail and 25% by truck. The RH waste will consist of contaminated trash (70%) and process waste (30%), which includes spent resins and solidified products of liquid-waste treatment. Because of its fixed form, process waste will make a negligible contribution to normal effluents in comparison with contaminated trash.

Loose particulates on the surface of the shipping casks used for RH TRU waste could, in theory, become airborne during the handling of contaminated casks in the cask-unloading-and-receiving area and the cask-preparation-and-

Table 8-5. Releases of Radioactive Isotopes to the Environment[a]

Isotope	Release (Ci/yr) Surface operations CH waste	RH waste[b]	Underground disposal area	Total
Cobalt-60		3.0×10^{-11}	1.7×10^{-7}	1.7×10^{-7}
Strontium-90		4.9×10^{-9}	2.6×10^{-5}	2.6×10^{-5}
Yttrium-90		4.9×10^{-9}	2.6×10^{-5}	2.6×10^{-5}
Ruthenium-106		4.3×10^{-11}	2.4×10^{-7}	2.4×10^{-7}
Rhodium-106		4.3×10^{-11}	2.4×10^{-7}	2.4×10^{-7}
Cesium-137		2.5×10^{-11}	1.4×10^{-7}	1.4×10^{-7}
Barium-137m		2.5×10^{-11}	1.4×10^{-7}	1.4×10^{-7}
Europium-152		6.2×10^{-12}	3.4×10^{-8}	3.4×10^{-8}
Europium-154		2.5×10^{-11}	1.4×10^{-7}	1.4×10^{-7}
Plutonium-238	2.5×10^{-10}	1.4×10^{-12}	2.5×10^{-5}	2.5×10^{-5}
Plutonium-239	2.8×10^{-9}	1.6×10^{-11}	2.6×10^{-4}	2.6×10^{-4}
Plutonium-240	6.8×10^{-10}	3.7×10^{-12}	6.3×10^{-5}	6.3×10^{-5}
Plutonium-241	3.6×10^{-8}	9.1×10^{-11}	3.5×10^{-3}	3.5×10^{-3}
Plutonium-242	5.8×10^{-14}		5.4×10^{-9}	5.4×10^{-9}
Americium-241	3.2×10^{-11}	2.6×10^{-13}	3.0×10^{-6}	3.0×10^{-6}
Radon-220[c]			4.0×10^{-2}	4.2×10^{-2}
Radon-222[c]			9.0×10^{-1}	9.0×10^{-1}
Total	4.0×10^{-8}	1.0×10^{-8}	3.9×10^{-3}	3.9×10^{-3}

[a]During a year of releases at the upper limits explained in the text.

[b]Includes RH TRU waste only. Experimental waste does not contribute to off-site doses during normal operation. (Because of special handling procedures and methods, no surface contamination will be expected.)

[c]These gases must be treated separately in the impact and analysis since they are not radwaste. These releases are therefore not included in the total for this table.

decontamination area. Because the surface of each cask will be decontaminated before shipment to the plant, it will normally be nearly free of radioactive surface contaminants. It is conservatively assumed that 20% of the shipping casks will be contaminated and that 1% of the surface radioactivity of the contaminated casks will be released to the building atmosphere in the cask-preparation-and-decontamination area. (The surface contamination per unit area of a contaminated cask is conservatively assumed to be the same as the surface-contamination level of a waste canister.) However, the contribution of airborne surface contaminants to the building release is insignificant when compared with that of the internal leakage of damaged canisters, discussed below.

Shipping casks will be vented in the cask-preparation-and-decontamination area. Slightly pressurized air inside the cask may carry a small fraction of the surface contaminants of the canisters contained in a cask. During degassing, radioactive particulates will be released to the hot-cell filter system connected to the ventilation system, where almost all of the particulates will be trapped by HEPA filters. Although the canisters will be decontaminated at their point of origin, it is conservatively assumed that 10% of the canister surface radioactivity will be released to the special system.

The loose surface contaminants released to the hot-cell atmosphere during hoisting are estimated to be 2% of the canister surface radioactivity; this estimate is conservative because the canisters are thoroughly cleaned before shipping.

Potentially, the most significant source of airborne activity in the hot cell will be internal leakage of damaged canisters. A canister is much less likely to be damaged than a drum or a box: the damage would have to occur inside a cask during shipping or in the hot cell during handling. It is a conservative assumption that one canister per year will have a crack covering 1% of the surface area of the canister. Assuming that the release is proportional to the area of the crack, 1% of the canister inventory will be released. If 4 hours pass before the canister is brought to the repair area and the spilled waste cleaned up, the amount of radioactivity that will become airborne is 0.1% (0.00023 x 4 x 100) of the release (Mishima and Schwendiman, 1973).

It is assumed that 40 canisters of high-level waste specially prepared for experiments will arrive at the plant over a period of 5 years. Because of the highly stable nature of this vitrified high-level waste, leakage from damaged or defective canisters will be negligible. Only the nonfixed surface contaminants of the contaminated canisters are available for release.

Airborne radioactive material from the handling of RH waste will be filtered by the HEPA filters in the ventilation system. The annual contribution of RH waste to the plant releases is given in Table 8-5.

8.6.3 Release from the Underground Disposal Area

In general, the containers moved underground will be free from surface defects since damaged or defective containers will be repaired or overpacked in the waste-handling building at the surface. The only radioactivity available for release will be the surface contamination of the containers.

Although the surface contaminants will be fixed to the surface of the containers, hypothetical chemical changes are assumed to release them to the surrounding air during underground disposal. The rates at which this chemically altered, nonfixed surface contamination is assumed to be released are 1% per year for CH waste and 0.5% per year for RH waste. Airborne surface activity in the underground disposal area will be released to the atmosphere without filtration. Annual release contributions from the underground disposal area are given in Table 8-5.

Radon-220 and radon-222 are released in all mining operations. They arise in the decay of two naturally occurring rock constituents, thorium-232 and uranium-238. They are radioactive gases with such short half-lives (54 seconds and 3.8 days, respectively) that they normally decay into nongaseous isotopes before they can escape from the rock structure. Mining, however, creates free surfaces that let these radon isotopes escape into the mine tunnels and thence to the atmosphere by way of the ventilation system. The releases from a repository in salt have been estimated to be 0.04 curie per year for radon-220 and 0.90 curie per year for radon-222 (NRC, 1976).

8.6.4 Release from Solid Waste Generated at the Site

Contaminated ventilation filters will be the largest single source of solid radioactive waste resulting from normal maintenance at the site. When removed from use, the filters will be compacted and packed in steel boxes. Although a portion of the airborne-particulate radioactivity will be precipitated onto the prefilters, most will be deposited on the HEPA filters. To estimate the amount of radioactivity on the filters, it is assumed that all of the airborne radioactivity will be loaded onto the first stage of the HEPA filters. The first stage of the filtration system in the waste-handling building will consist of 200 HEPA filters in parallel.

The total radioactivity per box of the solid waste generated at the site is shown in Table 8-6, which presents upper estimates of the radioactivity levels in each box. The actual levels in different boxes will vary from negligible values to the values given in the table.

8.7 NONRADIOACTIVE WASTE

Nonradioactive waste will be produced in mining operations by the use and maintenance of equipment and facilities and by the people working in the plant. This waste will be in the form of trash and refuse, mined salt, sewage, salt dust, emissions from fuel combustion, and some nonradioactive gases produced during experiments with high-level waste.

8.7.1 Sanitary Waste

During site preparation and the early stages of construction, portable toilets, maintained by an approved sanitation service, will be used. After the sewage-treatment plant is completed, trailers equipped with restrooms and

Table 8-6. Radioactivity of Solid Waste Generated at the Site[a]

Isotope	Radioactivity (Ci) per box[b]	Isotope	Radioactivity (Ci) per box[b]
Cobalt-60	3.8×10^{-6}	Europium-154	3.1×10^{-6}
Strontium-90	6.1×10^{-4}	Plutonium-238	3.1×10^{-5}
Yttrium-90	6.1×10^{-4}	Plutonium-239	3.5×10^{-4}
Ruthenium-106	5.4×10^{-6}	Plutonium-240	8.5×10^{-5}
Rhodium-106	5.4×10^{-6}	Plutonium-241	4.5×10^{-3}
Cesium-137	3.1×10^{-6}	Plutonium-242	7.3×10^{-9}
Barium-137m	3.1×10^{-6}	Americium-241	4.0×10^{-6}
Europium-152	7.8×10^{-7}		
		Total	6.2×10^{-3}

[a]During a year of releases at the upper limits explained in the text.

[b]Approximately 475 HEPA filters per year will be disposed of by compacting and packaging in eight steel boxes. The radioactivity per box is calculated as follows:

$$\text{Ci/box} = R(10^6)\ (1/8)$$

where R is the total particulate activity released from surface operations during 1 year (see Table 8-5).

day tanks for waste storage will be used until the sanitary-sewage system is completed. The day tanks will be emptied at the sewage-treatment plant. The peak rate of sewage generation during construction is estimated to be 30,000 gallons per day (gpd).

During normal plant operation, the sources of sanitary waste will be toilets, showers, sinks, and the cafeteria. It is estimated that the rate of sewage generation will be 45,000 gpd. Sanitary waste will flow to a sewage lift station, from which it will be pumped to the sewage-treatment plant.

The sewage-treatment plant consists of two parallel aerobic lagoons connected to a common effluent-holding pond. The effluent may be used for site landscape watering and dust control at the mined-rock pile. Provisions for hypochlorinating the effluent, as required, are made. Sludge dredged from the lagoons will be disposed of in the sanitary landfill or trucked away from the site for disposal. The plant effluent will meet all applicable New Mexico water-quality-control regulations. A chain-link fence 8 feet high will enclose the plant area to prevent the intrusion of any grazing animals or unauthorized persons.

Chemical toilets will be provided in the underground workings. The waste will be brought to the surface in tanks and either discharged to the sewage-treatment plant or hauled off the site for disposal. If electrical toilets are used, the final waste product will be in the form of ashes, which will be buried in the sanitary landfill.

8.7.2 Solid Waste

Trash

Most of the solid waste produced by the plant will be paper, rags, plastic materials, garbage from the cafeteria, wood scraps, sheet-metal scraps, tires, used batteries, and oily refuse. Metals and discarded equipment will be recycled through a commercial salvage company. All other materials will be collected and disposed of at the sanitary landfill. Three working shifts per day would produce an estimated 2500 cubic yards of solid uncompacted waste annually. During the operating life of the plant, 63,000 cubic yards of solid waste would be produced.

At the sanitary landfill, solid waste will be buried in levels separated by layers of soil. Landfill will be performed by conventional means, such as the cut-and-cover method, using a crawler tractor with a dozer blade. To minimize water seepage into the buried material, drainage from the area around the landfill will be diverted by an interceptor ditch. To make the landfill unobtrusive, a low-lying area has been selected for its location, and natural revegetation of filled areas will be encouraged.

Excavated salt

The excess salt removed during excavation and not used to backfill disposal rooms will be stored in the mined-rock pile. Approximately 2 million tons will be produced during the operational life of the facility, forming a storage pile 30 acres in area and 60 feet high. A ditch constructed around the pile will collect the runoff from the pile and carry it to an evaporation pond; no runoff laden with high levels of dissolved solids will be discharged from the plant area.

8.7.3 Liquid Waste

Most of the liquid waste produced at the plant will be sanitary waste (Section 8.7.1). Other liquid effluents processed with the sanitary waste will be water used for washing miners' boots.

Stormwater runoff from paved areas will be collected by storm sewers, which may also collect a very small amount of runoff from landscape irrigation; the remainder of the irrigation water will seep into the soil.

Rainfall-intensity data (Table 8-7) allow an estimate of the maximum volume of runoff water from the developed areas at the site: 466,000 cubic feet during a 30-minute storm. This estimate assumes a water-infiltration rate of 50% and a surface area of 150 acres. Runoff will be collected in ditches, carried away from the developed area, and discharged into drainage swales.

8.7.4 Chemical and Biocidal Waste

Since no chemical processing will be performed at the plant, there will be no appreciable chemical effluents. Residual chlorine levels from the treated sewage-plant effluent will be insignificant. The small quantities of waste

Table 8-7. Maximum Recorded Point Rainfall at Roswell, New Mexico[a]

Duration	Depth (in.)	Intensity (in./hr)
24 hours	5.65	0.24
12 hours	5.19	0.43
6 hours	4.82	0.80
3 hours	3.38	1.13
2 hours	2.88	1.44
1 hour	2.22	2.22
30 minutes	1.71	3.42
15 minutes	1.34	5.36
10 minutes	1.01	6.06
5 minutes	0.55	6.6

[a]Data from Jennings (1963). These data cover the time from 1905 to 1961.

hydraulic fluids, lubricants, and the like that will be produced during plant operation will be buried in the sanitary landfill or sent away for salvage. No biocidal waste will be discharged since none will be used.

8.7.5 Airborne Effluents

Airborne effluents will consist of salt dust from mining and the surface salt-handling system, small gas releases from experiments with waste, gases and particulates emitted by fuel-burning equipment and motor vehicles, and dust from erosion by the wind.

Salt dust

Salt dust produced in mining operations has been classified as "nuisance dust" by the American Conference of Governmental Industrial Hygienists (ACGIH), with the allowable concentration (threshold limit value) set at 10 milligrams per cubic meter (ACGIH, 1977; 30 CFR 57). Air samples from potash mines in the Carlsbad area show that the actual concentration of particulates in mine air is approximately 0.265 milligram per cubic meter. If 150,000 cubic feet per minute of such air is discharged through the construction-exhaust shaft, the discharged air will contain salt particles, and the amount released will be about 1300 pounds per year.

The surface salt-handling system includes systems for minimizing salt dust from salt moving and storage. These measures include covered conveyors, dry-dust-collection cyclones at conveyor transfer points, and the spraying of water onto the salt as it is discharged to the pile. Some salt will, however, become airborne during transfer from the mine to the pile. Salt will be blown from the mined-rock pile; data from potash mines (J. H. Metcalf, Sandia National Laboratories, private communication, 1978) and from salt-crushing mills (G. E. Barr, Sandia National Laboratories, private communication, 1978) suggest that for each ton of salt delivered to the pile about 10 grams of dust will be available to be swept completely off the pile. This proportion of dust would contribute about 4000 pounds per year of salt that would be released to the atmosphere. Emission factors determined for coal handling in the Western United States (PEDCo, 1976) produce an estimate that an additional 17 tons per year of salt will be released from the pile when equipment like bulldozers is used to shape the pile.

Gases from underground waste experiments

Gases from waste experiments will consist of small amounts of hydrogen from the corrosion of containers and the hydrolysis of brine, helium from radioactive decay, and hydrogen chloride from brine decomposition. The total volume of these experimental wastes will be about 150 cubic feet. It has been estimated (NRC, 1976, Table IV H-16; Bishop and Miraglia, 1976, Table 4.15) that a hypothetical high-level-waste and TRU-waste repository containing about 2 million cubic feet of high-level waste would generate annually 4 standard cubic feet per minute (scfm) of hydrogen, 0.001 scfm of helium, and 0.07 scfm of hydrogen chloride. These quantities should be divided by 13,300 (2,000,000/150) to produce an estimate for the WIPP. The results are shown in Table 8-8.

Table 8-8. Estimated Release Rates of Nonradioactive Gases from Experiments with High-Level Waste

Gas	Gas-release rate[a] scfm	Gas-release rate[a] lb/yr
Hydrogen	3.0×10^{-4}	0.91
Helium	7.5×10^{-8}	0.0004
Hydrogen chloride	5.3×10^{-6}	0.28

[a]Based on estimates by the NRC (1976, Table IV H-16).

Emissions from fuel combustion

There will be three principal sources of emissions from the combustion of diesel fuel: the emergency-power system, the surface handling equipment, and the underground handling equipment. In addition, an oil-fired drier may be required to dry the salt stored on the surface for backfilling the repository. Table 8-9 shows the calculated annual emissions. The calculations were based on emission factors published by the U.S. Environmental Protection Agency (EPA, 1977) and on the following assumptions: The emergency-power diesel-generator plant, with an installed capacity of about 10,000 horsepower, will be used 1% of the time (88 hours per year). The diesel-powered surface handling equipment (about 3400 horsepower) will be used about 10% of the time during one work shift each day. The underground salt-handling equipment (about 560 horsepower) will be used about 40% of the time during one work shift each day. The salt drier (approximately 30 million Btu per hour, using about 800,000 gallons of fuel per year) will be used during one work shift each day after mining has ceased.

Table 8-9. Estimated Annual Emissions from the Combustion of Diesel Fuel[a]

Pollutant	EPA emission factor (g/hp-hr)	Total (lb/yr)
EMERGENCY POWER PLANT		
Carbon monoxide	3.03	5,870
Hydrocarbons	1.12	2,170
Nitrogen oxides	14.00	27,100
Sulfur dioxide	0.93	1,800
Particulates	1.00	1,940
SURFACE HANDLING EQUIPMENT[b]		
Carbon monoxide	2.62	5,730
Hydrocarbons	0.85	1,860
Nitrogen oxides	14.9	32,600
Sulfur dioxide	0.89	1,950
Particulates	0.78	1,710
UNDERGROUND HANDLING EQUIPMENT[b]		
Carbon monoxide	2.62	3,780
Hydrocarbons	0.85	1,220
Nitrogen oxides	14.9	21,500
Sulfur dioxide	0.89	1,280
Particulates	0.78	1,120
MINED-SALT DRIER[c]		
Carbon monoxide	5.0[d]	4,000
Hydrocarbons	1.0[d]	800
Nitrogen oxides	22.0[d]	17,600
Sulfur dioxide	71.0[d]	56,800
Sulfur trioxide	1.0[d]	800
Particulates	2.0[d]	1,600

[a]Based on factors published by the EPA (1977).

[b]Emission rates based on one 8-hour work shift per day.

[c]Emission rates based on one 8-hour work shift per day after mining has ceased or decommissioning decision has been made.

[d]Units of pounds per 1 thousand gallons of fuel consumed.

Wind erosion

Fugitive soil dust will be dispersed to the atmosphere because of construction activities and naturally occurring soil erosion. Since all the areas of the WIPP used by vehicles are paved, the amount of dust caused by the movement of cars or trucks will be minimal once the plant is completed.

Some material will be blown off the mined-rock pile; a review of wind-erosion data (EPA, 1977) suggests that 1 to 3 pounds of material per ton of salt delivered might be blown off if the pile were to remain in place for

25 years without forming a crust that would resist erosion. Such an erosion-resistant crust will form on the pile under the influence of rainfall, atmospheric moisture, and moisture in the salt itself. The water sprayed for dust control will hasten the cementing of the surface, and water penetration will produce recrystallization of the salt. After stabilization by cementing and recrystallization, the pile will have few particulates available for wind transport. Most of the particulates that become available will be produced by drying after precipitation has dissolved part of the pile surface; in large part, they will be insoluble residues of the mined rock, not salt. In wind erosion studies of soils, it has been found that crusting of a material will reduce wind erosion by about a factor of 6 (Woodruff and Siddoway, 1962); accordingly, wind erosion of the pile could be expected to be less than 0.5 pound per ton of salt in storage.

Field examination of the mined-rock pile that used to be at the Gnome site (Intera, 1978) supports these expectations. In the Gnome project, carried out in 1961 at a site 9 miles from the WIPP site, an underground nuclear explosion took place in cavities that had been mined in the Salado Formation. The pile of mined materials remained at the site for 17 years. An upper limit to the deposition on the surrounding land is 0.1 pound of salt per ton of mined rock in the pile; because the distribution of this salt around the pile is uniform and shows no correlation with prevailing wind directions, the salt probably did not come from the pile but from other sources in the region, such as Laguna Grande de la Sal or potash tailings piles. Furthermore, measurements of the shape of the Gnome pile showed that less than 1% or 2% of it had moved in the 17 years that it had been in place; most of the material that had moved had remained within the berm surrounding the pile. Inspection of the surface and of cores taken from the surface showed that the pile was cemented and that most of the surface particulates freed during cycles of drying and wetting were not salt.

The mined-rock pile will contain no more than the approximately 2 million tons of material brought up from underground at the end of mining. A conservative estimate, therefore, is that the maximum rate of wind erosion from the mined-rock pile would be about 40 tons per year.

During the mine-backfilling period, total salt-dust emissions are expected to be about 26 tons per year, according to the emission factors given by PEDCo (1976). These emissions will result from loading the salt onto a salt crusher, from conveying the salt underground, and from the ventilating the mine.

8.8 AUXILIARY SYSTEMS

Besides the water and power systems, the plant's auxiliary systems include roads, a railroad, and communications systems.

8.8.1 Water

The estimated average daily demand for water at the WIPP is 90,000 gallons with a peak flow of 500 gallons per minute (gpm). Two aboveground storage tanks will be located at the WIPP site. Each tank will store 90,000 gallons of water for normal use and 90,000 gallons of fire-protection water. The water stored for normal use will be used for processes carried out in the plant and for the heating, ventilation, and air-conditioning systems.

The water for the plant will be purchased from, and delivered by, the Double Eagle Water System, which consists of a series of wells about 35 miles north-northeast of the site. The system has a 542-gpm reserve pumping capacity and a storage capacity of 336,000 gallons. It is expected that this system will be expanded by drilling new wells to meet future requirements.

A proposed new 24-inch line will run due south from the tie-in point for about 18 miles to the Carlsbad-Hobbs Highway (U.S.180) and continue along the site-access road for another 9 miles. At this point, a tee in the line will provide a branch to another Double Eagle Water System customer, and a 10-inch line will continue along the site-access road another 4 miles, terminating at the two on-site storage tanks.

8.8.2 Power

Most of the energy used at the plant will be electrical power purchased from a commercial utility company. Except for the fuel used by diesels, other automotive engines, and potentially the salt drier, fossil fuel will not be used.

Electrical power will be provided by the Southwestern Public Service Company from its 115-kilovolt Potash Junction substation through a 115-kilovolt transmission line about 14 miles long (Figure 8-3).

8.8.3 Roads

Present access to the site is by an unimproved caliche-surfaced road, extending from New Mexico Highway 128 to the site. The principal access to the site will be on a new road built from U.S. Highway 62/180, about 13 miles north of the site. This road will be built to State highway standards. A second road will reach New Mexico Highway 128, about 4 miles south of the site. Both roads will require a 200-foot right-of-way (Figure 8-3).

The routing of on-site roads (Figure 8-8) supports the waste-handling operations. These roads are designed for the movement of cask-containing waste transporters and the routine flow of maintenance vehicles. Vehicles will enter only through entrance gates. On-site parking is provided for employee vehicles, site-maintenance and staff vehicles, and waste-transportation vehicles.

8.8.4 Railroads

Railroad access to the site is required for receiving waste shipments by railcar. The proposed rail line to the plant originates from a spur at the Duval Corporation mine, about 6 miles west-southwest of the site (Figure 8-3). It will require a right-of-way of 100 feet.

On-site tracks are required for the efficient movement of railcars brought to the site. The on-site railroad layout, shown in Figure 8-8, provides a siding for railcar transfer from locomotives to plant railcar movers, individual CH- and RH-waste railspurs for access to the waste-handling building, and parking space for about 30 railcars.

8.8.5 Communications

The communication systems for the site are interconnected to insure that no operation will become isolated from the central control point and to provide for communication with off-site emergency services, such as ambulances, fire fighters, and local law-enforcement agencies. These communication systems may include telephones, radios, public-address apparatus, intercoms, and closed-circuit television.

Telephone service will be provided from Carlsbad by the General Telephone Company of the Southwest. The right-of-way for the telephone cable will be included in the right-of-way for the north access road (Figure 8-3 and Table 8-1).

8.9 RESEARCH AND DEVELOPMENT PROGRAM

To carry out the research and development that is part of the authorized mission, the WIPP will include a test area for in-situ experiments on the interactions of defense waste with bedded salt. A specially designed part of the underground workings will be used for this purpose. The small amount of waste used in the experiments will be removed at the end of the program; it will not produce any long-term residual effects on the WIPP. In addition, the project will include several other underground activities that can be characterized as development efforts. The further development of disposal and handling methods will be supported by demonstrations and by monitoring the structure of the mine; the TRU waste will be monitored to confirm the safety of the methods used in disposing of it. This section describes the current plans for the in-situ experiments during the SPDV program and during full operations at the repository.

The in-situ research studies in the WIPP are only a part of a larger program that includes laboratory investigations, bench-scale studies in large blocks of salt, a series of preliminary measurements in existing mines, and the development of analytical models for predicting the behavior of a repository. Much of this extensive "pre-WIPP" program is under way, and most of it will have been completed before the repository opens. More details and references to published data are given in Section 9.7.3.

The investigations in the WIPP mine will therefore be extensions of earlier studies. The in-situ studies will establish whether the results of the earlier experiments are fully valid in an actual repository and will check the analytical models; they will also serve as a demonstration of waste-disposal operations in bedded salt.

8.9.1 Development Activities Before Waste Emplacement

Although the techniques used to construct the underground workings will be conventional, the operations subsequently carried out there will produce some unconventional stresses in the mined structure. In addition to the stresses normally present in mined cavities, heat-induced stresses will appear in the experimental areas where heat-producing waste is emplaced; extensive boring of test holes and emplacement holes in the sides and the floors of some cavities may produce other unusual stresses and stress concentrations. To insure the development of efficient techniques and safe operations, experiments will monitor the response of the rock during the development of the site-validation shafts, during the development of the first underground rooms, and during continued operation of the repository.

Proposed activities to be conducted during the underground exploratory phases are discussed by Wowak (1979) and by Wowak and Sattler (1979). These activities include the following:

1. Monitoring of the shaft response and determination of rock properties at various locations in the shaft.

2. Exploration of the undeveloped portion of the repository horizon by horizontal core holes. The samples obtained will be compared with those previously obtained from surface drilling.

3. Monitoring of structural changes in rooms under conditions that simulate the effects of experiments with heat-producing waste.

4. Measurements of room deformation in a series of alternative design configurations and isolated test drifts.

Once the shafts are in place and the underground rooms are developed, a specific area will be devoted to a series of experiments conducted without radioactive waste. These experiments will be precursors to subsequent experiments with actual waste; their results will determine the final conditions and configurations for the high-level-waste experiments described in Section 8.9.3. The nonwaste experiments include the following:

1. Storage of simulated TRU wastes under actual repository conditions and under intentional inundation with brine.

2. Studies of the corrosion of alloys that might be used in waste containers and of the leaching of nonradioactive waste simulants. Backfill materials that have high capacities for sorbing radionuclides will also be investigated.

3. Studies of salt response to heating, including hole closure. Electrical heaters will produce the heating; studies in heated rooms and pillars will measure room deformation and establish the conditions to be expected during retrieval.

4. Studies of isotope migration with stable isotopes.

5. In-situ measurements of the permeability of rock salt.

6. Studies of the collection of moisture or brine around sources of heat. Electrical heaters will be used to examine mechanisms for brine migration by simulating conditions in an actual repository.

7. Studies of the sealing of shafts and holes. In developing methods for sealing a decommissioned repository, experiments will study various materials and techniques for plugging the mine shafts and minimizing future cracking or leaking in the seals (Christensen and Hunter, 1979). These studies will also examine the tendency of the shaft walls to develop stress-relief cracks. Most of this work will have been carried out by the time the WIPP opens.

8. Simulated operations with TRU waste. This work will include full-scale engineering demonstrations of the methods used to move waste containers through the plant and to bury them underground (Sandia, 1977). The continued development of safe and efficient techniques is the goal of this work, which in its final phase will include the retrieval of containers.

9. Retrievability studies for remotely handled TRU waste. Techniques and machinery for emplacing experimental wastes and remotely handled waste in retrievable configurations are already being developed (Stinebaugh, 1979). Demonstrations of retrievability in the repository will include the recovery of previously buried canisters of remotely handled waste.

10. Development of miscellaneous techniques for more efficient repository operation, including moisture-exchange measurements, development of mine-face-scanning equipment to identify inclusions or structural discontinuities in intact salt, measurements of background-radiation levels, and microseismic measurements.

8.9.2 Monitoring of Contact-Handled TRU Waste

Purpose and status

Studies carried out before the WIPP begins full operation will furnish detailed information on the properties of contact-handled TRU waste and on the interactions the waste will undergo in a bedded-salt repository (Molecke, 1978, 1979). This work will evaluate the criteria that will govern the acceptance of such waste at a repository. Although the Germans have been storing low-level and intermediate-level radioactive wastes at the Asse experimental repository for over a dozen years and have demonstrated the engineering practicality of this kind of waste isolation, no in-situ chemical and materials-interaction tests similar to those described for the WIPP have yet been performed.

Most of the required studies can be performed adequately in laboratories. Most of them are already in progress and will be complete by the time the WIPP opens (Sandia, 1979). The purpose of the planned in-situ TRU-waste tests is to verify the predicted behavior of TRU waste under normal operating procedures and under credible accident conditions. All TRU-waste tests in the WIPP will be based on previous laboratory results describing the degradation of waste and its interactions with its surroundings.

The studies planned for contact-handled waste are discussed below. Detailed descriptions and results of all the work will appear in reports to be issued as the program develops (Sandia, 1979). All TRU waste emplaced for in-situ testing, and compromised thereby, will be removed and repackaged; this waste may be sent away for further processing or emplaced in the disposal area for contact-handled waste. The TRU-waste test area will be decontaminated as necessary; it will thus pose no long-term safety risk.

Studies of gas generation with actual TRU waste

As the waste ages and degrades, it can produce gases through four processes: radiolysis, bacterial action, thermal degradation, and chemical interactions. Studies of gas generation by these four mechanisms are being carried out mainly in laboratories and through measurements on temporarily stored waste (Molecke, 1979). Activities proposed for the underground workings include

1. Determination of the quantity and the nature of gases, including water vapor, generated by emplaced waste. The primary sampling tool will be the monitoring of toxic, explosive, combustible, and radioactive gases (tritium, radon) that might conceivably be present. Such gases, as well as particulate matter and humidity, will be continuously monitored in the TRU-waste disposal rooms, TRU-waste test rooms, and adjacent drifts.

2. Determination of the effects that water vapor produced by heat and vaporization may exert on the minerals and equipment in the mine. One such concern is the behavior of the crushed salt that may be used to cover the containers of contact-handled TRU-waste. If the salt absorbs sufficient moisture, it may form a hard crust that would hinder the retrieval of the waste. On the other hand, the crust of salt may protect the buried waste containers by preventing moisture from reaching the interfaces between the salt and the containers.

3. Study of synergistic effects due to the simultaneous generation of gas by more than one of the four processes. This study is being performed in the laboratory to determine the effects produced when waste is stored under conditions that simulate the adverse effects of overburden pressure and water intrusion. It will be repeated in the mined experimental area in order to validate the laboratory results.

Other studies of waste integrity

In order to predict processes related to the long-term safety of the repository, a consequence analysis is being prepared. This analysis includes models of possible failure modes for a repository (Section 9.7.1). Some of the data needed for the detailed failure models are not available in thorough, quantitative form; the studies of contact-handled waste will help to supply these data through the following investigations:

1. Study of the physical integrity of waste packaging (Sandia, 1979).

2. Study of the leaching of the waste. These studies will determine the extent to which water can mobilize radionuclides from combustible and noncombustible wastes and from waste matrices now under development.

In the mine, a controlled amount of water will be intentionally introduced as a leachant into a small backfilled storage chamber containing contact-handled waste in deliberately damaged containers. Initially planned tests in the experimental area (Wowak, 1979) will be designed to check the extensive laboratory work now in progress (Sandia, 1979). For testing credible accident conditions, small groups of deliberately damaged TRU-waste drums (about nine per group) will be emplaced in test rooms along with small electrical heaters, to yield a 40 to 70°C overtest environment; because these temperatures exceed the temperatures expected in a repository, these conditions will overtest the drums. The wastes will be covered with crushed salt or mixtures of crushed salt and getter material. (Getter materials selectively sorb particular nuclides, thus retarding their movement in groundwater, and also act as partial barriers to the intrusion of brine.) Some of the groups of drums will be wetted with brine. The corrosion of canisters and the migration of radionuclides into the getter backfill will be monitored by periodically removing and inspecting the drums.

8.9.3 Experiments with Defense High-Level Waste: General Considerations

Experiments with defense high-level waste constitute a basic mission of the WIPP. These experiments are not so much concerned with the WIPP itself, which is not a repository for high-level waste, as they are with planning future high-level-waste repositories. They are to answer technical questions about the disposal of high-level waste in bedded salt and to provide a valid demonstration of the concepts involved. High-level waste generates more intense heat and radiation than do other types of waste, especially in its first several hundred years, before fission-product nuclides have decayed to insignificance. Thus it can affect its burial environment more severely than other wastes do. As many as possible of the high-level-waste experiments are being performed in laboratories first, but a thorough investigation cannot be carried out by laboratory study alone (OSTP, 1978); a demonstration is required. The objective of many of the in-situ high-level-waste tests is to validate the earlier laboratory results and the analytical predictive models based on them.

Studies of the interactions of waste with bedded salt were performed between 1965 and 1967 during Project Salt Vault, a project in bedded salt near Lyons, Kansas (Bradshaw and McClain, 1971). The WIPP high-level-waste experiments in progress since 1977 build on the knowledge gained from Salt Vault and from later laboratory studies. Using advanced instruments and techniques, the WIPP experiments will significantly extend the earlier data and also include several studies that were not part of Salt Vault--especially studies of radionuclide release and migration and measurements of chemical, material, and geologic interactions.

The basic goals of the WIPP experiments and the accompanying laboratory experiments are to study (1) the chemical and physical effect of the high-level waste on the surrounding salt, (2) the changes that will occur in the buried waste as it interacts with the salt, (3) the effectiveness of engineered barriers (canisters, overpacks, getter backfills), and (4) the subsequent transport of these radionuclides, especially by any fluids that are present.

WIPP experiments with solidified high-level waste will use material from the defense-waste reprocessing carried out at Hanford or at Savannah River. The experiments may also use specially prepared defense waste fortified with extra fission products to give a greater-than-average radiation and thermal output; their objective is to overtest the ability of the rock salt near the containers to contain the waste.

A fundamental concern in both laboratory and in-situ studies will be the great difference between the duration of the experiments and the duration of the processes the experiments are to study. The experiments may continue for several decades, but the processes in an actual repository may continue for thousands of years after it has been filled. To identify the mechanisms that will produce long-term effects and their consequences, the in-situ experimental program will include some efforts to accelerate these processes. Such experiments will, for example, use amounts of water or heat that are much greater than those expected in a repository; the effects on the waste and the salt will then be hastened or at least intensified. This kind of overtest experiment is not a direct simulation of the aging of a repository, but a careful analysis of its results should help in validating or testing the limits of the analytical models based on previous laboratory data describing important long-term processes. The experimental program will also include some experiments with high-level-waste materials that have been broken or ground into small particles. Such material represents severely degraded waste as it may appear thousands of years after burial, when the disintegration of containers has exposed waste material directly to the salt. This is another type of overtest to determine what might happen under extremely severe, but conceivable, conditions.

8.9.4 Experiments with Defense High-Level Waste: Specific Plans

Plans for in-situ experiments with high-level waste are in a preliminary stage. Details of the designs have evolved since early planning began in 1976; they will be elaborated and refined during the years before the repository is ready for underground experiments with radioactive material--no earlier than 1986. Results from laboratory and bench-scale studies performed during that time will guide the changes. Because the preliminary plans, though incomplete, nevertheless reveal the scope of the experiments, this section outlines them.

All of the experiments listed here will be in addition to the pre-WIPP laboratory work, much of which is already in progress. The studies performed in the WIPP will include repeating earlier laboratory studies for validation; a few other types of experiment can be carried out realistically only in actual underground workings. Molecke (1980) has given further details.

Studies of chemical effects, including radionuclide transport and migration

The in-situ experiments now planned include the following:

1. Determination of the composition and quantity of fluid inclusions in the host salt, measurement of their rates of migration under various thermal gradients, analysis of the effect of radiation on migration, and detailed study of the consequences of migration (Section 9.7.3.2).

2. Studies of radionuclide transport through bedded salt and surrounding rock by means of brine migration, both naturally occurring and artificially enhanced.

3. Studies of the ability of brine to leach radionuclides from waste. To accelerate this slow process, the experiments will include the leaching of "bare" waste (not protected by packaging material or other engineered barriers) that has been broken into small pieces.

4. Studies to determine how leach rates are affected by the heat, radiation, pressure, and chemical species present in a repository and by the radioactive-decay process.

5. Studies of getter-backfill materials (now being developed) and of clay and other impurities in the surrounding rock salt to determine their effectiveness in preventing or minimizing nuclide migration (Nowak, 1979).

6. Proof tests of emplaced canisters. These studies will measure the ability of waste canisters to retard the interactions between the waste and the salt, leaching, and subsequent nuclide transport. The tests will include measurements with normal undamaged canisters and with deliberately damaged canisters. They will also test the effectiveness of metallic overpacks or coatings on the canisters for greatly extended corrosion resistance; the purpose of this testing is further discussed in Section 9.7.3.3.

7. Monitoring of gases produced through radiolysis and corrosion.

8. Measurements of thermally driven solid-state diffusion, a mechanism for nuclide transport along grain boundaries in the salt.

<u>Studies of physical effects due to heat, radiation, and pressure</u>

Planned experiments include the following:

1. Measurement of energy stored in the salt through the "metamict" or Wigner effect, which occurs when the irradiation of the salt surrounding a waste container creates radiation-damage sites in salt crystals. The thermal fields that accompany this radiation tend to anneal the salt and prevent a buildup of stored energy. The annealing effects, however, vary strongly with temperature. The underground experiments will be a small effort intended to establish whether the earlier results, which predicted little risk or consequence from stored energy, are fully valid in situ (Section 9.7.3.5).

2. Measurement of the variations induced by heat, radiation, and pressure in bulk physical properties such as thermal conductivity, strength, and viscosity.

3. Investigation of the effects of these variations on the mobility and buoyancy of salt and waste canisters.

8.9.5 Experiments with Defense High-Level Waste: Methods

According to the preliminary technical and operational plans (Molecke, 1980), two classes of experiments will use solidified defense high-level waste in the WIPP underground workings: studies using "bare" radioactive waste unprotected by a container and studies using full-scale canisters of radioactive waste. The waste will include fission products and actinide materials fixed in a vitrified, low-leachability matrix; it may also be in other forms, such as metal matrices or ceramics, that are sufficiently developed and appear promising.

In both classes of experiments the underground emplacement of high-level waste and the subsequent sampling will follow strictly prescribed procedures. The experiments will not be routine operations. Detailed analysis will precede each experiment to insure its operational safety; this analysis will include planning for accidents that might occur during the experiment. Written operating procedures will specify each step in each experiment, the apparatus to be used, methods for dealing with events that might threaten to release radioactivity to the mine drift during the operation, and methods for retrieving radioactive material (Stinebaugh, 1979) after the conclusion of the experiments.

All the high-level waste used in experiments will be removed at the end of the testing. The emplacement-test area will be decontaminated as necessary to acceptable levels. There will therefore be no long-term hazard from the high-level waste. The only potential short-term risks posed by the emplaced high-level waste will be to the workers responsible for the experiments. All experiments will be closely monitored for safety purposes as well as for obtaining useful data.

Experiments with bare waste

This work will study the processes that may occur in the long term after the corrosion and the disintegration of containers have exposed radioactive-waste material to salt and brine. It will extend results obtained earlier in the laboratory and determine their applicability to an actual repository. Designed primarily to study chemical, rather than structural or thermal, effects, the bare-waste experiments will investigate the degradation of the matrix that encapsulates the waste, the leaching of waste materials, and the migration of radionuclides. Their design will represent adverse but credible conditions that may appear in a bedded-salt repository long after the waste is emplaced; they will be overtests, monitoring waste-repository interactions during a realistic time frame--months to tens of years. These overtest conditions will represent the following chain of hypothetical long-term events: the metallic waste canister has completely disintegrated, yielding corrosion products and bare waste; the waste matrix has partially disintegrated into chunks or into small particles the size of sand grains; brine or water vapor has intruded into the waste-emplacement hole; and brine or water is leaching the waste.

The experiments will be performed in "reaction chambers," unlined holes drilled into the salt floor of the WIPP mine in specially isolated areas. Bare-waste chunks or particles will be put into these chambers; other materials, including brine and corrosion products, may be added to simulate various stages of advanced interactions between the waste and the rock. In some chambers, getter-backfill material will surround the waste to minimize nuclide migration. To isolate the chambers from the mine drift, the hole from each reaction chamber up to the mine drift will be plugged or grouted shut. Instrumentation leads and tubes for sampling gases and liquids will pass through this plug.

Each of the bare-waste reaction chambers will hold about a quarter of the contents of a full-size high-level-waste canister. Each will be sampled periodically. Gaseous and liquid samples can be remotely withdrawn through the tubes in the plug; solid samples of rock salt, getter material, and waste fragments can be obtained by coring through the adjacent rock salt. All samples will be packaged and shipped to laboratories for analyses.

The experimental parameters will be varied in these bare-waste overtests. The waste forms will include defense high-level waste, some of which will be fortified with fission products. The size of the waste particles will vary from chunks to sand-size particles. The heat loading will vary; it may, for example, be 30 or 75 kilowatts per acre, with electrical heaters supplementing the heat from the waste. Various brine leachants and reactants will be artificially introduced. The backfill getters and corrosion products will be varied. The primary interactions to be monitored in situ are waste leaching and degradation, radionuclide migration near the waste, the effects of heat and radiation, and the effectiveness of the backfill getters.

Bare-waste tests that include all realistically possible variations of conditions plus replicates needed for statistical accuracy would require a large array of reaction chambers. Preliminary planning has tentatively established the number of chambers and the geometrical design of their emplacement; the number of reaction chambers is currently estimated to be approximately twenty per waste form. Efforts have been made to limit the extent of the in-situ tests to as small a number as possible. The results of laboratory studies will heavily influence the plans for in-situ experiments, for they will point out which interactions are the most important for further study underground and which interactions may be eliminated.

<u>Experiments with full-size canisters</u>

Testing full-size canisters of high-level waste under the actual conditions of a repository, and under some overtest conditions, will eliminate uncertainties introduced by extrapolating data from small-scale laboratory tests. It will permit the development and demonstration of procedures and equipment for handling and retrieving waste in future repositories. Full-size canisters are not intended to be as severely overtested as the bare waste will be; the experiments will use more conservative and realistic emplacement conditions.

In specially isolated underground experimental areas, the full-size high-level-waste canisters will be placed as they would be emplaced in an actual repository—in holes drilled into the floors. The holes will then be plugged and grouted. Instrumentation for sampling will be installed like the instrumentation for the bare-waste tests. After emplacement, the canisters will be periodically sampled by coring through adjacent salt to obtain specimens for laboratory analysis.

In order to force interactions to take place, some of the emplaced canisters will be compromised by coring into the canister to simulate a corrosion breach and introducing brine to simulate groundwater intrusion. Such tests will be somewhat similar to the bare-waste tests. Most of the canisters, however, will not be breached intentionally for many years, in order to follow their expected behavior or interactions in a repository. All waste emplacements will be closely monitored to avoid the risk of contaminating a mine drift.

Preliminary designs for the experiments with full-size canisters are not complete. The number of canisters of waste required for these studies will also be approximately twenty per waste form. The experimental parameters for both types of high-level-waste experiment are similar.

Some entire canisters of high-level waste will be retrieved after several years for thorough laboratory examination. All canisters will be retrieved at the end of the experimental period.

8.10 PLANS FOR RETRIEVAL

An important aspect of the WIPP project will be the ability to remove emplaced waste from the repository if such retrieval becomes necessary or desirable in the future. This section describes plans for retrieval. Actual demonstrations of retrieval will be regularly performed to train workers and to refine and improve the retrieval methods.

The retrieval of the TRU waste would take 5 to 10 years after a decision on retrieval is made. This decision will be made within 5 years after the first waste of each kind (contact handled or remotely handled) is emplaced. To permit access for retrievability the principal tunnels will not be used for disposal during the retrievability period. Special equipment, designed for both retrieval and subsequent repackaging, will be shielded to protect the workers.

Waste retrieval is more difficult, but still possible, after the planned retrieval period. Additional effort would be needed to locate and access the waste after backfilling. Once an excavation were made to the waste packages, the retrieval steps would be similar to those employed during the planned retrieval period.

8.10.1 Retrieval of Contact-Handled Waste

During the planned retrieval period any particular batch of contact-handled waste can be easily retrieved. Even after this planned period, retrieval can be safely accomplished. The retrieval process is begun by removing bulkheads from principal tunnels and restoring ventilation air flow. Next, electrical power and lighting are restored to the reopened tunnels, and radiation monitoring is performed to determine whether radiation levels are safe for personnel to proceed into these entries. After these procedures the roof of the tunnel is inspected for stability; scaling and rock bolting are then carried out as needed.

When these procedures have been completed, removing salt backfill from disposal rooms can commence. Once the stacked waste packages are uncovered, a forklift removes them from the stack and transports them to the pallet-reloading area, where all the surfaces of each package are checked for contamination and structural integrity. Overpacking and other repairs are then made as needed before the packages are stacked on pallets for transport to the waste shaft for return to the surface. Once returned to the waste-handling building, these wastes can be readied for transport away from the site.

The floor of the repository where wastes have been retrieved will be decontaminated by mechanically removing the contaminated salt, which will then be placed in sealable containers and handled in the same way as other contact-handled waste. The volume of salt removed in this operation is expected to equal the volume of waste removed. The fraction of this salt that is contaminated will depend on mechanical damage to the containers, the corrosion of the containers, the migration of the contaminants, and the care used in retrieval.

8.10.2 Retrieval of Remotely Handled Waste

The steps used for retrieving remotely handled waste will be the reverse of emplacement, with the addition of more extensive radiation-monitoring equipment and equipment for handling any container breach. The preparatory steps for the retrieval of remotely handled waste are identical with those discussed previously for the retrieval of contact-handled waste:

1. Principal entry bulkheads are removed, and ventilation air flow is reestablished.

2. Electrical power is restored, and radiation monitoring is performed before the workers enter the area.

3. The entry roof is inspected, and scaling and roof bolting are performed as needed.

The retrieval process from this point becomes essentially the reverse of the emplacement process except for a special tool that checks the canister for contamination before pulling it back into the facility cask. The process is shown schematically in Figure 8-13. After the removal of the canister from the salt, the package is transported to the waste shaft and returned to the waste-handling building at the surface for preparation for transport away from the site.

The principal tunnels in which canisters of remotely handled waste are to be emplaced will not be backfilled until near the end of the life of the WIPP. If a decision is made to decommission the repository without retrieving wastes, additional contact-handled waste will be stored in the principal tunnels previously used exclusively for canisters of remotely handled waste. These tunnels will then be backfilled with salt. If after this operation the decision is reversed, it will still be possible to retrieve the remotely handled waste after the contact-handled waste had been retrieved as described in

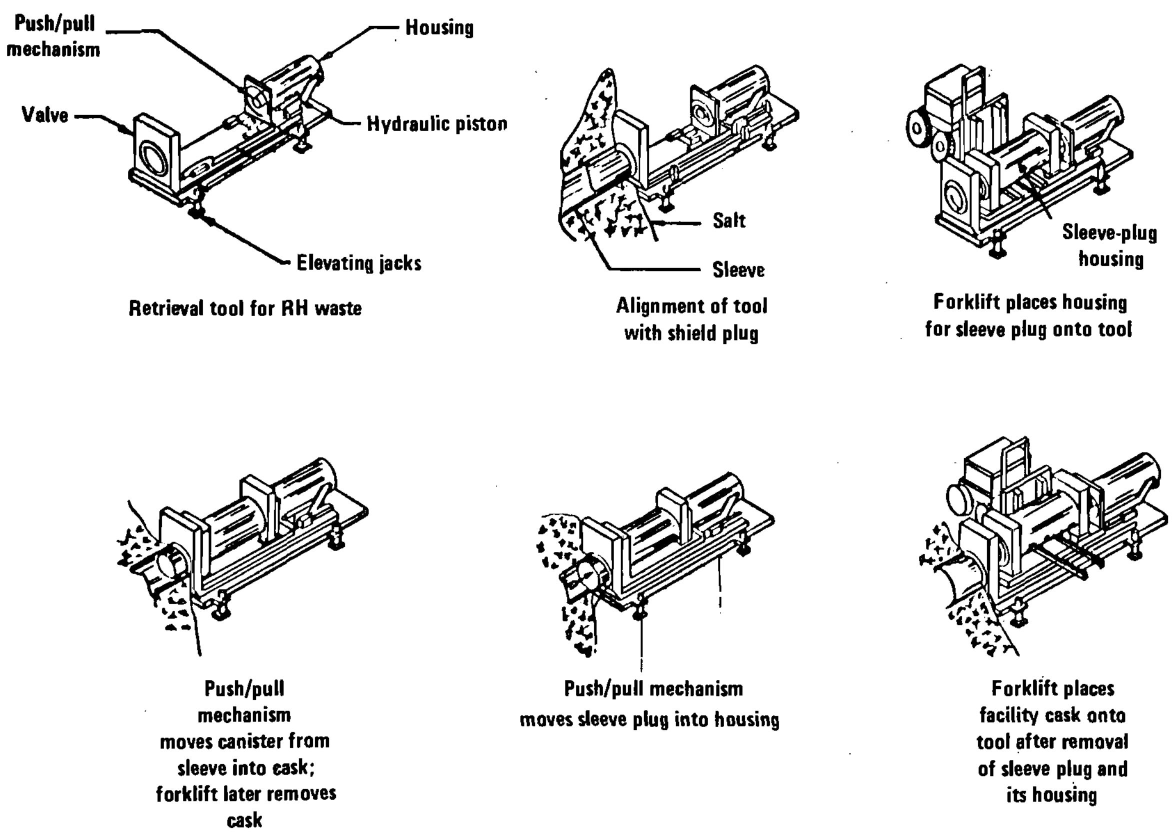

Figure 8-13. Schematic for waste retrieval.

Section 8.10.1. However, it is expected that contact-handled waste will not be placed in the tunnels containing canisters of remotely handled waste before a firm decision on retrieval has been made.

8.10.3 Retrieval of High-Level Experimental Waste

All wastes used in experiments (Section 8.9) will be removed during the operational phase of the WIPP program. Because these wastes will be in different forms, no single method will govern their retrieval. The plan for each experiment will include a procedure for removing the waste; this procedure will have to be approved by the DOE and the operator before the experiment can begin. The retrieval of canistered waste will be similar to that described for remotely handled waste in the preceding section, except that the experimental waste will have been emplaced vertically rather than horizontally. Any experimental waste emplaced in bare (unpackaged) form will be retrieved by overcoring the hole in which the waste was originally placed and packaging the mixture of salt and waste. The package will then be treated in the same manner as the other experimental waste.

8.11 PLANS FOR DECOMMISSIONING

At the end of the WIPP operation, a decommissioning program will be carried out for the safe permanent disposition of both surface and underground facilities. This section discusses the alternatives for decommissioning, the current plan for decommissioning and the ways in which the plant design anticipates this plan, the current studies of techniques for plugging shafts and boreholes, and the controls to be exerted after decommissioning.

8.11.1 Decommissioning Alternatives

The alternatives for decommissioning include mothballing, in-place entombment, decontamination and dismantling, and conversion to a new system. Although there are now no guidelines for decommissioning a radioactive-waste repository, the purpose of decommissioning is to protect the health and safety of the public.

These alternatives allow for decommissioning the plant under the following credible situations:

1. Decommissioning after the repository has been filled. The preferred methods would be in-place entombment of unusable underground structures, decontamination (as required), and dismantling of the surface structures.

2. Decommissioning after retrieving the waste. The surface and underground would be returned to nearly their original conditions; decontamination (as required) and dismantling would be the preferred methods.

3. Decommissioning before the repository is filled, leaving open the possibility of later returning to fill it. Mothballing of the surface and underground structures would be the preferred methods.

The present plan calls for decontaminating (as required) and dismantling surface facilities, entombing in the waste-disposal area all wastes generated in dismantling the surface facilities if they meet the waste-acceptance criteria (Chapter 5), backfilling the mine, and plugging the shafts and boreholes. Any wastes that did not meet the criteria would be transported to another location. The actual plan to be used will, however, be chosen at the time of decommissioning; it will insure that the environment and the public are protected.

Mothballing

Mothballing would consist of putting the plant into a state of protective storage for a few decades. This alternative would be selected if later repository operation or experiments were desired. It would require the eventual use of another alternative for the permanent decommissioning of the plant. The plant would be left generally intact except that all areas with hazardous levels of radiation would be isolated from the public by suitable barriers and other means. Useful equipment could be decontaminated, if necessary, and removed from the site. Adequate radiation monitoring, environmental surveillance, and security procedures would be established to protect the health and safety of the public. The shafts and underground facilities would be left intact.

Entombment

Entombment applies mainly to the shafts and mines. Entombment of the surface facilities would be similar to mothballing except that radioactive materials would be removed and placed in the mine or removed from the site. After the removal of usable equipment (and decontamination, if necessary), the mine would be backfilled with salt, and the shafts and boreholes would be plugged. In this alternative the mines and shafts would be permanently sealed; the surface facilities, however, would be available for some other use in the future.

Decontamination and dismantling

Along with the decontamination and dismantling of the surface facilities, the shaft and mine would be entombed as described above. Usable equipment would be decontaminated and removed; contaminated equipment and waste would be packaged and either placed in the mine or removed from the site if mine disposal were not feasible. Surface facilities would be demolished and debris removed or buried in the landfill. As nearly as possible, the surface would be returned to its original condition. The present plan for decommissioning, discussed in Section 8.11.2, uses these methods.

Conversion to a new system

It is possible that the plant could be put to another use after repository operations are completed. It cannot now be predicted whether the plant will be converted to another use, but since a railroad spur, roads, and utilities will be available, the site could be used for industrial purposes.

8.11.2 Present Plans for Decommissioning

Present plans call for decontaminating and dismantling the surface facilities and entombing the mines and shafts. All usable equipment and materials will be decontaminated as necessary and removed from the site. Contaminated structural debris and equipment that cannot be decontaminated will be packaged and placed in the mine. Structures will be disassembled after decontamination. Uncontaminated debris and unusable equipment will either be shipped away from the site for disposal or disposed of in the landfill. The evaporation ponds will be filled. In the underground areas, all equipment will be moved to the surface, decontaminated if necessary, and either shipped away from the site if usable or handled like unusable debris from the surface facilities. The mine will then be backfilled with salt from the mined-rock pile. The salt will be dried and compacted as closely as possible to its original density. Shafts will be plugged in accordance with acceptable borehole-plugging techniques (Section 8.11.3).

After these operations, the surface will be regraded to approximately its original contours. Markers will be provided for shaft locations and the landfill. If any of the mined-rock pile remains, it will be removed. Electrical-power and telephone lines, railroad spurs, and roads may be removed, depending on the future use of the site. If they are removed, the rights-of-way will be regraded to approximately their original contours. Water will be shut off at the original connection point; however, water lines will be removed only where they are not needed for other reasons and where their removal is necessary to restore the natural terrain.

Many aspects of the plant design are intended to facilitate decommissioning. These include the following:

1. Providing easy access to material and equipment that may eventually be recovered or dismantled.

2. Smoothing the surfaces of equipment to make decontamination easier.

3. Minimizing small dirt-catching spaces and corners to prevent the accumulation of radioactivity.

4. Using modular construction for ease of dismantling.

5. Using equipment that can be disassembled without cutting.

6. Minimizing the weight of blocks of material that will be moved.

7. To the extent possible, using standard equipment that can be used in other applications.

8.11.3 Borehole and Shaft Plugging

An essential task during the decommissioning of any waste repository will be plugging the remaining holes and shafts. Ideally the integrity of the plugs would be equivalent to that of the surrounding rock formations before human intrusion. It should be noted, however, that the long-term consequence analysis (Section 9.7.1) shows that an unplugged hole has only small environmental or safety consequences.

The DOE and its predecessors have conducted borehole-plugging research since 1963. The results obtained so far (and those expected in the near future, including demonstrations of techniques) give the DOE confidence that newly developed plugging methods will be available well before they are needed in decommissioning the repository.

The purpose of the borehole-plugging studies for the WIPP project has been to develop and test materials and methods for plugging holes and shafts in rocks and salt at the site. The plugs are to have long-term durability, low water permeability, resistance to groundwater attack, and physical and chemical compatibility with the surrounding rock. The plug materials are also required to bond to the surrounding rock, to expand to fill interstices, to be able to be handled in the field, and to be subject to quality controls that insure conformance with performance specifications. Preliminary design criteria for borehole and repository seals have recently been prepared (D'Appolonia Consulting Engineers, Inc., 1979). In addition to these DOE studies, Sandia National Laboratories has carried out field tests near the site and tests in the laboratory.

8.11.4 Controls After Decommissioning

The extent of post-decommissioning controls will depend on whether the wastes are permanently emplaced or have been retrieved. If wastes are permanently emplaced and the WIPP is decommissioned as presently planned, administrative controls will be established to prevent deep drilling, mining, or other activities that might allow water intrusion into the storage area. If surface facilities are not dismantled, fences and other security measures (like sealed doors and periodic inspection) will be needed to prevent public access. If wastes are shipped away from the site, the mine backfilled, and surface facilities dismantled, the need for post-decommissioning controls will be essentially eliminated.

Record maintenance and site markers

Systems that will maintain evidence of the WIPP site (written records and site markers, for example) are important aspects of the decommissioning of the WIPP. The primary objective of these systems is to insure continued environmental safety by preventing accidental intrusion into the repository for a few hundred years. A secondary objective is to provide long-term records of the nature of the plant during the period when waste hazards will be decreasing significantly (i.e., up to 1000 years). To meet the first objective, these systems must be designed to last for several hundred years. To meet the second objective, the systems must have additional stability and durability.

The final design of record-maintenance and site-marker systems will be completed before decommissioning; it will use state-of-the-art materials and methods. The plan presented in this section is conceptual and may be modified. Three principal components of the systems are written records, location markers for all shafts, and visible warning monuments.

Written records

Written documentation of the WIPP will be maintained in both Federal and local public-document depositories. Although printed records will be maintained, other records will use the most stable and durable media available. The information included in these records (waste characteristics and repository layout, for example) will be selected on the basis of its relevance to environmental safety and in accordance with Federal, State, and local regulations. Information like plant-building designs, methods of construction, and equipment specifications is not critical to environmental safety; these records will be maintained separately.

Shaft-location markers

Markers showing the locations of shafts will consist of permanent surveyor markings engraved with the elevation and coordinates and firmly anchored to the shaft plug. A uniform system of coordinates will be adopted, and the definition of these coordinates will be included in the permanent records.

Site monuments

A visible site monument will serve to minimize the possibility of intrusion into the repository during the short term; it may be the most durable record of the repository in the long term. The monument (or monuments) will be designed to be clearly visible from all locations in zones I and II, which are directly underlain by the waste repository and are most critical with respect to intrusion. The monument and its foundation will be designed to resist erosion and deposition. The materials composing the monument will be selected for durability under the local climatic conditions and possible climatic changes. A plaque will display the most critical information in a concise format. The information on the plaque will be recorded in modern language and in symbolic-logic notation designed to convey critical information. Inclusion of universally understood "danger" symbols will increase the likelihood of comprehension by virtually all people.

8.12 EMERGENCY PLANNING, SECURITY, AND SAFEGUARDS

This section discusses the measures to be taken in emergencies at the WIPP and the procedures and equipment that will protect it against intrusion and deliberate destructive acts.

8.12.1 Emergency Planning

A comprehensive program consistent with the policy and objectives of the DOE (ERDA Manual Chapter 0601) will be established to respond to emergencies at the WIPP. Formal emergency plans and procedures to cope with radiation emergencies will be promulgated.

Planning for emergencies at the site will be coordinated with local organizations such as law-enforcement agencies, fire companies, and hospitals. Before activities begin at the WIPP, firm arrangements will be made with these organizations and others to insure that additional support can be obtained if emergencies require assistance. The WIPP operators will work with these organizations to make appropriate equipment available and to accomplish the required training and orientation before an emergency occurs. This training will include proper response to a radiation emergency. The emergency plan will cover the requirements for the notification of the public and for possible, but unlikely, evacuation. Suitable contacts with emergency preparedness organizations in New Mexico will also be part of this plan.

Emergency facilities at the site

A central monitor-and-control system is provided in the WIPP design to serve as a coordinating center for monitoring and controlling site emergencies. All emergency alarms such as fire alarms, criticality alarms, security alarms, and radiation-monitor alarms are sounded and recorded by this system. The central monitor-and-control room in the administration building will be used as an emergency control center during site emergencies and will be manned by appropriate emergency-response personnel as specified by the emergency plan.

At the WIPP site there will be vehicles for fighting fires in both surface and underground facilities. A medical facility will provide emergency medical care and first aid; it will be capable of providing treatment for contaminated, injured personnel before their transfer to a hospital.

Emergency procedures

The WIPP operating contractor will develop procedures specifying the response to site emergencies such as an unplanned release of radioactivity, fires (underground or on the surface), underground cave-ins, explosions, radiation emergencies, national emergencies, and other emergencies. These procedures will have to receive complete review and approval by the appropriate government agencies before the WIPP begins operation. Provision will be made for periodic review and revision of these procedures as necessary. They will specify the notification of responsible WIPP operating management, who will determine what further notifications are necessary.

Emergency-response force

An emergency-response force will be established by the emergency plan, which will specify when and how these personnel respond to an emergency. They will take appropriate immediate action for the control of the emergency, provide for continuing control of it, and establish the means of recovering from it. The force will consist of immediate-action personnel, such as firefighting, medical, security, mine-rescue, and radiation-control personnel; it will include specially trained management and professional personnel who will man the control room to establish central control of the emergency. Adequate replacements for each position on the force will be specified. A call-in procedure for these personnel will be included in the plan to provide for emergencies occurring on backshifts, weekends, or holidays.

Personnel training

All personnel on the emergency-response force will receive special training and formal qualification to fulfill assigned duties. Selected personnel will be trained in firefighting and emergency techniques to form an effective fire brigade, mine-rescue teams, and other immediate-action teams deemed necessary. The training of these personnel will include response to underground and radiation emergencies.

Training will be provided to local and State personnel who might be expected to respond when requested. The extent of this training will be established by the WIPP operating contractor in cooperation with outside agencies. Drills will be conducted on at least a quarterly basis in accordance with established procedures to assess the adequacy of the emergency plan and the emergency-response force. In addition, drill scenarios will be developed in which parts of the emergency-response force or the entire force will be tested. The drills will include occasional testing of response capabilities outside the plant and the evacuation of the underground facilities. Provision will be made for the involved personnel to criticize all drills and actual emergencies.

8.12.2 Physical Security and Safeguards

The security program to be developed will comply with the requirements of the DOE (ERDA Manual Chapter 2406) to protect the WIPP against deliberate acts of vandalism, arson, and sabotage and the unauthorized removal of radioactive materials or plant equipment.

Program

A physical-security manual will be prepared; it will contain detailed instructions to the security force, describing actions taken for emergencies, patrol requirements, visitor-control requirements, and the like.

Physical security at the WIPP is provided by the following:

1. Design and arrangement of plant features to provide physical barriers that control or impede the access of personnel and vehicles to the plant and site.

2. Preemployment investigations of all employees.

In general, all buildings and equipment will be designed with safety and security as primary concerns. Protection from acts of violence, theft, and destruction will be enhanced by minimizing and controlling access to protected and restricted areas of the site.

Control of access

The WIPP is located on a site large enough to provide a controlled-access area between it and the general public (Figure 8-8). The facility itself will be fenced, and access to the fenced area by personnel and vehicles will be controlled by security personnel manning access points. Access to areas containing radioactive materials will be limited to authorized employees and escorted, authorized visitors only. Control over areas adjacent to the fence will be provided by periodic security patrols near the perimeter fence.

Employees will be controlled by personal recognition and identification badges. A system such as a card-key system will be used to control access to specified restricted areas. Visitors to the protected area will be assigned identification badges, signed in, and escorted. All personnel entering the protected area will pass security personnel for badge inspection and may be required to submit all packages for inspection both when entering and leaving the facility.

All entrances to the protected area will be locked and alarmed or controlled by the security force. The fence surrounding the protected area will be patrolled in accordance with the established security plan.

Only waste transporters and plant vehicles will normally be allowed in the restricted area surrounding the waste-handling building. Waste transporters will be allowed only in defined waste-handling areas. All vehicles, including delivery vehicles, will be inspected when entering and leaving the protected area. Employee vehicles will be parked in the parking lot outside the protected area.

Site and equipment monitoring

Protection against deliberate acts of damage or destruction and theft of radioactive material or plant equipment will be provided by monitoring the entrances to the protected area and the fence that encloses the protected area. These monitoring functions at the WIPP will be provided by security-guard patrols and by burglar alarms with tamper-indicating devices.

Employees and security personnel will be instructed to query persons entering protected areas who are not recognized, who are improperly badged, or who are unescorted. They will notify their immediate supervisor if there is reason to be suspicious.

Facilities and equipment

The fence enclosing the protected area will be lighted and regularly patrolled; all gates will be fitted with locks and alarms. Security personnel making routine patrols will follow security-manual procedures to check locks, alarms, and the perimeter fence.

The centers for security and emergency communication will be the central monitor-and-control room and the main guard station, both of which are in the administration building. These areas, manned 24 hours a day, will contain the equipment for sounding alarms. All alarms will be tested regularly, and records will be kept of test results and any required action.

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9 Analysis of the Environmental Impacts of the WIPP

This chapter describes and evaluates the impacts of the WIPP on the biophysical and sociocultural environment around the Los Medanos site.* These impacts may result from the withdrawal of public lands for the project, the construction of two deep shafts and an underground experimental facility in the site and preliminary-design validation (SPDV) program, the construction of the complete facility, the preparation of the waste for transportation and disposal, the operation of the facility, and the emplacement of radioactive waste. The impacts of transportation to the WIPP are discussed in Chapter 6.

In evaluating impacts on the quality of the human environment, as required by the National Environmental Policy Act of 1969, a clear understanding of the terms "action" and "impact" must be established. "Impacts" are not the same as "actions," which are the activities or operations that generate impacts. Actions are causes; impacts are results. For the purposes of this analysis, "impacts," "effects," and "consequences" are all synonymous. Accordingly, the activities at the site are all actions that may result in environmental impacts. For example, the removal of topsoil for the construction of a temporary building is not in itself an impact; it is an action, the impacts of which might be loss of vegetation and wildlife habitats, erosion, stream sedimentation with repercussions on aquatic organisms, and a loss of scenic quality.

To perform an environmental-impact analysis of the WIPP requires that the actions at Los Medanos be analyzed and interpreted in terms of their effects on the environment. Section 9.1 summarizes the actions of the WIPP project that may result in environmental impacts. This information is drawn from Chapter 8, which describes the construction and operation of the WIPP.

The human environment comprises a biophysical environment and a sociocultural environment. The biophysical environment includes such components as air quality, water resources, land surface, wildlife, vegetation, and aquatic organisms. The sociocultural environment includes such components as human populations, land-use patterns, recreation, community organizations, aesthetic resources, and economic activity. In this chapter the terms "biophysical environment" and "sociocultural environment" are used to distinguish between impacts on the natural environment and impacts on the environment formed or structured by people. Sections 9.2 and 9.3 describe the impacts exerted by the construction and operation of the WIPP on the biophysical environment, and Section 9.4 describes impacts on the sociocultural environment.

Section 9.5 deals with the effects on the human environment of possible accidents at the WIPP during operation.

A complete environmental impact analysis does more than identify the beneficial and the adverse consequences of a particular action. It also identifies the measures that can or should be taken to avoid or minimize undesirable

*In this chapter the terms "Los Medanos site" and "WIPP site" are synonymous.

environmental consequences. Accordingly, Section 9.6 of this chapter identifies the techniques, practices, and design standards that can serve to mitigate negative impacts. It discusses the mitigation measures included in the WIPP design as well as other mitigation measures that after evaluation were omitted from the design.

Section 9.7 describes effects that may occur after the plant ceases operation; it considers, among other effects, the consequences of hypothetical releases of radioactive material from the sealed repository. Section 9.8 discusses the impacts of removing the TRU waste from its present storage at the Idaho National Engineering Laboratory and of preparing it for shipment to a geologic repository.

9.1 ACTIONS AFFECTING THE ENVIRONMENT

9.1.1 Construction Phase

During the construction phase, environmental impacts result from the clearing of land; from the use of construction equipment, which generates noise and air pollutants; from the influx of workers and money into the local area; and from the consumption of natural resources.

Disturbed areas

Table 9-1 lists the areas that will be disturbed during the site and preliminary-design validation (SPDV) program and during the construction of the complete facility. During the SPDV program (Brausch et al., 1980) 169 acres of land currently under the control of the U.S. Bureau of Land Management (BLM) will be used, but much of this land will not be cleared of vegetation or graded. For the complete facility, a total of nearly 1100 acres will be used in constructing site facilities and rights-of-way, of which about 900 acres will be cleared of vegetation and graded. The land that is not cleared or graded will be largely unaffected, and any impacts that do occur, such as the disturbances suffered by wildlife, will be reversible in a short time. The land that is cleared and graded will be exposed to winds and rain, and the impacts it is subjected to will last much longer, perhaps for several decades.

Water discharges

No waterborne discharges are expected during the SPDV program or during the construction of the total facility.

During the SPDV program, drilling mud and other slurry material will be discharged to the spoils-disposal area, where the liquid fraction will evaporate or infiltrate into the top several inches of soil. Runoff from the salt-storage pile will be collected in a diked area around the pile and allowed to evaporate. Sanitary facilities provided during the SPDV program and the early stages of repository construction will be portable toilets maintained by a certified sanitation service. Washwater from temporary showers will be treated at the site. After the sewage-treatment plant is completed, treated wastewater will be used for dust control during subsequent construction.

Airborne emissions

Airborne emissions produced during construction at the site include the following:

1. Fugitive dust from topsoil-handling operations, construction activities, vehicle traffic on access roads, and wind erosion.

2. Salt dust from surface and underground handling.

3. Emissions resulting from the combustion of diesel fuel or gasoline by surface and underground construction equipment and light-duty vehicles.

The emissions expected during the SPDV program and the construction of the total facility are given in Section 9.2.1.

Table 9-1. Summary of Disturbed Areas

Type of disturbance	Area (acres)	
	SPDV program	Facility construction
Cleared of vegetation, graded, and used for surface construction	31	100
Cleared of vegetation, graded, and used for the mined-rock (salt) pile, the evaporation pond, and brine drilling-fluid spoils storage	15	37
Cleared of vegetation and used for spoils (earth removed during site grading), as borrow pits, and for sanitary landfill	3	55
Biological study plots	50	50
Rights-of-way		
Rights-of-way not cleared or graded	52	120
Rights-of-way cleared, graded, and covered with roads and railroads	0	112
Rights-of-way cleared and graded but not covered, including areas along roads, railroads, and maintenance trails	18	598
Subtotals		
Areas cleared, graded, and covered with structures	48	224
Areas cleared and graded but not covered with structures	19	678
Areas used but not cleared or graded	102	170
Total	169	1072

Noise

The construction of the SPDV facilities and the complete facility will generate noise in the vicinity of the site. The noise will be produced by heavy construction equipment, blasting during the sinking of shafts, the erection of buildings, and the vehicles used by commuting workers. The noise levels generated by these sources are estimated in Section 9.2.1.

Influx of workers and money

Like any large construction project, the WIPP project will attract large numbers of in-migrating workers and add large quantities of money to the economies of local communities. During the construction of the repository, the work force will reach a maximum of just under 1300 persons. The total construction cost, including the cost of the SPDV program, is $292 million. The influx of workers and money is described in Section 9.4, which also discusses other attendant effects on the area.

Resources

The resources committed during construction consist of (1) land temporarily disturbed as well as land occupied by the WIPP, (2) natural resources like fuels or building materials that cannot be recycled, and (3) terrestrial biota destroyed or displaced from the site. In addition, the construction may foreclose alternative uses of the land or resources for the life of the project. The natural resources consumed in this period are discussed in Section 9.2.2.

9.1.2 Operational Phase

During operations no additional land areas will be cleared, although the land cleared in construction will continue to be used. The use of equipment and the occupation of the site will result in some noise and air pollution. No significant waterborne discharges are expected. The impacts resulting from the operation of the WIPP are discussed in Section 9.3.1. Throughout the 25-year operational period, a stable work force will be required for the WIPP. Once this population has been established, any adverse impacts caused by the large transient work force employed during construction should diminish (Section 9.4).

For the WIPP operations the most significant action is the receipt and disposal of 6 million cubic feet of contact-handled TRU waste, up to 250,000 cubic feet of remotely handled TRU waste, and 150 cubic feet of high-level waste for experiments. This action will cause small routine releases of radioactivity; it may cause some low-probability accidental releases of radioactivity. The impacts of the normal operations and of the accidents are discussed in Sections 9.3 and 9.5, respectively.

At the Idaho National Engineering Laboratory the action resulting in environmental impacts is the retrieval and processing of stored TRU waste. Associated with this action are routine and possible accidental releases of radioactivity. The analysis of the resulting impacts is reported in Section 9.8.

9.2 EFFECTS DURING SITE PREPARATION AND CONSTRUCTION

The preparation of the site and the construction of surface and underground facilities will affect the environment. This section examines the impacts of those activities. During the 4.5 years of construction, the level of activity will vary with time and from place to place. It is expected that many of the adverse impacts of construction will begin during the SPDV program.

9.2.1 Biophysical Environment

Terrain

Impacts on the terrain will be minimal since the WIPP site is level to gently sloping (2% slope). The greatest change in the existing terrain will result from the disposal of mined material in a 30-acre, 60-foot-high pile just east of the main plant area in control zone II.

The topographic impact of this pile is not expected to be significant. Because of its small size in relation to watershed areas and because of the construction of drainageways around it, the pile will not disrupt drainage patterns in the region. The pile will be visible, on the clearest of days, for a distance of about 10 miles; some observers might consider it an unattractive addition to the landscape.

Soils

The construction of the SPDV facilities and the surface facilities of the complete repository will have an adverse impact on the soils in the disturbed areas. These impacts can be classified as follows:

1. Soil inadvertently dispersed over the area during site grading.

2. Increased wind and water erosion at the site.

3. Soil made sterile or less productive by being covered with salt (i.e., the soil beneath the salt-storage pile, the holding and evaporation ponds, and some of the spoils-disposal area during the SPDV program).

At present it is estimated that 78,000 and 1 million cubic yards of soil will be scraped and dumped during site-grading operations for the SPDV program and for repository construction, respectively. For each cubic yard of soil stripped and dumped, about 0.10 pound is expected to be dispersed (PEDCo, 1976). Accordingly, during the SPDV program and the construction of the repository, about 2.5 and 34 cubic yards of soil, respectively, will be lost to the immediate area.

The soil at the site (Section 7.3.8) is mainly a deep fine sand that is highly susceptible to wind erosion and dust production. The mean wind speed varies from about 8 mph in autumn to about 11 mph in spring. Since the spring is relatively dry and is also the windiest season, the potential for natural dust storms is greatest during this time, although the potential for airborne dust exists throughout the year. Vegetation tends to modify the dust-producing tendencies of sandy soils, high wind speeds, and low precipitation: it reduces wind speeds near the surface, its roots act as a soil binder, and it tends to retain the water that might otherwise run off. In general, the vegetation at the site is sparse, consisting primarily of woody plants, with small patches of perennial and annual grasses (Appendix H, Section H.5).

Because of stripping and grading operations, wind and water erosion can also be expected to increase. Increased erosion may lead to the loss of an additional 370 tons of soil during the 30 months of the SPDV program and 5000 tons of soil during the 2 years of construction of the complete repository.

In the course of construction, the underground areas of the WIPP will be excavated. As a result of this mining activity, approximately 2 million tons of bulk mined salt and other minerals will be stored in an aboveground mined-rock pile. The 30 acres of soil covered by the mined-rock pile will be rendered sterile by the stored salt. This impact on the soil beneath the pile will be essentially permanent. Small areas within the ditch around the pile and the evaporation pond (about 7 acres) will be affected by the accumulation of high salt levels in the soil—accumulations that result from water runoff.

The impacts on soil for about 900 acres will last for the life of the facility (Table 9-1). Impacts in other areas will, however, be brief because, once construction is complete, the vegetation will recover and the soil will return to its natural condition.

Unusual geologic resources

The mineral langbeinite, a form of potash, is the only uncommon geologic resource at the site. Should mining of langbeinite in control zones I, II, and III be prevented, these deposits will remain in their natural state. Section 9.2.3 discusses the denial of this resource and the economic significance of the denial. No adverse impacts on other unusual geologic resources are expected because no other existing or potential unusual geologic resources have been identified within the area of the site.

Any fossils found in the rocks at the site would be rare but of great interest. For example, in Texas, fossils have been reported in the lower part of the Rustler Formation. The fauna, consisting of 35 species of mollusks that lived in abnormally saline water, is thought to be the youngest of Permian age so far found in North America (Walter, 1953). Exploration and construction activities that might discover or expose fossils would therefore have a beneficial impact. Similarly, exploratory drilling and the construction of mine shafts and waste-storage chambers might provide unique exposures of rock in areas on which subsurface information is sparse. Therefore, the stratigraphic, lithologic, mineralogic, and structural information gained from exploration and construction at the WIPP site might be of scientific research value and of considerable benefit to the scientific and industrial communities. If fossils are found, a paleontologist will be consulted and significant specimens will be collected. However, blind-boring of the two shafts during the SPDV program will not allow the collection of fossils from these areas, and there is a possibility that some worthwhile fossils may be destroyed in the process.

Water resources

No waterborne discharges are planned during the construction of the SPDV facilities or the complete WIPP facility. All drilling fluid, salt-pile runoff, and washwater will be held within diked areas. The lack of shallow groundwater at the site and the brackishness of the deeper groundwater indicate that seepage from any of the diked areas will not result in groundwater pollution.

The large horizontal and vertical separation of the site from the Pecos River (the nearest perennial stream) and Nash Draw (the nearest significant ephemeral drainageway) indicates that the WIPP site is safe from major flooding. In addition, interceptor ditches at the site will divert upland flow caused by locally intense precipitation. Accordingly, it is not expected that flooding in the area of the site will result in any environmental impacts due to the presence of the WIPP.

Air quality

The SPDV program and the construction of the complete WIPP will have an adverse effect on local air quality, but construction-related emissions of air pollutants and dust will be short-lived. It is expected that most of the increases in air pollutants will occur during the early stages of construction.

Heavy-duty diesel-powered construction equipment emits carbon monoxide, hydrocarbons, nitrogen oxides, aldehydes, sulfur oxides, and particulates from the combustion of diesel fuel. Fugitive dust (i.e., uncontaminated soil dust from nonpoint sources) will also be produced during construction. To estimate the annual quantities of these pollutants, it is necessary to know (1) the type and quantity of equipment that will be used, (2) the annual number of hours of operation, and (3) the rate at which the pollutants are emitted.

Although exact descriptions of the construction equipment for the SPDV program are not available, estimates of the amount of diesel fuel to be consumed are available. The U.S. Environmental Protection Agency (EPA) has established emission factors based on the gallons of fuel burnt (EPA, 1973); the emissions estimated from these data are given in Table 9-2 for diesel-fuel combustion during the SPDV program.

Table 9-2. Emissions from Construction Equipment During the SPDV Program

Pollutant	Emission factor[a] (lb/1000 gal of diesel fuel)	Total emissions[b,c] (lb)
Sulfur dioxide	27	19,000
Carbon monoxide	225	158,600
Hydrocarbons	37	26,100
Nitrogen oxides	370	260,900
Particulates	13	9,200

[a]Emission factors from the U.S. Environmental Protection Agency (EPA, 1975).

[b]Total emissions over the 30-month construction period.

[c]Total diesel-fuel consumption during the SPDV program is 705,000 gallons.

A reasonable estimate of the type and the quantity of equipment used during the construction of the complete repository can be made by using previous large excavation and mining projects as guides. Emission factors for heavy-duty construction equipment have been compiled and published by the EPA (1977). Estimates of the equipment inventory and the annual number of hours of operation for the construction of the repository are given in Table 9-3.

From these figures it is possible to calculate the total annual emissions of air pollutants by applying the EPA emission factors for heavy-duty diesel-powered construction equipment. The emission factors are listed in Table 9-4; the calculated annual emissions are presented in Table 9-5.

Table 9-3. Estimated Equipment Inventory for the Construction of the Complete Repository

Category	Quantity	Operation times	
		Hours per unit	Hours per year
Track-laying tractors	6	1050	6,300
Track-laying loaders	6	1100	6,600
Motor graders	4	830	3,320
Off-highway trucks	16	2000	32,000
Miscellaneous	10	1000	10,000

Table 9-4. Emission Factors for the Construction Equipment Listed in Table 9-2

Pollutant	Emission factor (lb/hr)				
	Tractors	Loaders	Graders	Trucks	Misc.
Carbon monoxide	0.386	0.160	0.215	1.34	0.414
Exhaust hydrocarbons	0.110	0.032	0.054	0.437	0.157
Nitrogen oxides	1.47	0.584	1.05	7.63	2.27
Aldehydes	0.027	0.009	0.012	0.112	0.031
Sulfur oxides	0.137	0.076	0.086	0.454	0.143
Particulates	0.112	0.058	0.061	0.257	0.139

Table 9-5. Annual Emissions from Construction Equipment During the Construction of the Repository

Pollutant	Source strength (lb)					
	Tractors	Loaders	Graders	Trucks	Misc.	Total
Carbon monoxide	2432	1056	714	42,880	4,140	51,222
Exhaust hydrocarbons	693	211	179	13,984	1,570	16,637
Nitrogen oxides	9261	3854	3486	244,160	22,700	283,461
Aldehydes	170	59	40	3,584	310	4,163
Sulfur oxides	863	502	286	14,528	1,430	17,609
Particulates	706	383	203	8,224	1,390	10,906

Fugitive dust will be the most common air pollutant during the construction of the WIPP. It will be produced by the pulverization and abrasion of surface materials and the entrainment of dust particles in turbulent air currents or in high winds (EPA, 1975). The frequency and the intensity of these two phenomena can be described in terms of six parameters: soil type, wind speed, surface moisture, precipitation, vegetative cover, and traffic. Emission factors for activities at a construction site have been developed (PEDCo, 1976, 1978; EPA, 1975). The emissions of particulates produced during the SPDV program were estimated from the expected levels of various activities. The results are shown in Table 9-6.

Table 9-6. Particulate Emissions During the SPDV Program

Source	Emission factor[a]	Amount	Fugitive-dust emissions[b]
Site development			
Equipment for topsoil removal	16 lb/hr	800 hr	6.4
Caliche removal and dumping	0.177 lb/ton	29,400 tons	2.6
Wind erosion[c]	--	--	111.0
Site haulage			
Salt and other heavy-duty haulage	2.52 lb/VMT[d]	20,400 miles	25.7
Commuting by workers; use of other light-duty vehicles	2.02 lb/VMT	445,900 miles	450.4
Total	--	--	596.1[e]

[a]Emission factors from PEDCo (1976, 1978), EPA (1975), and a site-specific wind-erosion analysis.

[b]Total emissions in tons over the 30-month SPDV program.

[c]Greater wind erosion than that currently observed in a site-specific analysis (SCS, 1975).

[d]Pounds per vehicle-mile traveled.

[e]If construction is conducted 24 hours per day, 7 days per week, this emission rate corresponds to 6.9 grams per second during an average year.

The levels of activities producing fugitive dust during the construction of the complete repository are not as well known. However, preliminary estimates of fugitive-dust emissions have been made by taking into account the EPA emission factor for heavy-construction operations--1.2 tons per acre per month of construction--and the dust-control methods to be used during construction. A reduction of about 50% below the values established using the EPA generic emission factor can be expected because during repository construction all haul roads will be sprayed with water as needed or otherwise treated and all disturbed areas will be sprayed with water as needed. Accordingly, for the central site area the emission rate was estimated to be 60 tons per month for a 100-acre (complete-repository) construction area. The average emission rate over a 24-hour period is 21 grams per second.

Some salt will become airborne in the mine exhaust air, some during the transfer of salt from the mine to the storage pile, and some from the erosion of the salt pile by the wind. During the SPDV phase, salt will be transported to the storage pile by truck; emissions are expected during truck loading and dumping. It is estimated that salt-dust emissions will be a maximum of 55 tons per year (1.6 grams per second) during the SPDV program.

The construction of the complete repository will generate salt-dust emissions at a rate of about 19 tons per year (0.6 gram per second) during conveyance and dumping and from the equipment working the mined-rock pile. Because the mined-rock pile will be in its early years of development, a maximum of about 5 tons of salt per year can be expected to be lost from the pile by wind erosion (Section 8.7.5).

The effects of all of these emissions on local air quality were evaluated by using long-term dispersion factors derived from meteorological data collected at the site (Appendix H, Table H-49) and by establishing the meteorological conditions that would produce the maximum 24-hour concentrations of pollutants (Smith and Taylor, 1978). These meteorological factors and the emission source strengths were used to calculate the expected ground-level concentrations of pollutants at selected receptor sites (Table 9-7). The concentrations shown in Table 9-7 indicate that the increases in air pollution over current background levels (Appendix H, Table H-51) are not expected to cause violations of air-quality standards (Appendix H, Table H-50) outside the WIPP-site boundaries. Therefore, no significant environmental effects are expected.

Noise

Construction will occur in four phases: the SPDV program, site clearing and excavation, building erection, and shaft sinking. Although these phases will at times overlap, this distinction is convenient for assessing the impact of construction noise because each phase is different acoustically. Site clearing and excavation normally produce the highest noise levels.

During the SPDV program, increased sound levels will be produced in the vicinity of the site. These increased sound levels will primarily result from the use of construction equipment at the site; maximum sound levels will occur after the completion of shaft sinking and the start of underground mining in the experimental area. Table 9-8 lists the equipment to be used and the attendant sound-pressure levels (SPL) measured at 50 feet from each unit. Analysis of these data indicates that 1 mile from the site the noise level will be reduced by hemispherical divergence to about 73 dBA. At the nearest residence, the James Ranch, 3 miles to the south-southwest of the site, the sound level during the SPDV program will be about 62 dBA. These sound levels will be clearly discernible above the ambient noise level in the area, which has been measured as 26 to 28 dBA.

In analyzing the noise produced in site clearing and excavation, it was assumed that the site will be leveled to a base elevation of 3414 feet, using the construction equipment listed in Table 9-9. This table also lists the resulting probable sound-pressure levels per unit measured at 50 feet for

Table 9-7. Summary of Air-Quality Impacts During Construction

Pollutant	SPDV development: Emission source strength[b] (lb/yr)	SPDV development: Maximum concentration[a] at site boundary (μg/m³) Annual average	SPDV development: Maximum concentration[a] at site boundary (μg/m³) 24-hour average	Complete-repository construction: Emission source strength (lb/yr)	Complete-repository construction: Maximum concentration[a] at site boundary (μg/m³) Annual average	Complete-repository construction: Maximum concentration[a] at site boundary (μg/m³) 24-hour average
Suspended particulates						
Combustion products	1,560	0.1	0.1	10,906	0.3	0.4
Fugitive dust	303,400	8.1	10.7	1,440,000	38.4	50.5
Salt dust	60,000	1.6	2.1	48,000	1.3	1.7
Total	364,960	9.7	12.9	1,498,906	39.9	52.6
Carbon monoxide	27,000	0.7	1.0	51,222	1.4	1.8
Nitrogen oxides	44,400	1.2	1.6	283,461	7.5	9.9
Sulfur dioxide	3,230	0.1	0.1	17,609	0.5	0.6

[a]Maximum increase in ground-level concentration of pollutant at the site boundary. Analysis assumes a single ground-level source at the center of the WIPP site.

[b]Maximum emissions generated in any one year of SPDV development.

Table 9-8. Inventory of Noise Sources During SPDV Development

Equipment	Number of units: Drilling phase	Number of units: Underground excavation phase	Average SPL of unit at 50 feet from the source (dBA[a])
Air compressor	2	2	81
Bulldozer	1	1	80
Crane (mobile)	1	1	83
Drilling rig	1	0	98
Front-end loader	1	1	79
Generators	1	0	78
Trucks			
Light-duty	8	10	80
Heavy-duty	2	3	91
Ventilation fans	0	4	95

[a]Data from Bolt, Beranek and Newman (1971).

equipment idling and running at maximum load. It is assumed that no blasting will be required. Excess material excavated in construction will be placed in a spoils area immediately to the southwest of the plant. Table 9-10 lists the equipment assumed to be deployed at the spoils area.

It is also assumed that (1) all the equipment at the plant site and at the spoils area is to be operated at the maximum sound-pressure level 80% of the time and (2) the equipment is to be evenly deployed over both sites. These data and assumptions were used to predict probable sound-energy averages (L_{eq}) for site clearing and excavation. At a point 400 feet north of the waste-handling building, the L_{eq} will typically range from 80 to 90 dBA.

Table 9-9. Construction Equipment and Sound-Pressure Levels

Equipment	Number of units	Single-unit SPL at 50 feet (dBA): Idle	Single-unit SPL at 50 feet (dBA): Maximum
Front-end loader	1	75	90
Bulldozer with a ripper	2	75	90
Bulldozer	4	70	88
Scraper	10	70	86
Grader	1	74	89
Compactor	4	75	90
Flatbed truck	2	70	86
Cherry picker	1	65	81

Table 9-10. Assumed Equipment and Sound-Pressure Levels at the Spoils Area

Equipment	Number of units	Single-unit SPL at 50 feet (dBA) Idle	Maximum
Grader	2	74	89
Compactor	2	75	90
Bulldozer	2	70	88

Farther from the site, the noise level will be reduced by hemispherical divergence. One mile from the site, the probable L_{eq} will be 63 dBA. At the nearest residence, the James Ranch, the expected noise level will be 53 dBA. One mile from the site, the construction noise will be clearly discernible above the ambient level of 26 to 28 dBA.

Building-erection noise tends to be broad-band and continuous. It results from working with steel for building frames, concrete placement, crane operation, and diesel trucks. The noise will be similar to that for site clearing and excavation, with occasional sporadic impulsive noise, such as that made by impact wrenches. Overall, the noise level for building erection will be about 5 to 7 dBA lower than that for site clearing.

Excavation of the various underground areas will take place throughout the construction period. The noisiest part of the drilling operation will be during the first 50 to 90 feet of drilling. Below this depth, the sound of the drill biting through the earth and rock becomes softer than the sound of the power source for the drill. The noise contribution of the drill power source will mingle with that of the other construction equipment and will not be discernible at the work-site boundary.

Some blasting is expected in shaft excavation. The off-site noise from the blasting will be most intense within the first 50 to 90 feet of excavation. While this intermittent noise will occur throughout the shaft-construction period, the off-site intensity will decrease as the shaft goes deeper.

When site clearing and excavation are started, work will begin on access roads, the railroad spur, and utility rights-of-way, contributing to the noise along construction routes. The typical L_{eq} for these types of construction activity will range from 84 to 88 dBA at 50 feet. One mile from the site, the L_{eq} will be 45 dBA.

The commuting traffic along roads to the site may increase by roughly 400 cars per hour during peak commuting periods. The noise level may then reach an L_{eq} of about 54 dBA at 100 feet from the road. As construction materials are brought to the site, regular traffic along U.S. 62/180 will also increase. Each passing diesel truck will produce a momentary sound peak of about 84 dBA measured 50 feet from the road. The increased traffic is not expected to cause any major noise impact at the ranches along the roads. Most of the residences are set well back from the road, away from road-noise sources.

At present, there are no Federal or New Mexico State standards for community exposure to noise. The EPA, however, has issued some source-related guidelines for noise emissions from construction equipment. Their objective is to protect workers as well as to reduce undue noise. Most vendors of construction equipment offer machines that meet the EPA guidelines.

In summary, noise levels will be increased in the near-site area throughout the 4.5-year construction period. The maximum area of impact (i.e., that area in which noise levels could be expected to disturb residents and wildlife) can be roughly defined as a circle of 3-mile radius around the center of the site and strips about 2000 feet wide along off-site rights-of-way. Off-site noise levels will not be of sufficient duration or magnitude to cause any significant health effects (e.g., shifts in the threshold of hearing) on local residents exposed to the noise. Local wildlife will be disturbed, with larger species migrating to areas away from the noise. These impacts on biological resources are further discussed in the following section.

Biological resources

Adverse impacts on biological resources are expected to be slight for the following reasons (Appendix H, Section H.5):

1. No proposed natural areas are present on or near the site.

2. No endangered species of plants or animals are known to inhabit the site or the vicinity of the site; nor are any critical habitats known to exist on or near the site.

3. Water requirements for the site are low.

4. The land contains soil types and vegetation associations that are common throughout the region.

5. Access in the form of dirt roads is already available throughout the area; therefore, recreational use of the area is not likely to increase significantly.

Planned mitigation measures (Section 9.6) will prevent unnecessary damage to plants and animals in areas that might be affected by fugitive dust and dispersed salt. The removal of land from rangeland habitats during construction will produce other effects on biological resources; the acreages to be removed are listed in Table 9-1.

During the SPDV program and repository construction, a total of 49 and 192 acres, respectively, will be cleared of vegetation from the shinnery oak, senecio, sage-brush, yucca, mesquite, and broom snakeweed vegetation types. All vegetation and wildlife in this area will be removed for the duration of the project. Environmental studies conducted at nearby potash mines indicate that vegetation adjacent to the mined-rock (salt) pile will be reduced or eliminated (Appendix H, Section H.5). It is probable that, in small areas near the pile, enough material will be deposited to cause adverse effects, and some vegetation may be lost. However, a 1978 field examination around a mined-rock pile at the site of Project Gnome, an underground nuclear explosion carried out in 1961 9 miles from the WIPP site, found no identifiable salt-related stress on any of the vegetation in the area with the single exception of a mesquite tree growing on one end of the pile itself (Intera, 1978). There is thus some evidence that the local vegetation may be able to adapt to a more saline environment than it is now experiencing.

In addition to the areas that will be cleared of vegetation, 18 and 710 acres of existing vegetation will be disturbed, respectively, for rights-of-way corridors during the SPDV program and repository construction. For the complete repository, 112 acres of rights-of-way will be covered with roads and railroads (Table 9-1). Creosote bush may invade the roadway and railroad and thrive there, providing cover in these corridors. Much of the land cleared during construction will revert to natural vegetation. Although some of the removed plant species may remain absent from the rights-of-way for years, the impact is considered minor because the removed species are very common in the region.

Impacts on wildlife from construction can be classified as follows:

1. Direct mortality of nonmobile species, such as small and burrowing mammals, ground-nesting birds, reptiles, and insects.

2. Displacement of mobile species (including game species and birds) by the loss of habitat and human intrusion (visibility of people and increased noise levels).

3. Increased competition and stress among species in adjacent areas.

4. Direct loss of species from road kills and poaching.

No unique species or populations have been identified at the site, and the loss of individuals of the species present is not significant to the overall ecology of the site area.

The environmental impact of corridors has been studied by ecologists for a relatively short time, and concepts are still in the formative stages. A number of impacts can be expected from the construction of rights-of-way. Some raptor deaths may be caused by electrocution on utility lines, but the lines will be designed to minimize such occurrences (Bulletin 61-10 of the Rural Electrification Administration). Although some negative effects (increased animal mortality, inhibition of animal movements) should be expected when the roads are built, roadways often have a positive effect on local biota by increasing the diversity of habitats. Corridors provide habitat that may favor the establishment of small-mammal communities differing in composition from surrounding communities. Animals adapted to open areas may appear in the new communities, and transient species may be able to outcompete residents.

Right-of-way construction will frighten and displace the larger and more mobile wildlife inhabitants. This disturbance is attributed not only to habitat removal but also to an increase in the visibility of people and frequent sharp increases in ambient noise levels. The displaced species will migrate to adjacent undisturbed habitats and may temporarily cause an ecological imbalance or stress condition in local adjacent habitats, resulting in a loss of most of the displaced organisms. The highly mobile game species present at the site, the mule deer and the pronghorn, while displaced, are not expected to suffer any significant losses in their local population because the area of disturbance will be small when compared to the normally large ranges of these species. Bird populations, on the other hand, may benefit from right-of-way corridors (Anderson et al., 1977). The increased habitat diversity (the "edge effect") increases the densities of some bird species. Summer residents have sometimes increased in density at the apparent expense of year-round residents.

9.2.2 Resources Consumed During Construction

According to current estimates, the construction of the WIPP will require 22 million gallons of water during the 4.5-year construction phase. This water will be purchased from, and delivered by, the Double Eagle System, a part of the Carlsbad municipal water system. The use of this allotment of water by the plant will not preempt existing industrial, agricultural, or municipal uses of water. Although the City of Carlsbad has purchased the rights to this water, it has neither piped it in nor allocated it for municipal or agricultural uses. Moreover, the quantity of water required by the plant (about 17 acre-feet per year) is less than 0.3% of Carlsbad's current withdrawal from the Capitan reef (Appendix H, Section H.3).

The types and estimated quantities of building materials to be used during the construction of the WIPP, including the SPDV program, are given in Table 9-11. The use of these construction materials for the WIPP will not significantly affect their availability in the region. Because the quantities of materials required are very low in comparison with the national production of them, their use for the construction of the WIPP should not forestall other construction.

The electrical power and the fuels to generate electrical or mechanical power during construction are given in Table 9-12.

The electrical power for the construction as well as the operation of the WIPP will be purchased from the Southwestern Public Service Company (SPSC).

Table 9-11. Construction Materials for the WIPP[a]

Material	Estimated quantity	1976 U.S. production[b]
Concrete	125,000 bbl portland cement	387 million bbl portland cement
Steel	15,000 tons	127.9 million tons
Copper	150 tons	1.6 million tons
Lumber	0.5 million board feet	96,905 million board feet
Other materials	No estimate	

[a]Including SPDV development.
[b]Data from the U.S. Department of Commerce (1977).

The fuel required to produce this 4 million kilowatt-hours will be an insignificant addition to the fuel currently used to produce the 750 million kilowatt-hours that SPSC supplies each year to its Carlsbad service area.

The fuels required by the plant, and by the labor force for commuting to and from work will probably be purchased from regional sources and retailed by local suppliers.

Table 9-12. Estimated Energy Consumption During WIPP Construction[a]

Power source	Approximate quantity
Electricity	
Total, kilowatt-hours	4 million
Peak demand, kilowatts	1700
Normal demand, kilowatts	850
Propane, gallons	140,000
Diesel fuel, gallons	1.5 million
Gasoline, gallons	940,000

[a]Including SPDV development.

9.2.3 Denial of Mineral Resources

This section describes the economic significance of the specific quantities and grades of potash and hydrocarbon resources beneath the WIPP site. As discussed in Section 7.3.7, potash and hydrocarbons are the deposits that would be most affected. A more comprehensive discussion of these resources is given in the Geological Characterization Report (Powers et al., 1978, Chapter 8).

It is important to note that the denial of mineral resources is here considered only as it applies to the public, and not to the individual owner or lessee. If the WIPP is constructed, the individual can be compensated for his loss, but the possibly permanent loss to the public of natural mineral resources must be considered among the environmental consequences of land commitment to the project.

Apart from the denial of resources, the presence of these minerals may have another impact. This is their potential attractiveness to future generations, with the attendant concern that exploration or exploitation might lead to a premature breach of the repository. The possibility of such a breach and its consequences are considered in Section 9.7.1.5.

9.2.3.1 Summary

The mineral resources that are expected to underlie the four control zones of the WIPP site are caliche, gypsum, salt, sylvite, langbeinite, crude oil, natural gas, and distillate. Potassium salts (sylvite and langbeinite), which occur in strata above the repository, and hydrocarbons (crude oil, natural gas, and distillate), which occur in strata below the repository, are the only resources of practical significance and may be considered reserves (Table 9-13). ("Resources" are minerals that are currently or potentially of economic value; "reserves" are the portion of the resources that are economic at today's market prices and with existing technology.)

The commitment of land to the WIPP may reduce the availability of some potassium salts and hydrocarbons. In order to put the denial of these minerals in perspective, one needs to compare them with regional, national, and world resources and reserves. Table 9-14 contains the elements for such a comparison. The data reveal that, except for langbeinite (for which there are substitutes), the total land commitment has little effect on the regional availability of minerals and almost no national significance. This is true whether the comparison is from the standpoint of resources or reserves.

The DOE has found no technical or safety reason to prohibit drilling and mining in control zone IV of the type now practiced in the area. Therefore, the DOE may allow such drilling and mining; if it does, the impacts of withdrawing mineral resources and reserves will be reduced from those indicated for the total site. As shown in detail in Section 9.2.3.7, the exploitation of control zone IV would recover a significant fraction of the minerals--73% of the langbeinite reserves and 53% of the natural gas, for example.

Table 9-13. Total Mineral Reserves at the WIPP Site

Reserve	Quantity	Depth (ft)	Richness
Sylvite ore[a]	27.43 million tons	1,600	13.33% K_2O
Langbeinite ore[b]	48.46 million tons	1,800	9.11% K_2O
Natural gas[c]	44.62 billion ft^3	14,000	1100 Btu/ft^3
Distillate[d]	0.12 million bbl	14,000	53^{o} API

[a]The sylvite deposits are equivalent to 3.66 million tons of K_2O; they do not quite meet 1977 market conditions according to the U.S. Bureau of Mines (USBM, 1977).

[b]Equivalent to 4.41 million tons of K_2O. Data from the U.S. Bureau of Mines (USBM, 1977).

[c]Data from Keesey (1979).

[d]From data presented by Keesey (1979).

Table 9-14. Significance of the Resources and Reserves at the WIPP Site

Deposit	WIPP site	Region	United States	World
		RESOURCES[a]		
Sylvite (at lease grade)				
Quantity, million tons ore	88.5	4260	8500	850,000
Percentage at WIPP site		2.1	1.0	0.010
High grade	54.0			
Low grade	133.2			
Langbeinite (at lease grade)				
Quantity, million tons ore	264.2	1140	No estimate available	
Percentage at WIPP site		23 (21.5 as K_2O)		
High grade	77.6			
Low grade	351.0			
Crude oil				
Quantity, million barrels	37.50	1915	200,000	Not available
Percentage at WIPP site		2.0	0.019	
Natural gas				
Quantity, billion cubic feet	490	25,013	855,000	Not available
Percentage at WIPP site		2.0	0.057	
Distillate				
Quantity, million barrels	5.72	293	Not available	
Percentage at WIPP site		2.0		
		RESERVES[b]		
Sylvite[c]				
Quantity, million tons K_2O	3.66	106	206	11,206
Percentage at WIPP site		3.4	1.8	0.033
Langbeinite[d]				
Quantity, million tons K_2O	0.92[d]	9.3	9.3	Not available
Percentage at WIPP site		10	10	
Crude oil				
Quantity, million barrels	Nil	471.7	29,486	646,000
Percentage at WIPP site		0	0	0
Natural gas				
Quantity, billion cubic feet	44.62	3865	208,800	2,520,000
Percentage at WIPP site		1.15	0.021	0.0018
Distillate				
Quantity, million barrels	0.12	169.1	35,500	Not available
Percentage at WIPP site		0.07	0.0003	

[a]Data sources: Hydrocarbons, Foster (1974) for the site and region; potash salts, John et al. (1978) for the site and region; Brobst and Pratt (1973) for U.S. oil and gas and the world resources of sylvite.

[b]Data sources: Hydrocarbons, Keesey (1979) for the site, American Petroleum Institute (1978) for the region, the United States, and the world; potash salts, U.S. Bureau of Mines (USBM, 1977).

[c]The U.S. Bureau of Mines (USBM, 1977) does not consider any sylvite to be commercial today. However, one bed (mining unit A-1) of sylvite was marginal and has been added to the reserve list.

[d]Estimated from the AIM (1979) study. The USBM estimate for the WIPP site is 4.41 million tons K_2O equivalent, but no comparable USBM estimate is available for the entire district.

9.2.3.2 Potash Resources and Reserves

The basic study of potash resources was conducted by the U.S. Geological Survey (USGS) (John et al., 1978). The USGS has subsequently provided additional data in its comments on the WIPP draft environmental impact statement (letter, Larry E. Meierotto, Assistant Secretary, Department of the Interior, to Ruth Clusen, Assistant Secretary, Department of Energy). The amounts of potash at the WIPP site were estimated by using the three grade standards given in Table 7-6. The high grade is typical of that now mined in the Delaware basin, although ore of the intermediate, or "lease," grade is mined by some companies. The quantities of all three grades are summarized in Table 9-14, which uses the lease-grade standard for comparisons with other regions because it is the grade most comparable with the other information available.

Two separate studies (USBM, 1977; AIM, 1979) have been conducted to determine what portion of the potash resources at the WIPP site is presently (1977 and 1978) economic and may be considered as reserves. The two studies used the same basic information from the USGS (John et al., 1978), but they adopted somewhat different assumptions about the development of mining units and the time frame within which reserves would be developed. When these differences in assumptions are recognized, the variation in reserve estimates and values per ton of ore in place can be understood. The AIM report was developed particularly to provide estimates of lease values and the value of ore in place. The USBM study results in higher estimates for potash reserves than does the AIM study, and the larger USBM values will be used in most tables in this document. For comparison, however, AIM and USBM reserve estimates, in terms of product, are shown in Table 9-15.

Table 9-15. Estimates of Potash Reserves at the WIPP Site

Product	Estimated quantity (million tons) AIM Study	USBM Study
Langbeinite ($K_2SO_4 \cdot 2MgSO_4$)	4.2	14.1
Muriate (KCl)	1.8	4.9[a]
Sulfate (K_2SO_4)	4.2	6.0
Total	10.2	25.0

[a]Assumed marginally economic by the USBM.

These products are derived from 29.7 million and 75.9 million tons of ore for the AIM and USBM estimates, respectively. The value of in-place ore was estimated by AIM at about 14 cents per ton for sylvite and at a current value of 5 cents per ton for langbeinite, under the assumption that the langbeinite would not be developed until after 20 years. Using the higher USBM ore tonnage and the AIM values for in-place ore, the value of the reserves today amounts to approximately $6.3 million. This may be contrasted with the gross value of the product, if sold at "current" (1977) prices (langbeinite $48 per ton; muriate $42 per ton; sulfate $94 per ton), which would amount to about $1.4 billion.

Langbeinite, a relatively rare evaporite mineral found in commercial quantities only in the Carlsbad area and in eastern Europe, is used chiefly as a fertilizer. Containing soluble potassium, magnesium, and sulfur, it is desirable for soils that require such elements but cannot tolerate additional chlorine. Langbeinite is marketed directly as the refined mineral or used, together with sylvite, to manufacture potassium sulfate (K_2SO_4). Potassium sulfate is also beneficial to plant growth, but it lacks soluble magnesium. Immense potassium sulfate resources exist in the Great Salt Lake, Utah, and other brine lakes, and it is produced from these brines at present (AIM, 1979).

Langbeinite deposits are present in substantial amounts at the WIPP site, and their extent has been well delineated. Recent studies by the USGS (1979) report 1.14 billion tons of langbeinite resources at lease grade (averaging 6.6% K_2O) in the Carlsbad Mining District.

The langbeinite reserves at the WIPP site are equivalent to about 15 years of production at current rates, with 73% of this reserve occurring in control zone IV. The inner control zones (I, II, III) contain reserves equivalent to 4 years of production.

9.2.3.3 Significance of the Results of the Potash-Resource Evaluation

Estimates of the total potash resource are considered to be sufficiently accurate for this study because of the density of exploratory drilling at the WIPP site and in adjacent areas. The resource estimates are believed accurate to ±20%. The data base exceeds both in quality and in quantity that available to other investigators who have formulated national or worldwide resource estimates. Additional drilling in the area of the site would enhance the accuracy of the estimate of resources, but no change exceeding a few percent plus or minus is expected. The determination of reserves is more difficult, and drilling on centers as close as 1000 feet could be required to outline the boundaries of ore bodies to meet the rigid modern requirements of assumed economic minability.

Most of the site is underlain by deposits of potassium salts classifiable as resources. All but the very center and parts of the southwestern part of the site contain potash resources, when judged by the intermediate standard termed "lease grade" in Table 7-6 (Figure 9-1). This mineralization, discovered mostly by the 21 exploratory holes drilled by the DOE, has justified an expansion of the Known Potash District. When first selected in late 1976, the site was thought to lie mostly outside the district, but is now known to lie mostly inside.

However, these resources need to be placed in perspective. Although the numbers by themselves appear large, they are relatively small when compared with potassium salts available nearby in the Carlsbad Potash Mining District and even more so when compared with national and worldwide resources. The discussion will begin with sylvite, which has much smaller significance in terms of either regional or national resources.

The USGS estimates that the Carlsbad Potash Mining District contains 5400 million tons of potassic salts, mostly sylvite, that meet the lease standard

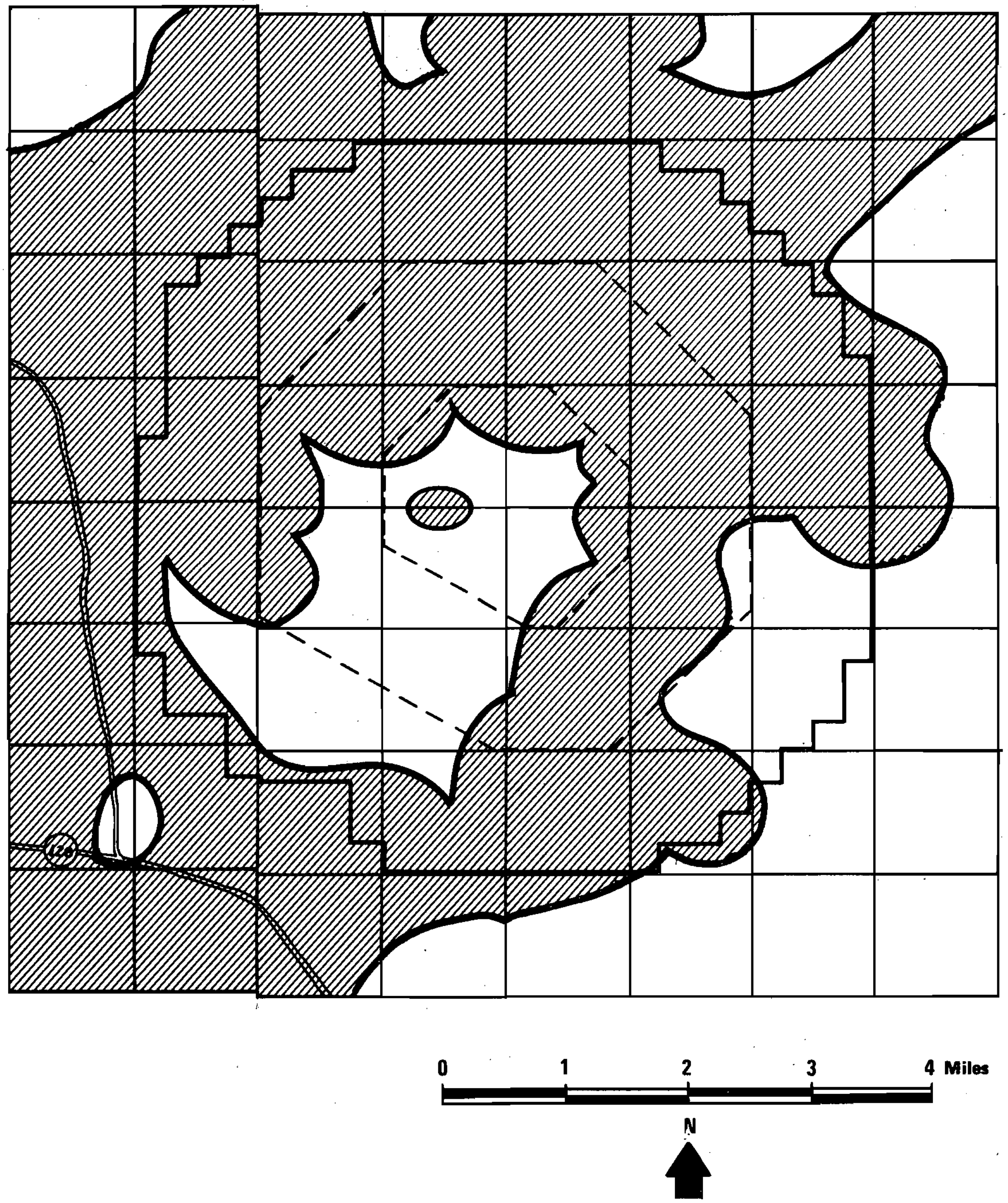

Figure 9-1. Composite map of mineralization in various ore zones at lease grade for sylvite and langbeinite. Shaded area lies within the Known Potash District (USGS, 1979).

(i.e., contain 10% of K_2O equivalent or better). The WIPP site contains 88.5 million tons of sylvite-bearing lease-grade resources, or only 2.09% of the resources available nearby. The potash resources of the entire United States that can meet the 10% K_2O as sylvite requirement are at least twice as large as those in the Carlsbad District. Hence, the total land commitment for the WIPP results in a denial of less than 1% of the national resources of sylvite.

Langbeinite contained within the site is of more significance. Langbeinite is both a rare and a useful potash mineral. Furthermore, Carlsbad is the only source of this mineral in the free world. Only two mining companies (International Minerals and Chemical Corporation and Duval Corporation) are presently mining and marketing langbeinite (about 300,000 tons per year), and they have made no public disclosure of their leased resources in order to protect their exclusive rights. The USGS has recently estimated that the langbeinite resources in the Carlsbad District amount to 1140 million tons at an average grade of 6.6% K_2O. The site contains considerable langbeinite resources, 264.8 million tons of 6.10% K_2O equivalent "ore," or about 21.5% of the total Carlsbad District resource (as K_2O). The grade of langbeinite currently being mined has not been disclosed, but is estimated to be approximately 8% K_2O equivalent. The USGS estimates that the site contains 79.2 million tons of langbeinite resources of this quality.

9.2.3.4 Significance of the Results of the Potash-Reserve Evaluation

Beginning with a resource lease standard of 88.5 million tons of sylvite-bearing mineralization and 264.8 million tons of langbeinite-bearing mineralization, the USBM determined that only 48.46 million tons of the langbeinite mineralization can be considered ore when using the economic criteria and product prices appropriate for the 1977 study (Table 9-14). This zone of economic langbeinite has been designated the B-1 mining unit, and it occurs in the northern portion of the WIPP site (Figure 9-2).

The 48.46 million tons of langbeinite ore in the WIPP-site portion of mining unit B-1 averages 9.11% K_2O, to provide 4.41 million tons of K_2O equivalent (USBM, 1977). No comparable economic study has been conducted for other langbeinite reserves, so the estimates from the AIM study are used to establish the comparable langbeinite reserve values for both the WIPP site and the region. The AIM estimates for recoverable langbeinite from the Carlsbad District and the WIPP site are 42.2 million and 4.2 million tons, respectively. Therefore, the WIPP site contains about 10% of the recoverable langbeinite. Since Carlsbad is the only district in the United States that produces langbeinite, these figures are significant in terms of possible resource commitment.

While the langbeinite at the site is a significant mineral reserve, mining it would not greatly extend the quantities that the Carlsbad area can produce. The Carlsbad area outside the WIPP site (AIM, 1979) may contain no more than 38 million tons of recoverable langbeinite reserves (8.4 million tons K_2O) or 63 million tons of recoverable langbeinite resources (13.9 million tons K_2O); thus the supply is exhaustible. Currently the reserves are being depleted by mining at a rate of 300,000 tons of K_2O per year (USGS, 1979;

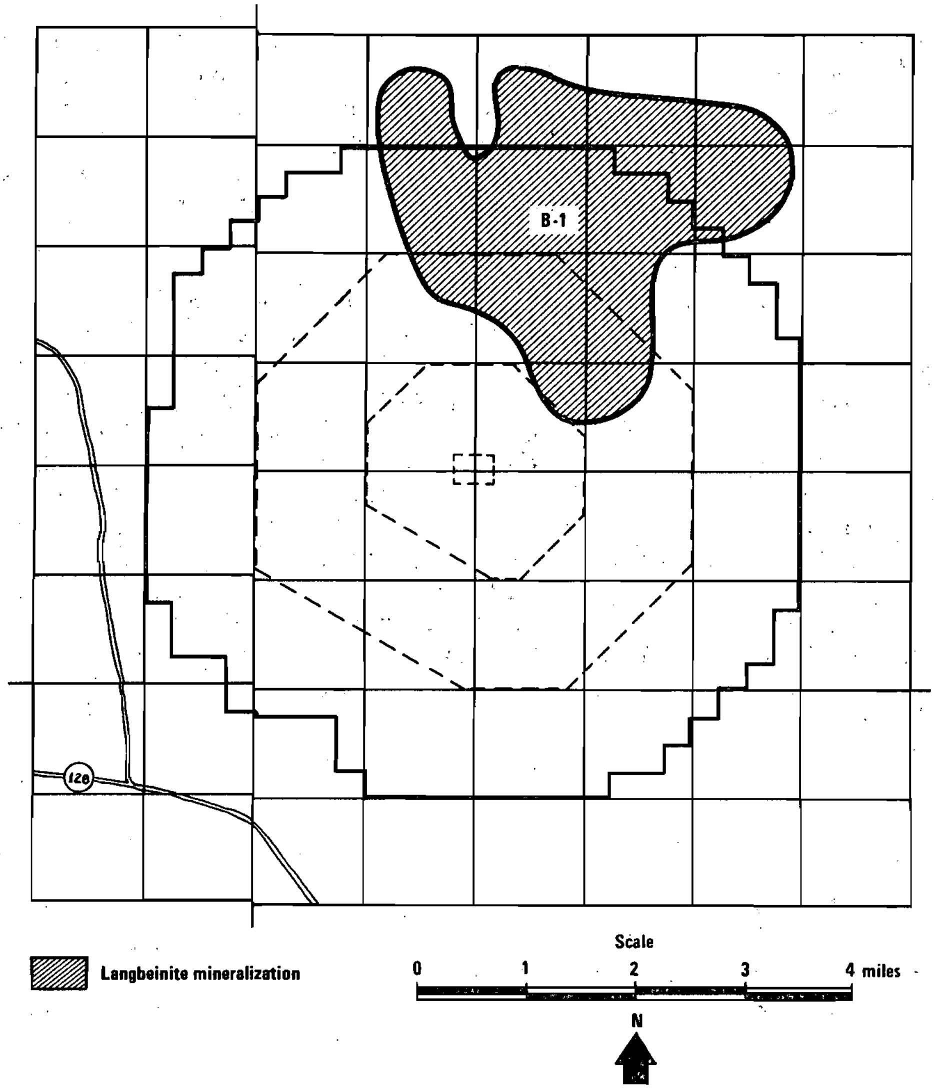

Figure 9-2. Economic langbeinite mineralization in mining unit B-1. (After USBM, 1977).

comments on the WIPP draft environmental impact statement). The projected life of the operations is 28 years if the projection is based on reserves and perhaps 46 years if the projection is based on resources. Because Carlsbad is the only known langbeinite district in the United States, it will eventually be necessary to substitute other minerals. The use of the total reserve at the site, as estimated by the USBM, would forestall this depletion by only 15 years at the most, and if control zone IV is mined, the WIPP reserves would account for only 4 years of production.

Although langbeinite is a desirable plant fertilizer, there are substitutes. Potassium sulfate is the principal beneficial ingredient. For that matter, some langbeinite produced from Carlsbad is transformed into potassium sulfate by a base-exchange process between langbeinite and sylvite:

$$K_2SO_4 \cdot 2MgSO_4 + 4KCl \longrightarrow 3K_2SO_4 + 2MgCl_2$$

Potassium sulfate can also be produced by the Mannheim process, a reaction between sylvite and sulfuric acid:

$$2KCl + H_2SO_4 \longrightarrow K_2SO_4 + 2HCl$$

Potassium sulfate is also present in the brine water of the Great Salt Lake, Utah, and is now being extracted commercially. Brines in Searles Lake, California, also contain commercial quantities. No estimate of the reserves of potassium sulfate contained in these brines has been published, but AIM engineers estimate that these reserves are approximately six times larger than what AIM believes is present in the langbeinite ores at Carlsbad. They also believe that a synthetic langbeinite can be produced by the solar evaporation of seawater. These alternative sources will be somewhat more expensive than the conventional mining and refining of natural langbeinite deposits.

If liberal allowance is given to the mining unit designated A-1 in Table 7-8, either by improvement in the market price for muriate or by advances in extraction technology, then the resources assigned to that unit could be classed as reserves. The average grade of this potential ore is 13.33% K_2O as sylvite. Therefore, the ore bed within the site contains 3.66 million tons of K_2O. The USBM has estimated that the Carlsbad District contains 106 million tons of K_2O as reserves; the site represents only 3.4% of that reserve. These percentages are considered to be so small that little effect can be expected from the denial of the sylvite reserves at the site.

The values associated with the potash reserves may be considered in several ways. Table 9-16 presents two evaluations. One, the gross product value, is the price the end product would bring when sold on the market at average 1977 prices. The other value is the price the in-place ore would be worth to a company. The latter recognizes such aspects as production costs, development times, and economics. The table also assumes the sylvite resource in the WIPP site is economic--a marginal assumption according to USBM studies.

Table 9-16. Product Gross Value and In-Place Ore Value of the Potash Reserves at the WIPP Site

Resource or product	Product gross value (million dollars)	In-place ore value (million dollars)
Sylvite	205.8	3.84
Langbeinite	676.8	2.42
Sulfate	564.0	--
Total	1446.6	6.26

The USBM (letter, 1977) has determined the income that would be foregone by the State and Federal governments if the portion of the B-1 mining unit within the WIPP site were not developed. The results are in Table 9-17.

Table 9-17. Income Foregone by Governments

Type of revenue	Income foregone (million dollars) State government	Federal government
Bonus bid	4.8	22.0
Royalty payments (State)	3.3	--
Royalty payments (Federal)	7.3	7.3
State taxes (property, severance, etc.)	4.9	--
State taxes (income)	2.0	--
Federal taxes (income)	--	16.5
Total	22.3	45.8

9.2.3.5 Significance of the Hydrocarbon Resources

Table 9-14 puts the hydrocarbon resources into perspective. While the quantities of hydrocarbons that may exist under the site are large, they account for only 2.0% of the crude oil, 2.0% of the natural gas, and 2.0% of the distillate that could exist in the region. (The region is here defined as the area studied by the New Mexico Bureau of Mines and Mineral Resources. That area contains 967,700 acres, or 1512 square miles, versus only 18,960 acres, or 29.625 square miles, for the site.) On a national basis, the expected crude oil at the site accounts for only 0.019% and natural gas for only 0.057% of U.S. resources.

9.2.3.6 Significance of the Hydrocarbon Reserves

The estimated hydrocarbon reserves at the site are 44.62 billion cubic feet of natural gas and 118,524 barrels of distillate. Table 9-14 compares these reserves with similar estimates for the region, the United States, and the world. The natural gas amounts to 1.15% of the quantity expected in the region. The distillate is less, 0.07%. On a national level, the percentages reduce to 0.021% for gas and 0.0003% for distillate.

The undiscounted gross value of these products, if sold at anticipated well-head prices, would be $146.4 million. The value of the products minus operating costs and discounted 16.25% is $83.1 million. The cost of drilling the 20 wells to produce these reserves would be $72.5 million. Thus the value of the reserves in place might be considered to be $10.6 million. (One may also consider the value of the resources, if they could be produced, by evaluating the production history of the other 34 hypothetical wells. This results in a gross well-head value of $141.1 million or a discounted (16.25%) value of $85.7 million. The cost of drilling these 34 wells would be $109.3 million--more than the discounted value of the hydrocarbons.)

The maximum potential values lost to the State of New Mexico have been determined by assuming that none of the 54 possible hole locations within the

WIPP site could be drilled and that no gas or distillate is produced, thereby foregoing the maximum resource estimates established by Keesey (1979). The estimate of State income lost is based on State royalties (12.5%) on the three State tracts (five wells) and the severance and ad valorem taxes from all 54 wells.

Since all these resources may be produced by vertical or deviated (directional) drilling from outside control zone III, none of the income in Table 9-18 is necessarily lost by the State of New Mexico. Section 9.2.3.7 and Table 9-19 discuss the reduction in impact that can be achieved by allowing the production of reserves in control zone IV. As noted in Section 9.6.5, at some additional cost all reserves can be developed by deviated drilling. These additional costs could make the venture unattractive to industry unless compensated by the government for the incremental costs.

Table 9-18. Maximum Possible Loss of State Income Due to Denial of WIPP Hydrocarbon Reserves

Type of revenue	Amount lost
State royalties	$ 5,030,000
Severance tax	4,364,000
Ad valorem tax	9,713,000
Total	$19,107,000

9.2.3.7 Reduction of Impact on Potash and Hydrocarbons by Exploitation of Control Zone IV

To a large extent the mineral deposits at the WIPP site lie under control zone IV, the outer control zone. Mining and drilling may be allowed in this zone if they do not affect the integrity of the site. Potash mining by methods employed in the present operations in the Carlsbad District would be permitted, but no solution mining would be allowed. Hydrocarbon exploration in control zone IV would be permitted by the DOE, but no water-flood recovery methods or extensive hydrofracture stimulation would be allowed. Holes would be plugged after their useful life.

Table 9-19 gives data showing the reduction in impact if the minerals in control zone IV are exploited. More than half the hydrocarbon resources and more than two-thirds of the potash resources would become available. Perhaps the most significant reduction would be in the impact on langbeinite: nearly three-fourths of the reserves can be reached by mining in control zone IV.

Applying the factors of Table 9-19 to the maximum values lost to the State government, one finds that exploitation in control zone IV would reduce this lost income to $6 million for potash and $9 million for natural gas. These are rough estimates that would require further refinement should such data be required as a basis for the settlement of claims.

Table 9-19. The Effect of Allowing the Exploitation of Hydrocarbons and Potash in Control Zone IV

Deposit	In total site	In inner zones (I, II, III)	Percentage of total recoverable in zone IV
	RESOURCES		
Sylvite,[a] million tons ore	133.2	39.1	71
Langbeinite,[a] million tons ore	351.0	121.9	65
Crude oil,[b] million barrels	37.50	16.12	57
Natural gas,[b] billion cubic feet	490	211	57
Distillate,[b] million barrels	5.72	2.46	57
	RESERVES		
Sylvite,[c,d] million tons ore	27.43	Nil	100
Sylvite,[c,d] million tons K_2O	3.66	Nil	100
Langbeinite,[c] million tons ore	48.46	13.3	73
Langbeinite,[c] million tons K_2O	4.41	1.21	73
Crude oil, million barrels	--	--	--
Natural gas,[e] billion cubic feet	44.62	21.05	53
Distillate, million barrels	0.12	0.03	75

[a]Data from John et al. (1978, Table 4).

[b]Computed from data presented by Foster (1974) by proportion of area of zone IV to the total area of the site.

[c]Data from the U.S. Bureau of Mines (USBM, 1977, Table 5).

[d]Sylvite resource is considered subeconomic by the USBM.

[e]Computed from data presented by Keesey (1979), considering that only reserves under the inner three zones are precluded from development.

9.3 EFFECTS OF PLANT OPERATION

This section describes the environmental effects of plant operation. It covers effects exerted on the biophysical environment, the effects of routine releases of radioactivity, the resources committed for operation, and the effects of decommissioning and dismantling the WIPP at the end of its operating life.

9.3.1 Biophysical Environment

Terrain

During the operation of the WIPP, salt and other mined materials will be removed from underground to provide repository space. The pile for storing this material will reach a maximum of 30 acres in area and 60 feet in height. This pile at the site could be considered an unpleasing anomaly in the natural terrain.

Soils

No additional acreage beyond that already set aside in the construction phase will be needed for WIPP operations, and no major additional impacts on soils are expected. Because material will continue to be added to the mined-rock pile during operation, fresh salt will be exposed to rain as well as to water sprayed from time to time for dust control. The airborne material will deposit on the soil. However, field investigations of a 17-year-old mined-rock pile that used to be at the Gnome site 9 miles southwest of the WIPP site suggest that the dispersion and deposition of mined materials will not induce severe impacts on the soils of the region.

Water resources

The sources of sanitary and other nonradioactive wastes generated during operation are described in Section 8.7. Although these wastes will be collected, treated, and disposed of, there is a possibility that they might adversely affect the environment. The potential adverse effects are described in this section for each type of waste.

Sanitary-waste discharges during normal operation will amount to about 25,000 gallons of treated effluent per day. The treated effluent will be used for landscape irrigation and dust control. Any effluent discharged by the sanitary-waste-treatment system will meet State water-quality standards (NMWQCC, 1977) for discharges onto or below the surface of the ground. Any discharge will be to a dry arroyo. No areally extensive groundwater is within 500 feet of the surface at this point. Accordingly, no effluents from the sanitary-waste-treatment system are expected to affect local surface-water or groundwater resources.

Small quantities of waste hydraulic fluid, lubricants, and the like will be generated during operation. These materials will be disposed of in the sanitary landfill or shipped off the site for salvage. Because of the small quantities involved, the environmental effects of these waste materials will be negligible.

Air quality

As described in Section 8.7.5, the maximum salt-dust releases during mining operation are expected to be as follows:

1. Exhaust from underground mining, 1300 pounds per year.

2. Emissions from the surface salt-handling system, 38,000 pounds per year.

3. Wind erosion of the mined-rock pile, 80,000 pounds per year.

During mine backfilling, total salt-dust emissions are expected to be about 52,000 pounds per year (Section 8.7.5).

A small quantity of nonradioactive gases will be released as a result of experiments conducted at the WIPP. These experiments (described in Section 8.9) will produce small amounts of hydrogen from the corrosion of containers and the hydrolysis of brine, helium from radioactive decay, and hydrogen chloride from brine decomposition (Section 8.7.5). The quantities released to the atmosphere will be very small; they will have a negligible effect on the environment.

There will be three major sources of emissions from the combustion of diesel fuel: the emergency-power system, the surface handling equipment, and the underground handling equipment. In addition, an oil-burning salt drier will be used at the mined-rock pile starting about 6 years after the WIPP begins operating. The total emissions from these systems are given in Section 8.7.5, Table 8-9.

For the area around the WIPP, Table 9-20 gives the annual average ground-level concentrations of suspended particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and the gases generated in experiments. None of these concentrations approach ambient air-quality standards. They are sufficiently low not to cause any discernible secondary impacts, such as reduced visibility or damage to vegetation. A comparison of the concentrations with air-quality standards (Appendix H, Table H-50) shows that these air-quality impacts are negligible.

Noise

Normal operating noise will come primarily from control zone I and the mined-rock pile. It will be louder in the day than at night. There will be several noise sources within the site. The primary sources and typical sound-pressure levels are listed in Table 9-21. An overall sound-pressure level of 50 dBA can be expected 400 feet from the waste-handling building This is within the range of the acceptable-noise guidelines issued by the U.S. Department of Housing and Urban Development (HUD, 1971) and shown in Table 9-22. At the James Ranch, the nearest off-site residence, about 3 miles away, the operating noise is expected to be inaudible.

The storage of mined rock will continue throughout construction and operation. Little fluctuation is expected in the noise level generated by this activity over the lifetime of the repository. The equipment used at the storage area during operation is assumed to be the same as that needed during construction (Table 9-9).

Table 9-20. Summary of Air-Quality Impacts During Operations

Pollutant	Mining phase			Backfilling phase		
	Emission source strength (lb/yr)	Maximum concentration[a] (μg/m^3)		Emission source strength (lb/yr)	Maximum concentration (μg/m^3)	
		Annual average	24-hour average		Annual average	24-hour average
Suspended particulates						
Combustion products	4,770	0.2	0.3	6,370	0.2	0.4
Salt dust	79,300	3.0	4.8	52,000	1.9	3.1
Total	84,070	3.2	5.1	58,370	2.2	3.5
Carbon monoxide	15,380	0.6	0.9	19,380	0.7	1.2
Nitrogen oxides	81,200	3.0	4.9	98,800	3.7	6.0
Sulfur dioxide	5,030	0.2	0.3	61,830	2.3	3.7
Gases from experiments						
Hydrogen	0.91	3.4×10^{-5}	5.5×10^{-5}	0.91	3.4×10^{-5}	5.5×10^{-5}
Helium	0.0004	1.5×10^{-8}	2.4×10^{-8}	0.0004	1.5×10^{-8}	2.4×10^{-8}
Hydrogen chloride	0.28	1.0×10^{-5}	1.7×10^{-8}	0.28	1.0×10^{-5}	1.7×10^{-5}

[a]Maximum increase in ground-level concentration of pollutant at the site boundary. The analysis assumes a single ground-level source at the center of the WIPP site.

Table 9-21. Typical Noise Levels Produced During Operation

Noise source	Noise level at 50 feet (dBA)
Water pumphouse	31
Hoist house	31
Transformer and switchyard	48
Mine-construction exhaust	41
Train movement	75

Table 9-22. Department of Housing and Urban Development Criteria for Noise Assessment (HUD, 1971)

HUD assessment	8-Hour noise level (dBA)
Unacceptable	75
Normally unacceptable	65-75
Normally acceptable	45-65
Acceptable	45

At 50 feet from the equipment, a maximum sound-pressure level of 97 dBA can be expected with all the equipment operating concurrently at full throttle and load. Rarely will all the equipment be operating simultaneously, and the sound-pressure level will be more typically in the upper 70s. At the James Ranch, the maximum sound level is expected to be 47 dBA. This sound level would be audible, but not sufficient to result in significant disturbance.

Noise at the site will disturb some wildlife species (e.g., mule deer), but most of the resident species will become accustomed to it.

Each of the three standby diesel generators is to be tested once a month for 1 to 2 hours. During the testing period, the noise from the diesel generator will be the loudest noise from the WIPP. Noise will radiate from the exhaust stack and through the air-intake louvers on the diesel-generator building. At the boundary of control zone I, the noise level is predicted to be 55 dBA. At the James Ranch, the noise will be inaudible.

For purposes of noise estimation, it was assumed that approximately 400 people will be employed by the WIPP during the normal one-shift operation. The peak traffic load along the roads could be increased by a maximum of 400 cars per hour during commuting hours. The increased passenger-car traffic will generate a sound-energy average of 52 dBA at 100 feet from the roads.

Truck traffic along the roads to the site will increase during operation. Some of the waste to be stored will arrive by truck, and there will also be trucks bringing supplies and materials. The number of passenger vehicles and trucks along U.S. 62/180 will be smaller during operation than during construction (Section 9.1). Noise levels are not expected to have a significant adverse impact on people or wildlife.

Most of the radioactive waste for the repository is to arrive by rail. To reach the WIPP rail spur, the railcars will pass through Carlsbad and along the Atchison, Topeka and Santa Fe line to Loving. At normal operating speeds along this route, the train noise will be about 92 dBA at 100 feet from the tracks and about 55 dBA at 1 mile. This noise level should not cause any adverse impact: wildlife will become accustomed to it. At the closest residence, the noise level will be below 55 dBA; there are no residences within a mile of the rail spur.

Comparison with the HUD general noise-assessment criteria (Table 9-22) shows that the operating noise at the James Ranch will be in the acceptable range (less than 45 dBA). Near the proposed new rail spur and along U.S. 62/180, the operating noise should be in the normally acceptable range (45 to 65 dBA). Accordingly, no significant noise impacts, such as health effects on local residents, are expected, but wildlife will be frightened and temporarily displaced until they become acclimated.

Vegetation

Because no new areas will be cleared during operation, impacts on vegetation will result primarily from the continued use of cleared areas. The dispersion and deposition of salt and other mined-rock particles from the storage pile will continually affect local vegetation. However, field observations at the Gnome-site salt pile (Section 9.2.1) indicate that these impacts may not be significant.

Wildlife

A fence will keep large animals out of control zone I and the evaporation pond in control zone II. There will be no migratory barriers at the site because antelope fences, which allow deer and antelope to pass, are planned for access roads and because other rights-of-way will not be fenced. Traffic on the access roads and railroad may be hazardous to nonmigratory animals; however, it will affect only populations within a few hundred feet on either side of the road.

Operational noise will frighten resident wildlife species, but after a period of time some animals will become acclimated to this kind of noise and return to their original habitat. Other, more sensitive, species will have been displaced from the area as a result of construction activities (Section 9.2.1). This disturbance should be a minor and insignificant impact.

Although access to the area is readily available on dirt roads, the presence of new roads in the area will allow easier access for hunting and other outdoor activities. This improved access will lead to increased road traffic, and intermittent off-road excursions may disturb vegetation and wildlife. The people who move into the Carlsbad area to work at the WIPP may increase the hunting pressure on wildlife in the area. These impacts are not expected to be significant.

9.3.2 Effects of Routine Releases of Radioactivity

The WIPP is designed to receive and store radioactive waste. Its operation will require the handling of packages and canisters, some of which may be externally contaminated with radioactivity. No canister will be opened, but very small quantities of nuclides may be released as a result of routine handling. The releases will be held to levels as low as reasonably achievable.

9.3.2.1 Exposure Pathways in the Environment

Radionuclides released to the environment can reach people through a variety of pathways, as shown in Figure 9-3. The pathways shown in the figure are the ones that were investigated in the analysis for this section. After the nuclides are released in the effluent gases, they may simply remain suspended in the air or be deposited on the ground or on vegetation. The radiation dose received by these pathways can be external or internal.

Two of the pathways--air immersion and direct exposure from nuclides deposited on the soil--are external. An air-immersion dose results from nuclides suspended in air. The nuclides deposited on the ground are sources of direct exposure while a person stands on contaminated ground. Air immersion and direct exposure to nuclides deposited on the soil are external pathways since no material is actually taken into the body.

The other pathways result in internal exposure; the nuclides are actually taken into the body. Nuclides deposited on the ground may be taken up by plant roots and eventually ingested by a person who consumes the plant. The nuclides may be directly deposited on leafy vegetables or plants that are then consumed. The process can be more complex; the food chain may involve an intermediary like beef or dairy cattle. Another possible internal pathway is inhalation. Although this list of exposure pathways is not exhaustive, it includes the potentially important pathways used in the analysis reported in this section. Usually one of these pathways, called the critical pathway, dominates the others.

Each nuclide behaves differently in the environment. For example, some nuclides that have been deposited on the soil transfer from the soil through plant roots and concentrate in leafy plants, while others will not transfer from the soil. Still others concentrate in the organs of domestic animals or wildlife that eat the plants and dirt clinging to roots. Usually one or two nuclides are the most likely to reach man and dominate the critical pathway.

Estimates of exposure

Human exposure through the pathways described above was calculated by using a modified version of the computer code AIRDOS-II, as described in Appendix G. The input used for these calculations and the results are discussed below.

The nuclide releases and meteorological data presented in Section 8.6 and Appendix H.4, respectively, were used to calculate human exposure. The expected annual releases from the WIPP are given in Table 8-6. The annual average atmospheric dispersion factors for various distances up to 45 miles and for each of the wind directions are given in Appendix H.4, Table H-49.

The study area was defined as the area inside a 50-mile-radius circle centered on the site. The area was divided into 16 wedge-shaped sectors (Figure 9-4), and each wedge was subdivided radially into 14 subsectors. In each subsector the population, agricultural area, significant water area, and beef- and

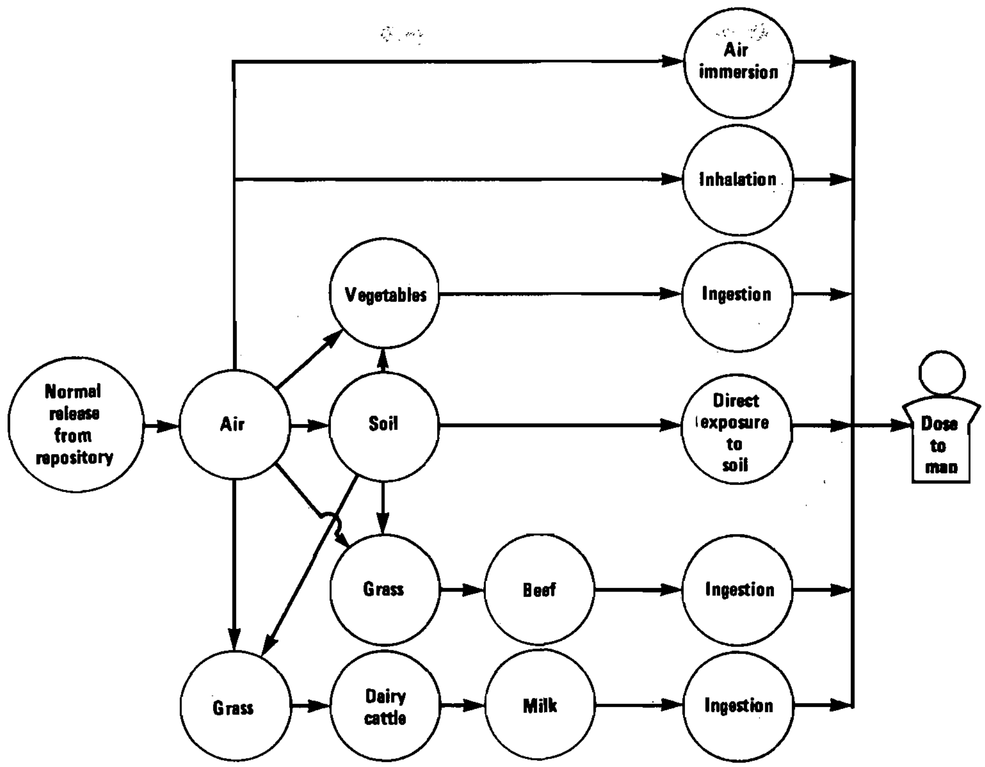

Figure 9-3. Primary pathways for nuclides released from the repository.

dairy-cattle populations were defined. The inputs used are shown in Figures 9-4, 9-5, and 9-6. An attempt was then made to define the living patterns of people living in the subsectors. Living-pattern and some miscellaneous data used in the analysis are presented in Table 9-23. These and other data were obtained from conversations with county agricultural agents and from other sources listed in Appendix G.

As can be seen in Figure 9-5, there is little agriculture within the study area. Because the fresh-produce-growing areas are quite limited in size, people in the study area were assumed to import 90% of their vegetables. Of the 10% not imported, a large fraction is assumed to be grown in home gardens. Few dairy herds exist in the study area (Figure 9-6), and the dairy farmers send their milk outside the study area to be processed and distributed. Therefore, it was estimated that only 1% of the milk consumed in the area is produced within it.

Beef-cattle ranching is the dominant agricultural pursuit in the study area. The sheep population was added to the beef-cattle population; this addition exaggerates the impact of beef. It was estimated that 50% of the beef consumed in the area is produced in the area, and an average individual was estimated to eat 0.3 kilogram of beef per day.

These data are shown in Table 9-23 as they were used to calculate radionuclide concentrations for the surrounding environs and to determine the radiological consequences to people.

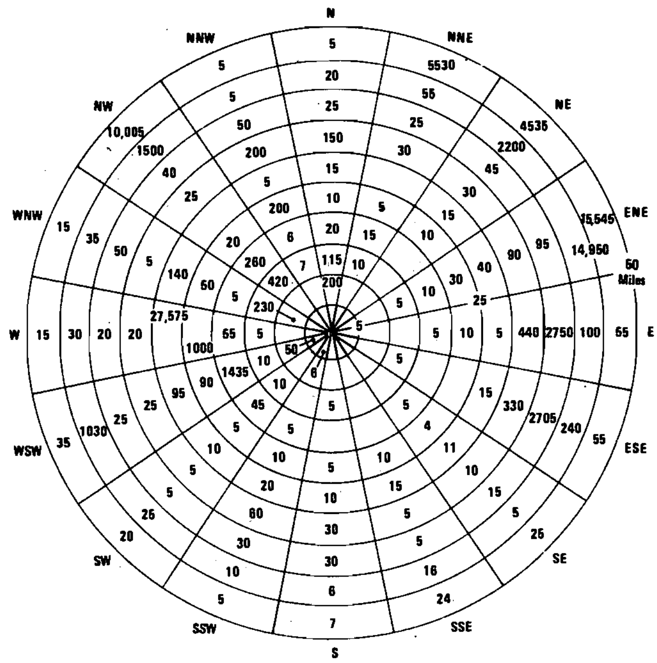

Figure 9-4. 1976 population within 50 miles of the site.

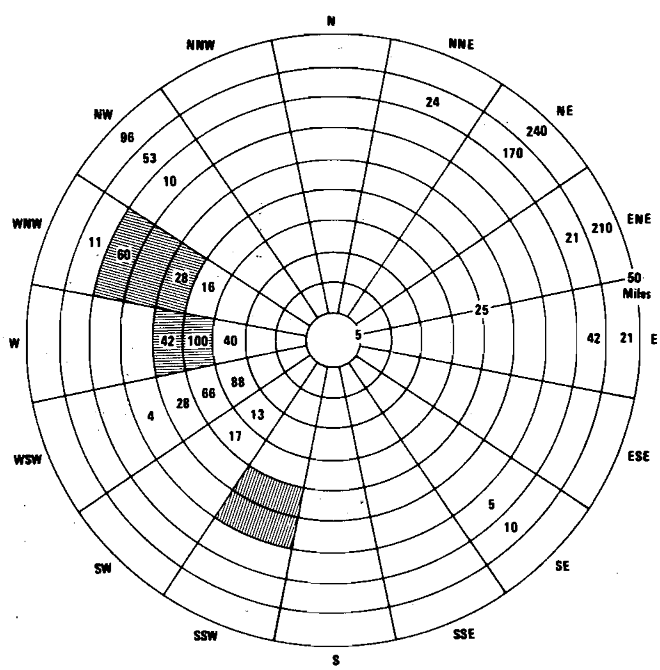

Figure 9-5. Agricultural areas. Values shown are millions of square meters cultivated in each sector. Shaded areas contain significant water, swimming might be possible in them.

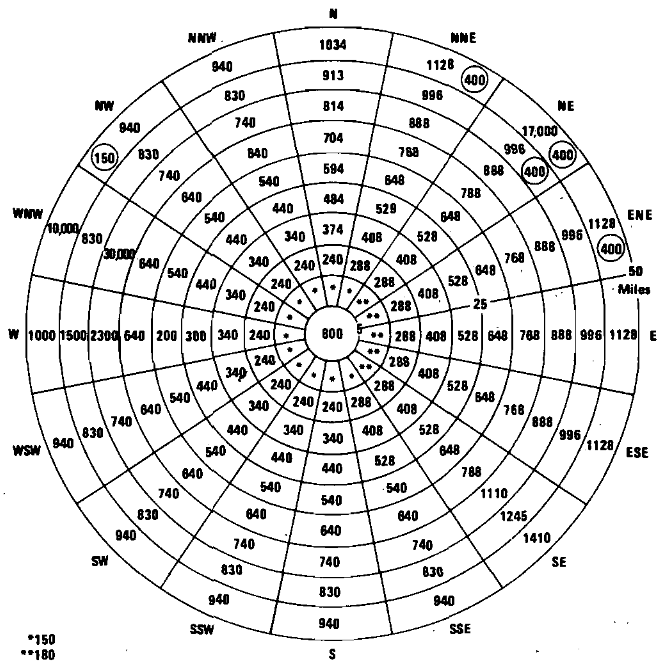

Figure 9-6. Beef cattle, sheep, and dairy cattle (circled) within 50 miles of the site.

Results

Radiation doses and dose commitments were calculated for each of the nuclides released. If the exposure is external, a dose was calculated; if the exposure is internal, a dose commitment was calculated. When an exposure is external, the exposure lasts until the source is moved away. For example, if people stand on a contaminated surface, they are exposed until they move away from the surface. When a radioactive material is taken into the body, part of it remains in the body until it decays or is eliminated by biological processes. By convention, the annual dose given off by the radioactive material while in the body is integrated, or summed, over a 50-year period after ingestion. The integrated dose resulting from each year's intake is called the 50-year dose commitment. For some materials that decay very quickly or are eliminated quickly, most of the dose commitment is received in the first year or two; for long-lived materials, the exposure lasts the entire 50 years.

Individual doses and dose commitments were calculated for a person living at the residence closest to the Los Medanos site (James Ranch, 3 miles to the south-southwest). Calculations were also made to determine an integrated population dose and dose commitment for all persons residing within the 50-mile study area. To calculate a population dose for a subsector, an individual dose was calculated and then multiplied by the population of the subsector. This calculation was performed for each subsector; the sum of the individual subsector doses is the population dose for the study area.

Table 9-23. Living Patterns and Miscellaneous Data Used in the Analysis of Human Radiation Exposure

Input	Population	Individual
Fraction of vegetables imported	0.9	0.0
Fraction of beef imported	0.5	0.0
Fraction of milk imported	0.99	0.0
Fraction of vegetables produced in 50-mile radius that is produced in sector	Not applicable	0.1
Fraction of beef produced in 50-mile radius that is produced in sector	Not applicable	0.5
Fraction of milk produced in 50-mile radius that is produced in sector	Not applicable	0.01
Buildup time for surface deposition, years	15	15
Length of grazing season, days	365	365
Time from production to consumption, days		
Vegetables	14	14
Beef	20	20
Milk	4	4
Soil surface area furnishing food crops for one person, m^2	1000	1000
Pasture area per cow, m^2	121,000	121,000
Dry areal density of man's above-surface food, kg/m^2	0.25	0.25
Dry-weight areal grass density, kg/m^2	0.014	0.014
Depth of plow layer, cm	23	23
Rate of increase of steer muscle mass, kg/day	0.4	0.4
Mass of muscle at slaughter, kg	200	200
Soil density, g/cm^3	1.4	1.4
Fraction of beef herd slaughtered per day	0.03	0.03
Number of milkings per day	2	2
Beef consumption, kg/day	0.3	0.3
Milk consumption, kg/day	0.85	0.85
Vegetable consumption, kg/day	0.18	0.18
Milk capacity of udder, liters	5.5	5.5
Grass consumption of cow, kg/day	50	50
Milk production of cow, liters per day	11	11
Fraction of time spent swimming	0.01	0.01
Depth of water to be used for calculating submersion doses, cm	152	152

The resultant dose commitments for an individual and for the population are shown in Tables 9-24 and 9-25, respectively. Of the several nuclides released, the largest contributor to the overall impact is plutonium-239, which contributes about 50% of the dose commitment. The rest of the impact is from the other plutonium isotopes and americium-241. The most important pathway is inhalation.

The overall impact from radionuclides released from the waste packages during normal operations is very small. The greatest individual radiation-dose commitment is 6.5×10^{-6} rem to the bone. This dose commitment is to be compared with the 5-rem 50-year dose commitment from natural-background sources. Thus the maximum dose commitment resulting from WIPP operation is to the bone and is 0.00013% of that from natural background radiation. This comparison is appropriate if the person receiving the dose lives at the James Ranch for 1 year. If he lives there for 5 years, his dose commitment would be approximately five times his first-year dose commitment. The annual whole-body dose from repository operation is 1.6×10^{-7} rem to a person living at the James Ranch. The health effects of such doses and dose commitments are discussed in Appendix O.

An analysis was also made to determine the impact from the radon isotopes released during mining activities. This analysis considers an individual breathing the air at the James Ranch for a year; it does not take into account the radioactive decay occurring while the radon is carried by the air from the site to the James Ranch. By assuming a continuous release during the year and by using calculated annual diffusion estimates for the site environs (Appendix H, Table H-49), the dose received by this person is calculated to be 2.5×10^{-7} rem per year to the lung. This is 0.00014% of the natural-background dose (0.18 rem per year) to the lung. Thus it is evident that the impact of the release of radon will be very small. Indeed, it will be no different from the releases at potash operations of similar size.

9.3.2.2 Radiation Exposures of Workers

The operational workers at the WIPP will be routinely exposed to low levels of radiation. The WIPP is designed to keep such exposure as low as reasonably achievable and to insure that the occupational dose is less than 1.0 rem per year per person.

Table 9-24. Dose Commitment Received by an Individual Residing at the James Ranch

Organ	50-year dose commitment (rem)[a]	Annual dose (rem) from natural background
Bone	6.5×10^{-6}	0.1
Lung	3.0×10^{-7}	0.18
Whole body	1.6×10^{-7}	0.1

[a]50-year dose commitment from a 1-year exposure.

Table 9-25. Dose or Dose Commitment Received by the Population Within 50 Miles of the WIPP[a]

Organ	50-year dose commitment (man-rem)	Annual dose (man-rem) from natural background
Bone	8.8×10^{-3}	9.2×10^{3}
Lung	4.0×10^{-4}	1.7×10^{4}
Whole body	2.2×10^{-4}	9.6×10^{3}

[a]The population within 50 miles of the WIPP is 96,000.

The topic of the occupational doses received by workers is addressed in detail in the WIPP Safety Analysis Report (DOE, 1980, Section 6.4). The results of the analyses performed for routine exposures are summarized in Tables 9-26, 9-27, and 9-28. The potential health effects of such exposures are discussed in Appendix O.

Table 9-26. Estimated Annual Direct Radiation Dose Delivered to Workers During Normal Operation

Functional area	Number of exposed workers	Annual dose (man-rem)
HANDLING OF RH TRU WASTE		
Shipping and receiving	8	2.3
Cask preparation	6	3.0
Cask unloading	2	0.2
Hot cell[a]	5	0.2
Cask transfer to waste shaft	4	1.4
Underground disposal	8	5.5
Total	21[b]	12.6
HANDLING OF CH TRU WASTE		
Shipping and receiving	6	1.1
Container preparation	9	7.0
Transfer of drums to waste shaft	9	2.8
Inspection and surveillance	10	7.0
General supervision	2	0.3
Underground disposal	11	4.6
Total	27[b]	22.8

[a]No one occupies the hot cell during waste handling; all persons operating the hot-cell equipment are working in the operating gallery.

[b]The total number of workers is not the sum of the individual workers involved in any category since the same workers may be involved in several of the categories.

Table 9-27. Estimated Annual Dose Received by Workers from the Unusual Occurrences Assumed To Release Radiation During Routine Operation

Assumed occurrence	Average dose rate (mrem/hr)	Exposure time (hr/yr)	Number of exposed workers	Annual dose (man-rem)
Externally contaminated cask arrives in handling area for RH waste	1	32	2	0.063
Damaged drums or boxes arrive in handling area for CH waste	10	16	3	0.48

Table 9-28. Estimated 50-Year Dose Commitments Received by Workers from a 1-Year Exposure to Airborne Contaminants

	50-year dose commitment (man-rem)			
Organ	RH-waste handling area	CH-waste handling area	CH-waste overpack and repair area	RH-waste underground disposal area
Whole body	5.8×10^{-7}	0.11	0.02	3.7×10^{-7}
Bone	2.3×10^{-5}	4.5	0.9	1.3×10^{-5}
Lung	8.4×10^{-5}	0.13	0.02	5.3×10^{-7}
Number of exposed workers	9	15	3	8

9.3.3 Resources Committed

The natural resources committed for WIPP operation include energy derived from fossil fuels, water, chemicals, and laboratory equipment.

The energy consumed during operation will be primarily electrical energy. The normal operating electricity demand has been estimated to be 20,000 kilowatts. This power will be supplied by the Southwestern Public Service Company (SPSC), which currently has a system-wide generating capacity of 2.7 million kilowatts; of this the Carlsbad service area consumes an average of 85,000 kilowatts. Industrial customers of the SPSC that have recently ceased operation in the Carlsbad area have used more power than the WIPP will require. The power for the repository will therefore not require additions to electrical power plants.

Diesel fuel will power waste-handling equipment both on the surface and in the mine and will supply the on-site generators during electricity-supply emergencies and during tests of the generators. The quantities of diesel fuel and gasoline that may be consumed during operation have been estimated to be 400 and 140 gallons per day (gpd) for the underground waste-handling equipment and the emergency generators, respectively. No natural gas will be used at the repository.

The water to be consumed by the repository will total approximately 25,000 gpd: 20,000 gpd for domestic needs and 5000 gpd for industrial needs. When economically feasible, the recycling of wastewater will reduce consumption; for example, treated sanitary effluents will be used for landscape irrigation and dust control at the site.

The following chemicals will be used in sewage treatment, water treatment, and on-site experiments: sodium hypochlorite (NaClO) and gases such as hydrogen, helium, and hydrogen chloride. Laboratory equipment will consist of laboratory software (glass, tubing, etc.) and holding containers, some of which may be made of special metals such as platinum.

9.3.4 Denial of Mineral Resources

Emplacement of radioactive waste in the WIPP will preclude for safety reasons the extraction of mineral resources from the geologic strata above or below the disposal levels. The quantities and values of these resources are discussed in Section 9.2.3.

9.3.5 Effects of Decommissioning and Dismantling

This section discusses the environmental effects of decommissioning and dismantling the WIPP at the end of its operating life: the expected radiological effects, the expected nonradiological effects, and the commitment of resources. The current decommissioning plan is described in Section 8.11.

All decommissioning activities will be performed under controls that will insure the safety of the general public and of the people involved in the decommissioning effort. This objective will be accomplished by the development of radiation-control and industrial-safety standards covering all activities. This development will be the responsibility of the DOE or its contractor responsible for the decommissioning. Where applicable, existing standards will be used; they will be reviewed for adequacy, and further investigations to develop adequate standards will be carried out when necessary. In addition, all detailed decommissioning plans will specify provisions for dealing with unusual or abnormal circumstances. At the time of decommissioning, the plans will be reviewed and approved by the DOE and any other Federal agencies under whose jurisdiction the decommissioning of the WIPP falls. Protecting both the public and the workers at the site, the procedures and standards will minimize the environmental effects of decommissioning.

Expected radiological effects of decommissioning

Because decommissioning involves the disposal of contaminated equipment, it could expose the work force to radiation. Temporary shielding and extensive decontamination will insure that the exposures of workers are kept as low as reasonably achievable, in accordance with Federal guidelines at the time of decommissioning.

Although it is possible in theory that the public could be exposed to radiation, the exposure is expected to be insignificant. The special procedures taken to protect workers at the site will severely limit any radiation doses delivered to the public. Packaging requirements will protect the public and the work force from radiation emitted by material shipped from the site. To insure that the health and safety of the public are protected, appropriate security procedures will be established, and radiation monitoring and environmental surveillance will be carried out. Further discussion appears in Section 8.12.

Expected nonradiological effects of decommissioning

The decommissioning operation is expected to be similar to a heavy construction project in that the same type of heavy equipment will be used (e.g., dump trucks, bulldozers, grading equipment, and railcars and engines). The environmental impacts will therefore be similar to those of construction, described in Section 9.2. The major impacts expected are an increase in noise and vehicular traffic, with associated dust and pollution. Control of the environmental impacts of decommissioning will use methods like those used during construction (Section 9.6).

The decommissioning is not expected to produce large quantities of chemical wastes; waste from decontamination operations will be handled in existing or temporary radwaste systems. Any additional facilities that may be required for these operations will be installed and operated in compliance with Federal, State, and local standards applicable at the time.

The decommissioning operation will not affect any known threatened or endangered species nor any historic or cultural sites.

The temporary socioeconomic impact of decommissioning will be an increase in employment, in that the process will require a decommissioning work force. The long-term effect, however, will be a decrease in the size of the labor force once the WIPP is shut down.

Commitment of resources

Resources used during decommissioning will include water and construction materials for site preparation and mothballing. The primary use of water will be for decontamination. Some water will also be used in construction activities.

It is expected that most of the land will be returned to grazing, its original use. The area could, however, be made available for other uses since a railroad spur is at the site. These alternative uses will be investigated at a later time.

9.4 ECONOMIC AND SOCIAL EFFECTS OF PLANT CONSTRUCTION AND OPERATION

This section tells how the authorized WIPP project would affect the social and cultural environment around the Los Medaños site in New Mexico. The analysis deals primarily with Eddy and Lea Counties, which would receive most of the impacts.

After a description of the general economic impacts and of the effects on employment and personal income, the population growth in the area is predicted. Because these analyses show that social institutions in the local communities will not be much affected, the discussion of social structure that follows them deals largely with the attitudes of the people toward the WIPP. The next part of this section describes effects in the private economic sector--effects on industry, trade and services, and tourism. Then two parts of the section present detailed impacts on housing and land use and on community services. The section ends with a review of the effects on government finances; this review is based on detailed tabulations in Appendix M.

9.4.1 Project Description, Setting, and General Impacts

The socioeconomic impacts discussed here are based on the conceptual design for the construction and operation of the WIPP. The impacts have been computed by economic modeling techniques that use an input-output procedure. This work was supplemented with a substantial effort in on-site inspection and data gathering.

Three communities have been closely analyzed for potential significant impact: Carlsbad and Loving in Eddy County and Hobbs in Lea County. Carlsbad and Hobbs are the only two communities with more than 25,000 inhabitants within 50 miles of the WIPP site. Two scenarios have been developed for the analysis. Scenario I assumes that the maximum impact is exerted on Carlsbad and Loving, while scenario II assumes a higher impact on Hobbs than is expected in scenario I. Both scenarios were developed to produce the highest levels of expected impact.

The construction of the WIPP is assumed to begin in mid-1980 and end in the fall of 1984. This includes construction in the SPDV program (Section 8.2.1). During that time, the number of construction workers in the surrounding labor-market area will increase. An underground-construction phase, similar to a mine-development or mine-construction operation, will take place concurrently with the surface-construction phase.

In addition to the workers employed by the construction contractor or subcontractors, certain management and design personnel employed by the Federal Government, Sandia National Laboratories, and the Westinghouse Electric Corporation and their subcontractors are expected to live in the local area during the construction and operation phases of the project. Although the number of these employees will vary over time, it will increase as construction proceeds. To simplify the analysis, these individuals and their impact on the economy will, unless stated otherwise, be included in references to construction activity.

As a result of the construction and mining activities, industries serving the population and those servicing other businesses (mainly some manufacturing, service, and wholesale operations) will experience increases in business volume and the need for additional employees.

The socioeconomic analysis assumes that the impact will be primarily spread over both Eddy and Lea Counties. A survey* of labor-location patterns for the potash industry in the area of the site shows that approximately 88% of the work force lives in Carlsbad, 11% in the remaining portions of Eddy County (with Loving assumed to receive 6%), and approximately 1% in Lea County. For scenario I, the direct impact of construction and operation is assumed to follow this established pattern, while the indirect impact is distributed as follows: 80% to Carlsbad, 10% to areas outside Carlsbad in Eddy County (3% to Loving), and the remaining 10% to Lea County.

A survey of the large mining companies in the area revealed that one company had a significantly different employee-location pattern. This company had recruited through offices in Hobbs. The employee-location distribution for this company served as a model for scenario II, in which Lea County, particularly the City of Hobbs, will receive a higher level of impact from the construction and operation of the repository than in scenario I. The distribution of direct and indirect impacts for scenario II is as follows: Eddy County, 58%, with Carlsbad receiving 54%, and Lea County, 42%, with Hobbs receiving 36%.

The procedures used to project employment, population, housing, income, and other socioeconomic effects are explained in Appendix L.

9.4.1.1 General Economic Impacts

During construction, approximately $291.5 million will be expended for labor, equipment, and other construction costs, including expenditures for management and design activities from mid-1980 through 1986.** Because certain expenditures for equipment rentals, supplies, labor, etc., will go to areas outside Eddy and Lea Counties, and in some instances outside the State of New Mexico, only $137.9 million will directly affect the economy of the two-county area. This figure covers labor costs and local procurements for the construction period, assumed to be slightly more than 4 years, and the checkout period preceding full operation in 1987. Indirect effects in the private sector will total an estimated $112.4 million. The government sector (State, local, and indirectly affected Federal agencies) will receive about $14.8 million in new activity. The greatest local economic impact (direct and indirect) during a single year is expected to be about $79.4 million during the third year of construction (1982).

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*This analysis is based on personal interviews with county potash-mining officials during 1978.

**Unless otherwise stated, all dollar figures are in constant 1979 dollars.

Associated with the construction of the WIPP surface and underground facilities will be several other activities, including preoperational testing, personnel training, planning for waste acceptance, and various other support activities. These activities are referred to as management and design activities. After the end of construction in the fall of 1984, the management and design activities will continue for several months. Checkout is scheduled for completion in the first part of 1985 and preoperational testing in mid-1985.

During the latter part of 1985 and through 1986, employment in the operation phase will gradually increase. The full operational impact of the WIPP is expected to be nearly static by the end of 1987.

As construction ends and the WIPP becomes operational, the economic impact will change significantly. Beginning in 1987, some $23.5 million will be spent annually for the operation phase; only $16.9 million will directly affect the economy of the area. The total local economic impact of the operation phase, both direct and indirect, will amount to almost $33.0 million annually.

9.4.1.2 Other Events with Economic Impact

In November 1977, Beker Industries and the Duval Corporation announced decreases in their Carlsbad-area labor forces of 100 and 200 employees, respectively. Since then, the labor market in Carlsbad has remained stable, with no appreciable increases or decreases in total employment. Regarding future activity, no organizations have announced firm plans to expand operations in the Carlsbad area.

The proposed Brantley Dam, an earthen structure to be built on the Pecos River between Artesia and Carlsbad, was to be under construction before 1980. However, funding for the project has been delayed, and it now appears that its construction will not overlap the construction of the WIPP. In fact, the Brantley Dam project may be delayed indefinitely. This possibility has been recognized in computing information for this study.

9.4.1.3 Employment

Much of the information presented in this subsection is summarized in Table 9-29, which shows, for each year of construction and operation, the number of jobs supported by the WIPP and the number of newcomers to the two-county area. These projections end in 1988 because it is assumed that the impact of operation will be nearly static by then.

Jobs directly connected with the WIPP have been estimated from information supplied by Sandia National Laboratories, the Bechtel Corporation, and the Westinghouse Electric Corporation. Jobs indirectly supported by construction and operation have been computed by a region-specific (Eddy and Lea Counties) input-output modeling process (see Appendix L).

Table 9-29. Yearly Averages of the Numbers of Jobs Supported by the WIPP Repository in Lea and Eddy Counties

Year	Direct jobs--construction period: Surface	Underground	Management and design	Subtotal	Indirect Jobs	Total jobs	Newcomers per year[a]
1980	4	56	5	65	90	155	117
1981	68	162	52	282	435	717	486
1982	415	355	152	922	1215	2137	1312
1983	551	119	281	951	1176	2127	318
1984	79	9	208	296	390	686	(1185)
1985[b]	--	--	269	269	346	615	(385)
1986[b]	--	--	417	417	484	901	226
	Direct jobs--operation period: General operation	**Security and remote control**	**Under-ground**	**Subtotal**			
1987	256	44	140	440	514	954	91
1988	256	44	140	440	514	954	12
After 1988	256	44	140	440	514	954	0

[a]Gain (or loss) of population in the two-county area resulting from the WIPP.
[b]The job figures represent a mix of management and design personnel, as well as persons who will be employed during operation.

Construction phase

Construction will take approximately 54 months, beginning in mid-1980; associated activities in management and design and preoperational testing will continue through 1987. The average employment for 1980 has been established at approximately 65 construction-related jobs, and by the end of 1980 approximately 85 new jobs will have been created by the construction phase and the associated management and design activities.

During 1981 employment is expected to increase dramatically. The average employment during 1981 will be approximately 230 jobs in construction and 52 jobs in associated management and design activities for a total (annual average) of 282 positions. By the end of the year, just more than 545 new positions will have been created by the construction phase and associated management and design activities.

In 1982 employment is expected to reach a peak. Direct construction-activity jobs are expected to peak in late-1982 at just fewer than 1100. Associated management and design positions should increase throughout the year, numbering approximately 210 by the end of 1982. The combined employment for construction and associated management and design is expected to reach just fewer than 1300 by the end of 1982. The average number of construction jobs in 1982 should be about 770, while the annual average for nonconstruction jobs should be approximately 150 for the year.

In 1983 the annual average employment at the site for construction and the associated management and design activities is expected to increase slightly to 951. A second employment peak is expected to be reached late in the year, with a work force of just over 1200. This peak in 1983 and the peak in 1982 are induced mainly by activity in the construction of surface facilities and should be short-lived.

Because construction is expected to be completed by the fall of 1984, the number of construction positions should decrease rapidly in the first half of the year. The average employment in construction for 1984 is estimated to be only 88. Associated management and design jobs will fluctuate throughout 1984, with the average number of jobs estimated to be 208. However, by the end of 1984, management and design personnel are expected to number only 163, and the actual construction of the WIPP will have been completed.

Survey information on construction workers (Old West Regional Commission, 1975) and job-applicant data for Eddy and Lea Counties from the State Office of Employment Security suggest that 54% to 61% of the workers directly employed in construction will be persons not residing in the area before the beginning of construction; the remaining workers will be drawn from the labor force in Eddy and Lea Counties.

The number of indirect, or spinoff, jobs supported by construction and the associated management and design activities will vary significantly during the construction period. The maximum impact on indirect jobs is expected to occur in 1982. The number of these jobs to be filled by newcomers migrating to the area because of the WIPP is difficult to determine. However, the area is now experiencing a significant population growth that is expected to continue. Taking this into account, it is assumed that approximately half the jobs created indirectly by construction will be filled by newcomers to the two-county area.

During peak employment periods for construction, the unemployment rate in the two-county area should drop substantially. Both Eddy and Lea Counties, which have experienced low unemployment rates in the past, are expected to have low unemployment during the beginning of the WIPP project. These low unemployment rates, as well as the availability of certain tradesmen in the area and past patterns of job migration, influence the estimates of the numbers of persons who will be attracted to the area by new construction jobs or jobs created indirectly by construction. During 1982 and 1983, the number of persons expected to be employed from the local labor force is approximately half the unemployed pool as represented by 1978 figures.

Operation phase

As the preoperation and checkout phase begins (late 1984 through 1986) and construction is completed, population and employment characteristics will change significantly.

During the latter half of 1984 and continuing through 1985, a "shakedown" period of facility checkout, preoperational testing, and personnel training will occur. Direct employment at the site will average some 269 in 1985 and will rise to 417 during 1986. As preliminary operations begin, this work force will have increased in an even fashion during 1985 and 1986, and by the end of 1986 a full complement of 440 operational positions will have been instituted for the start of full operation in 1987. Most of these jobs (256) will be directly connected with the general operation of the WIPP, while 140 persons will work on continuing underground operations and 44 will work in security and remote-handling operations. In addition, 514 jobs will be supported indirectly. The total number of jobs directly and indirectly created by the operation phase will thus be about 954. This level should be reached by 1987.

The nature of the operational jobs requires a long training period for the operational personnel, who will be hired throughout the construction period and trained by the operating contractor. Radioactive waste will not be received until late in 1985. Before that time 200 to 270 workers will be employed in checkout and preoperational testing, with an economic impact similar to that of the management and design activity.

Several important aspects of the operational phase should be noted. In economic terms, the operational impact will be significantly smaller than the impact of construction. Moreover, shuffling of population caused by losses of construction and mine-development jobs and gains in operational jobs will occur from 1984 through 1986. Thus, significant in-migration and out-migration will result, not only because the number of jobs will change but also because the required skills will change as well.

Studies of large construction projects have shown a lag in out-migration once a project has been finished. It is therefore expected that the unemployment rate may increase by 0.5% to 1.0% for 1 to 2 years after construction has been completed. Because of the expected lag and the decrease in the number of workers needed for operational jobs, a population loss will occur during 1984 and 1985. It is expected that many workers will seek employment elsewhere, causing 1500 to 1600 people who had been directly or indirectly connected with the construction of the WIPP to move out of the two-county area. The total population there may drop slightly or remain static during 1984.

9.4.1.4 Personal Income

Construction phase

During the construction and checkout of the WIPP (1980-1986), more than $93.2 million in new personal income will flow into the two-county economy in direct wages and salaries from construction and associated nonconstruction activities. In addition, about $45.7 million in wages and salaries will come from businesses indirectly affected.

Personal income from interest, dividends, and rents will add another $20.4 million during this period. The private sector will derive about $159 million directly and indirectly from construction through 1984 and the time before full operation in 1987. In the public sector, about $6.1 million in personal income will result from increased activity in the area and the additional State- and local-government employment required for support. Thus the total personal income added to the area during construction will be $165.4 million over 5 to 6 years. However, a net loss from transfer payments (generally Social Security payments) will decrease this to $157.5 million.

Operation phase

The personal income to be derived from the operation of the WIPP will be significantly lower than that derived during construction. As explained in Section 9.4.1.1, the amount of new money flowing directly into the economy during a normal year of operation will be approximately $16.9 million. Although this amount may vary with expenditure patterns in WIPP operation, a constant figure of $16.9 million is used here. This figure is significantly different from the local direct expenditures of more than $40 to 42 million during the peak years of construction (1982 and 1983). Because the direct impact is lessened, clearly the personal-income impact will be lessened.

The estimated $16.9-million annual flow directly associated with operation will affect new personal income as follows: (1) approximately $11.9 million will be realized from direct wages and salaries; (2) another $5.5 million will come from wages and salaries in businesses indirectly affected; (3) about $0.8 million per year will be derived from government payment for labor; (4) about $2.5 million will come from dividends, interest, and rents. During the first years of operation, net transfer payments will be negative; later they will have a net positive effect. Because of this balancing effect, transfer payments for an average year have been considered neutral. The net result, therefore, will be an increase in total personal income of approximately $20.7 million annually.

Personal-income distribution: scenario I

Carlsbad will receive approximately $134.6 million (net) of the additional personal income generated by WIPP construction; other areas inside Eddy County but outside Carlsbad will receive nearly $17.9 million. Personal income in Loving will be about $7.8 million, or 45% of the income received in the county outside Carlsbad. Additions to total personal income in Lea County will amount to about $6.6 million. These impacts will be spread over a 5- to 6-year period. During the operation phase, the annual impact in Carlsbad is expected to be $17.7 million. The total countywide impact (including Carlsbad) will be $19.9 million. Lea County should receive $0.9 million annually.

Personal-income distribution: scenario II

In scenario II, in which the impact on to Hobbs is increased, $66.2 million in new personal income will flow into Lea County during construction, with $56.7 million of this entering the economy of Hobbs and the remainder going to areas in Lea County outside Hobbs. While the impact on Eddy County in scenario II is significantly lower than that in scenario I, the total income flow during construction is still substantial: $91.4 million. Of this amount, $85.1 million will directly enter the economy of the City of Carlsbad, with the remainder going to other parts of the county.

As operation begins, the impact will be substantially decreased, with new personal income totaling approximately $8.7 million annually in Lea County and $7.5 million in Hobbs. The annual impact in Eddy County is higher, with $12.0 million for the county and $11.2 million for the City of Carlsbad.

9.4.1.5 Statewide Economic Impact

The socioeconomic analysis presented in this document is generally limited to the two-county area of primary impact--Eddy and Lea Counties, New Mexico. The period of impact covered begins with construction in mid-1980 and extends through the operation phase. However, before mid-1980 a significant amount of money will have been expended on the WIPP project for research, design, and various administrative activities. Some of this money will have flowed through parts of the State other than the two-county area. Although the distribution of this money through the State cannot be determined exactly, it can be estimated from the records of expenditures for the WIPP.

Since 1975 just less than $76 million has been expended through the end of fiscal year 1979, and between the end of fiscal year 1979 and May 1980, an additional $18 million is expected to be spent, for a total of just less than $94 million. However, only a portion of this money has directly affected the State's economy: just over 60%, or $57 million. Of that amount, approximately $39 million flowed directly through the Albuquerque economy, $16 million went through the Carlsbad economy, and just less than $2 million went to other areas of the State. Since these expenditures were made over a period of approximately 5 years, the annual direct contribution to the State's economy was about $12 million, with most of it going to the Albuquerque area.

The number of jobs directly created or supported by these expenditures varies from year to year. During fiscal year 1979, these expenditures directly supported just fewer than 200 jobs, including personnel from the Department of Energy, the Westinghouse Electric Corporation, Sandia National Laboratories, and various subcontractors. Multipliers for indirect impacts on a statewide basis are not available; however, because of the nature and salary levels of these jobs, the employment-multiplier effect should be between 1.25 and 1.75 additional jobs, or between 450 and 550 total jobs, including both direct and indirect jobs.

In terms of statewide employment, the effect is an increase of 0.1%. Proportionally, the employment impact in the Albuquerque area is about 70% of the statewide impact, or about 300 to 400 jobs on the average. In terms of the overall employment in the Albuquerque area, the effect is an increase of 0.2%.

As the project moves into the construction phase in mid-1980, some direct impacts will continue outside Eddy and Lea Counties. Except for several subcontracts with universities and individuals, most of the impacts will occur within the economy of Albuquerque.

Because Sandia National Laboratories and the Westinghouse Electric Corporation will carry out a significant part of their work through subcontracts and through the development of prototype equipment at various locations, it is difficult, if not impossible, to determine the economic effect of WIPP construction and operation on the Albuquerque area. However, it is apparent that the effect on the economy of Albuquerque will be significantly less than that occurring between 1975 and the beginning of construction. The effect after construction begins could possibly be less than half the effect that occurred before construction.

The indirect impacts that will be felt throughout the State in terms of new jobs and additional income (as a result of direct expenditures in Eddy and Lea Counties) should not be substantially greater than those reported for the two-county area. The linkages of those two counties with other business-serving areas of the State appear to be weak. The major trade areas (i.e., the geographic areas for which major wholesale sector linkages are delineated) do not connect the two-county area to Albuquerque, the only large wholesale center in New Mexico (Rand-McNally, 1979): the Eddy County area is connected with El Paso, Texas, while the Lea County area is connected with Dallas, Texas. These linkages show that there is a significant flow of money out of the State to purchase products for businesses in the two-county area. The spinoff effects on the Albuquerque area are expected to be low.

Certain taxes, other revenues, and expenditures may be accrued and incurred by the State. However, in relation to the total State operating budget and revenues from taxes, these fiscal impacts are not expected to be significant. Thus, the impact on areas outside Eddy and Lea Counties is not expected to be large enough in relation to existing activities to warrant detailed analysis.

9.4.2 Population

9.4.2.1 Population Growth

During the first year of WIPP construction (1980) fewer than 125 persons will be attracted to the area by construction and related activities (Table 9-30). In 1981, about 475 additional people will be attracted, and in 1982 the construction phase will bring in more than 1300 in-migrants. During the fourth year of construction (1983), about 325 additional migrants will come to the area. Thus, the 4-year cumulative (1980-1983) total addition to the population of the two-county area will be about 2250 people. As the construction effort slows down in 1984, a loss of almost 1200 persons is expected. In 1985 a continued loss of about 375 persons will occur.

The beginning of operations in 1986 should bring in about 225 in-migrants directly or indirectly associated with the WIPP. It is projected that approximately 100 people will arrive in 1987 and 1988, producing a total population loss of 1250 from the peak period of impact in 1983. The net change in population should remain constant throughout operation at about 1000.

Interviews with city officials (C. Tabor, City Manager, Carlsbad, 1979; K. Gleason, Assistant City Manager, Hobbs, 1979) indicate that Carlsbad and Hobbs will be able to accommodate the growth induced by the WIPP. Both cities have departments or agencies that carry on planning and associated functions and approve the development of new subdivisions.

Distribution of population: scenario I

As explained in Section 9.4.1, scenario I reflects current patterns in the place-of-residence choices of potash-company employees in the area; most of the WIPP-induced population change occurs in Eddy County. During 1980, fewer than 125 people are expected to migrate to the area because of jobs generated by the WIPP. Through 1981, 600 people will have moved into the two-county area because of construction. Most are expected to locate in Eddy County, with Carlsbad housing just fewer than 500 new residents. Lea County is expected to receive only about 25 people in 1981 as a result of the project. In 1982 another 1325 newcomers are expected in the two-county area. Most of these people (1275) will locate in Eddy County. Carlsbad should receive about 1125 new residents and Loving approximately 100. In Lea County new residents will number between 50 and 100. The pattern in 1983 will be similar, with only 325 new residents in the two counties. The peak population impact will occur in 1983, when Carlsbad will have received a cumulative total of about 1900 new residents, Loving just over 100, and other areas in Eddy County 100 people since the start of construction in 1980.

Table 9-30. Population Migration Resulting from Jobs Directly and Indirectly Related to the WIPP[a]

Year	Direct migration		Indirect migration		Total migration	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1980	75	75	50	50	125	125
1981	300	375	175	225	475	600
1982	825	1200	500	725	1325	1925
1983	b	1200	325	1050	325	2250
1984	(800)	400	(400)	650	(1200)	1050
1985	(25)	375	(350)	300	(375)	675
1986	200	575	25	325	225	900
1987	25	600	50	375	75	975
1988	b	600	b	400	b	1000
2010	0	600	0	400	0	1000

[a]Population rounded to the nearest 25 persons. Parentheses indicate a loss of population (out-migration).

[b]Fewer than 13 persons.

After 1983 the population impact will decline, with an expected out-migration of 1200 persons in 1984 and 375 in 1985. As operation begins in 1986, an in-migration of about 225 will occur. A slight WIPP-connected in-migration (less than 100) will occur in 1987, while the operational impact is expected to be static by the end of 1988, with less than 25 new residents during the year. The maximum impact in Lea County is projected at 150 new residents in 1983, with fewer than 100 during operation.

Overall population levels with WIPP-induced population changes under scenario I are indicated in Table M-1 of Appendix M.

Distribution of population: scenario II

Although the number of people migrating to the two-county area is the same in scenarios I and II, the distribution of population is significantly different. Of the 600 in-migrants attracted by the WIPP through 1981, about 350 will locate in Eddy County and 250 in Lea County. Carlsbad and Hobbs will receive 325 and 220 new residents, respectively.

The third year of construction (1982) will bring in another 1325 people: 550 into Lea County and 775 into Eddy County. Hobbs will receive an expected 475 people; Carlsbad should receive less than 725. Thus, since the beginning of construction in 1980, Lea County will have received 800 new residents.

The peak population impact on Lea County and Hobbs will occur in 1983, with 950 new county residents, 800 of whom will locate in Hobbs. After the transition from construction to full operation, the net population addition to Lea County is projected at 420 people, with Hobbs receiving 360. Under scenario II, the net operation-related population increase in Eddy County should reach 580, with some 540 persons locating in Carlsbad. Population projections for the area under scenario II conditions are given in Table M-2 of Appendix M.

9.4.2.2 Population Within 10 and 50 Miles

The population within 10 miles of the site is expected to change little in the foreseeable future. Only one new permanent residence is planned for construction, about 8 miles west-southwest of the site (J. Mobley, personal interviews, 1978).

Mining employment within 10 miles of the site may vary significantly with the national market for potash or with the level of existing mining operations. However, the outlook for New Mexico potash and the current level of operations do not appear to dictate any large changes in the commercially associated daytime population of the area. The population associated with the many oil and gas wells in the area varies from day to day, is highly localized, and is difficult to predict.

The population within 50 miles is expected to increase significantly at certain locations. The 50-mile radius includes parts of three counties in New Mexico and parts of six counties in Texas. The population increases in Lea and Eddy Counties through the year 2000 will be concentrated in incorporated population centers identified in Appendix H.

Tables M-3 through M-6 in Appendix M show the population projected to live within 50 miles of the site in 1980 (the first year of construction), in 1990, in 2000, and in 2010. Many of the areas have extremely small populations. Accurate forecasting for these areas is not possible since a variation of less than 100 people causes a high percentage variation in population figures. The population change for these sparsely populated areas is based on trends established in areas outside the incorporated places in Eddy and Lea Counties and on a continuation of present activities in each of the defined radius sections. Between 1980 and 2000, the population within 50 miles is expected to increase by about 37,700 persons, or about 35%. The WIPP, however, will account for less than 3% of the total growth during that time if, in fact, the population levels projected for those time periods are accurate.

9.4.3 Social Structure

The results of the impact analyses in Sections 9.4.1 and 9.4.2 show that the WIPP should have little effect on the social and cultural institutions of Eddy and Lea Counties. Any impacts that might occur in a particular community may be expected to vary in degree with the overall impact exerted by the WIPP on that community. The most widely recognized negative social impacts would result from a temporary housing shortage and an increase in population from the in-migration of transient workers. Factors that will mitigate any social impacts include the temporary nature of the housing shortage, minimal appreciable effect on public services, and relatively low levels of in-migration in comparison with the current population. Furthermore, since the in-migrants will probably be people of similar backgrounds, occupations, and transiency, inherent factors that would tend to create conflict will be limited.

The WIPP project may affect some classes and ethnic groups slightly more than others, but it will have relatively little effect on the region's community organizations.

9.4.3.1 Sociocultural Impacts

To obtain information on community attitudes toward, and perceptions of, the WIPP project, a series of unstructured discussions was conducted in the area of primary impact (Carlsbad, Loving, and Malaga in Eddy County; Hobbs in Lea County). The general topics raised during the discussions included social background, perceptions of the local community, perceptions of the costs and benefits of the WIPP, and perceptions about the need for a WIPP-type project and the storage of radioactive waste.

The discussions were carried out by two methods. In the first, a list of key informants was developed by identifying those persons whose statements about the WIPP project had appeared in either newspapers or other media. The key-informant group was then expanded by asking the persons on the original list to suggest other persons for the survey. The final key-informant group was composed primarily of persons who are active in political, civic, business, and environmental affairs. Discussions were conducted with a total of 55 persons, or 51% of the key-informant group.

In the second discussion method, a random sample of Carlsbad-area residents was drawn from local telephone listings. Discussions were conducted with 138 persons, or 60% of the random-sample group.

The key-informant and random-sample groups were intended to provide a cross section of citizens from which to assess attitudes and perceptions for the area of primary impact.

All of the discussions were conducted by trained research assistants: two men and two women. One of the research assistants was a Hispanic-American; two spoke fluent Spanish.

Local knowledge about the WIPP project

In recent months, the WIPP project has received much attention in local as well as State, regional, and national media. Public hearings have been very well attended, and local interest groups that support or oppose the project have been organized. It is not surprising that most area residents have some familiarity with the WIPP. None of the key informants and fewer than 3% of the random sample said that they had "no knowledge" about the project. Among the key informants, a total of 78% said that they knew "much" or "a great deal," with the remainder reporting they knew "something, though not a great deal" about the project. In contrast, among the random sample, only about 10% felt they knew "a great deal" about the project; most simply said that they knew "a little" or "something" about what was being proposed.

Primary benefits and problems associated with the WIPP project

Members of both the key-informant and the random-sample groups were asked to specify what they perceived as the primary benefits and major problems associated with the WIPP project. The benefits, which were perceived similarly by discussants in both groups, were classified in two major categories: (1) benefits that would accrue to the local communities and their inhabitants and (2) benefits that would accrue to the State or the nation. In the first category, many area residents perceived that the project would bring significant economic benefits to the local area in the form of new jobs, new housing, more business, and increases in local property values. Immediate economic benefits were anticipated from the population growth and new jobs generated by the construction of the WIPP. Long-term benefits were associated primarily with operational employment. Several said that the primary economic benefits would go to the local business community and that the "poor" and "minority" groups in the area would not be helped at all.

Most of those who identified national benefits made reference to the contribution that the Carlsbad area could make to the nation in providing a location for the disposal of radioactive waste. A theme of "national duty" was present in many of the discussions.

Several spokesmen for minority interests expressed the hope that new job-training programs could be developed from the project to teach new skills and provide new job opportunities for minority residents. The benefits could then be shared by a larger proportion of the population, including residents of the area's smaller communities, such as Loving.

Regarding the perceptions of major problems associated with the project, the key-informant group expressed negligible concern, while the random-sample group expressed numerous concerns that were much more diverse than were their perceptions of benefits. The major problem areas were the following:

1. Inflation and price increases associated with population growth.

2. Problems associated with providing services and facilities for an expanding population.

3. The attraction of "undesirable" people to the area, which would result in increased crime and other social problems.

4. Increased strain on housing and transportation.

5. Basic concerns about health and safety problems, including fears about contamination and accidents.

6. The belief that a rapid population growth could overwhelm the local culture, particularly in some of the smaller communities like Loving.

7. Problems created by outsiders who come to "agitate and protest."

8. The possibility of accidents and strikes at the construction site.

Each of these problems was identified by two or more of the discussants. The most prevalent concerns, however, were in the area of population growth and the provision of services and facilities.

Housing shortages were already perceived as a problem in the area, and most local residents were convinced these shortages would be exacerbated if the project is approved and large numbers of construction workers move into the area.

Distribution of impacts among area residents

As already mentioned, a number of people who identified specific WIPP-related benefits felt that these would not be distributed evenly in the community. The general feeling was that most of the economic benefits would be realized by the business community. Others said that those who owned property would benefit because the housing shortage would force real-estate values to increase drastically.

On the other side of the question, the discussants felt that those most likely to be affected negatively were retired people and those on fixed incomes. The reasons for the negative impacts were the expected rise in the cost of living and a shortage of housing. Minorities were expected neither to benefit nor to experience economic difficulty from the project. However, two key informants who represented the Hispanic-American community in Carlsbad and Loving expressed the belief that there would be negative impacts on minorities.

Impacts on recreation and tourism

In response to questions about the possible effects of the WIPP project on recreation and tourism, which are of critical importance to Carlsbad and some of the surrounding communities, most discussants expressed the view that there would be no impacts. The general feeling seemed to be that, since the WIPP site was isolated and underground, most people would simply be unaware of the existence of the facility unless it were advertised. A minority, however, felt there would be some negative impacts on local recreation. These were related particularly to fears of the area's being labeled the "nuclear wasteland of the world" or a "national sacrifice area."

Community change

One-third of the discussants felt that the quality of life in their area would be adversely affected by the WIPP. One-half of the key informants and slightly more than two-fifths of the random sample felt that the area would improve. A majority, then, anticipates either some improvement or no change in the quality of local life if the project becomes a reality. However, a significant minority felt that the overall effect on the quality of life would be negative because of increased strains on local facilities, a "boom-and-bust" cycle, fear and anxiety about the facility, a potential increase in the "transient" population, and increased costs for goods and services. Those who expected the area to improve felt that the economic boost and the increase in population would benefit Carlsbad and surrounding communities. Many expressed the hope that the area would not change because they like it very much as it is.

Each discussant was asked to indicate what community changes were likely to occur in such areas as health and mental-health care, family life, and civic affairs. A majority felt that health care would be upgraded to keep pace with demands, while mental-health concerns centered on the effects of anxiety and fear. Most felt family life would not change. No major changes were expected in local civic affairs.

Safety concerns

Many of the objections to the project, expressed by both groups, were concerns about safety. Fewer than half the key informants expressed concerns about safety at the site, but a majority of the random sample said that they did have some concern about safety. The major issues center on fear of human error, distrust of government, radiation leakage, and geologic instability at the site.

The discussions concerning potential transportation problems were similar. A majority of the discussants expressed some concern that the transportation of radioactive waste to the WIPP site could present a potential danger for the local area. Frequent mention was made of the generally poor quality of the existing highway system in the vicinity of the site.

Attitudes toward construction and operations workers

Because of the technical skills that would be required, most of the discussants expected that the large majority of the operating personnel would have to come from other areas. Although some Western communities have experienced significant problems associated with the in-migration of large numbers of construction workers, most of the discussants did not perceive the in-migration of construction workers to be a serious problem.

There was general consensus among both groups that as many local workers as possible should be used. Some persons expressed the hope that training programs could be established so that more local people could obtain employment.

Among the local communities, it was expected that Carlsbad and Hobbs would benefit most because of their proximity to the site and because of the size of their labor forces.

Attitudes toward radioactive waste

When asked about the general need for the disposal of radioactive waste, independent of the immediate local situation and personal interests, a large majority, about three out of four persons in both groups, said they feel there is an urgent need to store such waste in safe, permanent locations. Sixteen percent feel the need is less than urgent.

Although a majority feels there is a need for permanent disposal sites, less than half of both the key-informant and the random-sample groups felt that the WIPP site was desirable. Therefore, over half the discussants from both groups feel that the Carlsbad area is not a good location for the disposal of radioactive waste.

A number of sites were identified as being more suitable than the local area. The most frequent suggestion was to locate radioactive-waste repositories where "there is no population" or "away from people." Utah, Arizona, and Nevada were identified by several discussants as having lower population densities than New Mexico and thereby being more desirable as sites. Many respondents feel that the waste should be disposed of near its source.

Conclusion

The residents of the area feel that the area is a highly desirable place to live. They are generally aware of the WIPP project. Favorable economic impacts are expected along with some negative socioeconomic ones. Business is expected to benefit. Recreation and tourism will be unaffected. The quality of life in the area is generally expected to remain as it is. There is some concern about the safety of the project, and this is expected to be manifested by some anxiety and stress. Many of the discussants expressed a belief that the Carlsbad area may not be the best site for the permanent disposal of radioactive waste.

9.4.3.2 Labor Unions

Many WIPP employees, primarily miners, may be affiliated with a union. One of the several unions that represent potash and other workers in Eddy County might be expected to organize the workers, although the workers may choose to become affiliated with a union new to the area. In either case, the WIPP should not change the importance of organized labor in the region.

9.4.3.3 Social Services

The Carlsbad-Loving and Hobbs areas provide an extensive range of social services and activities for the various social, ethnic, and income classes that represent the population of the two-county area. The expected impacts from the population increases and the increased economic activities associated with the construction and operation of the WIPP will not affect the social-services facilities to the extent that they would be unable to accommodate demand. Only nominal staff increases would be necessary to accommodate WIPP-induced demand for area services.

9.4.3.4 Churches and Other Community Organizations

The influx of workers and their families will cause little increase in the number and types of churches and community organizations or in the memberships of existing organizations. The relatively small population increment is one reason. Another is that the new people, mostly blue-collar workers, will tend to join few organizations other than churches, which will probably show the greatest increases. The newcomers, if drawn from adjacent labor-market areas, will probably tend to be Protestants; the large number of small churches will probably absorb virtually all of them.

9.4.4 Private Sector

Although the private sector is strong in both Eddy and Lea Counties, its economic base is rather narrow, with most economic activities centering on mining. In Eddy County potash mining is the most active sector; in Lea County the oil-and-gas industry is more active than any other industrial sector. Retail trade and services (normally nonbasic sectors) are also partly a basic industry in Eddy County because of the heavy tourism attracted by Carlsbad Caverns. Other basic industries in the area, such as agriculture and manufacturing, are substantially less active than mining.

9.4.4.1 Industrial Activity

During the construction of the WIPP, certain industries in Eddy and Lea Counties are expected to become more active. Because the WIPP will need highly specialized equipment, much of the construction materials and nearly all of the technical equipment will be purchased outside the area. However, basic materials (sand and gravel, rock, certain electrical products, and concrete) can be purchased in the area. It is expected that construction will bring in approximately $8.7 million in new business to the manufacturing sector in the two counties (Tables 9-31 and 9-32).

As the project moves from construction into operation, its effect on the various economic sectors in the two-county area will change significantly. The operational phase will be similar to a warehousing operation with one important exception: the mining operations will continue.

During operation, the impact on local manufacturing is expected to be minimal. Examples of businesses that would experience some impact are chemicals, printing products, and machinery manufacturing. An impact may be felt indirectly in the manufacturing of food products because of increased demand. Spinoff to the industrial manufacturing system in the two-county area will be minimal.

Table 9-31. WIPP Construction and Operation: Estimated Indirect Impacts on the Private Sector (Millions of 1979 Dollars)[a]

Sector	1980		1981		1982		1983		1984		1985		1986		Operation	
	Volume	Jobs	Volume	Jobs	Volume	Jobs	Volume	Jobs	Volume	Jobs	Volume	Jobs	Volume	Jobs	Volume	Jobs
Agriculture	$0.1	0.3	$ 0.2	1.8	$ 0.5	5.2	$ 0.5	5.0	$ 0.2	1.5	$ 0.1	1.2	$ 0.2	1.7	$ 0.2	1.9
Mining	0.1	0.6	0.5	4.4	1.3	12.2	1.2	10.9	0.3	2.6	0.3	1.2	0.4	2.0	0.4	2.5
Construction[b]	0.1	1.2	0.2	6.3	0.4	17.5	0.5	18.6	0.2	7.5	0.2	1.4	0.3	10.6	0.3	12.7
Manufacturing	0.2	2.0	0.9	9.6	2.6	26.8	2.5	25.7	0.8	8.3	0.7	7.4	1.0	10.4	1.3	14.0
Transportation, communications, and utilities	0.4	7.2	2.0	37.3	5.5	102.6	5.2	100.3	1.8	34.3	1.6	30.9	2.2	43.1	3.0	53.4
Trade	1.2	43.3	5.9	207.4	16.2	574.8	14.3	525.2	4.0	155.2	3.1	126.5	4.3	176.6	4.7	192.4
Finance, insurance, and real estate	0.3	8.3	1.5	43.2	4.3	121.0	4.4	123.6	1.6	44.5	1.5	41.6	2.1	58.1	2.0	57.5
Services	0.3	16.3	1.9	80.3	5.4	224.5	5.8	237.3	2.3	93.2	2.3	92.4	3.3	129.0	3.0	121.4
Government	0.3	9.8	1.5	44.6	4.3	130.5	4.3	129.1	1.4	41.9	1.2	37.2	1.7	51.9	1.9	58.3
Total	$3.0	89.0	$14.6	434.9	$40.5	1215.1	$38.7	1175.7	$12.6	389.0	$11.0	339.8	$15.5	483.4	$16.8	514.1

[a]Includes indirect impacts from both construction and nonconstruction activities.

[b]A portion of the construction-sector impact is expected to be experienced in the finance, insurance, and real-estate sector because of the procedures followed in building the national input-output model by the Bureau of Economic Analysis, Department of Commerce. The exact impact of the portion cycled through the finance, insurance, and real-estate sector is not available.

Table 9-32. Typical Year of Full WIPP Operation: Estimated Indirect Impacts on the Private Sector (Millions of 1979 Dollars)

Sector	Volume	Jobs
Agriculture	$0.2	1.9
Mining	0.4	2.5
Construction[b]	0.3	12.7
Manufacturing	1.3	14.0
Transportation, communications, and utilities	3.0	53.4
Trade	4.7	192.4
Finance, insurance, and real estate	2.0	57.5
Services	3.0	121.4
Government	1.9	58.3
Total	$16.8	514.1

[a]Includes indirect impacts from both construction and nonconstruction activities.

[b]A portion of the construction-sector impact is expected to be experienced in the finance, insurance, and real-estate sector because of the procedures followed in building the national input-output model by the Bureau of Economic Analysis, Department of Commerce. The exact impact of the portion cycled through the finance, insurance, and real-estate sector is not available.

The mining operation will also have minimal effect in attracting new industry because potash mining already dominates an extremely large portion of the economy of Eddy County. The economic impacts of the WIPP mining operation will, for the most part, flow through industries that are already established.

9.4.4.2 Trade and Services

Trade will be one of the most significantly affected sectors outside the industries receiving direct impacts. It is expected that the increase in wholesale and retail sales during WIPP construction will total about $49.1 million. The largest impacts will occur in 1982 ($16.2 million) and 1983 ($14.3 million), when direct employment will total more than 900 jobs annually for the 2 years. Most of this impact will be created through increased buying in the household sector, although businesses will also make purchases from the retail sector. However, most of the local procurement for construction will be made from wholesale outlets. Substantial increases are also expected in the services sector, with nearly $21.4 million in indirect new business.

This analysis assumes that the construction-phase demand for goods and services will take advantage of the goods and services available in the area.

It also assumes that the variety of goods and services offered in the area will not change substantially during the construction period.

Beginning in 1987, the operation of the WIPP will add $4.7 million annually to wholesale and retail sales in the area; this will be larger than the impact on any other identified sector. Much of it will flow into the secondary and tertiary industries rather than into manufacturing or basic industries. The annual impact on finance, insurance, and real estate will be some $2.0 million, and the services sector will also enjoy a substantial increase, just more than $3.0 million per year.

In summary, the response of the private sector to both the construction and the operation of the WIPP will be expressed in new activity in many of the existing secondary and tertiary industries. The operational phase will bring very few new manufacturing firms. However, small-equipment manufacturers and fabricated-metal operations may be attracted by the maintenance and construction activities during the operational phase and the need for equipment repairs.

9.4.4.3 Tourism

Certain aspects of tourism in the two-county area may be affected by the WIPP. Detailed effects are, however, difficult to define at present.

Tourism directly affects retail trade, hotels and motels, eating and drinking establishments, service stations, and other trade and service subsectors. To a lesser degree, it also influences certain government operations (e.g., those of the National Park Service) and some manufacturing activities (e.g., curios and jewelry).

Tourism in the two-county area centers around the caverns in the Carlsbad Caverns National Park, 22 miles southwest of Carlsbad. The park is an unusual attraction, one not likely to lose its popularity because of the repository. Other areas, such as the Living Desert State Park just west of Carlsbad, offer a variety of recreational opportunities enjoyed by out-of-state visitors, but do not attract many tourists beyond those visiting Carlsbad Caverns.

The existence of nuclear-weapons laboratories and atomic-energy research establishments in New Mexico has not hindered tourism. A prime example is the city of Los Alamos, the site of the Los Alamos National Scientific Laboratory. Tourism in Santa Fe, only 40 miles away, has continued to increase, and Los Alamos itself has become a point of interest. Thus past experience indicates that the WIPP will exert no significant adverse impacts on tourism over an extended period.

There may, however, be some short-term impacts on hotels, motels, and other facilities serving tourists. As construction proceeds, a number of transient construction workers will locate in the area. Many are expected to live in temporary quarters for short periods. Past experience reveals that many construction workers stay in camping trailers, campers, or mobile homes owned by concession companies during the work week and travel home for weekends; others may stay in motels and hotels. The transient workers may therefore decrease the overnight facilities available to tourists. This impact is likely to last only 1 to 2 years. During operation this impact is not likely since temporary housing facilities will not be affected to any degree.

9.4.5 Housing and Land Use

9.4.5.1 Total Housing Requirements

The total demand for housing by the in-migrants directly or indirectly attracted by the WIPP is shown in Table 9-33. Housing demand peaks in 1983 with 880 total housing units, decreases to 330 total units in 1986, and thereafter remains stable.

The composition of housing demand (Old West Regional Commission, 1975) is expected to change as construction ends and operation begins. During construction, there is likely to be a relatively large demand for mobile homes and multifamily units; during operation, 81% of the demand will be for single-family units.

Table 9-33. Total Housing Demand Induced by the WIPP

Year	Total[a]	Permanent single family	Permanent multifamily	Mobile homes and others
1980[b]	50	20	5	25
1981	240	80	25	135
1982	770	260	80	430
1983	880	300	90	490
1984	390	130	40	220
1985[c]	240	135	20	85
1986	330	230	20	80
1987	360	290	20	50

[a]Total housing demand is based on projections of population migration resulting from direct and indirect jobs (Table 9-30).

[b]The allocation of total demand to housing types for 1980-1984 is based on the housing preferences of construction workers in Construction Worker Profile (Old West Regional Commission, 1975).

[c]The allocation of total demand to housing types for 1985-1987 is based on the averages of distinct housing-type preferences of construction workers and long-term residents.

9.4.5.2 Scenario I: Carlsbad

Housing

According to Table 9-34, the projected baseline-population increases for Carlsbad call for an addition of at least 1430 housing units from the end of 1977 through mid-1981; this figure, which would drop the vacancy rate to zero, comes from subtracting the total housing stock at the end of 1977 (9420) from the occupied housing in mid-1981 (10,850). When added to the current total of 34 substandard units not suitable for rehabilitation, this means an increase of about 1460 units over the 3.5 years, or an average of about 420 units per year--somewhat less than the rate of construction in 1977.

Housing construction planned by developers for the 4 years from 1978 through 1981 calls for somewhere between 1650 and 1750 new units. However, because of an extremely tight mortgage-loan market, the exact time when these units will be built is not known. Interviews with local bankers and the Carlsbad Planning Department indicate that there has been a slowdown in new housing starts over 1978-1979, and it appears that construction will not keep pace with projected demand. Thus, even under baseline conditions, Carlsbad could face a significant housing shortage by mid-1980.

To bring the vacancy rate up to 3% by mid-1981, a total of 1770 units must be added over the 3.5-year period (Table 9-34). This is an average of 505 units per year, somewhat above the maximum of 438 units per year planned for the 1978-1981 period. It thus appears that, if planned construction rates are continued into 1981, the addition to the housing stock will be insufficient to bring the total housing stock to a level providing a vacancy rate of 3%.

Baseline-population projections for the period 1981-1985 call for 1110 new housing units, or 270 per year. The next 2 years are projected to show an increase in housing demand of 590 units, or 295 per year. Maintaining a 3% vacancy rate over the 1981-1987 period would require an additional 2080 units, or 350 per year (Table 9-34).

The population increase associated with the WIPP project will raise housing demand for the 1980-1984 period to 1490 units, or 375 per year. The primary impact, however, will be in the year from mid-1981 to mid-1982: housing demand will increase by 890 units over the year versus 440 units under baseline conditions. Moreover, much of the increase will occur soon after the start of construction. It appears that a housing shortage might develop in 1981 or 1982 if scenario I conditions prevail (Table 9-34).

After reaching a peak of 890 units in 1982, the WIPP-induced housing demand will decrease to 240 units the following year. Housing-demand projections indicate that an excess of 120 units will exist in the Carlsbad area by 1984. This excess will be eliminated by 1985, and thereafter demand will level off (Table 9-34).

The increased vacancy rate in 1984 is attributed to a lag between the construction and full operation. As construction nears completion in late 1983 and early 1984, a significant number of workers will leave the Carlsbad area (Table 9-30). However, this reduction in staff and the corresponding increase in locally available housing will be short-lived and should cause no major problems.

There are three factors that might mitigate the shortage projected for 1981 and 1982. First, it is possible that interest rates will decrease, thereby expanding the availability of money for mortgage loans. Any housing shortage resulting from excess demand could then be expected to be controlled by an increase in housing supply. Second, a relatively large number of construction workers tend to prefer mobile homes (Table 9-35). Third, construction workers

Table 9-34. Housing Demand: Scenario I, Carlsbad

Year	Occupied housing		Change from previous year		Occupied housing plus 3% vacancy rate		Change from previous year	
	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP
1977	9,290[a]	--	--	--	9,420[b]	--	--	--
1978[c]	9,810	--	520[d]	--	10,120	--	700[d]	--
1979	10,130	--	320	--	10,450	--	330	--
1980[e]	10,530	--	390	440	10,850	10,900	410	440
1981	10,850	10,570	330	490	11,190	11,400	340	510
1982	11,290	11,060	440	890	11,640	12,320	450	910
1983	11,440	12,180	150	240	11,800	12,560	160	240
1984	11,740	12,060	300	(120)	12,100	12,440	310	(120)
1985	11,960	12,170	230	110	12,330	12,550	230	110
1986	12,260	12,530	290	370	12,630	12,920	300	380
1987	12,550	12,850	290	320	12,930	13,250	300	330

[a]Estimated year-end occupied units.

[b]Actual year-end housing stock, based on U.S. Department of Commerce, 1970 Census of Housing, and subsequent building-permit and demolition data for Carlsbad.

[c]Figures for 1978 and subsequent years are mid-year.

[d]Six-month change.

[e]Beginning year of construction. Impact assumed to be static after 1986.

Table 9-35. WIPP-Induced Housing Demand by Type: Scenario I, Carlsbad[a]

Year	Total	Permanent single family	Permanent multifamily	Mobile homes and others
1980	40	15	5	20
1981	210	70	25	115
1982	660	220	70	370
1983	740	250	80	410
1984	325	110	35	180
1985	205	70	20	115
1986	280	95	30	155
1987	310	105	35	170

[a]The allocation of total demand to housing types is based on the housing preferences of construction workers and other newcomers in Construction Worker Profile (Old West Regional Commission, 1975).

are highly mobile. Construction activity can be expanded more rapidly than most other industrial activities. In fact, the sudden increase in housing demand is itself a result of the assumption that the level of construction activity on the project can be rapidly expanded.

It is impossible to predict the extent to which these factors will mitigate the housing shortage at the start of WIPP construction. It appears that there will be some shortage, however, with an associated increase in rents and housing prices. If a housing shortage does develop, it is not likely to persist beyond the end of construction. The total demand for housing will decrease in 1984 as one phase of the project ends and another begins. Demand would not rise above the 1983 level until 1986. The cumulative demand from 1980 to 1985 could be met at a construction rate of 320 units per year.

Land use

Using the housing-demand estimates above and an estimated average lot size for new housing units of 0.25 acre, one finds that about 300 acres will be required for new residential development from the start of 1978 through mid-1980. From 1980 through 1987, an additional 505 acres will be needed under baseline conditions. When compared with the currently vacant area, which is more than 7500 acres, this 8-year cumulative demand of 805 acres clearly leaves ample surplus for commercial and industrial development as well as parks, streets, and other land uses.

It should be further noted that the existence of the 100-year floodway will not seriously hinder the use of land for either baseline or WIPP-induced housing construction. The floodway is already substantially developed. Moreover, most of the new construction is projected for the southern end of Carlsbad, which is not in the 100-year floodway.

If the WIPP is begun in 1980, an additional 75 acres will be required for residential development through 1987, bringing the 8-year cumulative demand to 875 acres. During peak construction (1983) additional residential land use due to WIPP will be about 140 acres under the expected housing-type demand (more than 50% mobile homes). Given the availability of vacant land, the implementation of the project does not appear likely to cause any land-use problems in Carlsbad.

9.4.5.3 Scenario I: Loving

Housing

The projected baseline-population increases for Loving call for an addition of at least 69 housing units from the end of 1977 through mid-1980 (Table 9-36). This figure, which would decrease the vacancy rate to zero, is derived by subtracting the total occupied housing stock at the end of 1977 (393 units) from the occupied housing in mid-1980 (462 units). This represents an annual rate of increase of approximately 27 housing units per year. In order to maintain a 3% vacancy rate in mid-1980, about 71 units will be needed--an annual rate of 28 units per year. Under baseline conditions, 67 new housing units will be required from 1980 through 1987, or about 10 per year.

The WIPP will increase the cumulative 1980-1987 requirements by 17 units, bringing the annual rate up to 12 units for the 7 years. Although the demand in the peak year (1983) may be as high as 41 units, more than half of the demand will be for mobile homes; it therefore does not appear that there will be any difficulty in meeting new housing requirements through 1987, with or without the WIPP project.

Loving, like Carlsbad, will have an excess of housing units in 1984 because of a lag between the end of WIPP construction and the beginning of full operation (Table 9-36). However, this decrease in demand will be extremely short-lived, lasting less than a year.

Land use

Using the present average lot size of 0.5 acre, the projected cumulative housing additions through 1987 will require about 35 acres under baseline conditions and approximately 43 acres with the WIPP. If the lot size is 0.25 acre, 17 acres will be required without and 21 acres with the repository.

Table 9-36 shows the WIPP-related housing demand by type. The pattern is the same as that projected for Carlsbad: during construction, there will be a greater demand for mobile homes and multifamily units, while during operation there will be a greater demand for single-family units.

There are an estimated 320 acres of vacant land inside the current Loving city limits. Most of this land is used for agricultural purposes. Land adjoining the corporate boundaries is also used primarily for agriculture. Because a large proportion of land inside and contiguous to the city limits is presently vacant, the community of Loving should experience no land-use problems with or without the WIPP project.

Table 9-36. Housing Demand: Scenario I, Loving

Year	Occupied housing		Change from previous year		Occupied housing plus 3% vacancy rate		Change from previous year	
	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP
1977	393	--	--	--	405[a]	--	--	--
1978[b]	429	--	36	--	443	--	38	--
1979	444	--	15	--	458	--	15	--
1980[c]	462	465	18	21	476	479	18	21
1981	465	477	3	12	479	491	3	12
1982	482	520	17	43	496	536	17	45
1983	483	524	1	4	498	540	2	4
1984	499	515	16	9	514	530	16	10
1985	514	525	15	10	530	541	16	11
1986	514	530	0	5	530	546	0	5
1987	529	546	15	16	545	561	15	15

[a]Estimated year-end occupied units.
[b]Figures for 1978 and subsequent years are mid-year.
[c]Beginning year of construction. Impact assumed to be static after 1986.

Table 9-37. WIPP-Induced Housing Demand by Type: Scenario I, Loving[a]

Year	Total	Permanent single family	Permanent multifamily	Mobile homes and others
1980	3	1	0.3	1.7
1981	12	4	1	7
1982	38	13	4	21
1983	41	14	4	23
1984	16	5	2	9
1985	11	4	1	6
1986	16	5	2	9
1987	17	5	2	10

[a]The allocation of total demand to housing types is based on the housing preferences of construction workers and other newcomers in Construction Worker Profile (Old West Regional Commission, 1975).

9.4.5.4 Scenario II: Hobbs

Housing

The projected baseline-population increases for Hobbs call for an addition of at least 770 housing units from the end of 1977 through the middle of 1980 (Table 9-38); this figure, which would drop the vacancy rate to zero, is derived by subtracting the total housing stock at the end of 1977 (10,880 units) from the occupied housing in mid-1980 (11,650 units). This represents an annual rate of about 310 units for the 2.5-year period, or about 52% of the record addition of more than 600 units in 1977.

To maintain a 3% vacancy rate in mid-1980, about 1130 units will be needed, or 450 per year. Under baseline conditions, 2470 new housing units will be needed from 1980 through 1987, or about 355 per year, a rate well below that for 1977.

The WIPP project will increase the cumulative 1980-1987 requirements by 130 units, bringing the annual rate up to 370 units for the 7 years; this rate is less than those achieved in 1976 and 1977. Although it does not appear that there will be any difficulty in meeting the projected new-housing requirements through 1987, the continuation of present (12%-15%) interest rates into 1981 would probably reduce housing starts and create some short-term shortages. However, it is difficult to predict the long-term effects of present mortgage-loan rates on housing construction. Other types of housing, such as mobile homes, could conceivably be used to cover any shortages that might occur because of a tight mortgage-loan market.

Table 9-39 shows the WIPP-induced housing demand by type. The pattern is the same as that projected for Carlsbad, mobile homes and multifamily units being preferred during construction and single-family units being preferred during operation.

Table 9-38. Housing Demand: Scenario II, Hobbs

Year	Occupied housing		Change from previous year		Occupied housing plus 3% vacancy rate		Change from previous year	
	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP	Baseline	With WIPP
1977	10,660[a]	--	--	--	10,880[b]	--	--	--
1978[c]	10,890	--	230[d]	--	11,230	--	350[d]	--
1979	11,300	--	410	--	11,650	--	420	--
1980[e]	11,650	11,670	350	370	12,010	12,030	390	--
1981	12,090	12,180	440	510	12,470	12,560	430	530
1982	12,430	12,710	340	530	12,820	13,110	350	550
1983	12,810	13,130	380	420	13,210	13,540	390	430
1984	13,200	13,340	380	210	13,600	13,750	400	210
1985	13,600	13,690	400	350	14,020	14,110	420	360
1986	13,870	13,990	270	300	14,300	14,420	280	310
1987	14,120	14,250	250	260	14,550	14,690	260	270

[a]Estimated year-end occupied units.
[b]Actual year-end housing stock, City of Hobbs Housing Count, 1978.
[c]Figures for 1978 and subsequent years are mid-year.
[d]Six-month change.
[e]Beginning year of construction. Impact assumed to be static after 1986.

Table 9-39. WIPP-Induced Housing Demand by Type: Scenario II, Hobbs

Year	Total[a]	Permanent single family	Permanent multifamily	Mobile homes and others
1980[b]	20	5	5	10
1981	90	30	10	50
1982	280	95	30	155
1983	320	110	35	175
1984	145	50	15	80
1985[c]	90	50	10	30
1986	120	80	10	30
1987	130	105	5	20

[a]Total housing demand is based on projections of population migration resulting from direct and indirect jobs (Table 9-30).

[b]The allocation of total demand to housing types for 1980-1984 is based on the housing preferences of construction workers in Construction Worker Profile (Old West Regional Commission, 1975).

[c]The allocation of total demand to housing types for 1985-1987 is based on the averages of distinct housing-type preferences of construction workers and long-term residents.

Land use

Using the present average lot size of one-seventh of an acre, the projected cumulative housing additions through 1987 would require about 460 acres under baseline conditions and about 480 acres with the WIPP. However, if the lot size of new homes is one-quarter acre, approximately 810 acres will be required without, and 840 acres with, the WIPP. During peak construction (1983) an additional 60 acres will be required for residental land use under the expected distribution of housing-type demand (more than 50% mobile homes).

Excluding land in the Hobbs Industrial Air Park, there are an estimated 1070 acres of vacant land inside the current Hobbs city limits, mostly in the north end of town. Thus there is more vacant land than will be required for the new housing units alone. There is some question, however, about the ability of the vacant area to accommodate new housing and new commercial and public development. Currently, there is an average of 1.25 occupied acres for every housing unit in Hobbs. If this average acreage is to be maintained, the projected housing additions (3370 units)* will require about 4200 acres, or about four times the available vacant area. While it is not suggested that actual nonresidential land requirements grow in direct proportion to those for residential purposes, it is probable that some of the currently vacant land will be used for nonresidential purposes. As a result, it is possible that

*For 1977 to mid-1980, 770 housing units; for mid-1980 to mid-1987, 2470 (baseline) plus 130 WIPP-induced housing units.

there will be little or no vacant land remaining inside the current city limits of Hobbs by the late 1980s.

To some extent, this increasing scarcity of land may cause some of the housing development projected for Hobbs to take place outside the city limits. This, in turn, may prompt expansion of the city limits, an action that must be initiated by petition from the residents or landowners in the annexed area. Any development outside the current city limits will most likely take place to the north of Hobbs. Land to the east and south of the city is owned by three individuals who are currently unwilling to sell, while the west is constrained by oil- and gas-field developments.

9.4.6 Community Services and Facilities

This section discusses the impacts that may be induced by the WIPP project on community services and facilities. Section 9.4.6.1 presents selected analyses of impacts that have related effects on Carlsbad and Loving. Section 9.4.6.2 analyzes the impacts that can be identified as being specific to Loving.

9.4.6.1 Scenario I: Carlsbad and Eddy County

Education: Carlsbad School District

Projections of school enrollments indicate that excess physical capacity will continue to characterize the Carlsbad school system. The 1986-1987 school-year enrollment will require approximately 72% of the available classroom space (Table 9-40). Overall, the student population should increase by about 15% (about 950 students) during the decade from 1976-1977 to 1986-1987. The principal effect of the WIPP project will be to accelerate the rate of increase in enrollment, with maximum impact in the 1983-1984 school year of 4.8% (approximately 325 students) over baseline conditions. The 10-year increase is projected to be 18% (about 1075 students). This accelerated rate of student-population growth, however, will not tax the capacity of the school system. The 1986-1987 enrollment level with the WIPP will require less than 74% of the current classroom space.

Increased enrollments may require additional teachers, although it is possible to allow the student-to-teacher ratio to rise. Maintaining the current student-to-teacher ratio would require about 50 additional teachers under baseline conditions by 1986-1987 and about 59 with the project. Requirements for administrative and staff personnel will probably grow as well, but not necessarily as rapidly as enrollment. Because enrollments with the WIPP are projected to be only marginally larger than those without the WIPP, they may not result in any increase in demand for administrative and staff personnel.

During the 1977-1978 school year, the Carlsbad school district reopened an elementary school in the south portion of the city, an area of high potential population growth. Thus a potential school shortage in that part of the city has been alleviated.

Table 9-40. Projected Enrollments in the Carlsbad School District

Year	Grade				Total
	K-6[a]	7-8	9-10	11-12	
		BASELINE			
1979-1980[b]	3568	981	1097	1000	6646
1980-1981[b]	3612	980	1024	974	6590
1981-1982	3731	998	1035	899	6663
1982-1983	3881	898	1022	830	6631
1983-1984	4092	834	1019	825	6770
1984-1985	4204	886	927	819	6836
1985-1986	4364	963	865	825	7017
1986-1987	4511	1029	930	753	7223
1987-1988	4641	1099	1010	704	7454
1988-1989	4734	1168	1079	758	7739
		WIPP SCENARIO I			
1980-1981[c]	3655	990	1033	983	6661
1981-1982	3879	1032	1067	928	6906
1982-1983	4125	956	1075	878	7034
1983-1984	4286	881	1062	863	7092
1984-1985	4306	912	950	839	7007
1985-1986	4458	987	886	843	7174
1986-1987	4624	992	955	775	7346

[a]Includes special education; kindergarten students counted as full time.
[b]Carlsbad 40-day average daily membership reports.
[c]Start of construction.

The WIPP project is not likely to cause any overcrowding problems at any grade level in the Carlsbad school system.

Groundwater and municipal water system

The City of Carlsbad has sufficient water rights for the next several decades. Table 9-41 contains projected withdrawals and depletions* for Carlsbad with and without the WIPP project. Baseline withdrawals are expected to rise from the 1977 level of 8800 acre-feet to 10,950 by 1987 and 13,250 by 2000. Implementation of the project will increase demand by as much as 6% during construction and 2% in subsequent years.

*The term "depletion" refers to the part of the water withdrawn that is no longer available because it has been evaporated, transpired, incorporated into products or crops, consumed by people or livestock, or otherwise removed from the water environment.

Municipal wastewater systems and treatment facilities

The new sewage-treatment plant now being constructed will be capable of serving a population of 50,000. Because its design capacity is well over projected population levels (with or without the WIPP) through the end of this century, the new plant should be adequate for the needs of Carlsbad for the next several decades.

Table 9-41. Water Demand in Carlsbad[a]

Year	Annual water demand (acre-feet)			
	Baseline		With WIPP	
	Withdrawals	Depletions	Withdrawals	Depletions
1970	7,100[b]	3500[b]		
1977	8,800[c]	5000[d]		
1980[e]	9,400[d]	5600	9,400	5600
1981	9,600	5800	9,750	5900
1982	9,950	6050	10,000	6350
1983	10,050	6100	10,650	6450
1984	10,250	6250	10,550	6450
1985	10,450	6400	10,600	6500
1986	10,700	6600	10,950	6750
1987	10,950	6800	11,200	6950
1988	11,250	7000	11,500	7150
2000	13,250	8650	13,550	8800

[a]Peak consumption in 1979 was 16 million gallons per day (mgd). In the year 2000 the peak baseline load will be 24 mgd; with the WIPP it will be 25 mgd.

[b]Data from the New Mexico Interstate Stream Commission and New Mexico State Engineer's Office (1975): County Profile, Eddy County.

[c]Data from the City Manager's Office, Carlsbad, New Mexico.

[d]Based on population projections made in this study and per-capita withdrawal and depletion projections by the New Mexico Interstate Stream Commission, adjusted for actual withdrawals in 1977.

[e]Start of construction.

The present sewer system will have to be extended into areas of new housing development. Moreover, population increases will result in increased wastewater flows through existing main sewer lines. City officials have stated that the existing main sewer lines can handle projected increases (with or without the WIPP) through the year 2000.

Electrical service

Projected occupied-housing additions to the Carlsbad-Loving area under baseline conditions total 2840 from 1978 through mid-1987. By mid-1987, this will result in a 6.4% increase in total electricity use over current levels if current rates of use continue. Moreover, new commercial hookups will be required by the end of 1986, causing an additional increase of 5.9% over current levels of electricity use.

The WIPP project will result in about 3157 new housing units between 1978 and 1987, with a 7.1% increase in electricity use. Commercial use will add about 6.5%. The net effect will be to increase the residential and commercial use of electricity by less than 2% by mid-1987. Total electricity use will be up about 1% as a result.

The WIPP itself will require as much electricity as many of the large industrial users in the area. Its demand level will be about one-tenth that of an area ammonia plant that recently closed. The closing of the ammonia plant in effect created sufficient excess generating capacity to cover about 10 times the projected WIPP demand.

According to officials of the Southwestern Public Service Company, the generating capacity will be sufficient for the projected demand. However, new distribution substations will be required, and there is a lead time of 3 to 6 months for new hookups.

Natural-gas service

Under baseline conditions, the housing demands projected through 1987 for the Carlsbad area show that residential hookups will increase 28.9% over current levels. At current consumption rates, this will increase the consumption of natural gas by 4.5%. Increased commercial use will raise consumption by another 1.7%.

The WIPP will increase the residential consumption of natural gas by 4.9%. Commercial use will rise 1.8% above current levels by the end of 1987. As a result of the WIPP, gas consumption will be about 0.5% above baseline levels in 1987.

Gas Company of New Mexico officials believe that these increases, with or without the WIPP project, can be met without difficulty.

Fire protection

To maintain current levels of fire protection in 1987, Carlsbad will need 36 full-time fire-department employees under baseline conditions and 38 employees with the WIPP--increases of six and eight employees, respectively, from the 1979 level. Two additional pieces of major equipment will be needed in 1987, either with or without the WIPP. Without the project, the one airport and three nonairport substations will provide sufficient coverage in 1987. However, the growth of the city with the WIPP will require an additional fire substation by 1987. The principal impact of the WIPP will thus be to require additional personnel and equipment at an earlier date.

Police protection

Under baseline conditions, the number of police employees will have to increase from 48 to 57 in 1987 to maintain the current ratio of police employees to city inhabitants. The WIPP will create the need for three more police employees (a total of 60 in 1987). Five additional Eddy County Sheriff employees will be needed in 1987. The WIPP is not expected to create any conditions that would significantly change the required number of Sheriff's Department employees. The implementation of the WIPP will change the times when additions to the police and sheriff's departments are needed.

Health care

To maintain current service levels, Eddy County will require 189 hospital beds by mid-1987 under baseline conditions and 196 with the WIPP. If occupancy rates are allowed to rise over current levels and if the per-capita demand for hospital beds remains unchanged, the 1987 baseline county population can be accommodated with about 147 beds. With the WIPP, about three more beds will be required. The resulting increase in occupancy rates will bring countywide occupancy to about 88% (90% with the WIPP). Thus, current hospital facilities appear to be adequate to meet demand through the 1980s if occupancy rates are allowed to rise. Moreover, the Guadalupe Medical Center has several double rooms that currently contain only one bed. The number of beds can therefore be increased fairly readily, bringing occupancy rates down.

The number of primary-care physicians required at current service levels will be 24 by mid-1987 under baseline conditions and 25 with the WIPP. Under Bennett's (1977) standard of one primary-care physician per 1200 people, the WIPP will increase the demand for primary-care physicians by about one.

Projected population levels for 1987 call for one additional ambulance under baseline levels. The WIPP will not add to this requirement.

Traffic and transportation

Access to the site will be provided by a road connecting the site to U.S. 62/180 to the north. A road to the south connecting with N.M. 128 is also planned; however, the main traffic flow is expected to be from the north. There may be temporary minor disruption of traffic on U.S. 62/180 and N.M. 128 while the access roads are being connected. Site construction itself will be several miles off the public roads and should therefore cause no disruption of traffic flows or patterns.

During construction and operation, there will be some increase in traffic on U.S. 62/180 between the site access road and Carlsbad. However, since present plans call for some workers to be bused to the site during all of the project's phases, the traffic-volume increase will be minimal. Since U.S. 62/180 is a four-lane highway, slow-moving buses will not impede other traffic.

Figure 9-7 shows the 1978 traffic volume for selected locations in Carlsbad. Table 9-42 presents peak traffic flows and street capacities for several of these locations. Currently, traffic flows are well within the existing capacity of the street system (New Mexico State Highway Department, 1978).

Projections of 1987 peak traffic flows are presented in Table 9-42; they are based only on projected population increases, with and without the WIPP, and not on the location of new housing developments. The only location where capacity is reached is site B on Canal Street. This is in the downtown business district, where the population-based projection is probably reasonably accurate. The other sites are feeder routes from expected new population

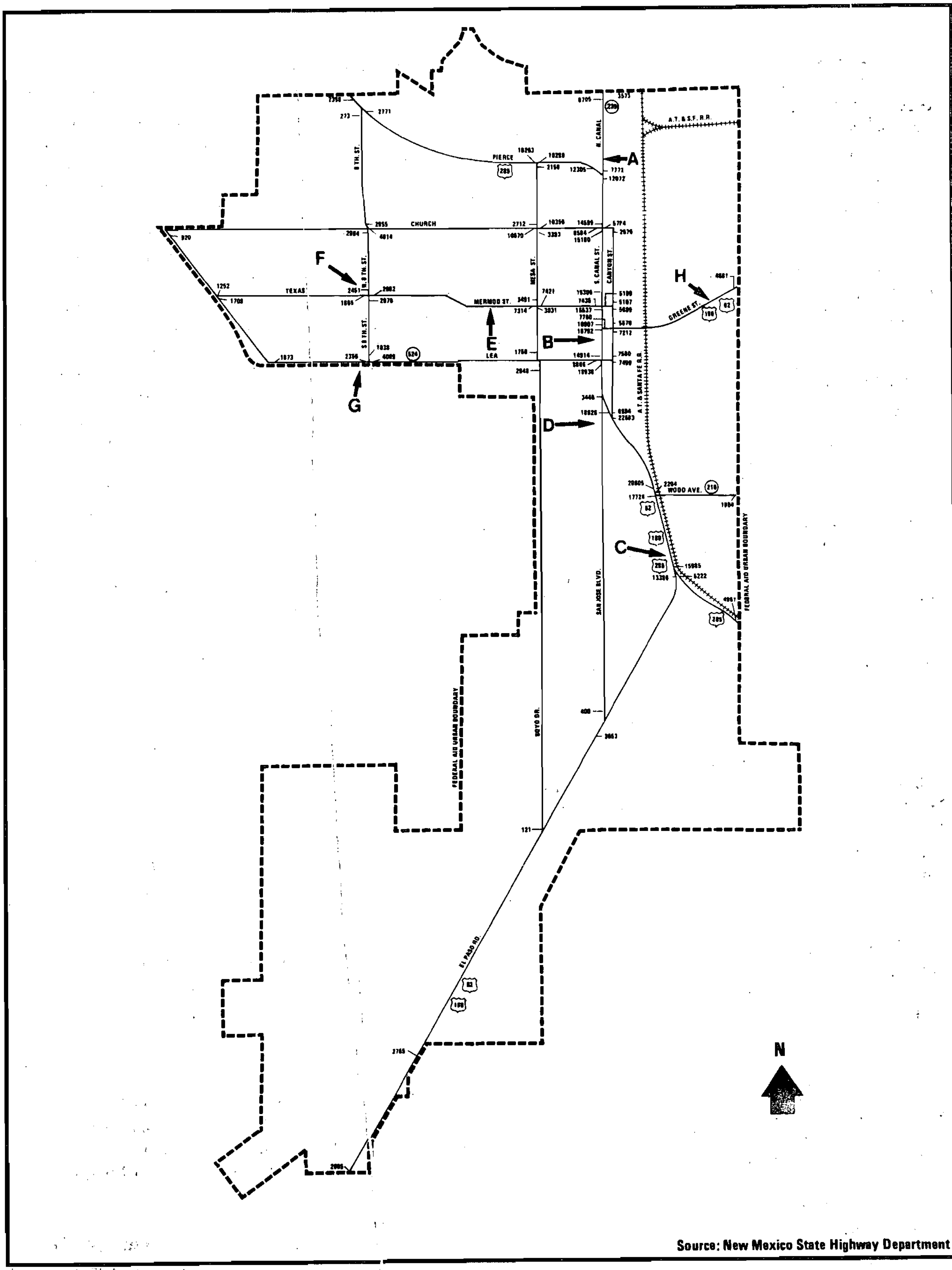

Figure 9-7. Carlsbad average daily traffic, 1978.

Table 9-42. Selected Traffic Flows and Road Capacities, Carlsbad

Site[a]	Street	Average daily traffic, 1978[b]	Peak hour (4-5 p.m.), 1978[c]	Projected peak hour, 1987[d] Baseline	WIPP	Peak-hour capacity[e]
A	Canal Street	7,772	710	850	870	1900
B	Canal Street	16,792	1530	1840	1880	1900
C	U.S. 285	15,985	1460	1750	1800	2900
D	San Jose Boulevard	3,446	310	370	380	950
E	Mermod Street	7,314	670	810	830	1900
F	Texas Street	1,865	170	210	220	950
G	Lea Street	2,356	210	250	260	950
H	U.S. 62/180	4,681	430	520	600[f]	2900

[a]See Figure 9-7.
[b]Data from the New Mexico State Highway Department (1978a), Traffic Flow Maps of Urban Areas.
[c]Based on percentage hourly loads; data from the New Mexico State Highway Department (1978b), Carlsbad Traffic Study.
[d]Assumes increase in proportion to population increase. See text.
[e]Based on street-capacity estimating procedures used by the Middle Rio Grande Council of Governments.
[f]Assuming travel from the site is during the peak hour and an average of two occupants per vehicle. Comparable figure for the peak construction year (1983) is 850.

centers to the downtown area. They are thus likely to receive impacts greater than those indicated in Table 9-42. Most, however, have considerable excess capacity.

On a subjective basis, it appears that the location of new housing will cause the most severe impact on San Jose Boulevard and Boyd Drive. (No traffic counts are available for Boyd Drive.) The extent of the impact is impossible to predict, however, since it depends primarily on the location of the place of work of residents in new homes. (For those working in the potash mines or at the site, it depends on the location of bus pickup points.) The place of work is of primary importance since about 50% of all trips with origins or destinations in Carlsbad are for work purposes.

<u>Communications services and facilities</u>

Under baseline conditions, by 1987 the number of telephone main stations in service will increase by about 3400, or about 28% over the 1978 year-end level. With the WIPP project, the increase will be about 3800, or 31%. As a result, the net effect of the WIPP will be to raise the demand for telephone service about 2% above baseline levels.

General Telephone of the Southwest expects to complete a new central office with automated switching in late 1979 or early 1980. Company officials state that this office will provide ample capacity to meet projected demands with or without the WIPP.

Recreation

Impacts on most community recreation facilities are difficult, if not impossible, to quantify for several reasons. First, recreation, particularly outdoor recreation, uses a much larger area than the city limits. Second, the information available from government agencies (the State of New Mexico in conjunction with the Heritage Conservation and Recreation Service of the U.S. Department of the Interior) that monitor capacity and use is limited to multicounty areas known as Recreational Market Areas (RMAs). Third, people who migrate to the area may not have the same recreational values as those who already live there.

The New Mexico State Planning Office defines seven RMAs, with RMA 6 covering the counties of Chaves, Eddy, Lea, Lincoln, and Otero. Analysis of recreational facilities and use patterns for this RMA indicates that facilities for two popular outdoor recreational activities, camping and pool swimming, will be insufficient by 1985 if present capacities are not increased.

Popular RMA activities that appear to have adequate facilities through the year 2000, given the population growth with and without the WIPP, are fishing (lake and stream), picnicking, tennis, and golf.

Demand for new swimming pools in Carlsbad is likely to develop in the next few years. The city currently has an adequate supply of city parks and recreational facilities in the Presidents' Park and Carlsbad Lake complex.

Indoor recreational activities are generally sponsored by the private sector. One major exception is recreation for senior citizens. The City of Carlsbad already provides a program to meet this demand, and it is expected that the WIPP will not significantly increase the demand in this category. Moreover, since the overall WIPP impact on the population of Carlsbad is only about 6% of the total population in the peak impact year (1983), no significant problems with indoor recreational facilities are expected.

Solid-waste management

The projected baseline increase in the population indicates that two additional vehicles will be needed to collect refuse in 1987. With the WIPP, three additional vehicles will be needed in 1987.

With an estimated remaining life of 30 years, the landfill in Carlsbad has enough capacity (even with the WIPP) to meet the needs of the city until after the year 2000.

9.4.6.2 Scenario I: Loving

This section presents analyses of the impacts that can be identified as being specific to Loving. Analyses of selected impacts that have related effects on Carlsbad and Loving are presented in Section 9.4.6.1.

Education--Loving School District

School-enrollment projections indicate that the municipal schools of Loving will still have excess capacity in all grades by mid-1987 with or without

Table 9-43. Current and Projected Enrollments in the Loving School District

Year	Grade K-6[a]	Grade 7-9	Total
	ENROLLMENT CAPACITY		
	288	140	428
	BASELINE		
1979-1980[b]	223	119	342
1980-1981	230	122	352
1981-1982	233	124	357
1982-1983	236	126	362
1983-1984	239	128	367
1984-1985	245	131	376
1985-1986	248	133	381
1986-1987	252	134	386
1987-1988	258	138	396
1988-1989	264	141	405
	WIPP SCENARIO I		
1980-1981[c]	232	122	354
1981-1982	241	126	367
1982-1983	248	130	378
1983-1984	249	132	381
1984-1985	250	133	383
1985-1986	252	135	387
1976-1987	258	136	394

[a]Includes special education; kindergarten students counted as full time.
[b]Loving 40-day average daily membership reports.
[c]Start of construction.

the WIPP project (Table 9-43). Under baseline conditions, the school district's enrollment will increase by approximately 13% (29 students). Under the assumptions of scenario I, enrollment will increase approximately 15% (35 students). Thus the WIPP project will cause a rise of only 2% (six students) in the overall student population; however, during the peak year (1983), an increase of 10 students over baseline projections is expected.

Groundwater and municipal water system

Water withdrawals in Loving are projected to increase from the current 280 to 490 acre-feet per year in 2000 under baseline conditions (Table 9-44). The WIPP will add about 19 acre-feet to water demand in the peak impact year of 1983. In 1988, the WIPP will add 9 acre-feet to annual demand. Total demand in the year 2000 with the WIPP will be 500 acre-feet, considerably less than current water rights of 800 acre-feet per year.

Table 9-44. Water Demand in Loving[a]

Year	Annual water demand (acre-feet)			
	Baseline		With WIPP	
	Withdrawals	Depletions	Withdrawals	Depletions
1978[b]	279	186[c]		
1980[d]	300[c]	200	300	200
1981	300	200	310	200
1982	320	210	340	220
1983	320	210	340	220
1984	330	220	340	230
1985	350	220	350	230
1986	350	230	360	230
1987	360	240	370	240
1988	370	240	380	250
2000	490	310	500	310

[a]Peak consumption in 1979 was 500,000 gallons per day (gpd). Peak consumption projected for the year 2000 is 880,000 gpd under baseline conditions and 900,000 gpd with the WIPP.

[b]Data from Molzen and Corbin and Associates, Consulting Engineers.

[c]Estimates based on population projections by this study and per-capita withdrawal and depletion projections from the New Mexico Interstate Stream Commission and the New Mexico State Engineer's Office (County Profile, Eddy County), adjusted for actual 1978 withdrawals.

[d]Start of construction.

If current use patterns continue into the future, peak day demand should reach system capacity in 1993 under baseline conditions. With the WIPP this will occur in 1992.

Municipal wastewater systems and treatment facilities

The current demand on Loving's sewage-treatment plant uses approximately 55% to 60% of the plant's capacity. The population increase projected to result from the WIPP project (Section 9.4.2) is not expected to create excess demand beyond the plant's current capacity. However, because the present plant does not meet the current effluent standards of the New Mexico Water Quality Commission, any increase in population will serve to aggravate the present effluent-quality problems until a new plant, which is being planned for construction if funds are available, is completed.

Electrical service

Because the area served by the Southwestern Public Service Company includes both Carlsbad and Loving, the impacts for Loving are covered by the discussion for Carlsbad (Section 9.4.6.1).

Natural-gas service

The housing demands projected for the Loving area through 1987 under baseline conditions indicate that residential hookups will increase 19% over current levels. At current consumption rates, this will increase the consumption of natural gas by 6%. Increased commercial use will raise consumption an additional 1.3%.

The WIPP project will increase residential and commercial use by 15.3% and 1.9%, respectively, by the end of 1987. As a result, gas consumption will be about 2% above baseline levels in 1987.

Officials of the Gas Company of New Mexico believe that these increases, with or without the WIPP project, can be met without difficulty.

Fire protection

To maintain the current levels of fire protection in 1987, Loving will need to purchase one additional piece of major equipment to replace aging vehicles. No new personnel will be needed. The WIPP project should not add to this requirement.

Police protection

Under baseline conditions or with the WIPP project, the number of police employees will not increase if the current ratio of police officers to city inhabitants is maintained.

Recreation

Under baseline conditions no additional recreational facilities should be needed by 1987. Neither the construction nor the operation of the WIPP should affect recreation requirements.

Communications services and facilities

Under baseline conditions, the number of telephone main stations in service by 1987 will increase by approximately 125, or about 23% over the 1978 year-end level. With the WIPP, the increase will be about 147, or 27%. The net effect of the WIPP project will be to raise demand for telephone service 3% above baseline levels.

Health care

To maintain current service levels, the El Centro Rural de Salud clinic should require no additional personnel or facilities either under baseline conditions or with the WIPP project. Short-term hospitalization is available in Carlsbad.

Solid-waste management

The projected baseline increase in the population indicates that one new vehicle will be needed to collect refuse in 1987. The WIPP should not change this requirement.

Table 9-45. Projected Enrollments for the Hobbs School District

Year	Grade K-6	Grade 7-9	Grade 10-12	Total
		ENROLLMENT CAPACITY[a]		
	4630	1990	1730	8350
		BASELINE		
1979-80	4231	1799	1753	7783
1980-81	4239	1748	1763	7750
1981-82	4274	1789	1696	7759
1982-83	4334	1815	1631	7780
1983-84	4519	1702	1589	7810
1984-85	4703	1602	1627	7932
1985-86	4885	1538	1654	8077
1986-87	5004	1619	1546	8169
1987-88	5090	1717	1444	8251
1988-89	5142	1804	1371	8317
		WIPP SCENARIO II		
1980-81	4257	1754	1768	7779
1981-82[c]	4338	1811	1714	7863
1982-83	4440	1853	1661	7954
1983-84	4604	1733	1613	7950
1984-85	4748	1620	1639	8007
1985-86	4926	1554	1665	8145
1986-87	5053	1638	1560	8251

[a]Estimated capacity, assuming 24 students per classroom.

[b]Data from Ray Wasson, Assistant Superintendent for Personnel, Hobbs Municipal Schools, personal interview, 1979.

[c]Start of construction.

The present Loving landfill is expected to be filled in approximately 30 years. With the WIPP project, it will reach capacity 2 months earlier.

9.4.6.3 Scenario II: Hobbs and Lea County

<u>Education--Hobbs School District</u>

School-enrollment projections indicate that the Hobbs municipal schools will experience crowding in all grades by the early to mid-1980s (Table 9-45). Classroom capacity will be particularly strained in grades K through 6 by 1982-1983. Under baseline conditions, the average class will exceed 24 students in the 1983-1984 school year. Under the assumptions of scenario II, this increase in class size will happen a year earlier. By the 1986-1987 school year, the average class will have more than 27 students under baseline conditions and somewhat more students with the WIPP.

To alleviate the projected overcrowding, new classroom space will be needed by the beginning of the 1986-1987 school year. This capacity could take the form of an entirely new elementary school, classrooms added on to existing schools, or the use of modular classrooms at existing elementary school sites. Any of these alternatives would either reduce or alleviate the projected overcrowding.

It should be emphasized that the additional classroom capacity will be necessary with or without the WIPP project. The entrance of WIPP dependents into the system would only exacerbate the problem.

Groundwater and municipal water system

With rights to just more than 18,800 acre feet per year, Hobbs has sufficient water rights to cover expected demand until well past the year 2000. As shown in Table 9-46, withdrawals are projected to be 10,500 acre-feet in 2000 under baseline conditions. With the WIPP, an additional 80 acre-feet would be required that year. The greatest impact would occur in 1983, with an additional demand of 175 acre-feet per year.

Although water rights are adequate for several decades, the current yield of the 28 existing wells (14 million gallons per day) is only slightly greater than the current peak-day demand. Peak-day demand is projected to exceed existing well yields in 1980. Unless additional wells are brought into production, there may be some temporary water shortages in the mid-summer of 1980, with the shortages becoming worse in succeeding summers. The WIPP project would increase the shortfall somewhat.

Municipal wastewater systems and treatment facilities

With an anticipated wastewater flow of 79.5 gallons per capita per day, an average of 2.88 million gallons per day (mgd) of wastewater will be generated in 1983 under baseline conditions. By 1990 this will rise to 3.3 mgd. With the WIPP, wastewater flows would reach 2.9 mgd in 1983 and 3.31 mgd in 1990. Since the capacity of the sewage-treatment plant under construction is about 5 mgd, with expansion to 6 mgd possible, there should be no problems with sewage treatment, with or without the WIPP, for the next several decades.

New main sewer lines, replacing or supplementing several existing main lines, will provide service from the north side of town, the area of expected population growth, to the sewage-treatment plant on the south side of town. As a result, no problems should be experienced in delivering wastewater to the treatment plant, with or without the WIPP.

The foregoing analysis assumes that all projected population increases in Hobbs actually occur within the city limits. However, as indicated in Section 9.4.5.4, there is a high probability that the current city limits will be unable to accommodate all of the projected population increase. In fact, much of the recent growth in the Hobbs area has taken place outside the city limits to the north. If future growth does occur in this area and the new housing units are not connected to the municipal sewer system, it will be necessary to use septic systems. Since conventional septic systems have presented problems

Table 9-46. Water Demand in Hobbs[a]

	Annual water demand (acre-feet)			
	Baseline		With WIPP	
Year	Withdrawals	Depletions	Withdrawals	Depletions
1970[b]	6,800	3100		
1977[c]	6,950	3850		
1980[d]	7,250	4350	7,250	4,350
1981	7,500	4500	7,550	4,550
1982	7,700	4650	7,850	4,750
1983	7,900	4800	8,050	4,900
1984	8,150	5000	8,200	5,050
1985	8,350	5100	8,400	5,150
1986	8,550	5250	8,650	5,300
1987	8,750	5400	8,850	5,450
1988	8,900	5500	8,950	5,550
2000	10,500	6850	10,550	10,600

[a]Peak consumption (based on peak-day factors) in 1977 was 14 mgd. Peak consumption projected for the year 2000 is 20.9 mgd under baseline conditions and 21.0 mgd with the WIPP.

[b]Data from the New Mexico Interstate Stream Commission and the New Mexico State Engineer's Office (1975): County Profile, Lea County.

[c]Estimates based on population projections by this study and per-capita withdrawal and depletion projections by the New Mexico Interstate Stream Commission, adjusted for the recent water-rate increase.

[d]Start of construction.

with seepage into groundwater, it is necessary to use the somewhat more expensive evapotranspiration systems. This, in turn, will mean a slight increase in housing costs.

Electrical service

By mid-1987, residential consumption of electricity will increase by 4.9% over 1978 year-end levels, with 0.9% attributable to the WIPP. If the current ratio of commercial to residential use is maintained, commercial use will require an additional 4.6%. The net effect of WIPP-induced residential and commercial use of electricity will be an increase of 0.29%.

Natural-gas service

The housing demands projected for the Hobbs area in 1987 under baseline conditions indicate that residential hookups will increase 30% over current levels. At current consumption rates, this will increase natural-gas consumption by 18.7%. Increased commercial use will raise consumption an additional 8%.

The WIPP project will increase the residential and commercial consumption by 19.7% and 8.3%, respectively, by the end of 1987, or by about 1% above baseline levels.

According to Hobbs Gas Company officials, the projected expansion of natural-gas service, with or without the WIPP project, can be accommodated without difficulty.

Fire protection

Without the WIPP, the Hobbs fire department will have to increase from 44 employees in 1978 to 55 in 1987 in order to maintain the current ratio of fire-department employees to city inhabitants. The WIPP project is expected to increase the number of employees needed by one. By 1987 the number of major fire-equipment units and substations will have to increase by two and one, respectively, if the current level of fire protection is to be maintained. The WIPP is not expected to alter that increase significantly.

Police protection

An additional 20 police employees, an increase of 24.6%, will be needed in Hobbs by 1987 under baseline conditions, in order to maintain the current level of service. With the WIPP, the number of additional employees needed will be 22, or two employees more than the number needed under baseline conditions.

Under baseline conditions, the Lea County Sheriff's department will need an additional six employees. With the WIPP project, the needed increase is expected to be one additional employee.

Health care

Projected population increases for Lea County to mid-1987 will increase the requirements for hospital beds to 100 under baseline conditions and current use rates. With the WIPP, the demand will rise to 101. Occupancy rates will rise to about 55% and 56%, respectively, well below the recommended level of 80% (Bennett, 1977).

Medical-personnel requirements in 1987 will be about 1% higher with the WIPP than without. If the current ratio of primary-care physicians to population is maintained, this means a WIPP-related increase of 0.3 physician. If the standard proposed by Bennett is used, the WIPP-induced population change in 1987 will result in the need for 0.5 extra primary-care physician. Overall, the WIPP will raise personnel requirements by less than 1% and will not increase capital facility requirements measurably. Ambulance requirements will rise to five vehicles with or without the WIPP.

Traffic and transportation

Access to the WIPP site from Hobbs will be on U.S. 62/180. Since this highway is well below peak-hour capacity, commuting by WIPP employees is not expected to have any significant impact.

Figure 9-8 indicates selected 1978 traffic flows for several locations in Hobbs. Table 9-47 presents peak traffic flows and street capacities for several of these locations. These projections are based on projected increases in population, with or without the WIPP, and should provide reasonably accurate results for the intracity traffic flows.

The impact of future population growth is expected to be particularly heavy on streets connecting the north side of Hobbs to other parts of town. However, the only north-side locations that appear to have any serious potential for crowding are the intersections of Dal Paso and Turner with Sanger, both of which are expected to exceed capacity by 1987.

Table 9-47. Selected Traffic Flows and Road Capacities, Hobbs

Site[a]	Street	Average daily traffic, 1978[b]	Peak-hour traffic, 1978[c]	Projected peak hour, 1987[d] Baseline	WIPP	Peak-hour capacity[e]
A	Turner	11,916	1192	1410	1430	2900
B	Grimes	11,372	1137	1340	1370	1900
C	Dal Paso	15,554	1555	1840	1870	1900
D	Bender	13,562	1356	1600	1630	1900
E	Turner	16,247	1625	1920	1960	1900
F	Dal Paso	16,769	1677	1980	2000	1900
G	Broadway	12,140	1214	1430	1460	1900
H	U.S. 62/180	5,868	587	690	730[f]	1900

[a]See Figure 9-8.

[b]Data from the New Mexico State Highway Department (1978a), Traffic Flow Maps of Urban Areas.

[c]Assumed to be 10% of the average daily traffic flow.

[d]Assumes increase in proportion to population increase. See text.

[e]Based on street-capacity estimating procedures used by the Middle Rio Grande Council of Governments.

[f]Assuming travel from the site is during the peak hours and an average of two occupants per vehicle. Comparable figure for the peak construction year (1983) is 830.

Peak flows are at or slightly above capacity under baseline conditions and would be marginally higher with the WIPP project. The intersection of Dal Paso with Bender will be approaching capacity in 1987 under either circumstance. The term "capacity" does not mean an absolute limit but rather that traffic movement is slowed as the capacity figure is approached. Thus, Turner and Dal Paso may experience some rush-hour problems by 1987, with the problems being slightly worse if the WIPP project is implemented. There may also be some evening-rush-hour traffic problems at some downtown locations, either with or without the WIPP.

Communications services and facilities

With the WIPP project, about 3300 additional main stations will be required by mid-1987, an increase of 31% over the 1978 level and 1% over the baseline conditions.

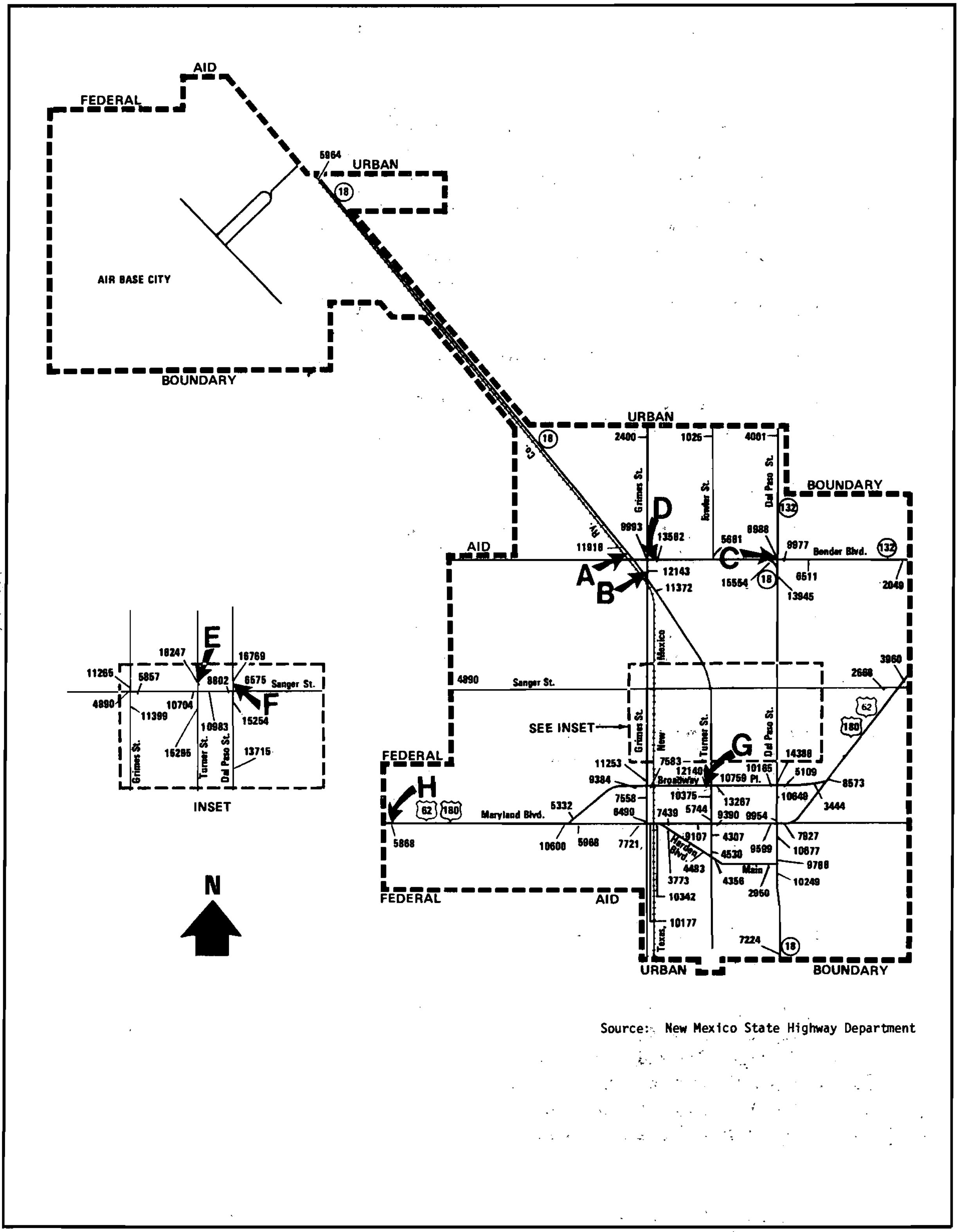

Figure 9-8. Hobbs average daily traffic, 1978.

General Telephone of the Southwest has recently installed a new exchange and plans additional installations in 1980 and 1981. It expects no difficulty in meeting projected demand with or without the WIPP.

Recreation

As stated in Section 9.4.6.1, outdoor recreation is generally measured over a larger area than municipal limits. In Regional Market Area 6 (RMA 6), which includes Chaves, Eddy, Lea, Lincoln, and Otero Counties, demands for camping and swimming-pool facilities may not be met by 1985. However, the lack of swimming pools as measured on an RMA-wide basis may not apply to the City of Hobbs. Hobbs has four pools, two open to the general public and two available to private members only, and it appears that the demand will not exceed the supply by the year 1985. A large State park in Hobbs (at the Hobbs Industrial Air Center), to be completed in 1983, will alleviate the current shortage of campsites within the RMA, particularly in the vicinity of Hobbs.

Peak impact on Hobbs is expected during 1983, at which time it is expected that overall recreational demands will be met.

Solid-waste management

Two additional vehicles will be needed in Hobbs in order to meet the refuse-collection needs in 1987. With the WIPP project the number of new vehicles needed will be essentially the same.

By 1982, five of the present collection vehicles will be more than 7 years old. Therefore, it is projected that seven new vehicles will have to be purchased by 1987.

With an estimated remaining life of 30 years, the landfill in Hobbs has sufficient capacity (even with the WIPP project) to meet the needs of the city until after the year 2000.

9.4.7 Government*

9.4.7.1 Scenario I: Carlsbad, Loving, and Eddy County

Carlsbad

In fiscal year 1982-1983, the year of maximum WIPP-construction impact on the population, Carlsbad municipal revenues are projected to reach $12.1 million (in 1979 dollars) under baseline conditions (for additional information, see Appendix M, Table M-7), or about $380 on a per-capita basis. With the WIPP project, revenues will reach $12.6 million in 1982-1983. The peak-year

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*For an explanation of the techniques used in projecting revenues and expenditures, see Appendix L. Revenues and expenditures are rounded, where feasible, to the nearest $0.1 million in this section. For detailed figures, see Appendix M.

impact of the WIPP will add about $0.6 million to Carlsbad revenues (Appendix M, Table M-8).

The long-run operation of the WIPP will result in an additional $0.3 million in annual municipal revenues. Total revenues without the project should reach $13.7 million in 1988-1989, while those with the project should be $14.0 million.

Carlsbad municipal expenditures are projected to be $8.8 million in 1982-1983 under baseline conditions; the WIPP project should increase spending to nearly $9.3 million. Thus, the WIPP will increase municipal expenditures by $0.5 million in the year of peak impact.

By 1988-1989, Carlsbad expenditures are expected to reach $9.7 million under baseline conditions and $9.9 million with the WIPP, which would thus increase fiscal 1988-1989 spending by $0.2 million.

As shown in Table M-8 of Appendix M, the net fiscal impact of the WIPP project is projected to be an excess of revenues over expenditures of nearly $0.1 million in 1982-1983 and less than $0.05 million in 1988-1989.

Loving

Loving revenues are projected to be $320,000 in 1982-1983, or $186 on a per-capita basis (for additional information, see Appendix M, Table M-9). The WIPP project will produce an additional $19,000 in revenues for Loving in that year (Appendix M, Table M-10). In fiscal year 1988-1989, the WIPP will add about $9000 to the projected $360,000 baseline revenue level.

Loving expenditures should be more than $320,000 in 1982-1983 under baseline conditions. With the WIPP project they are projected to be nearly $350,000, an increase of $22,000. In 1988-1989, baseline expenditures are projected to be more than $370,000. The WIPP project will add $12,000 to this baseline amount.

Given the current fiscal situation for Loving, the net effect of the WIPP will be to increase fiscal deficits slightly. The effect of these deficits is reflected in the increased debt service projected for Loving (Table M-10).

Eddy County

Eddy County revenues are projected to reach $5.8 million in fiscal year 1982-1983 under baseline conditions and $6.0 million with the WIPP (for additional information, see Table M-11). In 1988-1989, revenues should reach $6.4 million without the project and nearly $6.5 million with it. The peak impact of WIPP construction and operation will be to add $0.13 million to revenues in 1982-1983 and less than half of that in 1988-1989 (Table M-12). Expenditures for Eddy County are projected to be $4.6 million in 1982-1983 under baseline conditions. The WIPP should raise spending to $4.8 million in that year, for an increase of over $0.2 million.

Under existing conditions and assumptions used in this analysis, in fiscal year 1982-1983, the WIPP will add $48,000 more to expenditures than to revenues in Eddy County; in 1988-1989, additions to expenditures will exceed revenues by $21,000.

9.4.7.2 Scenario II: Hobbs and Lea County

Hobbs

The maximum population impact of WIPP construction will occur in fiscal year 1982-1983. In that year, Hobbs municipal revenues should reach $12.2 million under baseline conditions, or $343 per capita (for additional information, see Table M-13). The WIPP project will raise revenues to $12.5 million, an increase of $0.3 million for 1982-1983 (Table M-14).

In fiscal year 1988-1989, revenues are projected at $13.9 million under baseline conditions and $14.0 million with the project, a difference of $0.1 million.

Hobbs municipal expenditures are projected to be $10.2 million in 1982-1983 under baseline conditions and $10.4 million with the WIPP, which would raise spending by approximately $0.2 million in 1982-1983. In 1988-1989, municipal spending should reach $11.4 million without the project and $11.5 million with the WIPP, an increase of $0.1 million attributable to the WIPP.

The net effect of the WIPP project on the Hobbs municipal budget is projected to be a surplus of revenues over expenditures of $0.05 million in 1982-1983 and $0.02 million in 1988-1989.

Lea County

Lea County revenues are projected to reach $6.7 million in 1982-1983 under baseline conditions and show an additional increase of $0.05 million with the WIPP. For 1988-1989, baseline revenues should be $8.4 million, and the WIPP project should increase these revenues by approximately $0.02 million (for additional information, see Tables M-15 and M-16).

Lea County expenditures for 1982-1983 are projected at $4.8 million under baseline conditions and $4.9 million with the WIPP, which would raise spending by about $0.07 million for the year. In 1988-1989, the WIPP is projected to raise spending by $0.03 million from the $5.4 million baseline level.

The net fiscal impact of the WIPP on Lea County is projected to be small. For 1982-1983, it will raise spending by $20,000 more than revenues. In 1988-1989, the net deficit will fall to $9000.

9.4.7.3 School-District Finances

Scenario I: Carlsbad and Loving

The principal impact of the WIPP on Carlsbad school expenditures is expected to be on operation expenses. Major capital outlays should not be required because the school system is projected to have excess capacity, with or without the WIPP, for the foreseeable future. The peak impact on school spending is expected in 1982-1983, when expenditures increase about $814,000 over baseline levels (Table M-18).

The WIPP is expected to increase district revenues more than spending. In the peak-impact year of 1982-1983, revenues are projected to be $848,000 higher with the WIPP than without, largely because of increases in district property-tax revenues.

The Loving school district will experience an increase in revenues of $34,000 in 1982-1983 as a result of the WIPP (Table M-20). WIPP-related expenditures for the year are projected to be $39,000. In the long run, WIPP-related expenditures will exceed revenues by approximately $6000 per year.

Scenario II: Hobbs District

Hobbs will probably require a new school in the rapidly growing northern part of the city in the late 1980s; this school will be required with or without the WIPP. At current construction costs, a new 20-room school will add about $150,000 in debt service* to the annual debt service given in Table M-21. The share of this debt service attributable to the WIPP (three of the 20 classrooms) is approximately $23,000 per year.

The greatest WIPP-related increase in operating expenses ($288,000) will occur in 1982-1983 (Table M-22). District revenues are projected to increase by more than spending as a result of the WIPP during the mid-1980s. In 1982-1983, revenues will be $297,000 more with the WIPP than without it. In the long run, the debt service associated with the probable new school will cause WIPP-related expenditures to exceed revenues by about $18,000 per year.

9.4.8 Socioeconomic Effects Under Changed Circumstances

If the basic conditions assumed in this analysis change, the predicted impacts will change. If the project is delayed, apparent costs will rise because of inflation. If economic activities in Eddy and Lea Counties are appreciably different, then the degree of migration or employment of local individuals may change significantly. In general, if the economic conditions are not as bright as forecast, the impacts of the WIPP will not be as great because more construction workers will be available from the local area. Conversely, if the economic conditions are such that there is a shortage of construction workers beyond that forecast, then a heavier degree of migration to local communities will be necessary in order to meet WIPP employment requirements.

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*Based on an assumed construction cost of $1.5 million financed through 20-year 8% bonds.

9.5 ENVIRONMENTAL EFFECTS OF ACCIDENTS DURING OPERATION

Much of the planning for the WIPP project has been an effort to insure that accidents that may occur during the handling of the radioactive wastes will pose no serious risk to the environment. This section reports the results of accident analyses performed as part of this planning.

During repository operation, two types of accidents could affect the environment: those that release radioactive material and those that release hazardous substances emitting no radiation. The first part of this section discusses the accidents that may release radioactive material and predicts their impacts by using the techniques of consequence analysis: postulating severe, yet credible, accidents and calculating their effects. To predict the effects realistically, the calculations use experimental data whenever applicable data are available.

The second part of this section discusses accidents that may release hazardous nonradioactive material. The third part discusses the effects of earthquakes, thunderstorms, tornadoes, and range fires. The discussion of range fires estimates the consequences of the release of radioactivity assumed to have been biologically accumulated in plants as a result of routine releases over 25 years.

9.5.1 Accidents Involving Radiation

To assess the environmental impacts of accidents that could release radioactive material, scenarios were developed to model severe accidents. Although all of these accidents are unlikely, the scenarios are realistic in the sense that they are not incredible; the accidents could, in theory, occur during repository operation. Each scenario was analyzed in detail to determine potential impacts on the workers in the repository and on the general public. A typical scenario for an accident releasing the waste includes the following events:

1. A breach of the waste container.

2. The exposure of a portion of the waste to the air.

3. The suspension of the portion of the waste that is of respirable size in ventilation air.

4. The depletion or fallout of waste particles from the air stream when these processes are credible.

5. Release to the environment.

6. The dispersion of the airborne radioactivity to the site boundary and the delivery of radiation doses to the public.

This approach yields a consequence analysis, not a risk analysis. Risk, which equals consequence times probability of occurrence, is difficult to predict accurately because the probability values used in determining risk are often imprecise. This section presents the consequences of selected severe, but possible, accidents during plant operation and does not address the detailed probability of their occurrence.

During an accident, radioactivity can become available for release to the environment. The most serious release will result from an accident in which a shipping container or waste canister is damaged so severely that the waste is no longer contained.

Since the three types of waste to be emplaced in the WIPP--contact-handled (CH) TRU waste, remotely handled (RH) TRU waste, and high-level waste for experiments--vary in physical and radiological characteristics, available information was reviewed to determine the representative properties of each type of waste. These properties, summarized in Section 5.1 and Appendix E, include physical forms, radionuclide inventory, and radioactivity.

Accident scenarios were developed by reviewing the waste-handling procedures during each step in the flow of waste packages through the repository, from unloading in the receiving area to final disposal in the underground area. Normal operations with waste-handling equipment (forklifts and hoists) were studied to determine how accidental misuse or equipment failure could result in the release of radioactive material.

Tables 9-48 and 9-49 list the postulated accident scenarios and identify each accident by number. The analysis of each scenario proceeded by establishing values for the factors that affect the amount of accidental release. For example, the analysis estimated the quantities of surface activity and of waste that could be released from inside a container, the number of containers involved in the accident, the fraction of the activity that could become airborne, and the decontamination factor of high-efficiency particulate air (HEPA) filtration. These factors were then combined to determine the total radioactivity released to the environment.

The scenarios were grouped into the following categories: (1) fires in the waste-handling building, (2) container failures in the waste-handling building, (3) underground container failures, and (4) underground fires. Within each of these categories, the scenario with the greatest potential release of radioactivity to the environment was analyzed nuclide by nuclide as a representative and bounding example of that group. All other accidents within the groups would have less severe consequences.

The most severe accidents in the four categories are the following:

1. A fire on the surface caused by internal combustion or an external combustion source.

2. The dropping and puncturing of a waste package in the surface building.

3. The rupturing of a container through a failure of the mine hoist.

4. An underground fire ignited by an internal combustion source.

The least likely of these four scenarios are those involving fires. The design of containers and fire-protection systems are expected to preclude releases of radioactive material during fires. Fires from sources external to the waste containers would be infrequent and of limited size because of the lack of combustible materials in the handling areas. A fire started by

Table 9-48. Accident Scenarios for Contact-Handling Areas

Area	Accident	Possible scenario	Damage to waste package(s)
Receiving	C1	Vehicle collision with waste package	No serious damage (package classified as Type B)
Unloading	C2	Drop of whole package from crane	Drop less than 30 feet; same as C1
	C3	Drum drop on forklift (or down the dock)	Six drums drop; lid broken off one drum
Pallet storage	C4	Drum puncture by forklift	Hole in side of two drums; lid broken off third drum
	C5	Drop from forklift	Crack in one drum
	C6	Drum failure from excess internal pressure	Drum fails, releasing half the contents
	C7	External fire	Contents of two drums (or one box) released because of internal pressure and contents of one additional drum (or box) burned
	C8	Fire caused by internal combustion in drum	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one additional drum burned
Overpack and repair	C9	Drum drop on way to repair	Crack in one drum; size of crack five times that of C3 since drum is defective initially
	C10	Drum failure on way to repair	Drum splits open, releasing 100% of contents
	C11	External fire	Surface contamination vaporizes from 24 drums; contents of two drums released because of internal pressure and contents of one additional drum burned
	C12	Fire caused by internal combustion in drum (or box)	Surface contamination from eight drums vaporizes; contents of one drum released because of internal pressure and contents of one additional drum burned
Cage loading	C13	Hoist drop down mine shaft	48 drums crack open, releasing 100% of contents

Table 9-48. Accident Scenarios for Contact-Handling Areas (continued)

Area	Accident	Possible scenario	Damage to waste package(s)
	C14	Fire in hoist caused by internal combustion in drum	Surface contamination vaporizes from eight drums (or two boxes); contents of one drum (or one box) released because of internal pressure and contents of one additional drum (or one box) burned
Underground disposal	C15	Pallet hit by transporter	Lid of one drum knocked off and cracks appear in sides of three other drums; area of cracks is 2.75 in.^{2}
	C16	Drum punctured by forklift	Hole in side of one drum (or box); hole is 12 in.^{2} in area
	C17	Drum drop from forklift	Same as C5
	C18	Rock fall from mine-shaft walls	Holes in sides of 12 drums; holes are 12 in.^{2} in area
	C19	External fire during handling	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one drum burned
	C20	Fire caused by internal combustion in drum (or box)	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one drum burned
	C21	Drum puncture by back-filling equipment	Same as C4
Disposal room	C22	Fire caused by internal combustion in drum	Contents of two drums released because of internal pressure and contents of one drum burned

Table 9-49. Accident Scenarios for Remote-Handling Areas

Area	Accident	Possible scenario	Damage to waste package(s)
Receiving	R1	Cask drop	No serious damage to canister because cask is a Type B packaging
	R2	Crane impact on cask	Same as R1
	R3	Fire around transport vehicle during inspection of cask	Same as R1
Decontamination and cooling	R4	Cask drop	Same as R1
	R5	Cask overturn from transport roller	Same as R1
	R6	Dry cask with defective canisters, break in flexible hose	Loss of radioactive gas
	R7	Wet cask with defective canisters, break in coolant pipe	Loss of radioactive fluids
	R8	Cask drop	No serious damage to canister because cask is a Type B packaging
Hot cell	R9	Canister knockover by hot-cell crane	Crack in canister
	R10	Canister drop	Crack in canister
	R11	Fire from internal combustion in canister	Not credible; canister in transfer cask
	R12	External fire involving high-level waste for experiments	Same as R11
Canister	R13	Break in contaminated-waste discharge line during canister decontamination	Loss of radioactive fluid to decontamination cell
	R14	Fire from internal combustion in canister	Contents of one canister burned
Hoist-cage-loading station	R15	Hoist drop down waste shaft	One canister and facility cask broken
Underground transfer cell	R16	Canister drop	One canister breaks open
	R17	Fire from internal combustion in canister	Same as R11
	R18	External fire involving high-level waste for experiments	Surface radioactive material vaporizes from one canister
Disposal room	R19	Canister drop in hard salt	Crack in canister
	R20	Fire in transport vehicle	No serious damage to canister because it is protected by a shielding cask
	R21	Fire from internal combustion in canister	Same as R11

internal combustion would be highly improbable because of the small amount of combustible waste. The lack of air inside the container would not allow sustained combustion, and the waste-acceptance criteria require the containers to be metal or otherwise combustion-resistant boxes. Scenarios involving sources of radioactivity other than waste in containers (e.g., the failure of tanks in the liquid-radioactive-waste system) were also investigated but were found not to be significant.

In general, accidents that could occur during the retrieval of waste from the WIPP are expected to be no more severe than those that could occur during emplacement, since waste will be retrieved by a reversal of the emplacement process. Contact-handled TRU-waste containers will be removed one at a time so that each container can be inspected. If a container is found to be breached or externally contaminated, it will be overpacked (i.e., placed into a new container) at the retrieval site (Section 8.10). Similarly, the remotely handled TRU waste will be retrieved by removing the buried canisters one at a time; if a canister is externally contaminated, it will be overpacked. Because of the proposed inspection and overpacking procedures and unit-by-unit retrieval, any accident during retrieval would be limited to a single container. Accidents involving multiple packages could not occur until a batch of containers became available. Accidents involving the transport of retrieved waste away from the WIPP would be similar to transportation accidents during emplacement.

Description of accidents in the CH-waste area

The two most common waste containers in the area where CH TRU waste will be handled will be the DOT-17C drum (55-gallon steel drum) and the DOT-7A plywood box (4 by 4 by 7 feet) with a 3-millimeter-thick fiberglass-reinforced fire-retardant polyester coating.

Because the number of boxes expected at the WIPP at any time is much smaller than the number of drums, the number of accidents involving boxes is expected to be much smaller than the number involving drums. Also, the relative radionuclide abundance per liter is greater for drums. For these reasons, only the accident scenarios involving drums were analyzed.

Listed below are the general assumptions used for analyzing the accident scenarios for the CH-waste area:

1. Surface activity on the waste containers is many orders of magnitude lower than the activity inside. Since the waste containers are breached during the scenarios, the surface contamination is not explicitly included because its contribution is insignificant.

2. Contact-handled TRU waste is expected to have various forms; much of the waste is expected to be metal scrap, rags, sludge, and sludge-concrete mixes. The WIPP waste-acceptance criteria support an assumption that a maximum of 1% of the radioactive waste is less than 10 microns in size and that 25% of the waste is combustible.

3. A decontamination factor of 10^6 is allowed for the two-stage HEPA filters. This is believed to be a reasonable allowance; it is based on an experimentally determined (ACGIH, 1977) removal efficiency for test particles with diameters larger than 0.3 micron.

Brief descriptions of all the accident scenarios and the resulting damages are in Table 9-48. Four accidents--C7, C10, C13, and C22--were chosen for a detailed calculation of nuclide-by-nuclide release to the environment. These accidents represent the limiting, or worst, accident for their respective categories: surface fire, surface container failure, underground container failure, and underground fire. Table 9-50 lists the activity of each nuclide released in these accidents. Synopses of the four accident scenarios are given in the following paragraphs.

Accident C7: Surface fire. The lack of flammable materials in the building makes the following assumption reasonable: if a fire occurs in the surface facility, not more than the contents of one drum will burn and not more than two adjacent drums will pressurize and burst because of the heat. As a plausible way for a fire to start, it is postulated that a small puddle of diesel oil spilled under a pallet of waste drums somehow ignites even though it is very difficult to ignite diesel fuel; although such a fire would be small, the adjacent drums are assumed to fail and spill half their contents. The contents spilled from the adjacent drums do not burn, and only 1% of the spilled material is in powder form.

It takes 1 hour to put out the fire and to repack or cover the exposed waste. Since only 25% of the drum content is combustible and 1% of the activity in the combustible contents is released in respirable form, the burning releases a total of 0.25% of one drum in respirable form. In addition, it is assumed, from the experiments of Mishima and Schwendiman (1970, 1973a, 1973b), that 0.014% of the spilled powdered waste from the adjacent drums is released and respirable per hour; thus a total of 0.0014% of one drum is respirable and released from the material that is not burned. Each of the drums involved is assumed to contain the maximum radioactivity content of 85 curies (Table E-1 in Appendix E). The amounts of the released radionuclides are then reduced by HEPA filtration before they are released to the environment.

Accident C10: Surface container failure. An operator error may result in a forklift's hitting a stack of CH-waste drums. It is conservatively assumed that two drums are punctured by the arms of the forklift and that the lid of a third drum is knocked off as it falls from the stack. Operating procedures caution the operator not to back the forks out of the drums, but it is assumed that the drums become disengaged from the forks. Since not all of the waste is expected to fall out of the damaged drums, it is assumed that 25% of the radioactivity content is released from the drum that lost a lid and 10% is released from each punctured drum. To calculate the amount of radioactivity that is released and becomes airborne, it is assumed that 1% of the radioactive material with a particle size of less than 10 microns, which in turn is 1% of the total waste, is dispersed in the room air. It is further assumed that the lid falls off a maximally loaded (85 curies) drum and that the punctured drums contain an average load (3.4 curies each). The total release is thus 6.9×10^{-8} curie.

Accident C13: Underground container failure (hoist drop). The waste-hoist cage is equipped with multiple cables, providing a safety factor that makes its failure a very unlikely event. However, for accident analysis, a hoist-drop accident is postulated. This accident is assumed to occur while the cage is at the top of the shaft. Such a fall would result in an impact velocity

Table 9-50. Radioactivity in Respirable Material Released to the Environment During Representative Accidents in the Handling Area for CH TRU Waste

Nuclide	Radioactivity (Ci) released in accident scenario			
	C7[a]	C10[b]	C13[c]	C22[d]
Pu-238	2.6-9[e]	2.7-11	1.2-9	8.5-9
Pu-239	2.9-8	3.0-10	1.3-8	9.3-8
Pu-240	6.9-9	7.1-11	3.1-9	2.2-8
Pu-241	1.8-7	1.8-9	8.0-8	5.7-7
Am-241	3.3-10	3.4-12	1.5-10	1.1-9
Total	2.1-7	2.2-9	9.7-8	6.9-7

[a]Surface fire.
[b]Container failure.
[c]Underground container failure.
[d]Underground fire.
[e]2.6-9 = 2.6×10^{-9}.

sufficient to damage the CH-waste containers severely. The calculation assumes that all the waste in the cage is released, that the fine particulates in it mix with the air in the bottom of the shaft below the disposal tunnel, and that the hoist cage and its contents displace some of this air into the tunnel, where it enters the ventilation system.

The cage is assumed to contain its normal maximum load of two pallets of drums (48 drums). It is assumed that two of the 48 drums contain the maximum level of radioactivity (85 curies per drum) and the remaining 46 drums contain an average level of radioactivity (3.4 curies per drum), for a total activity of 376 curies. One percent of the radioactive material is in particles less than 10 microns in diameter.

The hoist will fall down the waste shaft into the 40-foot-deep pit at the bottom of the shaft (the depth from the bottom of the pit to the tunnel floor). The six hoist ropes (1-3/8 inches in diameter and 2200 feet long) and four tail ropes (1-3/4 inches in diameter and 2200 feet long) will fall into the pit first; they will fill an estimated 20-foot depth of the pit. As the rope coils are compressed, this distance is expected to decrease to 10 feet; however, no energy absorption due to the compressing coils is assumed. All the drums are assumed to rupture.

Any disturbance of the air in the pit can be ignored until the drums rupture. Because the flat bottom of the hoist takes up only half the area of the shaft, the air beneath the hoist is not compressed as the hoist enters the pit, but there is some turbulent mixing. Air equal in volume to the hoist and waste is displaced from the pit. Assuming all the drums rupture and all the waste in them is released, the turbulence is assumed to cause a uniform distribution of respirable particles within the remaining 30 feet of the pit. Assuming 1% of the total radioactivity content is respirable and assumming a remaining pit volume of 8500 cubic feet, the concentration of respirable radioactive matter in the air of the pit is found to be 1.36×10^4 picocuries per cubic centimeter.

The total respirable radioactivity displaced by the hoist cage into the ventilation air in the drift is 0.193 curie.

Of the total activity released to the drift in fine particles, 50% is depleted (Davies, 1966) within the mine by particle deposition, with a resultant release to the environment after filtration of 0.097 microcurie. This depletion factor reflects the fact that all particles larger than 7 microns will settle out in the drift and in the ventilation ducts. Resuspension is not considered because the ventilation-air velocity in the drift is only about 1.5 feet per second and the pit is a dead air space.

Accident C22: Underground fire. Vehicles used in the underground disposal area are diesel powered and contain sufficient fuel for one shift of operation (about 60 gallons). Because of the high flash point of diesel fuel, the probability of causing a fire with such a vehicle is quite low; such fires, however, have occurred in the past, and a fire is considered credible for this analysis. Even though CH waste is received in metal drums and steel-overpacked boxes, only a small portion of the waste is combustible, and there is a small probability that the two types of waste packages could be involved in a fire. Since the drums contain a higher total amount of radioactivity than the boxes, they are used in the calculation of the amount of radioactivity released in this accident. The following assumptions are made:

1. The combustible material is 60 gallons of diesel fuel contained in the full tank of a diesel-powered vehicle operating in the vicinity of a stored array of CH-waste drums.

2. After an accident or a collision causes the fuel tank to rupture, the diesel oil spills out and pools around the base of the drums.

3. The diesel oil ignites from a spark or other ignition source.

4. The heat of the diesel fire then causes the ignition of the waste in the drums. For consistency with the WIPP waste-acceptance criteria, 25% of the waste is assumed to be combustible. The waste is assumed to burn for about 13 hours (without any fire suppression), on the basis of tests with fuel of similar composition (Lawrence Livermore Laboratory, 1978). It is assumed that 100% of the combustible material (25% of the waste) is consumed in the fire.

5. Five percent of the burned waste is given off as particulates (Stearn, 1968), with 20% of the particulates being smaller than 8 microns in diameter (DOE, 1978).

6. Calculations made by the method described by Davies (1966) indicate that 50% of the particulates will be depleted from the release by fallout in the drifts and will not reach the environment.

Assuming in addition that all of the combustible contents of 90 drums are consumed in the postulated fire (87 drums containing the average amount of radioactivity and 3 drums containing the maximum activity) and that the decontamination factor for the HEPA filters is 10^6, it is calculated that the total radioactivity released to the environment would be 6.9×10^{-7} curie.

Description of accidents in the RH-waste area

Operations in the RH-waste area will handle RH TRU waste and high-level waste for experiments. The physical and radiochemical properties of these waste packages are described in Appendix E.

The analysis of accidents in handling RH waste makes six assumptions:

1. Before a canister enters the hot cell, no damage serious enough to release radioactivity can occur to the canister because it is overpacked with a Type B shipping cask.

2. Remotely handled TRU waste is transferred from the waste shaft to an appropriate disposal area by a diesel-powered RH-waste transporter. The waste is contained in a steel canister, and the canister is transported inside a shielded cask. The disposal operation consists of emplacing a canister of waste horizontally into a sleeved hole and then plugging the sleeve with a shielded plug. One canister is handled at a time, and after emplacement, its contents are isolated from all credible accidents. Before emplacement, the canister is inside the facility cask; the combination of this cask and the steel canister prevents the waste from becoming involved in any credible fire during a handling accident. Therefore, a fire involving RH waste would not result in a release of radioactivity to the environment or an exposure of workers.

3. There are no combustible materials in the experimental waste, and therefore no fire associated with an experimental-waste-handling accident will result in a release of radioactivity.

4. A decontamination factor of 10^6 is allowed for the two-stage HEPA filters.

These factors and assumptions are used to make conservative, yet realistic, judgments regarding possible accidents.

From the list in Table 9-49, the two scenarios resulting in the greatest release of radioactivity were chosen for detailed nuclide-by-nuclide calculations: the dropping of a canister of RH TRU waste in the transfer cell (R16) and a hoist drop (R15); the latter accident was analyzed for both RH TRU and experimental wastes. Table 9-51 lists the nuclides released in these accidents. The accidents are described below.

Accident R16: RH canister drop in transfer cell. A canister containing RH waste could be dropped into the transfer cell from the hot cell (a distance of about 36 feet) in the event that a grapple fails. Even with a drop over this distance, it is unlikely that a canister would be damaged enough to result in any release of radioactivity. For analysis, however, it is assumed that the canister does break and releases 1% of its total radioactive contents. Of the radioactivity released, 1% is less than 10 microns in diameter, and 10% of this fraction is assumed to become airborne in the air of the transfer cell. Depletion of material out of the air and resuspension back into the air are assumed to have equal, canceling effects. The total amount of radioactivity

Table 9-51. Radioactivity in Respirable Material Released to the Environment During Representative Accidents in the RH-Waste Area

	Radioactivity released (Ci)		
		Accident R15[a]	
Nuclide	Accident R16[b]	RH TRU waste	Experimental waste[c]
Co-60	1.0-9[d]	1.1-8	2.3-9
Sr-90	8.2-8	8.8-7	4.1-7
Y-90	8.2-8	8.8-7	4.1-7
Rh-106	6.9-10	7.3-9	2.4-8
Ru-106	6.9-10	7.3-9	2.4-8
Cs-137	4.1-10	4.3-9	8.7-6
Ba-137m	3.9-10	4.1-9	8.2-6
Eu-152	2.0-10	2.2-9	3.4-11
Eu-154	8.2-11	8.8-10	1.2-8
Pu-238	6.9-12	7.3-11	1.7-8
Pu-239	6.9-11	7.3-10	5.9-10
Pu-240	1.8-11	1.9-10	3.5-10
Pu-241	4.4-10	4.7-9	7.7-8
Am-241	8.2-13	8.8-12	7.3-10
Total	1.7-7	1.8-6	2.0-5

[a]Canister drop in transfer cell.
[b]Hoist drop.
[c]Only significant nuclides are listed.
[d]$1.0\text{-}9 = 1.0 \times 10^{-9}$.

that becomes airborne is assumed to be reduced by a factor of 10^6 by the HEPA filters. The canister is assumed to contain the maximum amount of radioactivity (1.7×10^4 curies). Under these assumptions, 1.7×10^{-7} curie of radioactivity would be released to the environment.

Accident R15: Underground container failure (hoist drop), RH TRU waste. The canister of RH waste is protected by the facility cask when being hoisted. Because of the design of the cask and the hoist and the capability of the cable under the hoist cage for absorbing energy, the postulated hoist-drop accident is not likely to breach the transfer cask and the canister simultaneously. Furthermore, the design safety factor of the waste-hoist cables makes this event very unlikely. However, such an accident is postulated, and both the cask and the canister are assumed to be severely damaged. The hoist-drop conditions are the same as those for CH waste. Furthermore, it is assumed that all of the waste is released from the canister, with 1% of the waste released assumed to be less than 10 microns in diameter and suspended in the pit air. As for the CH-waste hoist-drop accident, it is assumed that a volume of air equal to the volume of the cask, the transporter, and the waste cage is displaced from the pit into the disposal tunnel, where it enters the ventilation system. Half the radioactive material discharged to the tunnel is depleted before being discharged from the stack. The total radioactivity released to the environment as a result of this accident is 1.8×10^{-6} curie.

Accident R15: Underground container failure (hoist drop), experimental waste. Since the experimental waste is not handled in the same way as CH or other RH wastes, it is not subject to accidents that would result in releases of radioactivity in the work area. The experimental waste is, however, transported to the experimental area by the waste hoist and is therefore subject to the hoist-drop accident postulated as a limiting event.

The assumptions used in the analysis are listed below.

1. The hoist is assumed to fall from the top of the waste shaft 2200 feet into the 40-foot-deep pit at the bottom of the shaft.

2. The rope that collects at the bottom of the pit is compressed to 10 feet on hoist impact, reducing the effective depth of the pit to 30 feet.

3. On impact, 1% of the waste is assumed to break into particles less than 10 microns in diameter. This assumption is based on drop tests of similar waste in canisters not enclosed in a shielded cask (Smith and Ross, 1975). All of these particles are assumed to be suspended in the air of the upper 30 feet of the pit.

4. The total radioactivity content of the waste is 4.3×10^5 curies (Table E-4 in Appendix E).

5. Because of the size and the weight of the cask and the transporter, only one canister can be hoisted at a time.

6. Fifty percent of the material released as a result of the accident is depleted within the mine because of the low air-flow velocity and the long distance to the release point.

7. The actual release mechanisms are as described for RH waste.

As a result of the hoist-drop accident with one canister of experimental waste, 2.0×10^{-5} curie is released to the environment from the disposal-exhaust shaft.

Methods for computing concentrations of released radionuclides

Off-site doses from the accidental release of radioactivity can be received through the inhalation of contaminated air and external exposure from immersion in contaminated air and exposure to contaminated ground surfaces. Lesser pathways for the isotopes under consideration are the ingestion of contaminated food and water and immersion in contaminated water. Because the maximum individual dose will be delivered to a hypothetical person at the site boundary, there will be no exposure from immersion in water or from ingestion. The AIRDOS II computer code was used to calculate these maximum doses (Moore, 1977).

AIRDOS II uses the modified Pasquill equation (Gifford, 1961) to determine the downwind concentrations of radioactive material in the air. The meteorological conditions used in the calculation are the "worst-case" conditions for off-site doses described by the Texas Air Control Board (1977); these are Pasquill class F (stable) conditions and a wind speed of 2 meters per second.

An effective stack height was calculated for the waste-handling building and the disposal-exhaust shaft by using Rupp's equation for momentum-dominated plumes (Clinton Laboratories, 1948). The vertical mixing depth in the atmosphere was limited by using the worst-case winter-morning lid height of 300 meters (Holzworth, 1972).* Parametric calculations were done to verify that these conditions would result in the highest dose at the site boundary. An appropriate rainfall scavenging coefficient and dry-deposition velocity were used to calculate the quantity of radioactivity that is depleted from the cloud by rainfall and the settling of particles on the ground during the time it takes the plume to travel from the point of release to the site boundary. No credit was taken for any radioactive decay in the cloud, because of the long half-lives of the nuclides released, or for gravitational settling. These data were used to calculate the worst-case concentrations of radioactivity that would occur at the site boundary, both in the air at ground level and on the ground.

Calculation of doses received by people

From the calculated concentrations in the air at ground level and on the ground, 50-year dose commitments were calculated for the whole body, the lung, and the bone (the organs receiving the highest doses). These doses were determined by using 1- and 50-year inhalation-dose conversion factors calculated with the INREM computer code (Killough et al., 1975). When the internal dose is reported as an annual dose, it should be understood that the dose is received in a 1-year period immediately after the accident and that this dose is the highest annual dose that will be received during the exposure period. Parametric studies using annual integration periods from 1 to 10 years after inhalation were done to confirm the results.

Results

The dose commitments resulting from the accident scenarios for CH TRU waste are presented in Table 9-52 for a person living on the James Ranch at the boundary of the WIPP site. Since most of the exposure due to the CH TRU waste results from the direct inhalation of radionuclides, the values in the table are dose commitments. Most of the dose commitments result from plutonium.

The CH-waste scenario involving an underground fire (C22) would have the greatest impact; nevertheless, the impact on the general public would be negligible. Consider the bone-dose commitment for a person living at the James Ranch. Should an accident like C22 occur, this person would receive a 50-year dose commitment to the bone of 4.4×10^{-6} rem. During 50 years, however, natural background radiation will contribute a dose of 5 rem to the bone. The dose from the accident would therefore be a small fraction of the naturally occurring background exposure. None of the postulated scenarios for

*The dispersion coefficient χ/Q calculated for these conditions at the site boundary is approximately equal to the 5% (conservative) χ/Q values determined from site-specific meteorological data for a ground-level release (Appendix H, Annex 1, Table 33).

CH TRU waste could deliver significant doses to the public. The potential human health effects of the doses are discussed in Appendix O.

The results of accidents involving RH TRU waste and experimental high-level waste are also presented in Table 9-52. Since the important pathways include both internal and external exposures, Table 9-52 reports values for both doses and dose commitments. Judged by comparison with doses received from natural background radiation, the doses delivered to the general public in any of these accident scenarios are also very small. The potential health effects are discussed in Appendix O.

Table 9-52. Doses and Dose Commitments Received by a Person Living at the Site Boundary

Accident scenario	Dose or dose commitment (rem)		
	Bone	Lung	Whole body
	CH-WASTE AREA		
Surface fire (C7)	1.4-7[a]	6.8-9	3.3-9
Surface container failure (C10)	7.7-9	2.0-10	1.9-10
Hoist drop (C13)	6.0-7	1.5-8	1.5-8
Underground fire (C22)	4.4-6	1.0-7	1.0-7
	RH-WASTE AREA		
Canister drop in transfer cell (R16)	1.2-8	6.0-10	3.6-10
Hoist drop (R15)			
RH TRU waste	2.1-7	1.0-8	6.2-9
High-level waste for experiments	1.6-6	7.3-7	7.8-7
Natural background[b]	5.0	9.0	5.0
5-hour jet flight[c]			2.5-3

[a]1.4-7 = 1.4×10^{-7}.
[b]Data from the National Council on Radiation Protection and Measurements (NCRP, 1975).
[c]Mid-latitudes at 38,000 feet.

The impacts discussed above assume that the HEPA filters function properly. If for some unforeseen reason, however, the HEPA filters were not to work, most of the impacts would be increased because the filters would no longer provide the 10^6 decontamination factor. Without the HEPA filters, the CH-waste underground-fire scenario would still provide the greatest impact. The dose commitment to the maximally exposed person living at the site boundary would be 4.4 rem to the bone. This value is 88% of the 50-year dose from natural background radiation.

Doses received by repository workers

The WIPP Safety Analysis Report (DOE, 1980, Section 7.3) addresses in detail the radiation exposures received by repository workers in operational accidents. Table 9-53 summarizes the dose commitments from these accidents.

Table 9-53. 50-Year Dose Commitments Received by the Maximally Exposed Worker at the Scene of the Accident

Accident scenario	Maximum individual 50-year dose commitment (rem)		
	Bone	Lung	Whole body
Surface fire (C7)	(a)	(a)	(a)
Surface container failure (C10)	83.2	2.1	2.0
Underground fire (C22)	138.7	3.5	3.4

[a]Doses not calculated.

The potential health effects of such radiation-dose commitments are discussed in Appendix O. No worker exposure would result from the hoist-drop accident (C13) in the CH-waste area or the hoist-drop accident (R15) involving TRU or experimental high-level waste in the RH-waste area, because the underground workers are required to wait outside the ventilation tunnel until the waste hoist stops at the mine level. Similarly, no worker exposure would result from the canister-drop accident in the transfer cell (R16) in the RH-waste area, because the transfer cell and the hot cell are not occupied during canister-transfer operations.

9.5.2 Nonradiological Accidents Affecting the Environment

Accidents that may affect the environment without dispersing radionuclides are releases of chemicals, fuels, or other toxic materials as a result of chemical explosions, fire, or structural damage. This section discusses accidents that might occur during the handling of materials at the WIPP. The next section discusses accidents caused by natural events. The potential for these accidents will be reduced by the repository design, because surface structures designed to prevent the release of radioactive material will also resist the release of other hazardous material. Other safety features in the design are fire-protection systems, the isolation of hazardous materials, and protective dikes and berms. Contingency plans and cleanup procedures will be prepared to reduce the effects of accidents on the environment.

Explosive, flammable, or toxic materials that may be released as a result of an accident include sodium hypochlorite, used in wastewater and potable-water treatment; hydrogen gas, hydrogen chloride, and chemicals used in on-site experiments; and diesel fuel for emergency-power generators and waste transporters. It is not known at present how much of these materials will be stored at the site. Since only a health-physics laboratory will be located at the site, the quantity of laboratory chemical supplies kept at the site will not be large enough to pose a hazard. Furthermore, all potentially hazardous materials to be kept at the site will be stored in such a way as to minimize environmental hazards, as shown by the following examples:

1. Sodium hypochlorite will be stored in an open area in reinforced containers. State fire and safety codes for the use of this chemical in water treatment will be followed. The rupture of a container will not itself result in an environmental effect. However, on exposure to heat (e.g., sunlight), the sodium hypochlorite will release chlorine gas. Since the storage area will be open, any chlorine gas released will be diluted and dispersed.

2. Hydrogen gas and other explosive or combustible laboratory materials will be stored in clearly marked modular containers in a well-ventilated area to prevent buildup to explosive concentrations.

3. Diesel fuel will be stored in a tank surrounded by a dike that will contain any leakage from the tank.

4. Corrosive chemicals like hydrochloric acid will be stored in clearly labeled corrosion-resistant containers.

These precautions will preclude hydrogen-gas explosions and prevent the spread of flammable or toxic material in quantities or concentrations sufficient to endanger the health and safety of the public.

9.5.3 Effects of Natural Forces

9.5.3.1 Earthquakes

All surface buildings and systems that are essential for the safe handling of radioactive waste are designed to withstand the earthquake-induced ground movement that may be expected to occur at the site during the operational life of the repository. Accordingly, earthquake-induced releases of radioactivity to the environment are not likely. (The effects of other accidental releases of radioactivity are discussed in Section 9.5.1.)

Strong earthquakes may damage other surface structures (the evaporation pond and sewage-treatment plant, the mined-material-disposal systems, the administration building, and other support structures) that are not essential for the safe handling of radioactive waste. The failure of these structures and systems might result in the release of sewage, fuels, or chemicals, but this would not cause an off-site effect since the soil would absorb any spillage. There is a possibility of fire in such an event, but firefighting equipment and procedures would be available to control any fires quickly.

Available data on the effects of earthquakes in underground mines and tunnels indicate that they are significantly less susceptible to damage from earthquakes than are surface structures. Studies conducted by Dowding and Rozan (1978) indicate that tunnels have experienced no damage up to peak surface accelerations of 0.19g, few cases of damage between accelerations of 0.19g and 0.25g, and only minor damage to tunnels up through accelerations of 0.5g at the surface.

Reports on earthquake damage to underground mines have generally been qualitative. Quantitative data are rare and come from only a few sources. The information summarized below has been compiled by Pratt et al. (1979).

Several Japanese investigators measured earthquake acceleration simultaneously at the depth and surface. The results of these investigations indicated that underground motion was four to six times less than that at the surface.

A study by the U.S. Geological Survey of the Alaskan earthquake of 1964 reported no significant damage to underground facilities like mines and tunnels, although some rocks were shaken loose in places. Included in this analysis were reports of no damage in the coal mines of the Matanuska Valley, the railroad tunnels near Whittier, the tunnel and penstocks at the Eklutna hydroelectric project, and the Chugach Electric Association tunnel between Cooper Lake and Kenai Lake.

During the 1960 Chilean earthquake, one of the strongest on record, miners in coal mines heard strange noises, but felt no effects of the quake. Similar results were reported for the Peru earthquake of May 31, 1970. The earthquake, of Richter magnitude 7.7, did no damage to 16 railroad tunnels totaling 5710 feet under little cover in zones where the modified Mercalli (MM) intensity reached VII. Moreover, no damage was reported to the underground works of a hydroelectric plant, three coal mines, and two lead-zinc mines in the MM VII intensity zone.

Severe underground damage has occurred only in facilities that were actually crossed by a fault along which movement occurred.

It is therefore expected that for the peak surface accelerations predicted for the WIPP site (0.1g to 0.2g), little or no damage to underground facilities will occur.

9.5.3.2 Thunderstorms

Thunderstorms, with their high winds, heavy precipitation, hail, and lightning, can cause destruction; the damage, however, is usually less than that caused by tornadoes.

High winds and their possible effects are discussed in Section 9.5.3.3. All structures essential to the safe operation of the WIPP are designed to withstand winds with speeds of up to 183 mph. However, high winds may disperse mined material over a larger area than normal.

Hail is not a significant environmental problem. All structures necessary for radiologically safe operation are designed to withstand the impact of a tornado-driven missile, and the impact of a hailstorm would be trivial in comparison.

Large amounts of precipitation within a short period of time may be of concern. Although the average annual rainfall for southeastern New Mexico is only

13 inches, a 24-hour rainfall of 5 to 6 inches can be expected about once in 100 years. At the site, rainfall soaks into the sandy ground very quickly, and only occasionally does a severe storm produce enough rain to cause water to flow over the ground surface. Because the nearest perennial stream, the Pecos River, is 14 miles from the site, floods caused by heavy precipitation will not occur. A minor concern is the washoff and wind dispersion of the mined material on the conveyor. The mined-rock pile will be protected from runoff by a ditch.

9.5.3.3 Tornadoes

All surface buildings and systems essential for the safe handling of radioactive waste are designed to withstand tornado-force winds, tornado-driven missiles, and sudden pressure changes. A tornado would damage other buildings and scatter some of their contents; it would also scatter material in the open, such as salt from the mined-rock pile and liquids from the sewage pond, but this damage would not affect the tornado-resistant buildings.

Access to the underground disposal areas can be gained through the four shafts that link these areas to the surface and therefore to surface events like tornadoes. A tornado produces a sudden drop of surface atmospheric pressure, which might disrupt the ventilation system and cause some damage to ventilation equipment. The exhaust fans will not be affected by a tornado because they are in tornado-resistant structures. Since all air leaving the underground disposal areas will continue to be filtered, no radioactive materials will enter the atmosphere.

9.5.3.4 Range Fires

Because of the arid climate and desert vegetation in the region, there is a potential for range fires at the site. During operations, such a range fire would not be expected to cause extensive damage to the WIPP structures because of the buffer afforded by clearing vegetation from control zone I and the fire-protection systems employed at the site.

A range fire near the site, however, could release radionuclides accumulated biologically in vegetation from previous routine releases of radioactivity. Accordingly, the radiation-dose consequences of such a fire were analyzed.

In this analysis, it was assumed that the range fire occurs after 25 years of operation. The computer code AIRDOS II and long-term average atmospheric dispersion coefficients (χ/Q factors) from Table H-49 in Appendix H were used to calculate the highest ground-level concentrations of nuclides accumulated from routine releases. The area of greatest deposition was found to be an area about 1000 meters northwest of the center of the site. The 25-year accumulated ground-surface concentrations are shown in Table 9-54. To account for the worst possible fire, it was assumed that all of this radioactive material would be present in flammable form, either in vegetation or in detritus.

The amount of radioactivity that could be released in a range fire has been studied by Mishima (1973). That study, which was based on burning experiments

Table 9-54. Accumulation of Surface Contamination Near the WIPP Site

Nuclide	Surface contamination[a] (pCi/cm^2)	Nuclide	Surface contamination[a] (pCi/cm^2)
Co-60	6.2-8[b]	Eu-154	1.4-7
Sr-90	3.9-5	Pu-238	5.6-5
Y-90	3.9-5	Pu-239	7.3-4
Ru-106	1.7-8	Pu-240	1.8-4
Rh-106	1.7-8	Pu-241	3.1-3
Cs-137	2.2-7	Pu-242	1.5-8
Ba-137m	2.2-7	Am-241	8.1-6
Eu-152	2.9-8		

[a]Accumulation after 25 years in the area of greatest concentration.

[b]6.2-8 = 6.2 x 10^{-8}.

in a wind tunnel, indicated that little radioactivity would be released from a range fire of this type. In these experiments, as much as 4% of the total radioactivity became airborne immediately, with an additional 10% redistributed downwind later. (These tests were done with a wind of 20 mph. The median diameter of the material was 2 microns, with 85% of the particles smaller than 10 microns.) It should be noted that, even though 10% of the material was redistributed later, not all of the material would reach a person at some distance downwind. For the purposes of this analysis, however, it is assumed that the whole 14% is released instantaneously.

In calculating maximum individual doses, the spread of radioactivity downwind was calculated by assuming release from a 10-meter-high source rather than from the more exact plume rising from a broad area. The worst possible meteorological conditions (stable atmospheric conditions (Pasquill category F) and a wind speed of 2 meters per second) were used in the subsequent analysis, and the area of the source was taken to be 10 acres.

These data were used in calculating the maximum individual dose with the AIRDOS II computer code. The release rates are given in Table 9-55.

Using the release rates in Table 9-55 and the usual dose-conversion factors, it was calculated that the maximum radiation doses received by a person 1000 meters downwind of the fire in one day of inhalation would be as shown in Table 9-56.

The calculations in Table 9-56 show that the maximum individual radiation doses as a result of a range fire would be small fractions of the doses delivered by natural background radiation. The potential health effects of such radiation doses are discussed in Appendix O.

Table 9-55. Radioactivity Releases from the Postulated Range Fire

Nuclide	Rate of radioactivity release (pCi/sec)	Nuclide	Rate of radioactivity release (pCi/sec)
Co-60	1.1-7[a]	Eu-154	2.5-7
Si-90	7.0-5	Pu-238	1.0-4
Y-90	7.0-5	Pu-239	1.3-3
Ru-106	3.1-8	Pu-240	3.2-4
Rh-106	3.1-8	Pu-241	5.6-3
Cs-137	4.0-7	Pu-242	2.7-8
Ba-137m	4.0-7	Am-241	1.5-4
Eu-152	5.2-8		

[a] $1.1\text{-}7 = 1.1 \times 10^{-7}$.

Table 9-56. Radiation Doses Received from the Postulated Range Fire

Organ	Dose (rem)
Whole body	5.8×10^{-7}
Bone	2.3×10^{-5}
Lung	5.9×10^{-6}

9.6 MITIGATION OF IMPACTS

Various design features and construction practices could decrease the potential adverse environmental impacts of the WIPP. These practices were evaluated during the planning for the project. As discussed in Chapter 14, the DOE will obtain all applicable Federal and State permits and approvals; many potential adverse consequences of the project will be avoided by complying with these regulations and statutes. In addition, the facility will be designed and operated to comply with the applicable regulations of the Occupational Safety and Health Administration (OSHA) and the Mining Safety and Health Administration (MSHA) to protect the plant workers. Part of the design of the WIPP includes plans for preoperational, operational, and postoperational environmental monitoring (Appendix J). This monitoring will allow the DOE and its contractors to be continuously aware of environmental conditions in the site area and will alert them to any unexpected impacts. If such unexpected consequences are detected, appropriate action can be taken at that time to reduce the severity of any adverse impact.

This section summarizes the specific mitigating measures that the DOE or its contractors will employ as an integral part of WIPP construction and operation. It summarizes the measures that may be used if needed and the measures that were considered but not included in the design because their benefits do not justify their cost.

9.6.1 Protection and Restoration of Disturbed Areas

The mitigation of impacts on disturbed areas (Sections 9.2.1 and 9.3.1) consists of two basic parts: (1) minimizing the affected area and the associated impacts during construction and (2) restoring disturbed areas after completing the construction of the project. During construction, impacts on the terrain and soils will be reduced by the control of wind and water erosion. The watering of all disturbed areas as needed will reduce the amount of soil lost by wind. The construction of perimeter ditches early in the construction of the complete repository will greatly reduce soil erosion by water by intercepting runoff from rainfall. These interceptor ditches will be designed as "stable," or "noneroding," channels in accordance with accepted design practice for low-frequency, high-intensity storms. In other words, these ditches will be so designed and constructed that the water they carry, even the water resulting from an intense rainfall, will not cause excessive erosion in the channels.

Site traffic will be limited to designated roads and to specific parking areas as much as practicable. Construction materials will be confined to specified laydown areas. Only the areas in which facilities are to be constructed and the required material-laydown areas will be cleared of vegetation and graded; no additional clearing or grading will be performed. These measures will prevent indiscriminate disruption of the desert habitat. The wastes produced during construction will be buried in on-site disposal areas or hauled away for disposal in the Carlsbad or Hobbs sanitary landfill in accordance with local regulations. After construction, all temporary buildings will be removed.

The plant site, the mined-rock pile, the evaporation pond, and the sewage-treatment plant will be enclosed by fences to restrict access to ponded water by wildlife.

An alternative construction measure considered for the SPDV shafts is conventional shaft sinking, rather than blind boring. The DOE prefers blind boring because of cost and schedule advantages. Conventionally sinking the SPDV shafts would reduce the amount of disturbed area by eliminating the need for a 6-acre spoils-disposal area for wasted brine drilling fluid. A smaller disposal area would be needed for the rock removed from the shafts area. There is not a significant difference in impacts between blind-bored and conventionally sunk SPDV shafts because site restoration would reduce the long-term effects in either case and lead to eventual revegetation of disturbed areas.

The sandy Kermit-Berino soil that is present at the WIPP site does not have a well-differentiated topsoil, although the upper few inches are richer in nutrients than is the remainder. The removal of soil during construction may leave only shallow soil over the caliche. Such a condition would lead to increased runoff and subsequent erosion on the downgrade edge of the cleared area. Appropriate grading will mitigate this effect during the operational period. During site restoration, the soil will be replaced to its original depth. In the absence of steep grades, rapid invasion and stabilization of the bare soil by herbaceous annuals is expected. Natural plant succession and gradual return to preconstruction conditions will continue for several decades. What sort of vegetation program would help the site to return more quickly to natural conditions is not clear. Any planting should be with species indigenous to the area, but the most important feature in such a program is the creation of favorable soil conditions. The current DOE plan is to emphasize soil conditions and minimize actual planting.

9.6.2 Reduction of Pollution

Water pollution

During site preparation and the early phases of construction, chemical toilets will be provided for sanitary waste (Sections 9.2.1 and 9.3.1); these will be collected regularly and removed from the site for proper treatment and disposal. Once the sewage-treatment plant is completed, trailers with restrooms and day tanks for storage will be used until the rest of the system is completed. The day tanks will be emptied at the sewage-treatment plant. After this time and during operations, sanitary-waste effluents will undergo secondary treatment to meet State of New Mexico standards. Where recycling is economically feasible, wastewater will be recycled to reduce consumption; for example, treated sanitary effluents will be used for landscape irrigation and dust control at the site.

The DOE has considered the use of impermeable liners beneath the salt pile and the spoils-disposal area used in the SPDV program to minimize the potential for contaminating groundwater with salt. However, the lack of shallow groundwater at the site indicates that such liners are not needed.

Air pollution

Construction-related air pollution (Sections 9.2.1 and 9.3.1) will generally be limited to the immediate area of the site. The largest source of airborne pollutants will be the handling and transfer of soil, producing fugitive dust. To reduce this dust, permanent roadways will be paved and maintained, and disturbed areas, including any dirt roads, will be sprayed with water as needed. Other frequently traveled areas will be overlaid with gravel or caliche and watered as needed during working hours.

Conventional sinking of the SPDV shafts would probably increase dust levels as a result of blasting and rock removal. Blind boring using drilling fluid does not produce appreciable dust, but does result in the emission of combustion products from drilling equipment.

If a concrete batch plant is needed at the site during construction, the dust from its operation will be controlled by using the best engineering practices. Combustion emissions from construction equipment will be controlled by the use of all applicable EPA emission controls. If the burning of waste materials at the site is necessary, it will be carried out in compliance with applicable State open-burning regulations.

While the mined-rock-storage area is being prepared, water will be sprayed on disturbed surfaces to control dust. Covered conveyors will move the mined rock from the mine-shaft headframe to a stacker conveyor, on which the mined rock will be sprayed lightly with water during its trip to the storage pile. Ditches will channel natural drainage water around the pile and retain runoff.

Solid and chemical wastes

During construction, litter will be controlled by the use of trash and scrap containers located throughout the site. The trash and scrap will be removed to an approved disposal area or to an approved sanitary landfill. Standard procedures for the on-site landfill consist of excavation, disposal, and backfilling over the waste. The solid waste will be layered with fill dirt to control insect vectors and sprinkled with water to reduce dust. Low-lying areas will be selected to make the landfill unobtrusive, and natural drainage will be diverted around the site. Natural revegetation of the filled areas will be encouraged, and the site will eventually be suitable again for local wildlife.

All lubricants and other chemicals used during construction will be stored in approved standard containers with precautions against accidental spills or leakage. All fuels will be stored in conformance with applicable National Fire Protection Association and local codes. Waste chemicals and oil will be collected in approved and clearly marked standard containers. The containers will be stored separately from other waste and removed from the site for reprocessing or disposal in an acceptable manner.

Noise

The highest construction noise levels (Sections 9.2.1 and 9.3.1) will occur in the daytime during site preparation and excavation. The impacts of noise will be reduced by using equipment that meets the EPA noise-emission guidelines and by maintaining and servicing equipment to insure that excessive noise is minimized. Conventional sinking of the SPDV shafts would cause higher noise levels when blasting and drilling is done near the surface. After about 50 to 90 feet of penetration, however, the noise levels generated by conventional sinking would be much lower than those produced in blind boring.

By giving due consideration to noise-control engineering during the design phase, it will be possible for the WIPP to operate under normal conditions at a noise level that will not disturb the nearest residents. Specific mitigation measures include testing the emergency-power diesel generators during daytime hours only, providing silencers for the diesel-generator exhaust, and locating most pumps inside structures.

9.6.3 Reduction of Radioactive Effluents

The WIPP is being designed and will be operated in accordance with DOE procedures that limit the amount of radioactive material released during normal operations (Section 9.3.2) and under accident conditions (Section 9.5.1). The retrieval of the waste from the Idaho National Engineering Laboratory and the transportation to the WIPP site will also be performed in strict compliance with the applicable rules and regulations of the DOE, the U.S. Department of Transportation, and other agencies.

As discussed in Section 8.4.3, radiation monitors will be used to activate a system whereby the disposal-exhaust air will be diverted to HEPA filters if an accident releases radioactivity underground. The DOE assessed the possibility of continuous HEPA filtering of the disposal-exhaust air to lower the routine releases of radioactivity from the underground disposal area. It was concluded that the entrainment of nonradioactive salt particulates in the exhaust air would tend to clog the HEPA filters. Excessive maintenance, especially the replacement of filters, and reduced reliability in the event of an accident indicated that the benefits of such continuous filtering would be outweighed by the potential problems and cost involved.

9.6.4 Protection of Archaeological Resources

Before any construction is started, the DOE will consult with the New Mexico Historic Preservation Officer and the Advisory Council on Historic Preservation to identify any eligible properties in addition to those already known (Appendix H, Section H.1.5), to request a determination of effect, and to implement consultation to mitigate or minimize any adverse effects, as required by the National Historic Preservation Act. All the sites have been accurately mapped by a field surveying crew. The DOE will consult with the State Historic Preservation Officer and the Advisory Council on Historic Preservation to insure that proper mitigation measures are taken to preserve the archaeological resources present.

9.6.5 Access to Mineral Resources

Hydrocarbons

In principle, the hydrocarbon resources beneath the WIPP site can be exploited by deviated drilling from outside control zone IV or by vertical and deviated drilling within control zone IV. The DOE has already signified its intent to allow drilling in that zone under strict controls.

Deviated drilling is more costly than vertical drilling. The additional costs of exploring formations of interest throughout the entire WIPP site by drilling from control zone IV are shown in Table 9-57 (Keesey, 1979). The additional costs, over and above the cost of drilling vertically, are 21 million dollars (18% of the total drilling cost, or an increase of 21% over the cost of drilling vertically at all locations). Not all locations are geologically attractive; the most promising ones are in control zone IV and may be drilled vertically at no additional cost for deviated drilling.

Potash

The potash reserves below control zone IV may be mined by the techniques presently employed in the Carlsbad Potash District. Solution mining will not be permitted. Studies are under way to examine the long-term consequences to repository integrity of mining in control zones I, II, and III. The concern is over the consequences of subsidence on overlying rocks and aquifers and the possibility that such subsidence would lead to unacceptable rates of salt dissolution. The rates of dissolution in Nash Draw (less than 500 feet per million years vertically--see Section 7.4.4), where much more extensive natural subsidence has occurred than would result from mining at the WIPP site, indicate that such effects would be acceptable. However, these studies need to be completed before mining in the inner control zones can be accepted with confidence.

9.6.6 Reduction of Socioeconomic Impacts

Several Federal assistance programs are available to a local government in an area selected for a Federal project like the WIPP. These programs, however, operate under a variety of restrictions that severely limit their applicability. All impact-mitigation assistance programs deal primarily with impacts after the impacts have begun to occur. No planning assistance is available under these programs. Planning assistance and program development may be available to a local community under other Federal programs; however, the eligibility restrictions surrounding these programs are such that an affected community is given no preference or assurance that funds will be available when needed.

Mitigation assistance

Under Section 2208 of the Atomic Energy Act of 1954 (42 USC 2008 et seq.), the Atomic Energy Commission (and now the DOE) was given authority to make payments in lieu of taxes on lands taken off the tax rolls. This authority would be of little help in southeastern New Mexico. A more applicable feature of the law is one that allows the DOE to make payments for "special burdens" that have been cast on a State or local government by the activities of the

Table 9-57. Additional Cost[a] to Explore Hydrocarbons in the Entire WIPP Site by Drilling from Inside Control Zone IV

Number of wells in category	Horizontal deflection (feet)	Kickoff point depth (feet)	Measured depth (feet)[b]	Drilling days added[c]	Total drilling days[d]	Incremental dry-hole cost per well	Total dry-hole cost per well	Completion cost per well	Total cost per well	Total drilling and completion cost for all wells in category
32	0		14,750	0	75	0	1463	325	1788	57,216
3	1320	11,000	14,973	17	92	340	1803	336	2139	6,417
9	2640	8,750	15,302	24	99	480	1943	354	2297	20,673
2	4000	7,750	15,808	40	115	800	2263	382	2645	5,290
2	4400	6,750	15,879	42	117	840	2303	386	2689	5,378
2	5000	5,750	16,530	64	139	1280	2743	426	3169	6,338
1	6600	4,800	16,728	68	143	1360	2823	437	3260	3,260
1	7500	4,800	17,249	82	157	1640	3103	464	3567	3,567
3	8000	4,800	17,479	91	166	1820	3283	477	3760	11,280
55										119,419
Total cost to drill 32 straight holes and 23 directional holes from inside zone IV										119,419
Less cost to drill 55 straight holes at 1788 each										(98,340)
Total incremental cost										21,079

[a]Costs in thousands of dollars.
[b]14,750 feet plus depth correction.
[c]Extra days added to drilling time because of the deviated drilling.
[d]"Drilling days added" plus 75 days for the undeviated drilling.

DOE or its agents. The amount of payment, however, must take into consideration "any benefit occurring to the State or local government by reason of such activities." This type of cost-benefit analysis could be quite cumbersome and may conclude that no payments could be made.

The Education Act of 1956 (20 USC 236 et seq.) provides for assistance to local educational agencies in areas affected by Federal activity.

The Small Business Act of 1959 (15 USC 631 et seq.) authorizes the Small Business Administration to make direct and guaranteed or insured loans to small businesses that suffer economic injury as a result of displacement by a Federal facility.

The Uniform Relocation Assistance Act of 1971 (42 USC 4601 et seq.) directs all Federal agencies to compensate all persons displaced by a Federal project for real and personal property and for moving costs, and to make a relocation adjustment. Inasmuch as there is no one living on the WIPP site to be so displaced, this Act will be of no help.

Planning assistance

The primary programs designed to help a community in planning for rapid growth are the "701" program of the Department of Housing and Urban Development (HUD) and the Intergovernmental Personnel Program.

The "701" program (40 USC 461 et seq.) provides the broadest and most fundamental assistance available to a community about to be affected by a Federal facility. The 1974 amendments to the underlying act direct funds only to those units of government that are capable of carrying out areawide planning. With respect to the WIPP, this effectively limits such help to Eddy and Lea Counties or the State of New Mexico itself. There is an exception for cases of "special need" that might be construed to make cities like Carlsbad eligible.

The Intergovernmental Personnel Act of 1971 (5 USC 3371 et seq.) provides a variety of mechanisms to strengthen a local community's pool of trained resource people. The statute contains authority for grants and technical assistance to be used by local governments to improve personnel administration, to admit local people to Federal employee-training programs, and to assign Federal employees temporarily to local governments.

Other Federal planning-assistance programs include the Public Works and Development Act (42 USC 3121 et seq.); regional commissions; programs that provide aid for specified projects like hospital construction, drug abuse, law-enforcement hardware, and wastewater treatment; and community block grants (42 USC 5301 et seq.).

9.6.7 Reduction of the Impacts of Transportation

Chapter 6 analyzes the radiological consequences of waste transportation. Nevertheless, this EIS is not intended to be a final document establishing the basis for decisions on actual routes and methods for transporting waste to the WIPP. These decisions will be addressed in later documents. Decisions yet to be made final include decisions on routing, packaging, transportation methods, and emergency plans.

As indicated in Section 6.4, decisions on routing are constrained by the existing network of railroads and highways in this country. Packaging systems for WIPP-destined waste are still being developed. Yet to be decided is whether to use common carriers, contract carriers, or Federally owned carriers. Special trains have been suggested, but the Interstate Commerce Commission has concluded that, while these may decrease the radiological risks of accidents, they would increase the impacts of normal transportation (Section 6.2.3; ICC, 1977).

The DOE will prepare for the WIPP an emergency-preparedness plan that will include working with potential carriers, State officials, and local officials (Section 6.11). The DOE already has radiological-assistance teams available to oversee any required cleanup at the scene of an accident.

Actions taken at an accident will depend on its severity as determined by monitoring. They will almost surely include keeping unneeded people out of the way and not letting debris be picked up at random. Farm animals, crops, and milk will be inspected and, if necessary, condemned and destroyed. The degree of land and building contamination will be determined; land and buildings contaminated beyond existing guidelines will be decontaminated or interdicted from use.

9.6.8 Reduction of the Impacts of Operational Accidents

The emergency-preparedness plan will also be concerned with responding to accidents, both radiological and nonradiological, at the WIPP site itself (Section 8.12). The circumstances there will probably be more favorable than those in transportation accidents; equipment and trained people will be immediately available, and monitoring and control can be started right away. Moreover, there are no large numbers of people and no intensively used land nearby. Measures that can be taken will be much like those for transportation accidents.

9.7 LONG-TERM EFFECTS

During the long term, for thousands of years after the TRU-waste repository that is part of the WIPP has ceased operation and has been closed, no radioactive material is expected to enter the biosphere. Nevertheless, natural events or intrusion by people could conceivably cause such a release. The first section of this chapter studies unexpected releases by assuming that they will occur and by assessing their consequences.

The second section discusses long-term effects that do not directly involve any release of radioactive material; heat from the emplaced waste and natural subsidence could produce such effects. A final section briefly reviews the available technical information on interactions that may occur between the emplaced waste and the rock around it.

9.7.1 Effects Involving the Release of Radioactivity

9.7.1.1 Basis of This Analysis

The principal benefit expected from placing radioactive wastes deep underground is long-term isolation from the biosphere. Numerous studies have, however, examined the impacts that buried radioactive waste might exert on the environment if it escaped from a repository (Bradshaw and McClain, 1971; USAEC, 1971; Claiborne and Gera, 1974; McClain and Boch, 1974; Gera, 1975; Gera and Jacobs, 1972; Bartlett et al., 1976; Cohen, 1977; Cohen et al., 1977); a recent, detailed collection of references appears in a document published by the U.S. Nuclear Regulatory Commission (NRC, 1976). These analyses have pointed out that such releases of waste are highly improbable and that they would pose little hazard to the biosphere. Such results have encouraged the investigation of geologic disposal and have led to the detailed, site-specific analysis performed for the WIPP project and described in this section.

Since radioactive decay will reduce radiation levels as time passes, some studies have attempted to decide at what time after burial the waste is no longer dangerous. Different criteria for safety have led to different conclusions. Hamstra (1975), for example, compared the hazards of buried waste to those of buried uranium ore and concluded that deeply buried high-level waste is safe after about 1000 years of burial. Gera (1975) adopted a more conservative criterion. He compared the hazard of radioactive waste to the hazard of unburied uranium-mill tailings piles. Taking no account of the increased safety that burial would provide, Gera concluded that the waste decays to a safe level in 100,000 years. His study recognized, however, that this estimate could reasonably be reduced to a few thousand years under other assumptions.

The long-term integrity of the WIPP repository depends on multiple barriers, features that hinder the release of radioactivity. These barriers are the waste and its containers, the salt, and the geologic and hydrologic system in which the repository is embedded. The long-term safety analysis made for the WIPP shows that, except for certain direct-access events, the forms of the waste and its containers are not important in hindering the release of radioactivity; the important barrier is the massive salt bed itself.

About 1200 feet of rock salt lies above the waste horizon, and another 1200 feet of rock salt and anhydrite lies beneath it; no natural process is expected to disturb this 2400-foot barrier in any significant way during the period required for the wastes to decay to innocuous levels. If the salt were breached, however, the properties of the third barrier, the geologic and hydrologic system, would become important; the safety analysis for the WIPP has concentrated on the effectiveness of this barrier after a postulated breaching event has disturbed the other two barriers.

The basic plan for the analysis, therefore, is to estimate the consequences of different hypothetical events that might move wastes to the biosphere. After postulating mechanisms for the release of radionuclides from the burial medium, the study examines radionuclide transport through the surrounding geologic media and then through the biosphere. The amounts of radionuclides that might reach people along different pathways are estimated; these amounts are then used to calculate the radiation doses that might result from the hypothetical releases.

9.7.1.2 Methods Used in This Analysis

Fundamental plan

This study of long-term impacts follows the basic plan of earlier studies: it evaluates the consequences of well-defined hypothetical future events that could conceivably release waste from a repository. It differs, however, from previous studies in three important aspects that make the analysis directly applicable to the WIPP site, the WIPP conceptual design, and the waste to be received at the plant:

1. The wastes are not assumed safe after several hundred years or even a few thousand years. Consequences are evaluated as a function of time after each release event.

2. The WIPP disposal area is assumed to contain contact-handled TRU waste and remotely handled TRU waste. Earlier studies have usually considered only high-level waste.

3. The analysis is specific to the WIPP site. It uses detailed geologic and hydrologic models of the area around the site. These models include data from field investigations conducted as part of the WIPP project.

The principal tool used in this safety assessment is the analysis of "scenarios." The term "scenario" here refers to a hypothetical sequence of events that could release radioactive material from a repository. Four principal details are necessary for the description of a scenario; these details specify the following:

1. A release event that breaches the repository.
2. A mechanism for moving radionuclides through the breach.
3. The elapsed time between burial and the releasing event.
4. The response of the burial medium to the breach.

These details, combined with a source term specifying the radionuclide inventory and the physical and chemical condition of the waste at the time of release, give initial and boundary conditions for calculating the migration of radionuclides through the geologic media and to the biosphere. The movement of radionuclides to people and the doses delivered to them are then calculated. A block diagram of the overall systems analysis is in Figure 9-9.

Compilation of scenarios

Bingham and Barr (1979) have provided descriptions of waste-release scenarios at the WIPP site and have discussed the methods used to construct these scenarios. The compilation of scenarios began with the preparation of an extensive list of events that in concept are capable of leading to a release of radioactive waste from a repository in bedded salt. A fault tree used in a German study (Proske, 1976) and a fault tree constructed by the WIPP staff aided in the selection of release events. After elimination of those events whose occurrence at the WIPP site is physically impossible, 19 basic events remained.

Each of the 19 release events could in theory give rise to many scenarios, depending on the details of events that follow the basic release event. A total of 92 distinct scenarios were constructed from physical processes that are possible at the site. Of these 92 scenarios, 88 result in the introduction of radionuclides into the Magenta and the Culebra aquifers of the Rustler Formation above the repository. The remaining four scenarios result in the direct transfer of radionuclides to the surface.

There is, of course, no way of being sure that all potential release mechanisms and scenarios have been identified. To compensate for this lack of certainty, two extreme scenarios (numbers 4 and 5 in the list that follows) have been included in the analysis. These two extremes represent physically plausible worst cases for fluid disruption of the repository and for human intrusion into the repository.

Selection of scenarios for analysis

Five representative scenarios were chosen for the analysis. Scenarios 1 through 4 introduce the radionuclides into the Magenta and the Culebra aquifers. These radionuclides are subsequently transported in the aquifers to the outlet along the Pecos River near Malaga Bend, approximately 15 miles southwest of the site. At this point the radionuclides reach the biosphere. Scenario 5 introduces the radionuclides directly into the biosphere through a drill shaft penetrating the repository. The five scenarios are summarized below.

Scenario 1: A hydraulic communication connects the Rustler aquifers above the repository, the Bell Canyon aquifer of the Delaware Mountain Group below the repository, and the repository.

Scenario 2: A hydraulic communication allows water to flow from the Rustler, through the repository, and back to the Rustler.

Scenario 3: A stagnant pool connects the Rustler aquifers with the repository. In contrast to scenarios 2 and 3, which involve flowing water, this communication permits radionuclide migration to the Rustler only by molecular diffusion.

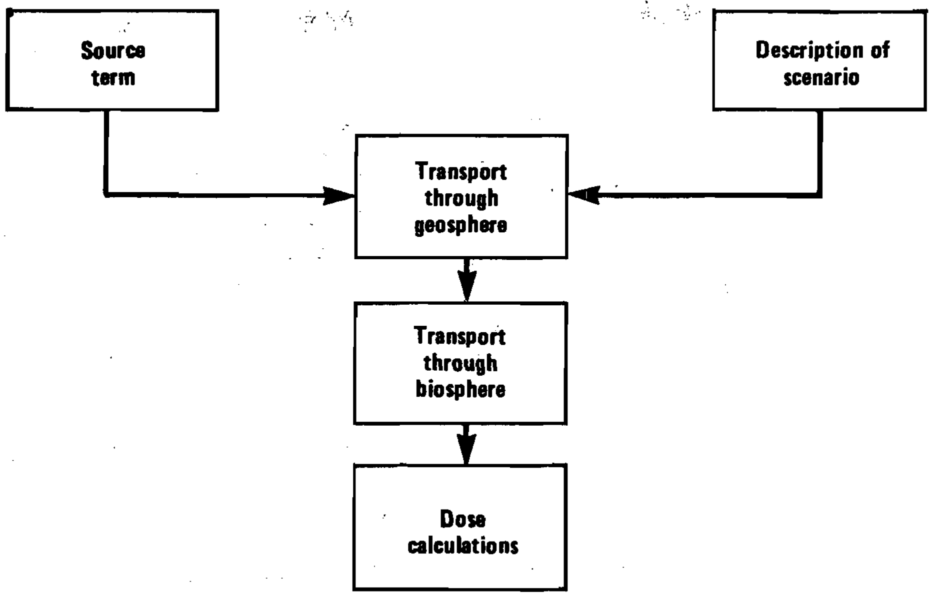


Figure 9-9. Plan of calculation.

Scenario 4: A hydraulic communication connects the Rustler aquifers with the repository; all the Rustler water normally moving above the repository flows through the repository and back to the Rustler. In contrast, scenarios 1 and 2 establish only a limited hydraulic connection.

Scenario 5: A drill shaft penetrates the repository and intercepts a radioactive-waste container; the radioactive material is brought directly to the surface.

Scenarios 1 through 4 are referred to as scenarios for liquid breach and transport because they postulate the existence of a water-filled communication that connects the repository with one or more aquifers. Scenario 1 represents circumstances where water flows between two aquifers and also intercepts the repository. Scenarios 2 through 4 represent circumstances where forced convection or mass transport by diffusion moves waste material from the repository to a single aquifer. An analysis of these scenarios for liquid breach and transport is given first, followed by an analysis of the scenario that does not depend on water to carry radionuclides to the biosphere.

9.7.1.3 Analysis of Scenarios for Liquid Breach and Transport

As explained in the remainder of this section, the analysis of the consequences of liquid-breach scenarios proceeds from a detailed description of each scenario to a calculation of radionuclide movement through the geosphere--movement from the repository and through the Rustler aquifers. Next the analysis predicts radionuclide transport through the biosphere after discharge into the Pecos River at Malaga Bend. The final calculations predict radiation doses received by people.

Source term

The first step in the analysis of the scenarios is to compile the source term shown as a block in Figure 9-9. Three major specifications compose the source term.

Specifications of model repository. The model repository used in the analysis of the scenarios is different from the WIPP repository described in Chapter 8 in only one respect: the remotely handled TRU waste is assumed to be placed separately from the contact-handled TRU waste. The area where the contact-handled waste is emplaced is the same as the area described in Chapter 8. Table 9-58 lists the assumed dimensions and waste volumes of each of the two areas.

Table 9-58. Specifications of Modeled Waste-Disposal Areas

Parameter	Contact-handling area	Remote-handling area
Depth, feet	2000	2000
Dimensions, feet	1700 x 2600	950 x 950
Area, acres	100	20
Thickness, feet	12	12
Percentage of volume occupied by waste	11.48	2.39

The larger dimension of the model contact-handled-waste area (2600 feet) runs in the north-to-south direction. The model area for remotely handled waste is connected to the western side of the area for contact-handled waste at its southern end.

The use of two distinct modeled areas permitted separate evaluations of the consequences of the release of each type of waste. As will be seen later, this distinction makes little difference in terms of the consequences of the scenarios for liquid breach and transport.

Radionuclide inventories. The amount of each radionuclide present during the release depends on the type of waste held in the repository and on the time at which release occurs. Because actual radionuclide inventories will vary among the containers received at the repository, it is necessary to specify typical values. For this purpose the study used actual assay data from the Idaho National Engineering Laboratory for contact-handled TRU waste. The contact-handled TRU waste is assumed to be in 55-gallon drums, each containing an average of 8 grams of plutonium among the waste mixture. The modeled 100-acre area for contact-handled TRU waste would be able to hold about 816,000 such drums at the stated ratio of waste volume to repository volume. The concentration of radioactivity in the remotely handled TRU waste is given in Appendix E. About 250,000 cubic feet (about 7 million liters) of remotely handled TRU waste could fit into the modeled area at the stated ratio of waste volume to repository volume.

The waste inventories change in time, of course, owing to radioactive decay and the production of daughter nuclides. The radionuclide inventories at times selected for scenario modeling were calculated from the initial inventories with a modified version of the ORIGEN code (Bell, 1973). Table 9-59 lists the calculated radionuclide inventories at the assumed repository-breach time of 1000 years. The table lists the radionuclides that are the most important in long-term consequence assessments in that they either produce nearly all of the radioactivity in the waste at 1000 years or are the parents of daughter radionuclides that are easily transported in the geosphere. Other radionuclides are important during time spans of less than 1000 years; these nuclide inventories are discussed in Section 9.7.1.4.

Physical and chemical condition of the waste. This analysis postulates conditions that produce upper bounds on the amounts of waste released. To this end the detailed models assume that when water comes into contact with waste the radionuclides dissolve with the salt. They also assume that the radionuclides are uniformly mixed with the backfill material at the time of release. In future analyses, these assumptions will be replaced if experimental data show that such phenomena as leaching, waste-matrix degradation, and the valence states of the radioactive species significantly affect the release rates.

Description of scenarios

The second step in the overall analysis illustrated by Figure 9-9 is the block that represents the description of a scenario. The description includes a detailed statement of each of four major specifications:

Breaching event. For purposes of computer modeling, a breaching event is described by specifying the communications that connect the repository with

Table 9-59. Nuclide Inventories in Repository at 1000 Years

Nuclide	Half-life (years)	Remotely handled TRU waste		Contact-handled TRU waste	
		Grams	Curies	Grams	Curies
Ra-226	1.6+3[a]	3.0-3	3.0-3	1.6-2	1.6-2
Th-229	7.3+3	1.0-3	2.1-4	5.6-3	1.2-3
Th-230	7.7+4	9.0-1	1.7-2	4.8	9.2-2
Th-232	1.4+10	1.1-1	1.1-8	5.6-1	5.6-8
U-233	1.6+5	6.8-1	6.3-3	3.6	3.3-2
U-234	3.4+5	3.8+2	2.3	2.0+3	1.2+1
U-235	7.0+8	3.2+4	6.7-2	1.7+5	3.6+1
U-236	2.3+7	7.4+3	4.6-1	4.0+4	2.4
Np-237	2.1+6	3.5+3	2.3	1.8+4	1.2+1
Pu-238	8.8+1	1.6+1	2.6	8.8-1	1.4+1
U-238	4.5+9	0	0	3.4	1.2-2
Pu-239	2.4+4	1.1-6	6.6+4	6.0+6	3.6+5
Pu-240	6.5+3	7.0+4	1.5+4	3.7+5	8.0+4
Am-241	4.3+2	9.3+2	3.0+3	4.8+3	1.5+4
Pu-242	3.9+5	0	0	2.0+3	8.0

[a]1.6+3 = 1.6 x 10^3.

other parts of the geosphere. Such communications might be the consequence of human actions or of natural geologic events. In liquid-breach scenarios, the communication is a hydraulic pathway along which waste materials could be transported.

Transport mechanism. In order for waste material to move from the repository, a mechanism is needed to carry it through the communications. In the four liquid-breach scenarios, the transport mechanism is either forced convection by flowing water or molecular diffusion in a stagnant water column.

Time of breach. The time of breach is the time at which communications are fully developed and the transport of waste material begins. This study of liquid-breach scenarios models breaches of the repository and releases to the aquifer at 1000 years after burial.

Response of burial medium to releasing event. The specification of burial-medium response generally involves two things: the changes in the shape and the size of the communications after the breaching event and the physical changes in the waste that attend changes in the burial medium. In the four liquid-breach scenarios, the burial medium (or that part of it near the communications) dissolves at a prescribed rate, and, as stated above, the waste dissolves at the same rate.

After specifying the breaching event, the transport mechanism, and the burial-medium response, one can predict the rates at which radionuclides leave the repository and enter the geosphere. These rates are then used as input to the geosphere-transport model shown as the first transport block in Figure 9-9.

Geosphere-transport calculations

The most effective mechanism for transporting radionuclides through the geosphere and into the biosphere is convection in flowing groundwater; only one of the four liquid-breach scenarios assumes a transport mechanism, diffusion, that is not convection. In the analysis of the consequences of the liquid-breach scenario, a numerical computer model was used to predict the rate of the transport of radionuclides from the breached repository through the Magenta and the Culebra aquifers and to the discharge point on the Pecos River at Malaga Bend. A detailed discussion of the model and its application to the analysis appears in Appendix K.

Biosphere-transport calculations

After moving from the repository through the Culebra and the Magenta aquifers, the radionuclides could reach the Pecos River near Malaga Bend. At that point the radionuclides, diluted when the aquifer water mixes with the river water, would enter the biosphere. Possible pathways by which they might move through the biosphere to people include the ingestion of fish, the ingestion of water, and activities like swimming, boating, and sunbathing.

The biosphere-transport calculations (a block in Figure 9-9) begin by converting the output of the geosphere-transport code, which provides mass fractions of radionuclide concentrations in the aquifer water. For each radionuclide, the mass fraction is converted to picocuries per year by the following equation:

(mass fraction)(aquifer flow rate)(specific activity) = (activity per year)

where the dimensions of the factors are

$$[(g/ml)/(g/ml)]\ (lb/yr)\ [(pCi/g)(g/lb)] = (pCi/yr).$$

Then the analysis calculates the yearly intake of radionuclides by a person exposed through the biosphere pathways.

Dose calculations

The consequence analysis next computes the radiation doses that result from the intake of radionuclides by a hypothetical person living near Malaga Bend. This calculation (Torres and Balestri, 1978), represented by the bottom block in Figure 9-9, uses the NRC computer code LADTAP.

When radioactive material is taken into the body, part of it remains there, emitting radiation until it decays or is eliminated by biological processes. To express the dose received from such material, the annual dose delivered while the material is in the body is integrated, or summed, over a 50-year period after intake. The integrated dose from a 1-year intake of radioactive material is called the 50-year dose commitment. Further discussion of dose commitments is in Appendix O.

In this calculation the yearly intake from ingesting water or fish is converted to a 50-year dose commitment by the following equation:

(yearly intake) (liquid-dose conversion factor) = dose commitment

where the dimensions of the factors are

$$(pCi/yr)\ [mrem/(pCi/yr)]\ (10^{-3}\ rem/mrem) = rem.$$

The conversion factors for this equation are taken from the NRC study NUREG-0172 (Hoenes and Soldat, 1977).

To account for swimming, boating, and the use of the river shoreline, the study uses the methods given in NRC Regulatory Guide 1.109, Revision 1 (NRC, 1977). It also uses the factors provided by this Guide for computing the exposures and doses received by individuals characterized by the Guide as "maximum" with respect to food consumption, occupancy, and other pathways. Further information on the biosphere-transport calculations appears in Section 9.7.1.4.

Scenario modeling

The paragraphs that follow present in detail the assumptions made in each scenario. The consequences of the scenarios, in terms of exposure or dose, are discussed separately in Section 9.7.1.4.

Modeling of scenario 1. This scenario develops a vertical connection between the upper aquifer (the Rustler) and the lower aquifer (the Bell Canyon) through a hypothetical 9-inch-diameter uncased borehole (Figure 9-10). Depending on the actual location of this borehole, flow may be either into or from the upper aquifer. Recent measurements (Powers et al., 1978) and the calculated freshwater potentials suggest that, for the purpose of analysis, the flow near the repository can be assumed to be upward, into the Rustler aquifer, under a pressure difference of 7.5 pounds per square inch. The calculations therefore assume this upward flow. Two locations for the borehole were assumed: the borehole penetrates the center of the modeled disposal area for remotely handled TRU waste (scenario 1A) and the borehole penetrates the center of the modeled disposal area for contact-handled TRU waste (scenario 1B).

The permeability of the wellbore was calculated by using Hagen-Poiseuille's law for laminar flow through a pipe. The hydraulic resistance of the wellbore was found to be negligible in relation to the resistances of the aquifers.

The calculation of the flow through the wellbore was performed by simulating the hydraulic conditions of the two aquifers connected by the borehole. In this scenario, water is withdrawn from one aquifer and injected into the other. Since the transmissivity of the upper aquifer is less than that of the lower aquifer, the upper-aquifer transmissivity controls the flow rate through the wellbore. A conservative, simple way of modeling this situation is to describe the upper aquifer numerically as a single layer with an infinite radius and the wellbore at its center. The boundary condition at the wellbore is schematically shown in Figure 9-10.

In this model, after an initial transient period, the flow becomes essentially constant. From two bounding values of the transmissivity in the Rustler aquifer, upper and lower bounds to flow rates through the wellbore were calculated to be 600 and 30 cubic feet per day. The predictions of the consequence analysis were calculated separately for each of the two assumed borehole locations, using the flow rate of 600 cubic feet per day.

It was assumed that the Salado and Castile Formations dissolve uniformly along the length of the wellbore and that the radioactive waste dissolves at the same rate as the salt formation. The diameter of the hydraulic communication increases as the water dissolves the salt; a dissolution front advances through the repository, eventually reaching all the stored waste. The amount of waste dissolved is proportional to the fraction of the geologic formations that is waste. If the borehole penetrates the area containing remotely handled waste, a steady-state flow at 600 cubic feet per day takes 120,000 years to completely leach the contents of the area; the dissolution front then passes into the disposal area for contact-handled waste, which is completely leached in the following 2.41 million years. If the borehole originally penetrates the contact-handled-waste area, flow at the same maximum rate takes 600,000 years to completely remove the contents of the area; the dissolution front then passes through the smaller area for remotely handled waste in

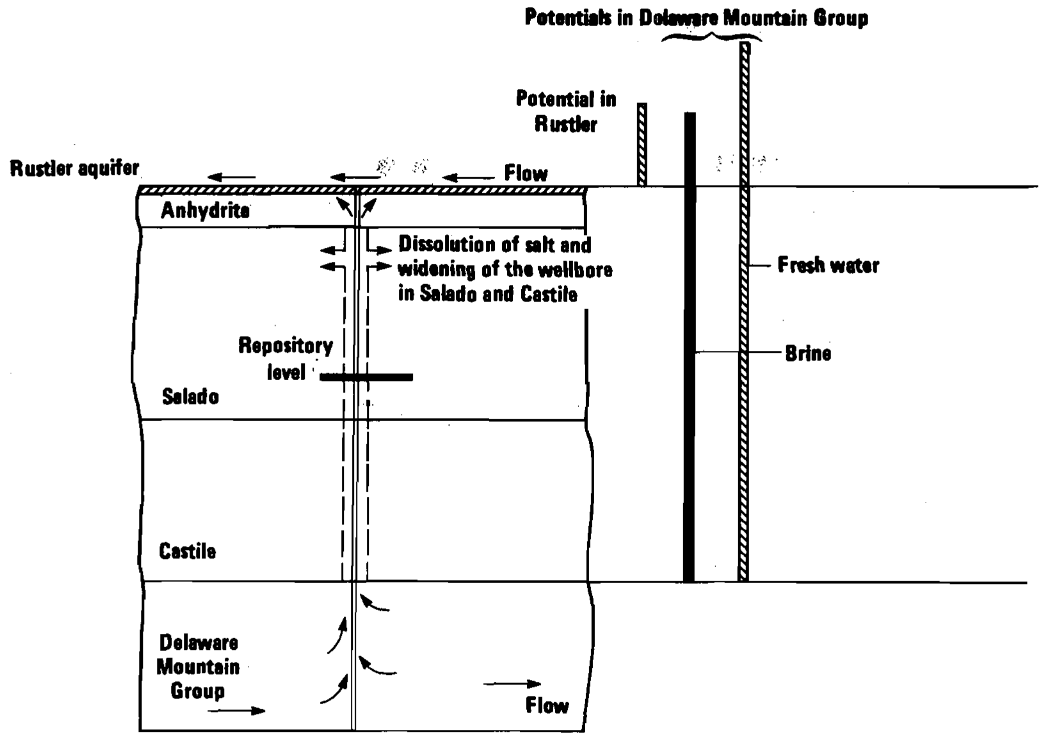


Figure 9-10. Schematic representation of scenario 1.

670,000 years. If the lower bounds on the transmissivity of the Rustler aquifer are used in these calculations, the dissolution times are longer by a factor of 20.

The sequence of events modeled in scenario 1 typifies the immediate consequences of other scenarios that involve the establishment of a communication between the Bell Canyon and the Rustler aquifers. As discussed in Appendix K, the transmissivity of the Rustler aquifer controls the flow rate if the area of the communication is large enough. The flow rate through the postulated 9-inch borehole is near the limiting rate even before the hole begins to widen. Thus, a different type of communication could be postulated in scenario 1 without much changing the immediate consequences. An uncased borehole is but one plausible type of communication; other, less plausible types include a conducting fault that connects the upper and the lower aquifers with the repository and a so-called breccia pipe (Section 7.3) that develops from the base of the Castile Formation and grows upward to eventually connect with the Rustler.

Modeling of scenario 2. The breaching events of scenario 2 consist of the failure of two wellbores that penetrate the repository and the establishment of a connection running between the failed wellbores and through the two modeled disposal areas. As shown in Figure 9-11, water from the Rustler aquifer flows down the upstream wellbore, through the repository, and then back to the Rustler via the downstream wellbore. In this process, salt is continuously dissolved along the flow path until the water becomes saturated brine. It is assumed that water entering the repository level has a total-dissolved-solids concentration of 8000 milligrams per liter and that the fluid reentering the

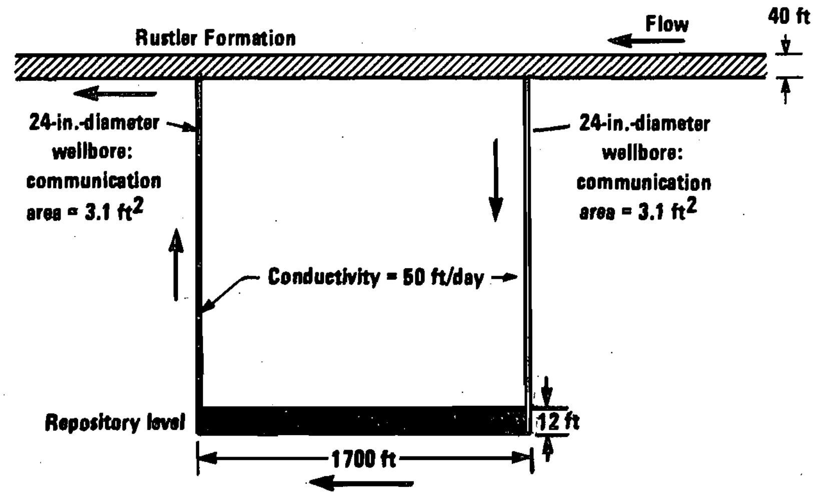


Figure 9-11. Schematic representation of scenario 2.

Rustler is saturated brine containing 410,000 milligrams of total dissolved solids per liter. The leach rate of waste is assumed to be equal to the leach rate of salt, as in the other liquid-breach scenarios.

For purposes of modeling, it was assumed that the upstream wellbore is located on the northwest corner of the disposal area for contact-handled waste and that the downstream wellbore is located 1700 feet to the south, at the northeast corner of the modeled disposal area for remotely handled waste. Both wellbores were assumed to be 24 inches in diameter and to have the same hydraulic conductivity. Since the hydraulic conductivity of the material in a failed wellbore may vary, two values were assigned for the modeling of scenario 2: 50 feet per day (scenario 2A) and 5 feet per day (scenario 2B). The hydraulic conductivity within the repositories was conservatively chosen to be 300 feet per day. Thus, the flow rate through the system turns out to be limited by the downstream wellbore, which, by assumption, does not enlarge, since it contains fully saturated brine.

The flow calculations for this scenario were made with a three-dimensional model. At a hydraulic conductivity of 50 feet per day, the steady-state flow through the system amounts to 0.724 cubic foot per day. At this rate of flow, 0.146 cubic foot per day of salt is dissolved, and the leaching of the contents of both disposal areas is completed in 2.81 million years. At a hydraulic conductivity of 5 feet per day, the steady-state flow is 0.0909 cubic foot per day, and leaching is completed in about 22 million years. Note that in scenario 2, no fluid is added to the Rustler aquifer. The velocity between the repository and the outlet at Malaga Bend is therefore unchanged, in contrast to scenario 1, where fluid from the Bell Canyon aquifer is added to the Rustler and the fluid speed in the Rustler increases slightly--roughly by a factor of 1/6.

The consequences of the events modeled in scenario 2 typify the immediate consequences of other scenarios that involve the establishment of a "U-tube" connection through the repository. The vertical parts of the connection need not be failed wellbores; they could, for example, be fractures produced at opposite sides of the repository through rapid subsidence. Though extremely improbable, connections developed through such fractures are plausible. The important points about any U-tube connection are that the conductance of the downstream leg of the "U" will determine the flow rate through the repository and that the transmissivity of the Rustler aquifer will ultimately dominate for large values of conductance (see discussion of this point in Appendix K). Scenario 4 will represent the extreme consequences of a U-tube connection.

Modeling of scenario 3. As in scenario 2, it is assumed that a vertical connection develops between the repository and the Rustler aquifer. However, the lack of horizontal communication in this scenario prevents water flow within the repository (Figure 9-12). The only mechanism for waste transport from the repository to the aquifer through the stagnant water column is molecular diffusion in the liquid phase.

Diffusion in the stagnant water column is modeled by using the following boundary conditions: saturated brine (at a total-dissolved-solids concentration of 410,000 milligrams per liter) is the assumed concentration at the repository level, and water containing 8000 milligrams of total dissolved solids per liter is assumed in the Rustler. The latter boundary condition is a good approximation so long as the velocity of the water flowing through pores in the Rustler aquifer is higher than the velocity of mass transport by diffusion up the water column. Liquid-liquid diffusivities are on the order of 10^{-3} square foot per day (10^{-5} square centimeter per second) (Perry, 1963); thus, the diffusive flux velocity along the 1200-foot water column is on the order of 10^{-6} foot per day, which is smaller than the calculated natural water velocities (2.1×10^{-4} to 4.1×10^{-2} foot per day) in the Rustler.

Steady-state diffusion is assumed, and salt is allowed to dissolve from the walls of the water column at a constant rate. Under these conditions, the rate of flow of salt into the Rustler aquifer is constant, and the controlling parameter for salt and waste transport into the aquifer is the area of the communication. To show the effects of variation in communication area, two areas are assumed for this scenario: 1% of the total repository area (scenario 3A) and 50% of the total repository area (scenario 3B). Under both assumptions, the dissolution of the repository begins at 1000 years. With the 1% areal communication, the dissolution is completed in 3.3 billion years, and with the 50% areal communication, the dissolution time is about 66 million

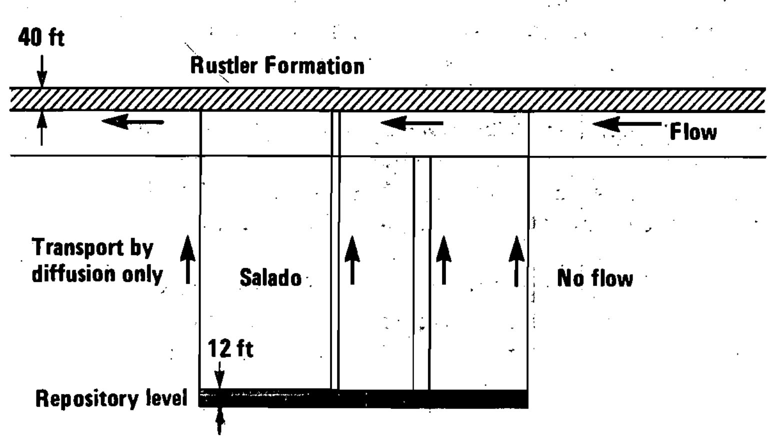


Figure 9-12. Schematic representation of scenario 3.

years. As in scenarios 1 and 2, the dissolution and transport of salt are assumed to determine the dissolution and transport of waste materials within the communications.

The breaching event in scenario 3 has not been expressly stated, because a wide variety of events could lead to such one-channel, one-aquifer types of breach. Simple circumstances producing breaches similar to scenario 3 might include one or more drill holes penetrating the Rustler and reaching the repository. A series of deep, parallel cracks above the repository might, in theory, also give rise to this scenario. Although such penetrations could eventually fill with water, there would be no driving force to make the water flow--unless horizontal communications developed between the cracks (as in scenario 2) or one or more cracks passing through the repository encountered a pressurized brine pocket. The immediate consequences of a one-channel, one-aquifer communication with a brine pocket are outlined below as a variant of scenario 3 that involves forced convection instead of diffusion.

Effects of brine pockets. The following informal scenario explores some of the immediate effects that follow the penetration of an undetected brine pocket located under the WIPP repository if a connection joins the pocket, the repository, and the Rustler aquifer.

The hypothetical brine pocket is assumed to lie 200 feet directly below the repository; it is assumed to be 1 square mile in area and 3 feet thick. The saturated brine in the pocket would be in equilibrium with lithostatic pressure (approximately 2200 pounds per square inch (psi)) and would occupy a volume of 83,600,000 cubic feet. If a connection of the kind mentioned above were to become established, some brine would flow out of the pocket and into the connection--conceivably reaching the Rustler after passing through the repository level and picking up some waste material. The amount of brine that would flow out depends on the bulk compressibility of brine and the lithostatic pressure in the Rustler, which are here taken to be 3×10^{-6} psi^{-1} and 1100 psi, respectively. Under these assumptions, 276,000 cubic feet (about 49,000 barrels) of brine would flow out of the pocket.

The flow of any saturated brine through the repository level would, under the assumptions made for scenarios 1, 2, and 3, produce no release of waste ma- terial since the waste was assumed to dissolve with the salt. However, it ap- pears likely that some radionuclides could leach into saturated brine, though the amounts and the rates are at present uncertain. To gain an estimate for this informal scenario, it is assumed that waste materials are as soluble in brine as pure salt is in distilled water (say, 390,000 parts per million in saturation at 40°C). Under this assumption, the passage of 276,000 cubic feet of brine through the repository would remove no more than 50,000 cubic feet of waste. Thus, no more than 0.8% by volume of the contact-handled waste or 20% by volume of the remotely handled waste could be transferred to the Rustler aquifer through the postulated connection.

The consequences of intercepting a brine pocket have not been carried further in this study for several reasons. First, brine pockets of the size assumed in this example are extremely unlikely near the repository. Such pockets are apparently structurally and stratigraphically controlled in that they are associated with anticlines in the evaporites; they have been observed only in the Castile Formation, about 1000 feet below the level of the repository (see Section 7.3 for further discussion of structure near the site).

Second, the development of a continuous natural connection with a sufficiently high hydraulic conductivity or a large enough area is considered unlikely--particularly if the connection must penetrate to the Castile in order to intercept a brine pocket. A cased wellbore that penetrates a pocket would indeed provide a connection--but one that would result in the release of no waste other than the material intercepted during drilling (see scenario 5 for the consequences of drilling).

Modeling of scenario 4. The three scenarios described above depict repository failures that, though unlikely, are physically possible. An extreme example of scenario 2 is also of interest as a bounding condition since it displays what could ultimately develop from a U-tube connection made at the Rustler-Salado interface. In scenario 4, therefore, the total flow in the Rustler Formation over the entire width of the repository passes through the repository level and back to the Rustler (Figure 9-13) after the layers of overlying salt have been dissolved. Water entering the repository is assumed to contain 8000 ppm of total dissolved solids, the concentration of the Culebra and Magenta waters; water coming out is saturated brine with a total dissolved-solids concentration of 410,000 ppm. The repository is assumed to dissolve, with the dissolution of radioactive waste controlled by the dissolution of the salt as in the other liquid-breach scenarios.

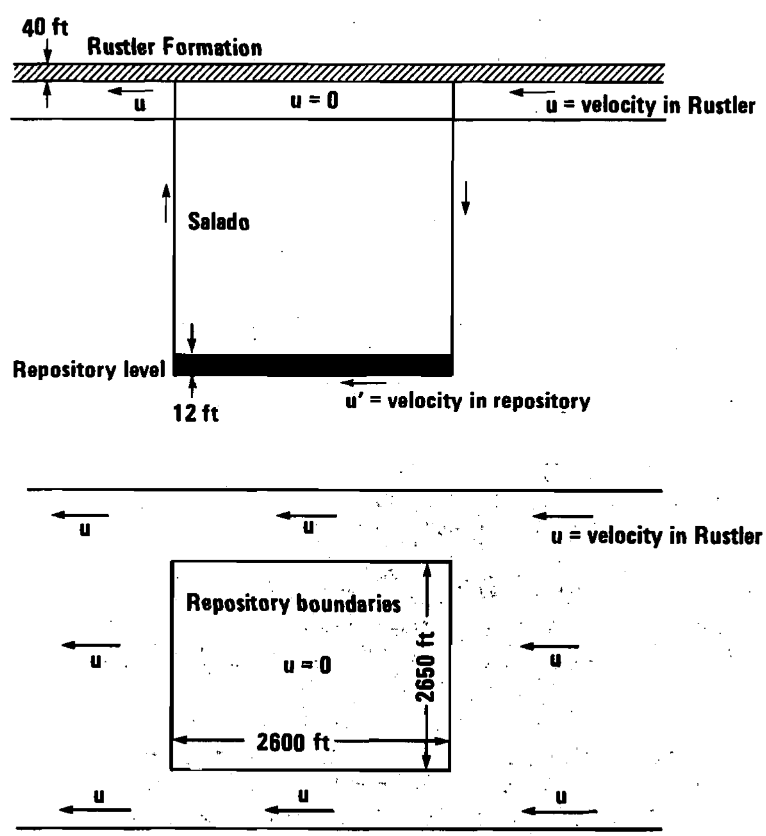


Figure 9-13. Schematic representation of the bounding condition (top) and velocities in the Rustler during the bounding condition (bottom).

Once all of the salt above the repository is dissolved, a steady flow of water in the amount of 420 cubic feet per day through the repository level is set up. As in scenarios 1 and 2, the flow rate is limited by the transmissivity of the Rustler. At this steady rate, about 85 cubic feet per day of salt is removed; the waste material and backfill at the repository level are thus leached in a term of 2600 years.

Obviously, such a massive connection would take a long time to develop. If the flow rate of 420 cubic feet per day could be maintained during the dissolution of overlying salt, about 250,000 years would elapse before the water could reach the waste. For this reason, scenario 4 was modeled at a release time of 250,000 years instead of the 1000-year time used for the other liquid-breach scenarios. However, it should be emphasized that development times for such a breach could be much longer than this under the flow assumed for the Rustler aquifer and that a 250,000-year initiation time is conservatively short. The types of initial connections from which scenario 4 could develop are the same as those quoted for scenario 2.

Nuclide transport

Geosphere-transport calculations for the four liquid-breach scenarios are confined to the Rustler Formation with the discharge point at Malaga Bend on the Pecos River. The potential contours in the Rustler (Figure K-6 in Appendix K) show that flow paths between the repository and Malaga Bend (toward the Pecos River) are essentially one-dimensional and that all water flowing along these paths discharges into the river. Therefore, dispersion calculations in the cross-flow direction do not provide much additional information; the entire plume of water carrying radionuclides would eventually discharge into the river.

The flow rate of radionuclides at the centerline of the radionuclide plume in the aquifer was determined at Malaga Bend and at a location 3 miles from the center of the repository (i.e., at the boundary of the site). For the latter location, a simple procedure obtained plume-centerline transport rates from one-dimensional model calculations. These transport rates, or discharge activities, are shown as functions of time in Tables 9-60 and 9-61. Discharge is measured in curies per year in order to show the amount of radioactivity passing into the Pecos River per year or flowing past the 3-mile location.

According to Table 9-60, appreciable discharge at Malaga Bend begins at 300,000 years for all scenarios but scenario 4, which begins to show appreciable discharge at 500,000 years. The peak discharge rate occurs near 1.2 million years for all scenarios but scenario 1A, for which the peak rate occurs at 1.4 million years. The radionuclide-transport calculations followed the development of the radioactive plumes in the Rustler aquifer out to 3.0 million years in order to determine the times at which the peak discharge rates occurred.

In all four scenarios, the radionuclides contributing the most to the total discharge activity at Malaga Bend are, in the order of their contribution, uranium-236, uranium-235, uranium-233, and radium-226. The uranium nuclides account for over 90% of the activity. Apart from these nuclides, other nuclides contribute a trace amount of radioactivity at the discharge point; these others are thorium-229, thorium-230, thorium-232, neptunium-237,

Table 9-60. Discharge Activities at Malaga Bend: Liquid-Breach Scenarios

Time[a] (years)	Discharge (Ci/yr) 1A	1B	2A	2B	3A	3B	4
300,000	3.6-25[b]	3.8-25	2.7-25	2.4-26	3.3-28	1.2-26	0
400,000	4.6-20	4.6-19	2.2-19	2.7-20	1.9-22	9.3-21	0
500,000	8.8-16	2.4-14	7.9-15	9.9-16	6.7-18	3.4-16	2.9-26
600,000	3.2-12	8.4-11	2.3-11	2.8-12	1.9-14	9.6-13	1.3-19
700,000	1.2-9	3.1-8	7.4-9	9.2-10	6.2-12	3.1-10	1.8-14
800,000	6.4-8	1.6-6	3.6-7	4.5-8	3.1-10	1.5-8	1.3-10
900,000	8.2-7	1.7-5	3.6-6	4.5-7	3.0-9	1.5-7	9.1-8
1 million	4.4-6	4.8-5	1.0-5	1.3-6	8.8-9	4.4-7	7.3-6
1.1 million	1.1-5	6.4-5	1.4-5	1.7-6	1.2-8	5.9-7	8.8-5
1.2 million	1.6-5	6.6-5[c]	1.4-5[c]	1.8-6[c]	1.2-8[c]	6.1-7[c]	2.0-4[c]
1.3 million	1.6-5	6.6-5	1.4-5	1.8-6	1.2-8	6.0-7	9.5-5
1.4 million	1.6-5[c]	6.4-5	1.4-5	1.8-6	1.2-8	6.0-7	1.3-5
1.5 million	1.6-5	4.9-5	1.4-5	1.8-6	1.2-8	6.0-7	1.6-6

[a]Time elapsed since repository breach.
[b]3.6-25 = 3.6×10^{-25}.
[c]Peak discharge activity (before rounding to two significant figures).

Table 9-61. Discharge Activities at 3 Miles from the Point of Release: Liquid-Breach Scenarios

Time[a] (years)	Discharge (Ci/yr) 1A	1B	2A	2B	3A	3B	4
100,000	8.2-9[b]	2.2-7	5.0-8	6.3-9	4.3-11	2.1-9	0
200,000	1.9-6	5.1-5	1.1-5	1.4-6	9.4-9	4.7-7	0
300,000	1.1-5	9.0-5	1.9-5	2.4-6	1.6-8	8.2-7	1.7-8
400,000	2.2-5	9.4-5	2.0-5	2.5-6	1.7-8	8.6-7	3.3-4
500,000	2.3-5	9.8-5	2.1-5	2.6-6	1.8-8	9.0-7	1.5-4
600,000	2.4-5	1.0-4	2.2-5	2.7-6	1.8-8	9.3-7	3.3-5
700,000	2.5-5	1.0-4	2.2-5	2.8-6	1.9-8	9.6-7	3.1-5
800,000	2.5-5	5.6-5	2.3-5	2.9-6	2.0-8	9.8-7	2.9-5
900,000	2.6-5	2.9-5	2.4-5	3.0-6	2.0-8	1.0-6	2.8-5
1 million	2.7-5	2.8-5	2.4-5	3.0-6	2.1-8	1.0-6	2.8-5
1.1 million	2.8-5	2.7-5	2.5-5	3.1-6	2.1-8	1.1-6	2.7-5
1.2 million	2.8-5	2.7-5	2.5-5	3.2-6	2.2-8	1.1-6	2.6-5
1.3 million	2.9-5	2.6-5	2.6-5	3.2-6	2.2-8	1.1-6	2.6-5
1.4 million	2.9-5	2.6-5	2.6-5	3.3-6	2.2-8	1.1-6	2.5-5
1.5 million	3.0-5	2.5-5	2.7-5	3.4-6	2.3-8	1.1-6	2.5-5

[a]Time elapsed since repository breach.
[b]8.2-9 = 8.2×10^{-9}.

and uranium-238. The highly sorbed plutonium nuclides do not contribute to the discharge even at 3 million years; these species are retained in the aquifer near the repository, while their much less sorbed uranium daughters are transported at about one-tenth the aquifer flow speed. Although the distribution coefficient of thorium is greater than that of plutonium, some thorium appears beyond the vicinity of the repository because of the generation of thorium daughter nuclides from the faster-moving uranium nuclides.

Other radionuclides with half-lives that are short compared with the transit times mentioned above are not explicitly included in the geosphere-transport calculations because they are in approximate equilibrium with their parent nuclides. However, the dose effects of the short-lived daughters of the nuclides with detectable discharge rates are taken into account in Section 9.7.1.4, where the consequences of the liquid-breach scenarios are described.

Since the times for peak discharge activity are nearly the same for all scenarios, the relative severity of the scenarios can be ranked at this point. This ranking is summarized in Table 9-62. As might be expected, the consequences of the liquid-breach scenarios in terms of the potential radiation doses delivered to people follow a similar ranking.

Table 9-62. Ranking of Scenarios by Severity

Rank	Scenario	Peak discharge activity at Malaga Bend (Ci/yr)
1	4	1.95×10^{-4}
2	1B	6.60×10^{-5}
3	1A	1.63×10^{-5}
4	2A	1.42×10^{-5}
5	2B	1.78×10^{-6}
6	3B	6.08×10^{-7}
7	3A	1.21×10^{-8}

9.7.1.4 Consequences of Scenarios for Liquid Breach and Transport

In assessing the consequences for people of the liquid-breach scenarios, the exposure pathways included the ingestion of fish and water, boating, swimming, and shoreline activities at the Pecos River in the vicinity of Malaga Bend. The interfacing of the computer codes used in this assessment is described by Torres and Balestri (1978). The calculations assumed that the minimum flow rate of the Pecos River remains the same as now, 515 liters per second (Claiborne and Gera, 1974).

The maximum individual radiation doses are presented in this section for each of the liquid-breach scenarios. These doses are expressed as the 50-year dose commitment (in rem) that would accrue to a hypothetical person who is exposed to the calculated concentrations of radionuclides. It can be shown that the 50-year dose commitment is numerically of the same magnitude as the dose rate (in rem per year) experienced by an individual in the final year of a 50-year term during which exposure is continuous and the degree of exposure remains constant. This fact makes possible the comparison of involuntary doses received by the hypothetical person residing near the Pecos River with doses that are voluntarily received from natural and man-caused sources.

Scenarios 1, 2, and 3

The whole-body and organ dose commitments received by a maximally exposed person in scenarios 1, 2, and 3 are presented in Tables 9-63, 9-64, and 9-65, respectively. The first column of these tables specifies the affected organ; the second column gives the 50-year dose in millirem delivered to that organ; and the third column gives, in order of contribution, the dominant radionuclides and the associated pathways that contribute to the dose. The notation "fish" implies that part of the dose is received by eating fish taken from the Pecos River near Málaga Bend. The notation "drink" implies that part

Table 9-63. Maximum Doses from All Radionuclides at Malaga Bend: Scenario 1, Peak Times 1.2 to 1.4 Million Years

Organ and scenario	Dose (mrem)	Dominant nuclides	Pathways
Whole body			
1A	1.4-3[a]	Ra-226	Fish, drink
1B	7.7-3	Ra-226	Fish, drink
Bone			
1A	2.5-3	Ra-226	Fish, drink
1B	1.3-2	Ra-226	Fish, drink
GI-LLI[b]			
1A	5.3-5	U-235, U-236	Drink
		U-235, U-236, Ra-226	Fish
1B	2.2-4	U-236, U-235	Drink
		Ra-226, U-236, U-235	Fish
Kidney			
1A	1.5-4	U-236, U-235	Drink
		U-234, U-236, Ra-226	Fish
1B	6.0-4	U-236, U-235	Drink
		U-236, U-235	Fish
Liver			
1A	1.1-6	U-235	External
1B	4.6-6	U-235	External
Lung			
1A	1.1-6	U-235	External
1B	4.4-6	U-235	External
Skin			
1A	1.3-6	U-235	External
1B	5.5-6	U-235	External
Thyroid			
1A	1.1-6	U-235	External
1B	4.4-6	U-235	External

[a]1.4-3 = 1.4 x 10^{-3}.
[b]GI-LLI = gastrointestinal tract (lower large intestine).

Table 9-64. Maximum Doses from All Radionuclides at Malaga Bend: Scenario 2, Peak Time 1.2 Million Years

Organ and scenario	Dose (mrem)	Dominant nuclides	Pathways
Whole body			
2A	1.7-3[a]	Ra-226	Fish, drink
2B	2.1-4	Ra-226	Fish, drink
Bone			
2A	2.8-3	Ra-226	Fish, drink
2B	3.5-4	Ra-226	Fish, drink
GI-LLI[b]			
2A	4.7-5	U-236, U-235	Drink
		Ra-226, U-236, U-235	Fish
2B	5.8-6	U-236, U-235	Drink
		U-236, U-235, Ra-226	Fish
Kidney			
2A	1.3-4	U-236, U-235	Drink
2B	1.6-5	U-236, U-235	Drink
Liver			
2A	9.9-7	U-235	External
2B	1.2-7	U-235	External
Lung			
2A	9.3-7	U-235	External
2B	1.2-7	U-235	External
Skin			
2A	1.2-6	U-235	External
2B	1.5-7	U-235	External
Thyroid			
2A	9.3-7	U-235	External
2B	1.2-7	U-235	External

[a] $1.7\text{-}3 = 1.7 \times 10^{-3}$.
[b] GI-LLI = gastrointestinal tract (lower large intestine).

of the dose is received through the normal consumption of water from the Pecos; and the notation "external" covers all doses received through exposure during boating, swimming, and shoreline activities. The doses presented in these tables for the indicated routes of exposure are the largest possible ones under the assumptions made in each scenario; the concentrations of radionuclides at Malaga Bend are lower before and after the peak times shown in the tables.

It is seen that scenario 1B, a two-aquifer connection initially passing through the contact-handled waste, produces the largest consequences among scenarios 1, 2, and 3. Scenario 3A produces the smallest consequences.

Table 9-65. Maximum Doses from All Radionuclides at Malaga Bend: Scenario 3, Peak Time 1.2 Million Years

Organ and scenario	Dose (mrem)	Dominant nuclides	Pathways
Whole body			
3A	1.4-6[a]	Ra-226	Fish, drink
3B	7.0-5	Ra-226	Fish, drink
Bone			
3A	2.3-6	Ra-226, U-236	Drink
		Ra-226	Fish
3B	1.2-4	Ra-226, U-236	Drink
		Ra-226	Fish
GI-LLI[b]			
3A	4.0-8	U-235, U-236	Drink
		U-235, U-236, Ra-226	Fish
3B	2.0-6	U-236, U-235	Drink
		Ra-226, U-236, U-235	Fish
Kidney			
3A	1.1-7	U-236, U-235	Drink
		U-236, U-235	Fish
3B	5.6-6	U-236, U-235	Drink
		U-236, U-235	Fish
Liver			
3A	8.4-10	U-235	External
3B	4.2-8	U-235	External
Lung			
3A	8.0-10	U-235	External
3B	4.0-8	U-235	External
Skin			
3A	1.0-9	U-235	External
3B	5.0-8	U-235	External
Thyroid			
2A	8.0-10	U-235	External
2B	4.0-8	U-235	External

[a]1.4-6 = 1.4×10^{-6}.
[b]GI-LLI = gastrointestinal tract (lower large intestine).

Scenario 4

The worst liquid-breach scenario evaluated in this analysis is the bounding condition, an event in which all the Rustler waters normally moving above the repository pass completely through the repository. It is included to provide an upper bound to the impact of the WIPP repository.

The whole-body and organ dose commitments received by a maximally exposed person in connection with this bounding scenario are presented in Table 9-66. The format of this table is identical with that of Tables 9-63, 9-64, and 9-65. The whole-body dose in the bounding scenario is 92% higher than the whole-body dose in scenario 1B.

Table 9-66. Maximum Dose Commitments from All Radionuclides at Malaga Bend: Scenario 4, Bounding Case, Peak Time 1.2 Million Years

Organ and scenario	Dose commitment (mrem)	Dominant nuclides	Pathways
Whole body	1.5-2[a]	Ra-226	Fish, drink
Bone	2.6-2	Ra-226, U-236 Ra-226	Drink Fish
GI-LLI[b]	6.3-4	U-236, U-235 Ra-226, U-236, U-235	Drink Fish
Kidney	1.8-3	U-236, U-235 U-236, U-235	Drink Fish
Liver	1.3-5	U-235	External
Lung	1.2-5	U-235	External
Skin	1.6-5	U-235	External
Thyroid	1.2-5	U-235	External

[a] $1.5\text{-}2 = 1.5 \times 10^{-2}$.
[b] GI-LLI = gastrointestinal tract (lower large intestine).

Summary for liquid breach and transport

The doses received by the maximally exposed person from scenarios 1 and 4 are very small, compared with the annual average whole-body doses received by persons in the United States from various sources (EPA, 1972). This comparison is made in the following compilation (in units of millirem) for the year 1980:

Scenario 1B	0.008
Scenario 4	0.02
Television	0.1
Consumer products	1.0
Air transport	1.0
Medical X-rays: abdominal dose	90
Natural background (WIPP site)	100

9.7.1.5 Scenario 5--Direct Access by Drilling

Scenario 5 was chosen to represent a situation in which people bring some of the repository contents directly to the surface. The sequence of events that must occur in this scenario would be broken by the failure of any event in the sequence, which is listed below.

Event	Consequence
1. Institutional control is lost or fails	No release of radiation
2. Knowledge of the repository is lost, or fear of radiation effects is overcome by complacency	No release of radiation
3. There is an economic incentive to explore in the area of the site	No release of radiation
4. The repository area is chosen for drilling	No release of radiation
5. The contents of the repository go unrecognized as radioactive material before and during drilling	No release of radiation
6. Drilling intercepts concentrated radionuclides	No release of radiation
7. The material brought up is left untreated and exposed	Drill crew receives dose
8. The maximally exposed person remains in place continuously for 1 year after drilling	Maximally exposed person receives the dose calculated in this study

Scenario 5 is modeled in two separate studies. In each of these two studies, it is assumed in separate calculations that contact-handled TRU waste is intercepted and that remotely handled TRU waste is intercepted.

The first study models a well drilled for oil or gas, using today's drilling technology. It assumes a borehole 10 inches in diameter. The cuttings from the hole are mixed with an equal volume of drilling mud (a mixture of bentonite and barite); the total amount of material brought to the surface (approximately 100 tons) is assumed to be left at the site in a pit with a surface area of 720 square feet. At 10-foot intervals, the drillers collect down-hole samples for analysis: one side-hole core (1 by 0.75 inch) and one chip sample (2 grams). Two sets of these samples (0.1 liter per set) are assumed to be taken from the repository horizons.

The second study models a hole drilled during exploration for minerals. It assumes a core drill 3 inches in outside diameter; this drill produces a continuous core 2.12 inches in diameter. The core, which contains 1.86 liters of contact-handled TRU waste or about 7.0 liters of remotely handled TRU waste, is assumed to be retained and examined by a geologist. The drilling mud and cuttings are assumed to be left at the site in a pit with a surface area of 144 square feet.

External dose received by drill-crew members

In calculating the direct exposures received by the drill crew, the analysis examined current work practices to determine the amounts of time that drill-crew members spend near samples. The highest individual external dose is received by the geologist, who is assumed to examine the samples for 1 hour at an effective distance of 1 meter. The core and chip samples are treated as point sources with no self-shielding effects.

The doses that an individual drill-crew member might receive in each of the direct-access studies are shown as functions of time in Figure 9-14. The figure shows these doses separately for (1) drilling through the disposal area for contact-handled TRU waste and (2) drilling directly through a canister containing remotely handled TRU waste. The highest dose occurs if a core sample from the 3-inch hole intercepts a canister of remotely handled TRU waste shortly after closure. This dose, about 1.5 millirem to the whole body at 100 years, is 1.5% of annual dose received from natural background radiation.

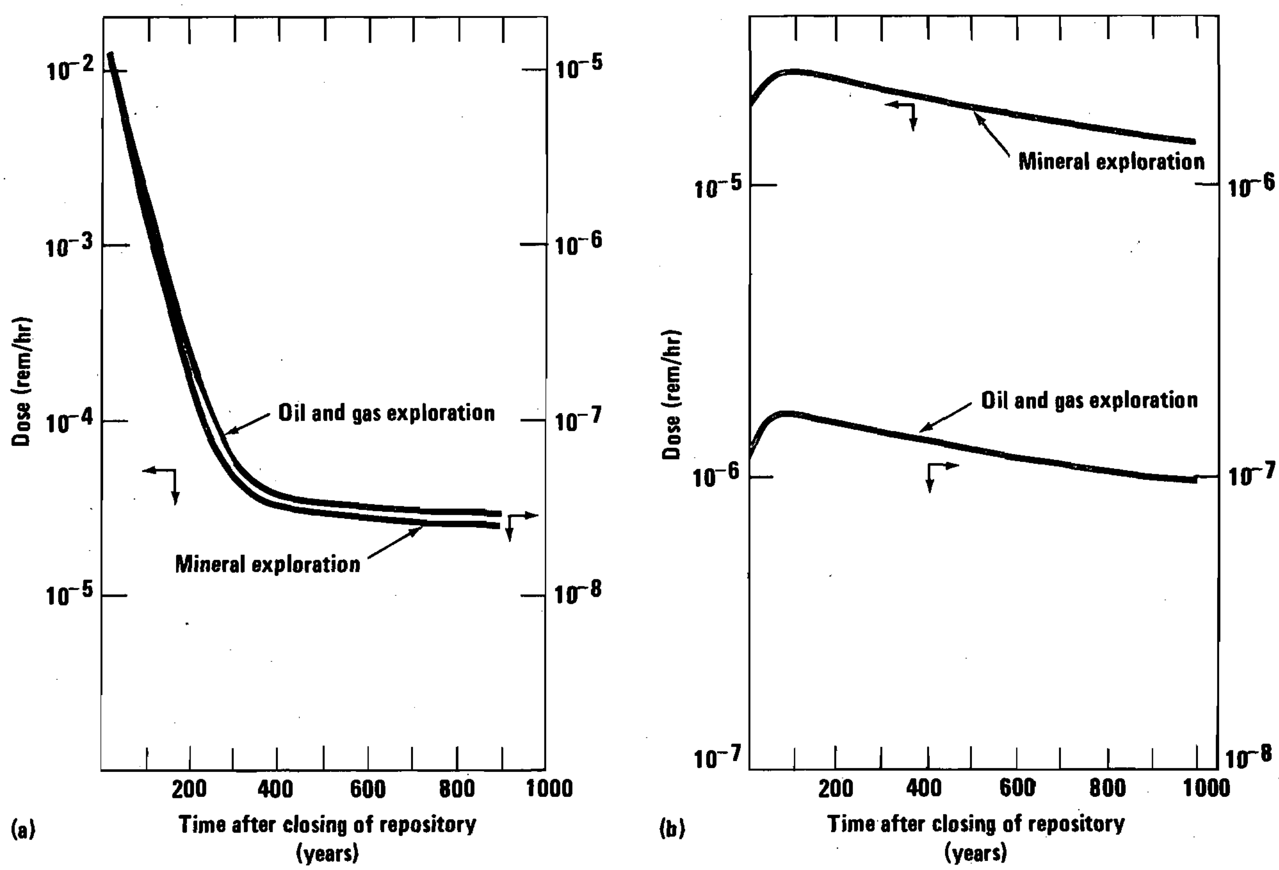


Figure 9-14. External doses received by drill-crew members from chip and core samples for drilling (a) through a canister of RH TRU waste and (b) through CH TRU waste.

Doses received through indirect pathways

In addition to the exposure of the drill crew, the impact on persons living near the site was evaluated. Water erosion of the mud pit, which delivers radionuclides to people primarily through the ingestion pathway, is ignored; in the arid region around the site, wind erosion is the dominant mechanism for the introduction of radionuclides into pathways leading to people. Such a pathway would deliver radionuclides principally through inhalation.

Details of the exposure calculations appear in Appendix K. Calculations of the airborne dispersion of radioactive material from the mud pit are based on measurements taken over 20 years at the GMX area of the Nevada Test Site (Healy, 1977). The air-suspension model parametrized for the Nevada Test Site observations and the climate at the WIPP site come from the NRC Reactor Safety Study (NRC, 1975).

Although at present there are no farms within several kilometers of the WIPP site, for this analysis it is assumed that a single-family farm exists 500 meters downwind from the mud pit. The farm is assumed to produce leafy green vegetables, dairy products, and beef. The people living on the farm are assumed to eat the food produced there and to breathe the air contaminated by the windborne particles from the pit.

Two drilling locations were assumed: (1) the 10-inch hole is drilled through the disposal area for remotely handled waste and (2) the 10-inch hole is drilled through the contact-handled-waste area. For each location, a 50-year dose commitment after 1 year of exposure is listed in Table 9-67; the exposure is assumed to occur either 100 or 1000 years after the closure of the repository.

For drilling through contact-handled TRU waste, the maximum calculated dose commitment is 2.2×10^{-4} rem to the bone 100 years after closure; the dominating pathway is inhalation, and the radionuclides dominating the dose are plutonium-239, plutonium-240, and americium-241. The results of drilling through remotely handled TRU waste are similar: the maximum dose commitment, 3.2×10^{-4} rem to the bone, occurs principally through the inhalation pathway at 100 years after closure, but the radionuclides dominating the dose are plutonium-239, strontium-90, and plutonium-240. The doses at 1000 years after closure are not radically different from the 100-year doses; at 1000 years the dominant radionuclides are plutonium-239 and plutonium-240.

9.7.1.6 Direct Access to WIPP Wastes by Solution Mining

Solution mining is one way by which some of the TRU waste contained in the WIPP could inadvertently be brought into contact with the biosphere after knowledge of the purpose and location of the WIPP had been lost. The techniques of solution mining are used to extract soluble minerals and also to create underground storage cavities for liquids and gases. The soluble minerals halite (NaCl) and sylvite (KCl), a form of potash, exist under the WIPP site and are of economic value. Only experimental extraction of potash minerals by solution mining has been attempted in the area, however, because the water supply in the arid Delaware basin is limited. Nevertheless, it is possible that solution-mining activity in the Delaware basin could increase in the future, given an increased water supply or an increased demand for potash or halite. There is also a small chance that underground storage cavities will be created in the vicinity of the WIPP; storage cavities in the salt domes of the southeastern states are being used to contain petroleum and natural gas, and these resources exist in the Delaware basin of New Mexico and Texas.

Table 9-67. Maximum Doses Received by a Person Through Indirect Pathways: Direct-Access Scenario

Pathway	50-year dose commitment after 1-year exposure (rem)		
	Organ	100 years	1000 years
	REMOTELY HANDLED TRU WASTE		
Inhalation	Bone	2.7-4[a]	1.7-4
	Lung	1.7-5	9.4-6
	Whole body	9.1-6	4.3-6
Ingestion			
Crops	Bone	4.3-5	6.9-6
	Whole body	1.7-6	1.8-7
Meat and milk	Bone	4.0-6	8.5-9
	Whole body	1.3-7	6.0-10
	CONTACT-HANDLED TRU WASTE		
Inhalation	Bone	2.2-4	1.9-4
	Lung	1.2-5	1.0-5
	Whole body	5.8-6	4.8-6
Ingestion			
Crops	Bone	9.4-6	7.7-6
	Whole body	2.8-7	2.0-7
Meat and milk	Bone	1.6-8	9.5-9
	Whole body	7.1-10	6.7-10

[a] $2.7\text{-}4 = 2.7 \times 10^{-4}$.

Though each of the modes of intrusion mentioned above could, in theory, release waste to the biosphere, an analysis of their consequences has not been carried out for the present study, because intrusion into the WIPP repository by solution mining is considered to be an event of very low probability. The soluble evaporites whose presence would provide the motive for solution mining underlie at least 3.5 million acres of the Delaware basin. A random penetration of these evaporites for any reason would thus hit the 120-acre repository with a probability of 3.4×10^{-5} (or about 3 chances in 100,000). There are, moreover, site-specific reasons for believing that intrusion into the repository is unlikely. These reasons are outlined in the paragraphs that follow.

Solution mining for potash

The potash ores sylvite and langbeinite existing under the WIPP site are contained in 11 thin ore zones within the McNutt member of the Salado Formation. The base of the McNutt lies approximately 1740 feet below the surface, or about 400 feet above the level of the repository (Section 7.3). Only the sylvite component of the ore is extractable by solution mining.

Two methods for potash solution mining are currently possible. The first method uses a single well in which the same wellbore is used for both injection and production. This method usually produces deep cavities of limited areal extent and is therefore most suitable for thick ore bodies. The second method employs two or more wells; solvent circulates between pairs of wells after initial conduits between the wells have been formed by hydrofracture. The second method offers good control of cavity depth relative to cavity area and, for thin ore bodies, a more efficient use of solvent. The multiwell method has been used for the experimental solution mining of thinly bedded potash in the Carlsbad basin (Davis and Shock, 1970).

Because of the thinness of the potash ore zones and the limited supply of water near the WIPP site, future solution-mining efforts would probably use the multiwell method to extract potash under the site. The degree of control over cavity depth offered by the method suggests that there would be no direct contact with waste in the repository 400 feet below the lowest ore zone. The conditions favoring an eventual intrusion into the repository by water would, however, be enhanced because of the increased permeability of the mined-out ore zones. Although the long-term consequences of mining out the McNutt member have not been studied specifically, the consequences for the WIPP repository are not likely to be worse than those calculated for the bounding scenario (Section 9.7.1.4).

Solution mining for halite (salt)

Halite is the dominant constituent of the evaporites underlying the WIPP site. Evaporite formations within the site boundaries contain about 1.98×10^{11} tons of salt, the purest of which occurs in the Castile Formation below the level of the repository (Powers et al., 1978, Section 8.4.7). The mass of salt contained within the volume of the proposed 100-acre disposal area for contact-handled TRU waste is only about 3.61×10^{6} tons. This represents about one-sixth of the United States annual consumption of salt in the 1960s. Thus even if all the salt consumed in the United States at current rates were to be mined exclusively within the WIPP-site boundaries, a time on the order of 10,000 years would elapse before the actual repository would be reached with high probability. Furthermore, the presence of numerous beds of relatively impermeable anhydrite and polyhalite in the Salado makes this area unattractive for the solution mining of halite. The development of a reasonably sized mine cavity in the salt would be extremely difficult. Large masses of salt occur elsewhere in the Delaware basin, and adequate reserves of salt exist nearer to the continental centers of demand. These factors have led to the conclusion that it is highly unlikely that the repository will ever be breached in the process of mining halite.

Analyses of solution-mining release scenarios for domed-salt repositories containing high-level reprocessing waste and spent fuel (with larger inventories and concentrations of long-lived radionuclides than proposed for the WIPP repository) indicate that such events do not constitute significant societal risks (DOE, 1979b).

9.7.1.7 Summary of Calculated Doses

The following conclusions are drawn from the analysis of the five scenarios:

1. The greatest consequences from a liquid-breach scenario are for scenario 4. Under the assumptions made for that scenario, the greatest whole-body and organ doses are less than 0.02% of the whole-body dose from natural background radiation at the WIPP site.

2. The consequences of a liquid-breach scenario depend on the flow rate of water through the breached repository. A factor-of-4000 difference in the flow rates for the analyzed scenarios translates into a hundredfold difference in the maximum doses received by a person at Malaga Bend. The consequences of scenario 3, which involves transport only by diffusion, are directly proportional to the area of the communication that connects the repository with the Rustler aquifer.

3. Under the assumptions made concerning plutonium distribution coefficients, no plutonium enters the biosphere during the time considered for scenarios 1 through 4.

4. It is not considered likely that a drill crew would inadvertently drill into the repository only 100 years after sealing. If they did, however, the greatest external dose received by the drill crew is calculated to be about 1.5×10^{-3} rem to the whole body under the assumption that the drill has penetrated a canister of remotely handled TRU waste. The maximum external dose from drilling through contact-handled TRU waste would occur 80 years after repository closure; it would be 2.4×10^{-5} rem.

5. The 50-year dose commitment received through indirect pathways by a person living on a nearby farm 100 years after closure is conservatively estimated to be 2.2×10^{-4} rem to the bone if a drill penetrates the contact-handled TRU waste and 2.7×10^{-4} rem to the bone if it penetrates a canister of remotely handled TRU waste. These calculated dose commitments are upper bounds to the dose commitments that people might receive.

9.7.2 Effects Not Involving the Release of Radioactivity

9.7.2.1 Effects of Heat from Emplaced Waste

The long-term effects of heat from emplaced waste are discussed in this section, which predicts the changes in temperatures, the creation of buoyant forces that might lift the waste upward in the rock column, and the uplift of the rock column and the ground surface due to thermal expansion. Although these effects may be significant in repositories for high-level waste, the waste emplaced in the WIPP will release little heat: the analysis summarized in this section predicts no possibility that these effects could breach the repository.

In keeping with the practice of computing upper bounds to the impacts of the WIPP, the analysis of the effects of heat assumes that the heat load will be more than 25 times greater than the expected load. The expected heat load can be estimated by assuming that 72,000 cubic feet of contact-handled TRU waste is emplaced per acre of the repository, with half this volume in drums and half in boxes. At typical loadings of 8 grams of plutonium per drum and 13 grams of plutonium per box, the heat produced will be 0.11 kilowatt per acre if the plutonium is assumed to be weapons-grade material producing 0.0024 watt per gram. If all the containers are loaded with plutonium to the maximum allowed by regulations (200 grams per drum and 350 grams per box), the heat load will reach 2.8 kilowatts per acre. Remotely handled waste could, at 55 canisters per acre, produce as much as 3.3 kilowatts per acre, but only a small part of the repository will hold such waste. The effects of heat from the WIPP are therefore overestimated by assuming a heat load of 2.8 kilowatts per acre.

Calculations with the computer code STEALTH have investigated the thermomechanical effects that this heat load might exert on the environment of the repository. The model represents the repository rock layers to a depth of 3000 meters in a cylindrical volume with a radius of 4000 meters. It uses actual laboratory measurements of the properties of the strata above and below the repository; in this way the model accounts for the temperature-dependent physical properties of the rock layers. The salt is allowed to creep nonlinearly under stress. The repository is modeled as a 180-acre disk loaded to a power density that is initially 2.8 kilowatts per acre and decreases with time. Details of the calculation are given by Thorne and Rudeen (1979).

Figure 9-15 shows examples of the long-term temperature responses calculated from the model. At the center of the repository, the rise in temperature reaches a maximum of less than 2°C at 80 years after waste emplacement and then falls steadily; at this level, no appreciable temperature changes appear at radii greater than 1 kilometer. At the top of the Rustler Formation above the repository, the maximum temperature rise is less than 0.3°C. At a depth of 41 meters from the surface, the maximum temperature increase, not shown in the figure, is about 0.03°C; it occurs approximately 640 years after emplacement.

Buoyancy

Figure 9-16 shows the effects of buoyant forces. According to these data, a point at the top of the emplacement level is displaced by at most 10.4 millimeters; the maximum displacement occurs about 90 years after waste emplacement.

Most of the displacement occurs within 1 kilometer of the center of the repository. A point in the Rustler Formation will rise to a maximum displacement of about 8.7 millimeters before sinking slowly toward its starting position.

Surface uplift

The surface uplift predicted by the computer calculations appears in Figure 9-17. The maximum displacement, less than 6 millimeters, occurs about 1000 years after waste emplacement. The uplift subsides slowly; at 1500 years the total displacement is about 3 millimeters. Such a surface uplift, occurring over a distance of kilometers, would not affect the land or the rock strata above the repository.

9.7.2.2 Effects of Subsidence

The underground mined openings of the repository will eventually close because of the weight of the overlying rock and the plasticity of the salt. This section discusses the closure process and its effects at the surface and in the intervening rocks.

The collapse of underground openings is well known. It has been extensively studied, especially in coal fields, to determine its effects on mine safety and the integrity of surface structures. Both in coal mines and in potash mines, the surface area affected by subsidence exceeds the area of the underground openings. The angle between the vertical and a line connecting the edge of the surface subsidence and the edge of the underground opening is called the angle of draw; this angle is typically about 45 degrees for potash mines near the WIPP site, which are shallower than the WIPP mine will be (BLM, 1975).

The rate of subsidence depends on the depth of the openings, the extraction ratio (the area of the openings divided by the area of the mine), and the nature of the overlying rocks.

These principles can be applied to the WIPP repository. The surface area affected can be estimated by applying a 45-degree angle of draw to the area and depth of the underground workings. If the WIPP mine is assumed to contain 180 acres at a depth of 2100 feet, this procedure suggests that subsidence will affect the ground surface out to a radius of about 3700 feet, an area of about 1000 acres. Because the WIPP will contain only about 120 acres, the affected area will be smaller.

The following equation (General Analytics, Inc. 1974) was used to calculate the maximum subsidence:

maximum subsidence = (subsidence factor) (cavity height) (percent of cavity remaining after backfill) (percent extraction)

This equation assumes that the mine will be at the critical extraction width (the width of the area that must be extracted to produce maximum subsidence at the center of a subsidence trough); that it will have a subsidence factor (ratio of vertical surface displacement to cavity height) of 2/3, the

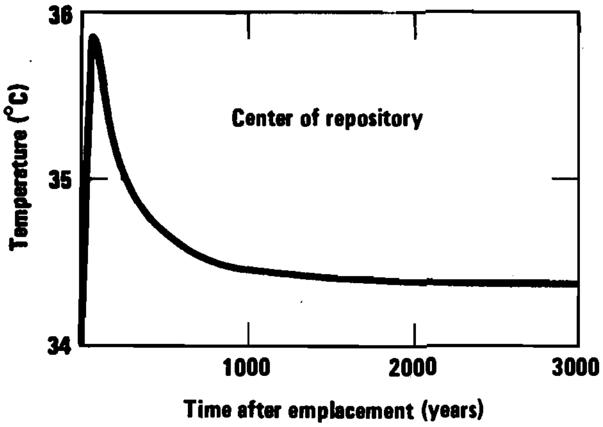


Figure 9-15. Temperatures at points on a vertical line passing through the center of the repository.

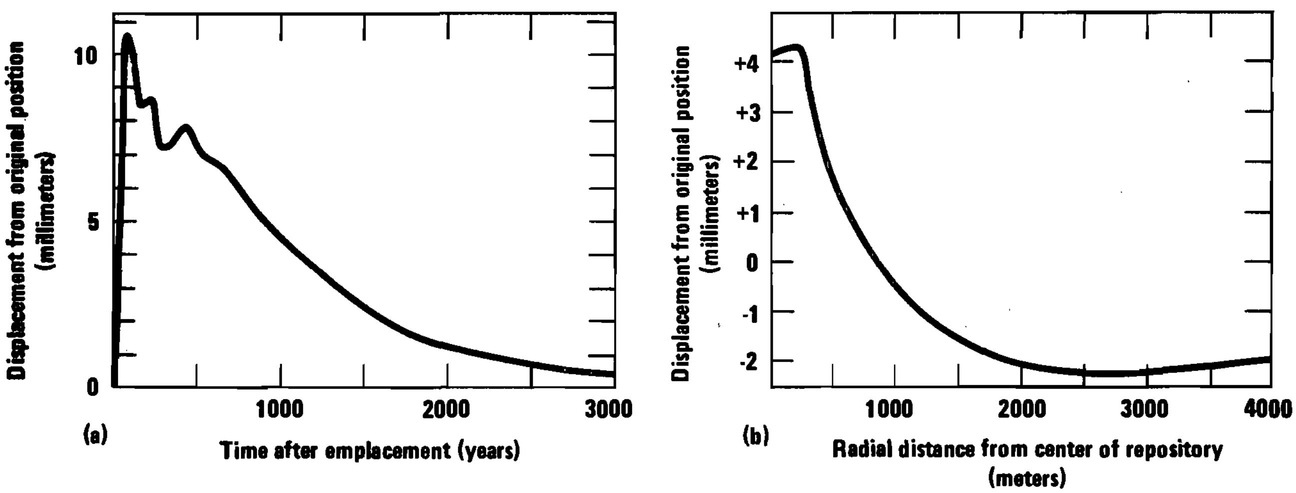


Figure 9-16. Displacement at repository level as a function of (a) time at repository center and (b) radial distance at 1000 years after emplacement.

ratio at nearby potash mines (BLM, 1975); and that it will have an extraction ratio of 30%.

Cavity heights of 16 feet would produce a subsidence of about 1 foot at 70% backfill and 1.6 feet at 50% backfill. These are maximum values, occurring over the center of the subsidence; they decrease from the center to the edge of the affected area, less than 3700 feet from the center. Subsidence of the same magnitude, although more restricted in area, could be expected if the SPDV underground area were developed but the WIPP project proceeded no further.

The closing of the mined cavities will proceed quickly on the geologic time scale; the resulting deformations will be quickly translated to overlying units. How the overlying units will respond is not known in detail. The predicted surface subsidence of 1 to 1.6 feet will be insignificant inasmuch as

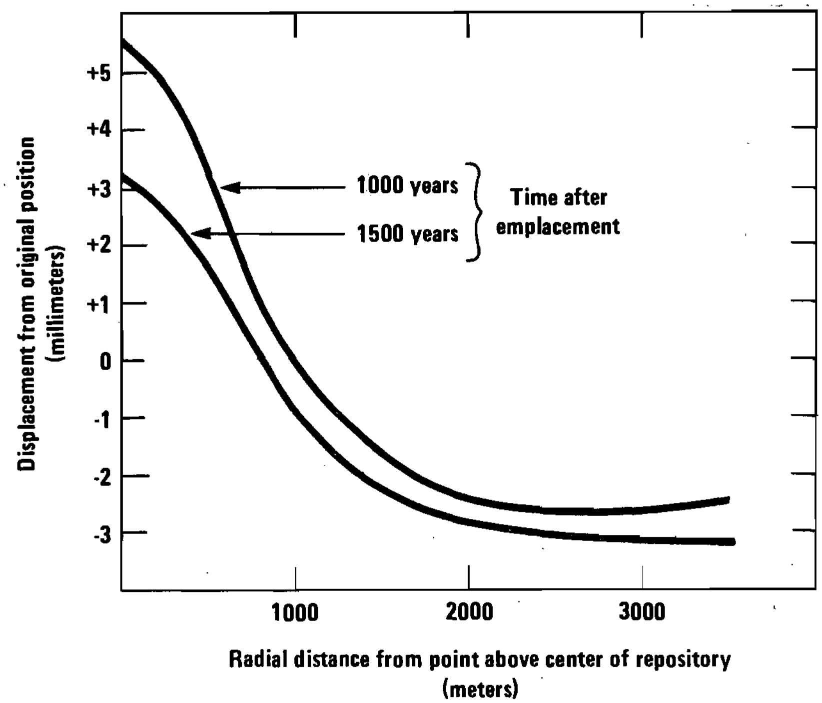


Figure 9-17. Uplift of ground surface over repository.

the natural relief at the site is greater; furthermore, there is no integrated surface drainage to disturb.

In Nash Draw subsidences on the order of 200 feet are suspected to have created vertical interconnections between water-bearing strata in the Rustler Formation. Hydrologic testing has not yet determined whether this is true, but the possibility remains that to a lesser extent, because of the smaller subsidence, interconnections may also appear over the repository. Water from the Magenta and the Culebra aquifers might then be introduced to the top of the Salado salt. That by itself would have little significance because of the 1200 feet of salt intervening between the top of the salt and the disposal level. At worst, pathways for water intrusion similar to those postulated in scenarios 2 or 4 (Section 9.7.1.3) might be initiated. It has been noted that the radiation doses produced as a consequence of these scenarios are much lower than doses from natural background radiation. Therefore subsidence, even when extrapolated to an extreme, would not significantly affect public health and safety. Furthermore, water has not flowed into the local potash mines in spite of much more severe subsidence than the repository will experience.

Investigations of subsidence continue. A first-order level-line survey line was laid out in 1978 to establish baseline elevations at the site and to monitor subsidence over certain active potash-mining operations. These field observations will help in developing a better understanding of the subsidence processes and in providing data for testing models. Other studies are now investigating the effects of subsidence on the surface, on the rock column, and on the aquifers.

9.7.3 Interactions Between the Waste and the Salt

Some of the unresolved technical issues in the analysis of waste disposal in bedded salt involve interactions between the waste and the salt. This section discusses the most frequently mentioned interactions. It summarizes the present state of knowledge about them, emphasizing their applications to the WIPP but leaving extended discussion to referenced documents when appropriate documents are available. Since investigations into the details of these interactions are continuing as part of the WIPP project, this discussion also mentions the programs now under way or planned.

9.7.3.1 Gas Generation

It is believed that stored radioactive waste may be able to generate substantial amounts of gas. Because contact-handled TRU waste sometimes contains organic and other gas-producing material, it has received closer scrutiny than remotely handled TRU waste. Nevertheless, both types of waste might, in theory, release gases. There are two basic questions to be answered about gas generation:

1. How is the gas generated--by what mechanisms, in what amounts, and at what rates?

2. After generation, how will the gas affect the repository?

Mechanisms, amounts, and rates

Mechanisms so far identified for gas production from TRU waste are radiolysis, bacterial degradation, thermal decomposition and dewatering, and chemical corrosion. Extensive studies of these mechanisms have produced data collected in review documents (Molecke, 1979; Sandia, 1979), which are the sources for the discussion that follows except where other references are cited.

Gas production by radiolysis has been investigated for existing temporarily stored TRU waste and for several matrices: cellulosics (paper, wood, rags), plastics, rubbers, concrete, asphalt, mild steel, and sludges. The work was done primarily at the Los Alamos National Scientific Laboratory and the Savannah River Laboratory. These experiments show very low rates of gas production, less than 0.05 mole per year per drum except for process sludges and asphalt.

Among the four mechanisms, bacterial degradation has the greatest potential for generating significant quantities of gas (Table 9-68). Bacterial degradation can occur in TRU waste that contains organic matter like paper, wood, rubber, and oil. Some bacteria or fungi will be present in the existing matrices or on their containers after temporary storage. The gas produced will be primarily carbon dioxide. Gas-generation rates, which will depend on how well the bacteria flourish, may vary widely among individual waste drums. Experiments at the University of New Mexico are measuring the gas-production rate from the microbial degradation of mixed organic wastes, asphalt, and wood in aerobic or anaerobic atmospheres; the test conditions vary temperature and moisture content (dry, wet, and brine saturated).

The thermal decomposition of mixed organic-matrix waste, paper, and polyethylene has been measured at 70 and 100°C by observing gas-pressure increases. The work was performed at Los Alamos. The measurement of gas production at 40°C is still in progress; the expected range of gas production at 40°C, based on existing data, is 0.02 to 0.2 mole per year per drum of waste. At 25°C, the gas production is expected to be negligible. The release of water vapor from existing process sludges was measured at 25 to 100°C. Thermal dewatering of sludges can be significant, even at 25°C. Because of these results, process sludges were judged unacceptable in the WIPP repository without further processing.

The corrosion and gas-generation rates for mild steel (TRU-waste containers, contaminated metal scrap), were measured at Sandia National Laboratories at 25°C under dry, moist, and brine-inundated conditions. Hydrogen will be generated by corrosion only in an anaerobic and wet or inundated storage environment, at a maximum rate of 2 moles per year per drum. In an air atmosphere, with moisture present, oxygen will be consumed. Under the dry conditions expected in a repository, the corrosion of steel is not expected to yield significant quantities of gas.

A comparison of measured gas-generation rates for the different mechanisms and for several matrices is presented in Table 9-68, taken from a review document (Molecke, 1979). These data do not take into account various aging factors. These factors tend to decrease gas production; they include localized matrix depletion because of radiolysis, an unfavorable geochemical environment, increasing pressure, and competition between differing mechanisms.

Gas could also be produced from the high-level waste used in WIPP experiments and from remotely handled TRU waste. It could arise from chemical reactions of the waste containers with brine, if any brine is available, and from the radiolysis of waste inside the containers. Radiolysis is known to produce only about 0.1 cubic centimeter of hydrogen per calorie of energy stored in the salt (Jenks and Bopp, 1977). Since the hydrogen would be released on the dissolution of the salt, the amount of gas produced by these wastes could be estimated from the chemical reactions alone--that is, from the mass of iron in the canister. Laboratory experiments will provide further data on gas generation from experimental high-level waste before the experiments begin.

Effects of evolved gas on a repository

The void volume left behind in a sealed repository will be about 50% of the original mined opening because the backfill salt will be at a density about 50% of the rock-salt density. As the salt flows under lithostatic pressure, this open volume in the repository will close, probably in 50 to 200 years (Baar, 1977, p. 136). Closure to full salt density is expected because the air in a room and tunnel is only 4×10^5 moles, not enough to maintain appreciable openings in the salt. Nevertheless, some volume may become available for storing evolved gas because of dilatancy (Jaeger and Cook, 1976, p. 85): as the salt creeps into openings in the repository, it is at a reduced density. Gas evolved from the waste could compress the salt back to full density, creating gas-filled volumes that might amount to roughly 10% of the volume that the creeping salt had filled.

Table 9-68. Rates of Gas Generation from the Degradation of TRU Waste[a]

Mechanism	Matrix	Gas limit (moles per year per drum)[c] Lower	Upper	Range
Microbes				
Aerobic	Organic composite	0	12	0.9-5.5
	Plywood box	0	3.0	0.44-2.2
	Plywood box (3.2 m^3)	0	19	2.8-14
	Asphalt	0	8.4	0.1-2.6
Anaerobic	Organic composite	0	32	1.2-4.2
	Plywood box	0	4.1	1.1-3.7
	Plywood box (3.2 m^3)	0	26	6.8-23
	Asphalt	0	4.8	0-1.9
Heat	Organic composite (40°C)	0	0.4	0.02-0.2
	Paper (70°C)	0.5	2	1.3
Radiolysis	Cellulosics (0.04 Ci)	0.002	0.012	0.005-0.011
	Polyethylene (0.04 Ci)	0.003	0.008	0.007
	Polyvinyl chloride (0.04 Ci)	0.01	0.08	0.03-0.042
	Organic composite (0.04 Ci)	0.002	0.006	0.005
	Asphalt (7.7 Ci)	0.1	1.0	0.15-0.76
	Concrete-TRU ash (poured, 15 Ci)	0.03	1.0	0.045-0.93
	Concrete-TRU ash (heated, 15 Ci)	0.0002	0.05	0.0005-0.035
Corrosion	Mild steel	0	2.0	0
Alpha decay	TRU nuclides (helium generation)			0.00002
Average for all mechanisms	Existing INEL TRU waste (average over total volume)	0.0005	2.8	0.3-1.4

[a]Data from Molecke (1979).
[b]Most probable range.
[c]Volume of drum is 0.21 m^3 except as noted.

While mine closure may be complete in 200 years, gas may evolve from the waste over much longer times; gas production will apparently be slow compared with mine closure. Depending on the permeability of the salt, the gas may disperse in at least one of three possible modes:

1. The medium is permeable enough to allow gases to move away from the repository without any significant pressure buildup.

2. The medium is impermeable, and gas accumulates until the medium fractures under the gas pressure.

3. The medium is impermeable, but the accumulation of gas is sufficiently slow for the medium to flow plastically, adjusting the void volume; the pressure never becomes much more than lithostatic, and the medium remains intact.

These modes have been tested by mathematical calculation using experimental values for gas permeability. Experiments show that the gas permeability, while not zero, is small enough for some accumulation of gas to be possible; the proper representation of the problem requires simultaneous consideration of the mine response with the gas generation. Some of these calculations have been completed (Sandia, 1979). According to initial estimates based on them, there is little possibility of repository failure from overpressurization at gas-generation rates of less than 5 moles per year per drum. Since these conclusions depend on the gas permeability and the mechanical properties of the repository medium, they will be subject to some revision when data are available from the actual underground workings.

9.7.3.2 Brine Migration

A number of papers on the movement of fluid inclusions in alkali halide crystals have drawn attention to the possibility of similar movement by the naturally occurring brine inclusions in the bedded salt of southeastern New Mexico. Laboratory experiments and theoretical analyses performed so far (Anthony and Cline, 1974), as well as the one field experiment (Bradshaw and McClain, 1971; Bradshaw and Sanchez, 1969), are idealizations of the problem of fluid-inclusion movement in the thermal field of high-level or other heat producing waste. According to experimental studies, these movements depend on thermal gradients and are credible only for sources with a substantial thermal power output. Therefore, because TRU waste is not heat-producing, these effects are not appreciable for TRU waste in the WIPP repository. They are discussed here because some commentors on the draft environmental impact statement expressed concern about brine migration.

<u>Description of the problem</u>

Because of the idealizations involved in the work already published, it is necessary to describe in some detail the physical situation in the vicinity of canisters containing heat-producing waste.

The initial conditions are established with the driving of the drift in the salt and the drilling of the emplacement hole for the waste canister. This excavation produces a free surface that is no longer at a lithostatic pressure of 150 to 200 atmospheres, but rather at about 1 atmosphere. Thus there is a stress-relieved region around the emplacement hole, normally containing an abundance of microcracks extending a short distance into the medium. After a waste canister is inserted, the remaining volume is backfilled to improve thermal contact with the walls of the canister, and a plug seal is placed over the canister. The initial surface temperature of the canister is between the free-air temperature and the temperature at which the canister and the salt will equilibrate in the short term.

The salt now experiences a time-dependent thermal load that raises the temperature of the salt and accelerates plastic flow in the vicinity of the canister. This creep continues until the stress returns to the lithostatic value; the pressure in the vicinity of the canister begins to return to what it was before disturbance.

It is known experimentally and theoretically how and under what circumstances inclusions move up and down the thermal gradient in a single crystal.

If inclusions reach the canister, they will probably affect the rate of canister corrosion and subsequently the leach rate of the waste. It has been suggested that, if enough fluid accumulates in a heated zone, the local structural properties of the salt will be altered (Bredehoeft et al., 1978). The size of the zone in which fluid accumulates can be estimated roughly from the amount of water available per unit volume of repository salt and from estimates of the amount of solid material per unit amount of fluid material required to form eutectic mixtures (Stewart, 1978); the width of the zone of expected structural alteration around a canister would range from a few centimeters to, at most, a few tens of centimeters. It has been further suggested (Anthony and Cline, 1974) that when inclusions reach the waste their gas fraction could be altered enough to make them move back down the thermal gradient, away from the heat source. Of these possibilities, the corrosion and leaching properties are currently under study in the laboratory (Sections 9.7.3.3 and 9.7.3.4). The phase alterations and structural consequences thereof are under investigation by the Office of Nuclear Waste Isolation and by the U.S. Geological Survey, which is also characterizing the brine inclusions in salt at the WIPP site and determining their history. Sandia National Laboratories is investigating the movement of inclusions. Whether in fact any radionuclides can be mobilized by a moving fluid inclusion is unknown and is being studied at the Argonne National Laboratory.

Known effects

In laboratory studies (Anthony and Cline, 1974), fluid inclusions with less than 10% gas are observed to migrate up the thermal gradient toward the heat source. Large inclusions break into two or more small inclusions with different distributions of gas and liquid and with different rates of movement. The inclusions move up the thermal gradient because the solubility of sodium chloride in water increases slightly with temperature. Since the end of the inclusion closer to the heat source is warmer, dissolution proceeds at the closer end, with precipitation at the farther end; the inclusion moves toward the heat source.

Fluid inclusions containing vapor are observed to migrate down the thermal gradient away from the heat source (Wilcox, 1968; Anthony and Cline, 1974). Water evaporates at the hot end of the inclusion; the vapor moves to the cooler end and condenses, dissolving salt in the unsaturated water. The inclusion thus moves away from the heat source.

Boundary and initial conditions

In analyses done so far, the changing thermal field has been approximated by a constant gradient. Actual brine migration toward emplaced waste takes place in a time-dependent thermal field; according to estimates based on simple calculations, the heat from an emplaced canister will, within a few months, increase the heat load at the next emplacement hole in the array. The thermal gradients around the canisters will shortly thereafter become so uniform that inclusions will cease to migrate.

Furthermore, no consideration has been given in past analyses to the changing pressure field. Since the amount of vapor in an inclusion will depend on both the temperature of the fluid and the confining pressure, so will the direction of motion.

Bounds on migration

Anthony and Cline (1974) obtained their results on the velocities of brine-inclusion travel for a temperature gradient of 3 kelvins per centimeter (K/cm), but they also present data at lower gradients. The velocity of inclusion movement falls drastically as the gradient decreases and is essentially zero at 10^{-3} to 10^{-4} K/cm, which is the geothermal gradient. (If the movement did not fall to zero, there would be no fluid inclusions in natural salt.)

According to unpublished calculations (M. E. Fewell and E. C. Sisson, Sandia National Laboratories, internal memorandum, 1977) for a canister hotter than those at the WIPP, the initial gradient is greater than 3 K/cm close to the canister, about 1.3 K/cm over the first 30 centimeters outside the surface of the canister, and about 0.3 K/cm at 1 meter. At the velocities determined by Anthony and Cline for 3 K/cm, only an inclusion within the first 30 centimeters could reach the canister in a year. The total volume of water in fluid inclusions within such a region is about 7.5 liters per meter of canister length when the radius of the canister is about 15 centimeters.

The actual situation is much more complicated. The waste canister is not embedded in a single crystal, but is in a mass of many small crystals. Experiments done in crystalline masses using heaters indicate that when an inclusion reaches a crystal boundary, it may stop there or it may continue to travel in one of three ways: across the boundary as an inclusion, along the boundary as a surface film, or through the space between boundaries as a vapor. Experiments done on 1-cubic-meter salt blocks over periods of several months show a monotonically decreasing accumulation of water at the heater; after 8 weeks the rate of water collection was only 3 cubic centimeters per week (Hohlfelder, 1979). This result suggests that the local supply of mobile fluid will be exhausted soon after the emplacement of a hot waste canister.

In summary, the experimental results presently available suggest that the following phenomena are likely:

1. Inclusions move up or down the thermal gradient in the manner described by Anthony and Cline and by Wilcox only while within a single crystal.

2. Inclusions do not generally appear to move across crystal boundaries.

3. Fluid inclusions reaching a crystal surface are believed to move as vapor or as surface films.

4. After a short time, less than a year, the temperature field around an assemblage of canisters will have become so uniform that the weak thermal gradient will bring no more inclusions to the canisters during the period of high heat production.

5. At some distance (10 to 100 centimeters) from the canister, there will probably be a halo of fluid inclusions immobilized in single crystals in the weak thermal gradient.

6. From experimental data, the total volume of fluid drawn to any canister can be estimated crudely; it may lie between 0.1 and 20 liters, with 0.1 liter more likely (Anthony and Cline, 1974; Hohlfelder, 1979).

Rigorous verification of these expectations will require further investigations. Brine migration is now being studied in its entirety, both experimentally and theoretically. Current knowledge is sufficient to predict that brine migration will be of little concern in the WIPP repository, because no contact-handled TRU waste and little remotely handled TRU waste stored there will produce significant thermal gradients.

Further research under WIPP auspices will provide data that will be useful in the detailed analysis of the effects of remotely handled TRU waste and in the design of future repositories for high-level waste. Laboratory and bench-scale work has been under way for a year. Experiments are planned for salt in a mine, where the lithostatic pressures and boundary conditions will approach those to be encountered in the WIPP repository. Experiments on brine migration will also be carried out in the repository (Section 8.9.4).

9.7.3.3 Container Corrosion

Waste containers are indispensable in waste processing, temporary storage, transportation, and other physical handling. They are not intended, however, to be the major long-term barrier preventing radioactive materials from entering the biosphere. The burial medium is the most significant barrier, for the geologic structures surrounding the waste provide a container several thousand feet thick. In the long term, thousands of years, the ability of the container to resist corrosion is of little importance.

In the short term, corrosion resistance is important in being able to retrieve the containers. Since the TRU-waste containers at the WIPP must be retrievable for as long as 10 years after emplacement, it is desirable that they not corrode excessively during that time. Future repositories may require that containers be retrievable for longer periods, perhaps as long as 25 years; the design of containers that will not corrode over 10 to 25 years is therefore useful, although available data show that existing TRU-waste containers may last hundreds of years in a dry salt mine. There is, however, no incentive to design TRU-waste containers that will last for hundreds or thousands of years.

The corrosion rate of mild steel, used in the construction of TRU-waste containers, has been extensively measured in the laboratory as a function of humidity under dry, moist, and brine-inundated conditions. The steel samples were in direct contact with rock salt. Under all test conditions, except inundation with aerated brine, the bare metal of the drum would not corrode through for several hundred years. The use of anticorrosion coatings such as paint on the drum can significantly decrease the corrosion rates of the bare metal. Laboratory evaluations on such coatings are in progress (Sandia, 1979, Chapter 7).

The examination of mild-steel painted canisters holding low-level waste in the salt repository at Asse, Germany, revealed minimal corrosion after periods of up to 12 years under dry, moist, and brine-inundated test conditions (Sattler, 1978; Sandia, 1979). The corrosion of contact-handled-waste containers in the dry WIPP salt is expected to be similar. The retrieval of contact-handled waste in intact containers is, therefore, expected to pose no problems at the WIPP repository.

The selection of materials for high-level-waste canisters or canister overpacks depends on their purposes and on the lifetime required for them. Because the canisters for WIPP experimental high-level waste must be retrievable for at least 20 years, the materials for them may be selected primarily to allow for easy retrieval. An intact, uncorroded high-level-waste container is not, however, an absolute requirement for retrieval; methods of retrieving degraded canisters from salt by overcoring are being developed (Sandia, 1977).

Although the WIPP experimental high-level waste is to be removed before the repository is closed, the canister-development program is working on the option of providing a canister that can remain intact for 300 to 500 years. Such a canister could be desirable in repositories for high-level waste, in which the major heat producers are cesium-137 and strontium-90, with half-lives of about 30 years. If the waste canister remains unbreached for more than 10 half-lives, 300 years or longer, the thermal output of the waste will be reduced by at least a factor of 1000. The thermal driving force for interactions like leaching will then be reduced also.

Many of the metallurgical-compatibility studies at Sandia National Laboratories are testing whether candidate metals can survive for 300 years or more in bedded salt; much overtesting is also in progress. Laboratory and bench-scale testing has identified such materials. The testing has measured the effects on corrosion rate of solution composition, radiation, temperature (70 to 250°C), time, oxygen concentration, moisture content, pressure, welding and crevices, stress-corrosion cracking, and other variables. Laboratory results and other analyses show that it is both technically and economically feasible to provide a 300-year-plus canister than can delay or minimize thermally driven interactions such as corrosion and leaching. Descriptions of the studies and results are given by Braithwaite and Molecke (1980).

The final testing and demonstration of the adequacy of containers for TRU waste and canisters for experimental high-level waste will begin with the first acceptance of waste packages at the WIPP repository. As the laboratory and field-test corrosion studies progress, the results will be made available (Braithwaite et al., 1980; Magnani and Braithwaite, 1979).

9.7.3.4 Leaching

The leachability of radioactive waste could be important to the WIPP repository: leaching by water or brine would have to take place before intruding water could mobilize radionuclides. Although the intrusion of water into the WIPP disposal areas is of very low probability, it is the basis for the most credible scenarios describing the release of radionuclides from the sealed repository (Section 9.7.1.3). Interactions among the waste, canisters, backfill and getter materials, and dry salt could also be important because they might, in theory, enhance or retard leach rates and nuclide migration. Other conditions that could affect leaching are radiolysis of brine that might be present, rock constituents other than sodium chloride, corrosion products of the waste containers, lithostatic pressure, and elevated temperature. Studies of these topics are in progress (Braithwaite and Johnstone, 1979; Westik and Turcotte, 1978).

Consequence analysis is the principal tool for predicting the long-term importance of leaching; experimental data on leaching and interactions with salt are desirable inputs to the study. The consequence analysis in Section 9.7.1 assumes that water removes radionuclides from waste at the same rate as water dissolves salt. It makes this unrealistic assumption because directly applicable data were not available during the study. When experiments have provided more of the necessary input data, the analysis can become more realistic and less conservative. It is significant, however, that the analysis in Section 9.7.1 predicts that the WIPP repository would produce no serious long-term effects even if leaching occurred as rapidly as salt dissolution.

Much research in leaching has already been performed. The leachability of matrices proposed for encapsulating radioactive waste has been a subject of study for many years in the United States, Europe, and Japan. In fact, the durability of radioactive-waste forms is often specified by leach-rate measurements. Because collections of these data and discussions of their significance are readily available (Katayama, 1976; ERDA, 1977; Scheffler and Riege, 1977; Westik and Turcotte, 1978; Braithwaite and Johnstone, 1979), they are not reviewed here.

Some of these data were obtained under laboratory conditions that did not adequately simulate conditions at the WIPP repository. Some of the later studies are overtests; they deliberately create conditions more severe than those in the repository in order to supply interpretable data in a short period of time. Applying these data to the specific geologic conditions of the repository will require additional study. Moreover, some questions not addressed in studies to date are of interest to WIPP analyses and to the design of future repositories for high-level waste. Experiments to answer many of the unresolved questions will be performed over the next several years in both laboratory and in-situ studies (Molecke, 1980). Leaching studies of high-level waste are in progress. The leachant solutions include saturated brine, groundwater, and deionized water; temperatures of 25 to 100°C are being used. Overtests are using temperatures of 150 to 250°C and above and pressures of up to 180 atmospheres. As explained in Section 9.7.3.3, however, waste leaching at high temperatures can be delayed or minimized by the proper selection of canister or canister-overpack materials.

Laboratory data are being used to formulate analytical models that predict leaching behavior over hundreds to thousands of years. The models will be tested in the laboratory under accelerated conditions; they will be retested in the WIPP in-situ program (Section 8.9). The results of these studies and the interpretations of their significance will be made available as the experimental programs develop further.

9.7.3.5 Stored Energy

An often-raised question is whether energy stored by radiation damage in the salt surrounding buried waste or in the waste matrix could be released and produce a serious thermal excursion or some other undesirable effect. This question has been under study at the Oak Ridge National Laboratory (ORNL) since 1970; the arguments and conclusions presented here are based primarily on data collected there.

Of the alpha, beta, gamma, and neutron radiation emitted by the waste, only gamma rays and neutrons enter the salt. In the absorption process the radiation interacts with the crystal lattice of the salt to produce crystal defects. The gamma-ray interactions primarily produce electron vacancies when the photons excite chlorine electrons into the conduction band. By a series of processes the lattice adjusts, and energy is stored in the crystal structure; the subject is discussed in an ORNL report (Jenks and Bopp, 1974). The interaction with neutrons is likely to store energy by producing ionic displacement directly in the crystal lattice. Extensive studies at Oak Ridge (Jenks and Bopp, 1974) have shown that energy stored by either process can be released by annealing the salt at a temperature above 150°C; little energy from radiation damage is stored above that temperature.

Contact-handled TRU waste, which is the primary concern of the WIPP repository, has virtually no gamma output--less than 10 millirads per hour from 200-liter drums. The actinide limit as determined by INEL inventory has been less than 10 grams of plutonium per drum during the years for which the inventory is available. With the mix of plutonium isotopes assumed for contact-handled TRU waste (Appendix E), this limit suggests a maximum dose rate of 1.6×10^{-4} rad per hour for neutrons (Bingham and Barr, 1979).

Contact-handled TRU waste is placed in large rooms. Even after the total closure of the mine and the compression of the waste, the material remains in bulk, approximately 15 by 130 by 1 meter; the only major contact with salt is along the outside of the bulk material. Since for both the gamma and the neutron radiation deposit most of their energy in a distance of 10 to 15 centimeters, most of the stored energy from radiation damage is located inside the waste matrix. At the dose rates expected for TRU waste (less than 10 and 0.16 millirad per hour for gamma rays and neutrons, respectively), the total dose over 1 million years is less than 10^8 rads. This dose will produce stored energy in the waste matrix and salt at a concentration lower than 1 calorie per gram, an insignificant amount (Jenks and Bopp, 1977, Figure 6; Jenks, 1975, p. 3). Temperatures in contact-handled TRU waste, which produces essentially no heat, never rise to the annealing temperature of salt.

No studies of energy storage near heat-producing wastes are directly applicable to the WIPP repository; these analyses have so far been performed only for high-level waste. Because the effects of high-level waste are generally upper bounds on the effects of remotely handled TRU waste, this discussion reports predictions from the available studies.

The waste configuration assumed here is the one defined by Zimmerman (1975), reduced to 3.5 kilowatts: a canister 30 centimeters in diameter and about 3.5 meters long with a thermal output of about 3.5 kilowatts and surface-dose rates of about 2×10^5 rads per hour for gamma rays and about 40 rads per hour for neutrons. These parameters describe reprocessed pressurized-water-reactor fuel 10 years out of the reactor.

In the burial configurations now under study, a high-level-waste canister is in intimate contact with salt and is separated from other canisters by distances much greater than the distances through which the gamma radiation penetrates the salt. This length is about 15 centimeters; in 30 centimeters, about 90% of the gamma radiation has been absorbed. In addition to the radiation damage in the salt, there is radiation damage in the waste matrix. Inside the canister, however, temperatures are above the so-called annealing temperature, and most of the radiation damage is healed. A similar annealing phenomenon occurs in the salt, reducing the total energy stored. Temperature profiles (Jenks and Bopp, 1974) show that the temperature in the salt remains higher than 150°C at distances of about 60 centimeters for times longer than the half-life of the primary heat-producing nuclides, cesium-137 and strontium-90. After adjustment to a maximum of 60 calories per gram (the maximum stored energy) and expansion to 60 centimeters, the total amount of energy stored beyond 60 centimeters is negligible (Jenks and Bopp, 1974, Figure 8). The average energy stored in this salt is about 3.5 calories per gram.

The same document discusses the mechanical and structural consequences of the sudden release of this energy by annealing and concludes that they would be "practically negligible."

In addition to annealing, there is another possible means for the sudden release of stored energy: dissolution of the salt. Release by this mechanism produces a minor temperature change because at least 2 cubic centimeters of fresh water is required to dissolve 1 cubic centimeter of sodium chloride. The dissolution process is somewhat autocatalytic since the solubility of sodium chloride depends on temperature, increasing slowly as the temperature rises. On the average, however, particularly if there is any convective motion in the fluid dissolving the salt, the average temperature change in the fluid is about 2°C, a temperature excursion that does not threaten catastrophe.

Remotely handled TRU waste, which will probably be emplaced in a manner similar to that under study for high-level waste in future repositories, is modestly heat-producing. The gamma output is less than 100 rem per hour, which implies no saturation of stored energy in the salt. The temperatures of salt in contact with remotely handled TRU waste will be less than those for high-level waste; annealing will be less important. Other comments concerning the local chemistry in the salt near high-level waste also apply to remotely handled TRU waste.

In summary, the temperature requirement for sudden release through annealing, 150°C, demands local energy inputs that are not available. The more credible mechanism for the release of stored energy is salt dissolution, an unlikely occurrence. If salt dissolution were to occur, its consequences near a canister of remotely handled TRU waste could be a local temperature rise, averaging a few degrees Celsius; hydrogen-gas production through radiolysis; and possible alteration of the chemical and mineral constituents of the material near the canister. For contact-handled TRU waste the energy is deposited mostly in the waste matrix. Whether this energy, less than 1 calorie per gram, is available on dissolution is a matter for study, but the consequences are expected to be negligible. No credible mechanical or thermal mechanism for the catastrophic release of stored energy from radiation damage has been identified.

9.7.3.6 Nuclear Criticality

The contact-handled TRU-waste containers to be emplaced in the repository will contain amounts of fissile material ranging from several grams in typical packages to as much as the 200 grams permitted by shipping regulations. The fissile material will not, however, form a critical mass, because it will be widely dispersed through other material that does not moderate and reflect neutrons adequately. Simple comparison of this mixture of material with assemblies known not to be critical has shown that emplacement configurations are not critical (Claiborne and Gera, 1974; Bingham and Barr, 1979).

To estimate criticality more quantitatively, it is possible to use techniques developed in the nuclear-weapons program for analyzing complex assemblies of fissile and nonfissile materials. D. R. Smith of the Los Alamos National Scientific Laboratory has used these methods (Lathrop, 1965) to calculate the infinite multiplication factors that would characterize the contact-handled TRU waste emplaced in a repository. The infinite multiplication factor is a quantity describing the criticality of an assembly containing fissile material; it is the ratio of the number of fissions in one generation to the number of fissions in the preceding generation. If this ratio is less than unity, no self-sustaining chain of fissions can occur, even in an infinitely large assembly.

Using a criticality program called DTF IV, Smith has modeled the emplacement of contact-handled TRU waste by assuming drums loaded with various amounts of material in an infinite array. He has calculated that, for the multiplication factor to reach unity, the drums would have to contain amounts of plutonium far above the amounts now allowed by the U.S. Department of Transportation (Section 6.2.1). For example, a drum holding 140 kilograms of waste would have to contain over 5 kilograms of plutonium before the fissile material could form a critical mass; drums typically contain less than 0.01 kilogram of plutonium, and none are allowed to contain more than 0.2 kilogram.

A manyfold reconcentration of fissile material would have to occur in the repository before a critical mass could form. Such a reconcentration would require extensive dissolution of the salt and the waste; after dissolution, additional unlikely processes would have to act on the waste, selectively removing fissile nuclides from their surroundings and collecting them into a separate mass. The only natural processes that are known to have concentrated fissile material into a critical mass occurred in the Oklo phenomenon (IAEA, 1975; Cowan, 1976); these processes operated on a body of underground fissile material that was much more concentrated than the contents of the WIPP repository will be.

Furthermore, even if criticality could occur in a repository, it would tend to be self-limiting; because it would heat the solution in which the critical mass formed, it would give rise to faster neutrons, which are less effective in producing fissions. If a critical assembly were to form, its primary effects would be the production of hot brine and an altered fission-product inventory.

Further studies will, however, continue to investigate hypothetical scenarios (Bingham and Barr, 1979) describing the reconcentration of fissile material. If any of these scenarios appear to have an appreciable probability of occurring, additional calculations will study their effects; the mere formation of a critical mass does not necessarily have important consequences for the repository (Bingham and Barr, 1979). Calculations investigating criticality and its consequences will be completed during the next 2 years. In view, however, of the self-limiting behavior of a critical assembly and the reconcentration required to produce it, there is no expectation that nuclear criticality is a threat to the WIPP repository.

It is important to note that, even if the materials could form a critical assembly, they still could not explode. Although the terms "critical-mass formation" and "nuclear explosion" seem to be used interchangeably by the public, they represent entirely different concepts. For buried waste to become a nuclear bomb, it would not only have to form a critical mass but would also have to undergo extremely rapid compression to a very high density while simultaneously experiencing a flux of neutrons much greater than any sources in the mine will produce. No known mechanisms can compress underground radioactive waste to such densities in the short time (perhaps a fraction of a microsecond) required to make the fissile material explode. A nuclear explosion of the buried waste is not a credible threat to the repository.

9.7.3.7 Thermal Effects on Aquifers

Section 9.7.2.1 presents the results of calculations showing that temperature increases in the aquifers above the WIPP repository will be less than 0.3°C. Although it is possible that excessive heat from a repository for high-level waste might alter the water flow or induce cracking in aquifers, the WIPP repository will not exert these impacts.

9.8 EFFECTS OF REMOVING THE TRU WASTE STORED AT IDAHO

9.8.1 Introduction: Current and Future Practices

About 75% of the pad-stored defense TRU waste in the United States is located at the Radioactive Waste Management Complex (RWMC) of the Idaho National Engineering Laboratory (INEL) (Table 2-3). This chapter discusses the environmental impacts in Idaho of removing this waste from its temporary storage and preparing it for shipment to the WIPP.

This section is a summary of a detailed report that contains supporting calculations and full discussions (DOE, 1979a). The analysis assumes that the retrieval campaign for removing the waste begins in 1985 and continues for 10 years.

9.8.1.1 Waste Characteristics and Current Management Methods

Since 1970, contact-handled TRU waste received at the RWMC has been stored at the 56-acre Transuranic Storage Area (TSA), a controlled area surrounded by a security fence with an intrusion alarm system. The waste is stored on two asphalt pads, each approximately 150 by 700 feet.

Currently, the solid TRU waste to be stored on TSA pads is received from the Rocky Flats Plant and other DOE operations in government-owned ATMX railcars or on commercial truck trailers in Type B shipping containers. The ATMX shipments are made under the authority of a special permit issued by the Department of Transportation (Section 6.3.1). The waste is contained in 4- by 4- by 7-foot plywood boxes covered with fiberglass-reinforced polyester, 55-gallon steel drums with polyethylene liners, and 4- by 5- by 6-foot steel bins. (Some of the waste placed earlier on the TSA was stored in containers of nonstandard sizes.) The containers are intended to be retrievable, contamination-free, for at least 20 years. The drums are stacked vertically in layers, with a sheet of 1/2-inch plywood separating each layer. When a stack has reached a height of approximately 16 feet, a cover consisting of 5/8-inch plywood, nylon-reinforced polyvinyl sheeting, and 3 feet of soil is emplaced.

From 1970 (when TRU waste was first stored on the TSA) until 1972, the plywood boxes used as containers were not covered with fiberglass-reinforced polyester. Such boxes constituted approximately 25% of the boxes placed on the TSA through the end of 1977. Because boxes currently received are covered with polyester, it is estimated that by 1985 (the approximate date at which retrieval might begin) this percentage will have been reduced to 15%. Similarly, until 1972, the steel drums placed on the TSA had no polyethylene liners. (The 90-mil polyethylene liners provide additional containment for the TRU waste and additional assurance of container integrity for the 20-year storage interval.) Such drums constituted about 44% of the drums on the TSA as of the end of 1977. Because drums currently received are lined, it is estimated that by 1985 this percentage will have dropped to about 30%.

It is estimated that by 1985 approximately 2 million cubic feet of TRU waste will be stored at the TSA. The analysis performed for this study did not include the effects of any TRU waste that might be sent to, or generated at, the INEL after 1985. The effects of any such post-1985 waste on INEL operations and impacts are addressed in the detailed report (DOE, 1979a).

More complete descriptions of the INEL, the RWMC, and the TRU waste stored on the TSA pads can be found in the detailed report (DOE, 1979a).

9.8.1.2 Methods for Retrieving, Processing, and Shipping Waste

Several operations will be involved in removing the waste and shipping it to the WIPP: retrieval, processing and packaging, and shipping. Several options were considered for each operation. For retrieval and for shipping, only one option each was evaluated in detail; for processing and packaging, several options were evaluated in detail.

Three methods of retrieving waste containers were considered: manual handling by operators; handling by means of operator-controlled equipment; and handling by means of remotely controlled equipment. The first method was not evaluated further because it would expose the workers to unnecessary amounts of radiation. The third method was not examined further because the preliminary indications of current studies are that no significant overall advantages accrue from remote-control handling.

Four confinement methods for waste retrieval were considered: (1) open-air retrieval (no confinement); (2) the use of an inflatable fabric shield to protect against the weather; (3) the use of a movable, solid-frame structure operating at ambient pressure; and (4) the use of a movable, solid-frame structure operating at subatmospheric pressure. The last method was pursued because it is the only one of the four that provides positive control against the possible release of contamination. Depending on the condition of the waste containers at the time of retrieval, the second and third methods may also be acceptable.

Four processing options were considered: (1) shipping as is; (2) overpacking; (3) repackaging only; and (4) incineration and packaging.

Waste shipped to the WIPP will have to meet the WIPP waste-acceptance criteria, and it is therefore necessary to evaluate waste-processing methods in terms of their ability to yield an acceptable product. The evaluation of processing methods conducted in preparation for the draft of this EIS was based on the interim waste-acceptance criteria of July 1977. The July 1977 criteria indicated that the INEL waste would have to be incinerated in order to eliminate combustible material. An evaluation of various incineration methods (FMC, 1977) showed that only the product of slagging pyrolysis would satisfy all of the interim acceptance criteria without a separate immobilization step and without sorting and shredding the waste. Thus, slagging pyrolysis and packaging was studied in detail for processing the waste.

After the draft EIS was issued, revised acceptance criteria were formulated in July 1979 (Chapter 5). In response to these criteria, two processing methods that had not been evaluated in the draft EIS were studied in detail: repackaging the waste in new lined 55-gallon drums and overpacking the original waste containers in similar but larger containers. Three possibilities for overpacking were examined: overpacking 100% of the retrieved waste containers, overpacking only 10% of the retrieved waste containers, and overpacking none of the waste containers. The third possibility is equivalent to shipping the waste as is.

Another processing method--compaction, immobilization, and packaging--has been studied (DOE, 1979). It is not discussed here because the other processing methods provide upper and lower limits for its expected environmental and other effects. That is, the environmental effects of the compaction, immobilization, and packaging concept would be within the range covered by the other three concepts. The upper and lower limits of environmental effects of the three evaluated processing methods also bound the effects expected from several other processing methods that were considered (DOE, 1979a, Section B.4).

It was assumed that the waste would be shipped by rail, which is cheaper than shipment by truck. It was also assumed that ATMX railcars would be used, although they may be replaced by the start of the retrieval campaign (Chapter 6).

Thus, the sequence of operations selected for study was (1) retrieval with operator-controlled equipment inside a movable, solid-frame structure at subatmospheric pressure, (2) processing, and (3) shipment in ATMX railcars. The processing methods studied were slagging pyrolysis with the slag packaged in 55-gallon drums, repackaging without further processing in lined 55-gallon drums, and overpacking in larger containers. The operations and their effects are briefly discussed below. Detailed descriptions of the operations and of their effects are given in the detailed report (DOE, 1979a).

9.8.2 Retrieval

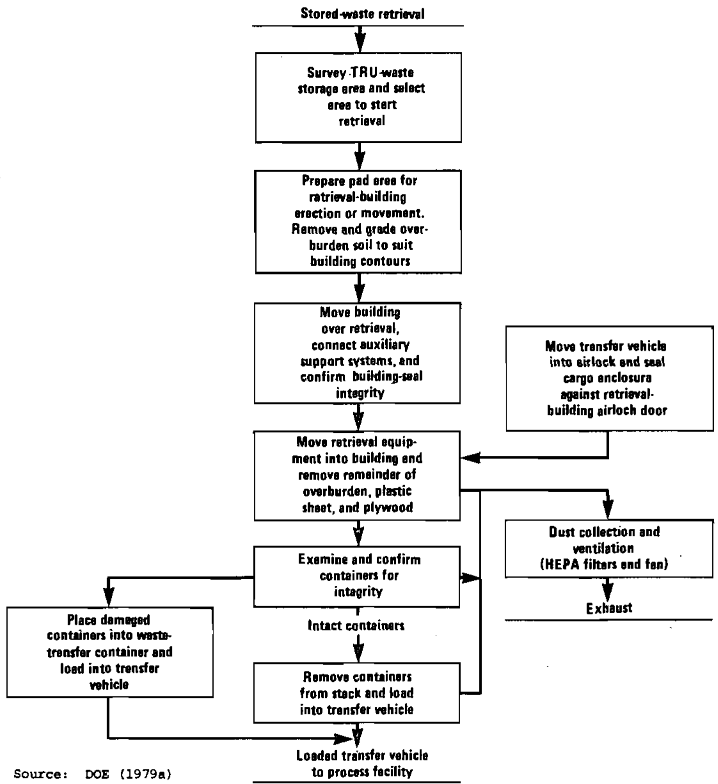
9.8.2.1 Retrieval Building and Operations

The retrieval building will be a mobile, single-walled structure. Subatmospheric pressure will be maintained inside to prevent the escape of contaminants. The ventilation system will include roughing filters and a bank of high-efficiency particulate air (HEPA) filters, for an estimated overall decontamination factor of 1000.

The sequence of retrieval activities is shown in Figure 9-18. The building will be erected on an asphalt pad extending from a waste-storage pad. Most of the soil cover will be removed from the area to be covered by the building. After the building has been moved over this area, the remainder of the soil, the polyvinyl sheeting, and the plywood cover will be removed.

The retrieval equipment (forklift and front-end loader) will have environmentally isolated cabs with self-contained breathing-air supplies. The breathing air will maintain a positive air pressure inside the cab to preclude the inleakage of possibly contaminated air. Preliminary calculations indicate it will not be necessary to provide shielding for the retrieval workers; however, if required, removable shields will be mounted on the equipment.

The waste containers will be inventoried and examined to confirm their integrity. Any breached containers will be placed in a waste-transfer container and loaded into a transfer vehicle. Forklifts will remove the intact containers from the stacks and place them into the transfer vehicle. The



Source: DOE (1979a)

Figure 9-18. Block diagram for the retrieval of stored TRU waste.

waste will be transferred from the retrieval building to the processing plant in low-speed semitrailers pulled by a conventional tractor over committed roadways within the Radioactive Waste Management Complex. The van bodies of the trailers will be designed to resist rupture in the event of an accident.

During loading or unloading, the body of the trailer will be mated and sealed to an airlock entrance, thereby forming an airtight extension of the airlock. Contamination of the exterior of the vehicle is not expected.

9.8.2.2 Environmental Effects of Retrieval

The radiological effects of retrieving the stored waste will be limited because it is intended that the stored TRU waste be fully contained at the time of retrieval. However, for bounding the effects of possible releases, it was assumed that 1% of the containers will have been breached before retrieval begins and 0.1% of the radioactivity in each breached container will be released into the retrieval building, with 0.01% of the released radioactivity becoming resuspended. Table 9-69 shows the average release rates, the maximum levels of soil contamination from releases, and the present radionuclide concentrations in INEL soils from natural background radiation and atmospheric fallout due to weapons testing. The latter are several orders of magnitude higher than those projected to result from retrieval operations.

The maximum annual radiation-dose commitments for any person not involved in the operation and for the population within 50 miles of the retrieval facility are compared in Table 9-70 with doses received from natural background radiation. In calculating the maximum individual dose commitment, it was assumed that the person resides at the point of maximum airborne concentrations throughout the year. The assumptions, supporting data, and details of the dose-commitment and risk calculations summarized here are to be found in the detailed report (DOE, 1979a).

As shown in Table 9-70, both individual and population dose commitments from routine releases during retrieval will be several orders of magnitude lower than doses received from natural background radiation.

The nonradiological effects of retrieval will be those associated with a commitment of manpower and the use of other resources (Table 9-71). Neither the construction nor the operation of the retrieval facility will measurably increase the total dust emissions at the INEL. The overall effect on land use will be to restore the area now used for waste storage within the RWMC to its once-vegetated state--a beneficial effect.

The resources used are not insignificant, but their use will not place any strain on either the local or the national economy. Other effects, such as water use and sanitary-waste disposal, will be in proportion to the employment levels.

Table 9-69. Comparison of Soil Contamination Resulting from Routine Releases During Retrieval Operations with Existing Natural and Fallout Concentrations of Radionuclides[a]

Nuclide	Average release rate from building (pCi/sec)	Maximum cumulative concentration in soil (nCi/m^2)	Present concentration in INEL soil (natural and fallout contributions) (nCi/m^2)
Pu-238	2.2×10^{-4}	4.8×10^{-5}	0.15
Pu-239	1.8×10^{-4}	4.1×10^{-5}	(b)
Pu-240	4.3×10^{-5}	9.5×10^{-6}	(b)
Pu-241	8.2×10^{-4}	1.4×10^{-4}	(c)
Pu-242	1.0×10^{-9}	2.4×10^{-10}	(c)
Am-241	7.2×10^{-4}	1.6×10^{-4}	0.3
Cm-244	9.8×10^{-6}[d]	1.7×10^{-6}	(c)
U-233	7.8×10^{-6}[d]	1.8×10^{-6}	(c)

[a]Data from the detailed report (DOE, 1979a).
[b]The total concentration of these two nuclides is 1.1 nCi/m^2.
[c]Not measured.
[d]This table lists nuclides (uranium-233 and curium-244) not listed for contact-handled TRU waste in Appendix E. The appendix describes typical waste from the Rocky Flats Plant, whereas the waste stored at the INEL, though primarily Rocky Flats waste, has come from other sources as well. The quantities of these nuclides are small and are considered only in the analysis presented in this section and in Appendix N.

Table 9-70. Dose Commitments from Routine Releases During Retrieval Operations

Organ or tissue	Maximally exposed person (mrem)[b]	Population within 50 miles (man-rem)[c]
Whole body	2.4×10^{-11}	2.9×10^{-10}
Lung	4.5×10^{-7}	4.1×10^{-6}
Bone	4.6×10^{-7}	4.2×10^{-6}
Liver	3.4×10^{-7}	3.1×10^{-6}
Kidney	1.6×10^{-7}	1.5×10^{-6}

[a]Data from the detailed report (DOE, 1979a).

[b]The annual whole-body dose from natural background radiation is 150 mrem.

[c]The annual whole-body dose received by this population (assumed to be 136,000 persons in 1985) from natural background radiation is 2×10^4 man-rem.

Table 9-71. Resources Used in Waste Retrieval[a]

Construction period, months	9
Average number of construction workers	50
Pieces of heavy equipment used	10
Diesel fuel used, gallons	54,000
Particulate emissions, pounds	5900
Operations period, years	10
Number of workers	39
Estimated annual payroll	$624,000
Diesel fuel used, gallons	88,000
Electricity use, kW-hr/yr	600,000
Particulate emissions, lb/yr	9500

[a]Data from the detailed report (DOE, 1979a).

9.8.2.3 Radiological Risk to the Public from Retrieval Operations

A number of potential accidents were considered in connection with retrieval, including a fire in the retrieval building, the dropping of a waste container during handling, and the puncture or crushing of a container by retrieval equipment. For the dominant accidents, Table 9-72 summarizes the calculated dose commitment and risk for the individual receiving maximum exposure and for the public within 50 miles. (Risk is defined here as the 50-year dose commitment multiplied by the annual probability of the accident.)

A number of abnormal events, generally related to natural disasters, could also affect the waste in the retrieval building. Examples are earthquakes, tornadoes, volcanic action (the RWMC lies at the edge of a volcanic rift zone), and aircraft impact. These abnormal events would not be a result of retrieval operations, because they could occur even if the waste were left as is; therefore, they are not discussed further here. They are taken up in Appendix N as events that may affect the stored waste if no TRU-waste repository is built and the waste is left at the INEL. Comparison with results given there shows that the radiation dose from such natural disasters could be orders of magnitude higher than that for the worst accident listed in Table 9-72.

9.8.2.4 Hazards to Workers During Retrieval

Hazards to workers can be classified as radiological and nonradiological. The former are due to the radioactivity of the waste; they consist of hazards associated with normal operations and hazards associated with accidental releases. The nonradiological hazards are those that could exist even if the waste were not contaminated with radionuclides (e.g., falls and electrical shocks). A number of measures will be taken to hold these occupational hazards within normally accepted levels.

The radiation levels to which workers are exposed will be monitored by health-physics personnel; radiation doses will be held to levels as low as practicable by following specified procedures. The daily and accumulated doses will be monitored.

To minimize the possibility of contamination, retrieval workers will work in dust-tight enclosures, will wear protective clothing, and will be provided with respiratory protection as needed. Workers will be surveyed frequently whenever the possibility of external contamination exists. Bioassays will be performed periodically.

In addition, continuous-air-sampling and radiation-monitoring instruments in the work areas will promptly detect and annunciate abnormal or accident conditions. Special procedures will be established for evacuating people, controlling the spread of contamination, and correcting accident conditions.

Preliminary calculations indicate that, during normal operating conditions, unshielded operators retrieving stored waste will receive radiation doses (an estimated maximum of 0.3 rem per year) that are well below the established limits for radiation workers (5 rem per year). Operators have been placing waste into storage on the TSA for 9 years without receiving exposures near the radiation-worker limits.

Some of the worker doses resulting from accident conditions can be estimated by comparison with the public-risk results in Section 9.8.2.3. The maximum individual doses given there can be used as estimates of worker doses for accidents in which significant quantities of radionuclides would escape from the facility.

Other accidents in which workers could receive significant doses while inside the building were also examined. For example, accidental inhalation exposure could occur if a box were dropped and breached simultaneously with a

Table 9-72. Summary of Dose Commitments and Risks from Accidents During the Retrieval of Stored TRU Waste[a]

Event	Maximally exposed person					
	50-year dose commitment (rem)			Risk (rem/yr)		
	Whole body[b]	Bone	Lung	Whole body	Bone	Lung
Fire	3×10^{-7}	3×10^{-4}	4×10^{-4}	2×10^{-10}	3×10^{-7}	4×10^{-7}
Container drop	3×10^{-12}	5×10^{-9}	7×10^{-9}	3×10^{-14}	5×10^{-11}	7×10^{-11}

Event	Population in 1985					
	50-year dose commitment (man-rem)			Risk (man-rem/yr)		
	Whole body[c]	Bone	Lung	Whole body	Bone	Lung
Fire	3×10^{-4}	4×10^{-1}	8×10^{-1}	3×10^{-7}	4×10^{-4}	8×10^{-4}
Container drop	6×10^{-9}	7×10^{-6}	1×10^{-5}	6×10^{-11}	7×10^{-8}	1×10^{-7}

[a]Data from the detailed report (DOE, 1979a).
[b]The 50-year whole-body dose from natural background radiation is 7.5 rem.
[c]The 50-year population whole-body dose from natural background radiation is 1×10^{6} man-rem.

failure of the worker's environmental cab. The airborne radioactivity was estimated to be 10^{-12} curie per milliliter. An operator would receive a maximum permissible body burden from a breached box in approximately 40 minutes and from a breached drum in 10 hours. The workers would be expected to evacuate the building within minutes.

The number of nonradiological injuries that retrieval workers might incur was estimated by comparing the operations involved in retrieval with similar operations in other industries for which occupational injury rates are available. The results indicated an estimated eight nonradiological injuries during the 10-year retrieval campaign. One additional injury might be expected during the construction of the retrieval facility. In addition to these normal nonradiological hazards, special nonradiological hazards may be associated with the retrieval of the stored waste, which may contain pyrophoric materials and toxic chemicals.

9.8.2.5 Costs of Retrieval

The cost estimates presented here and in Appendix N include capital costs, operating and maintenance costs, and the cost of decontamination and decommissioning. The estimates are not considered budgetary cost estimates because they are based on a preconceptual design. Uncertainties of as much as a factor of 1.5 are not unusual in this type of estimate, but this degree of accuracy is considered sufficient for the present study. The costs are based on 1979 dollars.

The estimated costs of retrieving the stored waste that will have been accumulated to 1985 are as follows (DOE, 1979a):

	Millions of 1979 dollars
Capital	9
Operating and maintenance	20
Decontamination and decommissioning	1
Total	30

9.8.3 Processing for Repository Acceptance

For purposes of this study, it was assumed that a processing facility will be constructed near the TSA to prepare the waste for shipment to the WIPP. The processing methods studied were (1) slagging pyrolysis, (2) repackaging the waste in 55-gallon drums (reducing the size of large items as necessary), and (3) overpacking. Also studied in connection with overpacking was the possibility of shipping the waste as is.

9.8.3.1 Plant and Operations

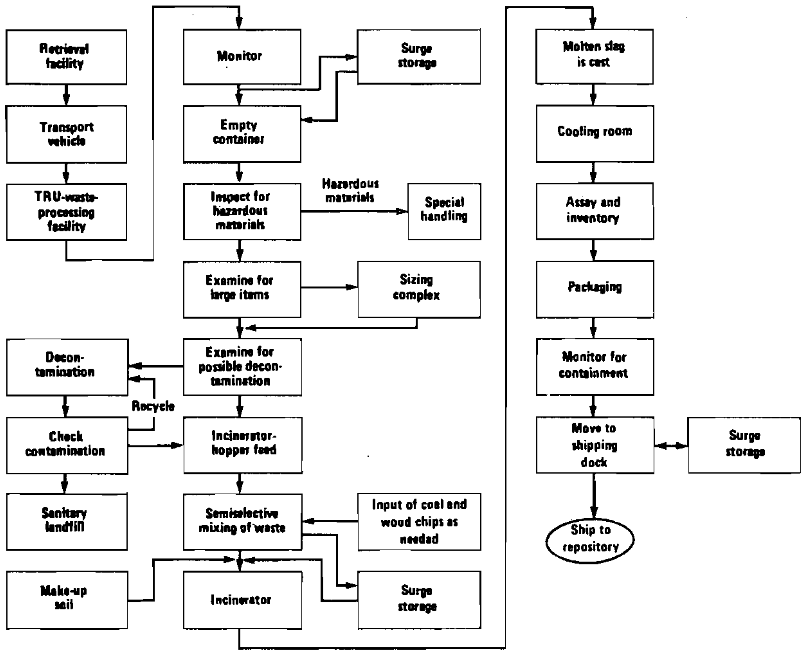
Slagging pyrolysis

A block flow diagram for slagging pyrolysis is shown in Figure 9-19. A slagging unit with a daily feed rate of about 16 tons of waste and 25 tons of makeup soil was assumed. The building would be designed with three separate air zones, each equipped with its own ventilation system to maintain progressively lower pressures between the outside atmosphere and the innermost zone, which would include the waste-processing areas. All air removed by the ventilation systems would pass through appropriate HEPA filtration systems.

Retrieved waste would be transferred from the TSA to the receiving airlock of the processing plant. All operations in the plant, from the entry of waste through the airlock to final packaging, would be remotely controlled. After being monitored for contamination, incoming waste containers would be emptied. The waste would be spread on a conveyor belt and inspected for hazardous materials.

The waste would be blended to achieve some uniformity of the feed material. Makeup soil (assumed here to be 1.5 pounds per pound of waste) would be added to facilitate the formation of a glasslike slag of minimum leachability. Coal and wood chips would be added to the waste to provide supplementary fuel and to increase the porosity of the feed material. The molten slag would be poured into molds, cooled, and packaged into steel drums, which would be labeled and loaded into ATMX railcars for shipment to the WIPP repository. The expected rate for shipment during the 10-year processing period is 190 railcars per year.

An offgas-treatment system for the slagging incinerator would be employed to limit the releases of particulates, aerosols, and volatile compounds to



Source: DOE (1979a)

Figure 9-19. Block diagram for processing TRU waste by slagging pyrolysis.

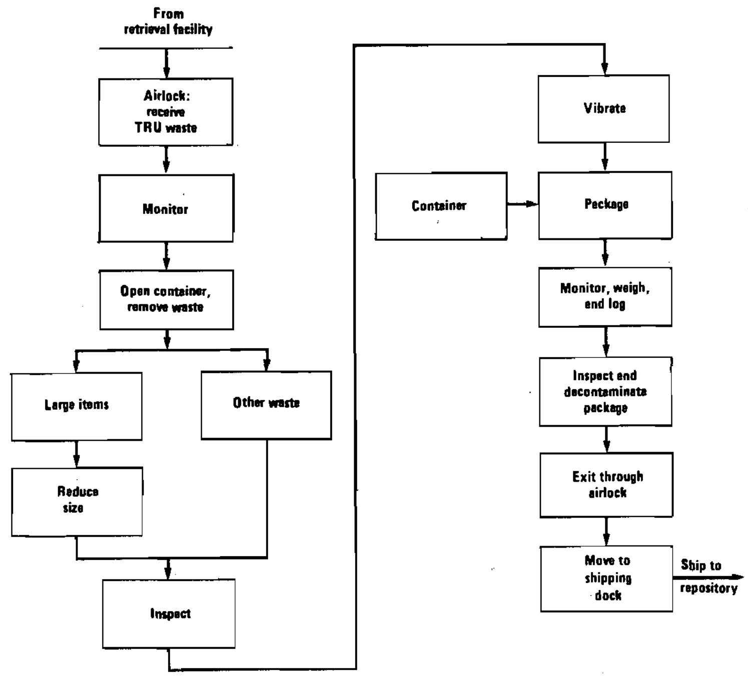
levels complying with standards set by the Environmental Protection Agency, the DOE, and other government agencies.

Repackaging only

In a facility designed for the purpose, the waste would be sorted as necessary to comply with the WIPP acceptance criteria, reduced in size as necessary, packaged in new 55-gallon drums, and prepared for shipment. The drums would conform to Department of Transportation (DOT) Specification 17C and would be lined with 90-mil-thick, rigid, high-density polyethylene. A block flow diagram of the process is shown in Figure 9-20. The drums would be loaded into ATMX railcars for shipment to the WIPP. The expected shipment rate during the 10-year campaign is 268 railcars per year. This estimate is based on the conservative assumption that the volume of the packaged waste would be 80% of that in the original containers.

The preceding discussions of certain aspects of slagging pyrolysis--the control of environmental releases, remote operations, and the entry of waste into the facility--apply to the repackaging method as well.

A concept was also considered in which the waste would be repackaged, as just described, in the retrieval building, rather than in a separate repackaging facility. This concept was not developed because (1) the inclusion of size-reduction equipment would result in a building too large to be readily movable and (2) the amount of electrical power required for the size-reduction equipment and for additional ventilation equipment would probably be too great to be suppled by mobile diesel generators.



Source: DOE (1979a)

Figure 9-20. Block diagram of the repackaging-only process.

Overpacking

Because sorting of the waste is not included, it is not certain that simply overpacking the waste containers would comply with the WIPP acceptance criteria. Nevertheless, overpacking is discussed here as a minimum-processing method.

Three alternative assumptions were made about the extent of the contamination that might be found on the outside surface of the retrieved containers; an overpacking method was developed for each assumption. The first assumption was that 10% of the waste containers would be contaminated as a result of container deterioration. In reality, fewer than 10% of the containers, if any, are expected to be contaminated at the time of retrieval. The second assumption was that all the waste containers would be contaminated. This highly unlikely situation was studied only as a limiting, worst-case example. The third assumption was that none of the waste containers would be contaminated. The three methods developed for the three assumptions are, respectively, (1) retrieve, survey for exterior contamination, overpack waste containers as necessary (assumed to be 10%), and ship to the repository; (2) retrieve, overpack all waste containers, and ship to the repository; and (3) retrieve and ship as is to the repository, after surveying for external contamination.

A small addition would be permanently attached to the retrieval building to house the survey and overpack operations. Ventilation provided by the heating, ventilation, and air-conditioning system of the main retrieval building would keep a subatmospheric pressure within the addition.

Any 55-gallon steel drums that require overpacking could be inserted into 83-gallon drums or steel boxes. Waste in wooden boxes, with or without fiberglass reinforcement, would probably be overpacked in steel boxes. Overpacks for the waste in steel bins would probably be larger steel bins. Workers performing the overpack operations would wear protective clothing and air masks.

The waste containers and overpacked containers would be transferred on a flat-bed truck from the overpack addition to the railcar-loading station for shipment to the WIPP. For the methods with 100%, 10%, and 0% overpack, the numbers of railcars shipped annually would be 175, 140, and 136, respectively, during the assumed 10-year campaign. It is conceivable that the campaign could be completed in as little as 3 years. However, the limited number of suitable railcars that may be available for shipping the waste would make this shorter campaign unlikely.

9.8.3.2 Environmental Effects of Processing

The radiological impact of processing operations will result from two sources of airborne radioactive effluents: (1) contamination generated when material is being sorted, reduced in size, or packaged and (2) offgas from the slagging-pyrolysis process. Before release from the slagging-pyrolysis facility, these streams will pass through HEPA filters with an estimated decontamination factor (DF) of 10^6 and offgas-treatment systems with a DF of 10^8. For the repackaging facility, the DF is assumed to be 10^6, and for the overpacking addition, 10^3.

One consequence of the airborne effluents will be the gradual buildup of released radioactivity in the environment. Table 9-73 summarizes the average release rates, the maximum levels of soil contamination, and the present radionuclide concentration in INEL soils from natural background radiation and atmospheric fallout. The implications of these estimates can be understood in the context of the resulting radiation-dose commitments. The maximum radiation-dose commitments received annually from airborne effluents by any individual and by the population within 50 miles of the processing facilities are presented in Table 9-74. As shown there, both individual and population annual dose commitments from processing facilities would be several orders of magnitude lower than doses presently received from natural background radiation.

The nonradiological effects of waste processing would be limited essentially to those associated with a commitment of manpower and the use of other resources. A summary listing of the resources used and of the particulate emissions is given in Table 9-75.

The increment in particulate emissions from the construction and operation of any of the processing facilities would not be measurable, nor would it cause current limits to be exceeded.

The impact on local communities, particularly Idaho Falls, where two-thirds of the work force are expected to live, would probably be felt most in the schools, which are already operating near capacity because of recent growth in the area.

Table 9-73. Comparison of Soil Contamination Resulting from Routine Releases During Facility Operations with Existing Natural and Fallout Radionuclide Concentrations[a,b]

Nuclide	Average release rate from plant (pCi/sec)		Maximum cumulative concentration in soil (nCi/m^2)		Present concentration in INEL soil (natural and fallout contributions) (nCi/m^2)
	Slagging pyrolysis	Repackaging	Slagging pyrolysis	Repackaging	
Pu-238	1.1	0.15	0.38	0.053	0.15
Pu-239	0.85	0.12	0.32	0.044	(c)
Pu-240	0.21	0.028	0.077	0.01	(c)
Pu-241	3.9	0.53	1.1	0.16	(d)
Pu-242	5.0×10^{-6}	6.9×10^{-7}	1.9×10^{-6}	2.6×10^{-7}	(d)
Am-241	3.3	0.47	1.2	0.17	0.3
Cm-244	0.047	0.0065	0.014	0.0019	(d)
U-233	0.046	0.0052	0.017	0.0019	(d)

[a]Data from the detailed report (DOE, 1979a).
[b]Average release rates from the overpacking facility would be orders of magnitude lower than those from the repackaging facility; they would be indistinguishable additions to the values given for retrieval in Table 9-70.
[c]The total concentration of these two nuclides is 1.1 nCi/m^2.
[d]Not measured.

Table 9-74. Dose Commitments from Routine Releases from Processing Facilities[a,b]

Organ or tissue	Maximally exposed person (mrem)[c]		1985 population within 50 miles (man-rem)[d]	
	Slagging pyrolysis	Repackaging	Slagging pyrolysis	Repackaging
Whole body	1.9×10^{-7}	2.6×10^{-8}	2.3×10^{-6}	3.2×10^{-7}
Lung	3.5×10^{-3}	4.9×10^{-4}	3.3×10^{-2}	4.5×10^{-3}
Bone	3.6×10^{-3}	5.0×10^{-4}	3.3×10^{-2}	4.6×10^{-3}
Liver	2.7×10^{-3}	3.7×10^{-4}	2.5×10^{-2}	3.4×10^{-3}
Kidney	1.3×10^{-3}	1.8×10^{-4}	1.2×10^{-2}	1.7×10^{-3}

[a]Data from the detailed report (DOE, 1979a).
[b]Dose commitments from the overpacking facility would be orders of magnitude lower than those from the repackaging facility; they would be indistinguishable additions to the values given for retrieval in Table 9-70.
[c]The annual whole-body dose from natural background radiation is 150 mrem.
[d]The annual whole-body dose to this population from natural background radiation is 2×10^4 man-rem.

Table 9-75. Nonradiological Effects of Waste Processing[a]

Item	Slagging pyrolysis	Repackaging	Over-packing[b]
CONSTRUCTION			
Duration, months	20	18	0-6
Average number of construction workers	275	200	0-5
Pieces of heavy equipment used	30	20	0[c]
Diesel fuel used, gallons	360,000	220,000	0-5000
Particulate emissions, pounds	40,000	24,000	0-500
OPERATION			
Duration, years	10	10	10
Workers	195	40	0-12
Estimated annual payroll, million $	3.3	0.64	0-0.192
Electricity use, million kW-hr/yr	24	3	0-0.1
Coal used, tons/yr	4000	0	0
Wood chips used, tons/yr	6000	0	0
Diesel fuel, gal/yr	80,000	0	0
Particulate emissions, lb/yr	0.03	0	0

[a]Data from the detailed report (DOE, 1979a).

[b]The ranges of values for overpack entries reflect the ranges of effects from 0% overpacking to 100% overpacking.

[c]The overpacking addition would be constructed as part of the retrieval facility.

The plant will occupy a maximum of about 1.4 acres, the area of the slagging-pyrolysis plant. Construction and operation would result in devegetation of this area. The area has, however, already been disturbed and is no longer in its natural state.

9.8.3.3 Radiological Risk to the Public from Waste Processing

In evaluating the dose commitments and risks from waste processing, potential accidents such as fires, explosions, spills of loose waste, and breaks in process lines were considered. The projected effects of the dominant accidents are summarized in Table 9-76.

The discussion of waste disruption by natural disasters (e.g., earthquakes and volcanoes) in Section 9.8.2.3 applies to waste processing as well.

Table 9-76. Summary of Dose Commitments and Risks from Accidents During the Processing of Stored TRU Waste[a]

	Maximally exposed person						Population in 1985					
	50-year dose commitment (rem)			Risk (rem/yr)			50-year dose commitment (man-rem)			Risk (man-rem/yr)		
Event[a]	Whole body	Bone	Lung	Whole body	Bone	Lung	Whole body	Bone	Lung	Whole body	Bone	Lung
SLAGGING PYROLYSIS												
Fire	4×10^{-9}	7×10^{-6}	1×10^{-5}	4×10^{-11}	7×10^{-8}	1×10^{-7}	8×10^{-6}	1×10^{-2}	2×10^{-2}	8×10^{-8}	1×10^{-4}	2×10^{-4}
Explosion with failed confinement	4×10^{-5}	7×10^{-2}	1×10^{-1}	4×10^{-10}	7×10^{-7}	1×10^{-6}	8×10^{-2}	100	200	8×10^{-7}	1×10^{-3}	2×10^{-3}
REPACKAGING ONLY												
Fire	2×10^{-9}	2×10^{-6}	4×10^{-6}	2×10^{-11}	3×10^{-8}	4×10^{-8}	3×10^{-6}	4×10^{-3}	8×10^{-3}	3×10^{-8}	4×10^{-5}	8×10^{-5}
Explosion	8×10^{-9}	1×10^{-5}	2×10^{-5}	8×10^{-12}	1×10^{-8}	2×10^{-8}	2×10^{-5}	2×10^{-2}	4×10^{-2}	2×10^{-8}	2×10^{-5}	4×10^{-5}
OVERPACKING[b,c]												
Dropped container	3×10^{-12}	6×10^{-9}	8×10^{-9}	3×10^{-14}	6×10^{-11}	8×10^{-11}	6×10^{-9}	8×10^{-6}	2×10^{-5}	6×10^{-11}	8×10^{-8}	2×10^{-7}
Natural background radiation (1 year)	7.5						1×10^{6}					

[a]Data from the detailed report (DOE, 1979a).
[b]Data are given only for the overpacking method that leads to the largest dose and risk.
[c]It was assumed that the data for a fire in the overpacking facility would be the same as for a fire during retrieval (Table 9-72).

9.8.3.4 Hazards to Workers During Processing

The general discussion in Section 9.8.2.4 on the potential hazards to workers and preventive measures applies to processing as well. The occupational hazards of the overpacking operations would be essentially the same as those for the retrieval operations. All operations in the slagging-pyrolysis facility or the repackaging-only facility would be remotely controlled, including much of the maintenance. The doses received by workers during normal operation are expected to be well below the allowable limits.

On some occasions, maintenance workers would be required to enter contaminated areas of the slagging-pyrolysis or packaging-only facilities. They would probably wear plastic bubble suits, supplied with breathing air from a central source. Under normal conditions, and under most accident conditions as well, the external and internal radiation exposures of these workers would be well below radiation-worker limits. However, damage to the bubble suit could result in contamination of the worker. A maximum airborne contamination level of about 1×10^{-12} curie per milliliter could exist. A worker would receive a maximum permissible body burden in such an atmosphere only if he remained in the cell for about 40 minutes, breathing contaminated air. Evacuation within a matter of minutes is expected. If the bubble-suit damage were caused by a pointed or jagged object, the worker's skin could also be punctured. Contamination could thereby be deposited beneath the skin. Any puncture injury under these conditions would receive special medical attention.

Workers could also be exposed to the consequences of the accidents discussed in Section 9.8.3.3, involving releases of radionuclides to the outside environment of the processing plant. The doses received are expected to be similar to those listed for the maximally exposed person.

The numbers of nonradiological injuries sustained by workers during the 10-year campaign are estimated to be 75 for slagging pyrolysis, 8 for repackaging only, and 0 to 2 for overpacking. In addition, the numbers of injuries expected to occur during plant construction are, respectively, 14, 9, and 0.

9.8.3.5 Costs of Processing

The costs of processing the stored TRU waste that will have accumulated at the INEL by 1985 were estimated by the methods described in Section 9.8.2.5. The results are summarized below (DOE, 1979a).

	Cost (millions of 1979 dollars)		
	Slagging pyrolysis	Repackaging	Overpacking[a]
Capital	372	109	1
Operation and maintenance	226	92	1-14
Decontamination and decommissioning	37	11	0.1
Total	635	212	2-15

[a]The ranges of costs for overpacking cover the ranges of the three methods studied.

9.8.4 On-Site Transfer, Handling, and Loadout for Shipment to the Repository

9.8.4.1 Operations

The procedures for handling waste containers during retrieval are described briefly in Section 9.8.2.1, which also discusses the methods for transferring the containers from the retrieval building to the processing plant. The overpacking methods would require transfer of the waste containers to a railcar-loading dock, rather than to a separate processing facility. The handling procedures to be followed in the processing plant are briefly discussed in Section 9.8.3.1.

9.8.4.2 Environmental Effects

Vehicular noise and emissions associated with on-site waste transfer would be both small and isolated. The number of workers required for these activities would also be small. The Radioactive Waste Management Complex already has its own rail siding, and extending it would not involve significant effort nor use additional acreage outside the Complex.

No releases of radionuclides are expected during waste transfer from the retrieval building to the processing plant. Releases resulting from the handling of containers inside these buildings are included in the analyses of Sections 9.8.2.2 and 9.8.3.2.

9.8.4.3 Radiation Risk to the Public

The radiation-dose commitments and risks calculated for handling and transfer accidents inside the retrieval and processing facilities were covered in the analyses of Sections 9.8.2.3 and 9.8.3.3 (Tables 9-72 and 9-76, respectively). The radiation-dose commitments and risks to the public would be small in comparison with those from other accidents (e.g., fires) that could occur during retrieval and processing.

Table 9-77 summarizes accidents and incidents that have occurred since 1970 during the handling of TRU waste at the Radioactive Waste Management Complex. Approximately 88,000 containers have been handled in that time. Only one of the events listed led to the release of radioactive material, and no contamination was found on the workers.

During transfer from the retrieval building to the processing plant or to the railcar-loading dock, the waste material would be contained within at least two barriers. Although the transfer vehicle could become involved in an accident (for example, a rollover accident or a collision with another vehicle), the expected frequency of such accidents is low. There would be few, if any, other vehicles on the committed roadway used by the transfer vehicle, and the speed of the vehicle would be limited to 20 mph by a governor. The vehicle would be designed for extra stability against rollover.

The estimated dose commitments and risks from the accidents that might involve the transfer vehicle are given in Table 9-78, which also includes the

Table 9-77. Accidents or Incidents in TRU-Waste Handling at the Radioactive Waste Management Complex Since 1970[a]

Year	Incident	Effects
1975	Internal pressure generated in solid-sewage-sludge drum, causing bulging of lid. Drums were repacked in overpack containers.	No release of radioactive material.
1976	Partial drum penetration by forklift. No breach of inner liner.	No release of radioactive material.
1978	Drum penetration by forklift. A small portion of contents was spilled onto the cargo container floor.	Small amount of local contamination, which was immediately contained. The drum was overpacked. There was no airborne activity. Thorough survey after recontainment found no residual contamination.

[a]Data from the detailed report (DOE, 1979a).

estimated dose commitments and risks for accidents that could occur during the on-site portion (about 7 miles) of the rail shipping route to the repository. Such accidents might include derailments, collisions, and fires.

Accidents or incidents that have occurred since 1970 during TRU-waste shipment from the waste generators to the INEL are listed in Table 9-79. None of these events resulted in a release of radioactive material.

9.8.4.4 Hazards to Workers

The hazards to workers during on-site waste transfer and handling have been included in the discussions of both retrieval and processing hazards. The preventive and protective measures against radiological hazards would be the same as those discussed in Section 9.8.2.4.

Under normal conditions, workers operating the transfer vehicles would be exposed to minimal hazards. Under accident conditions, the operators could be exposed to the small amounts of radioactive material that might escape from the vehicle. These exposures are expected to be smaller than those that could occur in other waste-management operations.

Table 9-78. Summary of Dose Commitments and Risks from Accidents During the Transfer of Stored TRU Waste and During the On-Site Portion of Shipment to the Repository

Accident	Maximally exposed person[a]					
	50-year dose commitment (rem)			Risk (rem/yr)		
	Whole body[b]	Bone	Lung	Whole body	Bone	Lung
Transfer accident[c]	2×10^{-8}	3×10^{-5}	6×10^{-5}	2×10^{-14}	3×10^{-11}	6×10^{-11}
Transfer accident[c] with fire	2×10^{-6}	3×10^{-3}	6×10^{-3}	6×10^{-13}	9×10^{-10}	2×10^{-9}
Shipment accidents[d]						
Slagged waste	8×10^{-11}	1×10^{-7}	2×10^{-6}	1×10^{-19}	2×10^{-16}	4×10^{-16}
Overpacked and repackaged waste[e]	8×10^{-10}	1×10^{-6}	2×10^{-6}	1×10^{-18}	2×10^{-15}	3×10^{-15}

Accident	Population in 1985					
	50-year dose commitment (man-rem)			Risk (man-rem/yr)		
	Whole body[f]	Bone	Lung	Whole body	Bone	Lung
Transfer accident[c]	5×10^{-5}	6×10^{-2}	1×10^{-1}	5×10^{-11}	6×10^{-8}	1×10^{-7}
Transfer accident[c] with fire	5×10^{-3}	6	1×10^{1}	1×10^{-9}	2×10^{-6}	3×10^{-6}
Shipment accidents[d]						
Slagged waste	2×10^{-7}	2×10^{-4}	4×10^{-4}	3×10^{-16}	4×10^{-13}	1×10^{-12}
Overpacked and repackaged waste[e]	2×10^{-6}	2×10^{-3}	4×10^{-3}	3×10^{-15}	3×10^{-12}	5×10^{-12}

[a]Data from the detailed report (DOE, 1979a).
[b]The 50-year whole-body dose commitment from natural background radiation is 7.5 rem.
[c]The data given are for transfer from the retrieval facility to the processing facility. For transfer to the railcar-loading dock, the accident dose would be unchanged and the risk would change by less than a factor of 4.
[d]Accidents occurring in on-site portion of shipment to the repository.
[e]The data given are for the 0% and 10% overpack methods. The other processing methods would result in doses and risks differing by less than a factor of 3.
[f]The 50-year whole-body population dose commitment from natural background radiation is 1×10^{6} man-rem.

9.8.4.5 Costs

The costs of handling the containers, loading in, loading out, and transfer from the retrieval area to the processing plant are included in the costs of retrieval and processing (Sections 9.8.2.5 and 9.8.3.5). The costs would be only a few percent, at most, of the total cost of retrieval and processing.

Table 9-79. Accidents or Incidents[a] Since 1970 During Shipments of Waste to the Radioactive Waste Management Complex

Date	Location	Incident	Effects
March 1970	Blackfoot, Idaho	Seal missing on a truck trailer	Load intact, no other problem
June 1971	Unknown	Evidence of fire on piggyback trailer inside ATMX car: charred wood, not known whether there were signs of fire on containers themselves	No breach, no release
August 1973	Blackfoot, Idaho	Derailment during switching of ATMX car	No release, no apparent damage
March 1976, September 1976	Unknown	Evidence of hard humping of ATMX car: some wooden blocking was broken, and four or five waste containers were dented	No breach, no breakage

9.8.5 Conclusions

The effects in Idaho of retrieving, processing, and shipping the stored TRU waste would be minimal. The largest radiological impacts from normal operations would be dose commitments of 3.6×10^{-6} rem (bone) and 1.9×10^{-10} rem (whole body) for the maximally exposed individual and 3.3×10^{-2} man-rem (bone) and 2.3×10^{-6} man-rem (whole body) for the surrounding population, per year of operation (Table 9-74). From hypothetical accidents, the maximum dose commitments would be 1×10^{-1} rem (lung) and 4×10^{-5} rem (whole body) for the maximally exposed individual and 200 man-rem (lung) and 8×10^{-2} man-rem (whole body) for the surrounding population (Table 9-76). The maximum radiological risks from hypothetical accidents would be 1×10^{-6} rem per year (lung) and 4×10^{-10} rem per year (whole body) for the maximally exposed individual and 2×10^{-3} man-rem per year (lung) and 8×10^{-7} man-rem per year (whole body) for the surrounding population (Table 9-76). The radiological effects of all of these exposures would be far smaller than the corresponding effects from natural background radiation. Nonradiological environmental effects would be limited to relatively minor commitments of manpower and other resources.

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10 Unavoidable Adverse Impacts

10.1 CONSTRUCTION

The impacts of constructing the WIPP at the Los Medanos site will be like those of other large building projects. They include increased noise levels near the site, increased air pollution from earth-moving and vehicular activities, and the disruption of existing land uses on the site and along new road and utility rights-of-way.

Approximately 224 acres will be removed from rangeland and wildlife habitat during both the construction and the operational phases of the plant. An additional 878 acres will be temporarily disrupted during construction. The details of acreages committed are given in Section 9.1.1. Scaled quail, mourning dove, and mule deer will lose some habitat, but extensive areas of similar habitat exist throughout the region. Similarly, the loss of individuals of the more sedentary species (e.g., rodents, lizards) during construction will have little impact on the population of these species in the area. The site and most areas in which land will be disturbed are rangeland where 60 to 64 acres per animal-year has been an acceptable grazing capacity. However, the recent average density of grazing on the lands at and around the site has been about one head per 100 acres. Therefore, the loss of grazing land will mean a reduction in grazing capacity of about 11 animals.

Most of the construction workers are expected to reside in Carlsbad and Hobbs, New Mexico. Although some of the workers will be drawn from the local labor force, many workers will move into the area to work on the project, increasing the demands on existing community services and community resources. In Carlsbad a temporary housing shortage may develop; it would be met by the development of trailer parks or other temporary accommodations. In Hobbs the capacity of the school system is now expected to be exceeded by 1983; if a major fraction of the construction workers choose to live in Hobbs, the capacity may be exceeded 1 year earlier. Highway use in Eddy and Lea Counties will increase because of the commuting of construction workers and the transport of construction materials.

These impacts of the influx of construction workers will require increases in public expenditures; operating costs will increase. Because revenues normally lag behind expenditures, local governments may experience some short-term problems in meeting the demands for public services. The communities, however, are already capable of planning to meet these impacts, which will be mitigated or offset by increased tax revenues, decreased unemployment, and highway improvements associated with the construction of the plant. Section 9.6.6 discusses the Federal assistance programs that may be available to local governments in areas selected for Federal projects, such as the WIPP, to mitigate adverse socioeconomic effects.

10.2 OPERATION

During the operational phase of the WIPP project, approximately 224 acres of land will remain unavailable for rangeland and wildlife habitat. The impacts of this removal are discussed in Section 10.1.

The mined-rock pile will grow and become a more obvious feature of the landscape. Rainwater falling on it will dissolve some salt and sterilize the soil under the pile and in the surrounding ditch. Some salt will be blown onto the surrounding land and may cause changes in vegetation.

The main access to the plant will be U.S. Highway 62-180. Traffic levels will increase, but this highway's capacity will be adequate both for the work force and for trucks transporting waste to the plant. Certain segments of the road to Hobbs to the east of the site may need to be upgraded.

The increase in the population of the area will result in an increased demand for primary health care. Current physician-to-population ratios are not at recommended levels, although hospital facilities are adequate.

The development of the site and facilities will hinder or deny the future recovery of potash and oil and gas in the inner zones beneath the site. These impacts are discussed in Sections 9.2.3 and 11.1.

The operation of the plant will release some radioactivity. The greatest annual dose commitment is to the bone and is estimated to be 6.5×10^{-6} rem (0.0065% of annual background radiation) for an individual living at the James Ranch.

The transportation of waste to the plant will expose people near the transportation routes to radiation. The average radiation dose received by these people will be a small fraction of the natural background dose; furthermore, it will be a small fraction of the limits recommended for the protection of the general public from all sources of radiation other than natural and medical sources.

The maximum credible dose would be received by a hypothetical person who is at the side of the road and at the side of the railroad as every shipment passes. That person would receive an annual dose of 1.5×10^{-4} rem, 0.15% of the dose delivered by natural background radiation.

The final shutdown of the plant will narrow the economic base of nearby communities.

10.3 LONG-TERM IMPACTS

The only certain long-term impact of the WIPP project is the residual disturbance of the surface after the WIPP is closed and the surface structures are razed. The 1060 acres disturbed during construction and operation will probably always show some slight sign of previous activities there. The waste that is emplaced underground is not expected to release any radioactivity; it will therefore produce no long-term radiological impact. Nevertheless, future governments may feel an obligation for long-term monitoring.

10.4 COMPARISON OF ALTERNATIVES

Unavoidable adverse impacts are most clearly defined for alternative 2, the authorized alternative, because it is the only action alternative that has been studied in detail and with a specific site in mind. Unavoidable adverse impacts associated with the other two action alternatives are similar but not identical. Since alternatives 3 and 4 involve decisions not to select a specific alternative site or facility at this time, the comparison of environmental impacts is based on generic estimates rather than specific evaluations. The selection of alternative 3 or 4 could allow such specific comparisons at a later date. Additional environmental documentation would be required for site selection and repository construction under alternatives 3 and 4, including any high-level-waste repository at the Los Medanos site.

Table 4-13 compares the environmental impacts of alternatives 3 and 4 to the impacts of alternative 2. All the alternatives would produce some physical impacts of construction. The principal differences depend more on the choice of a host rock than on the choice of an alternative. The choices that lead to the use of salt entail more impacts from their mined-rock piles because salt is very soluble in water. The choices also differ in the degree to which they lead to interference with the exploitation of mineral resources. It appears at present that alternative 2 entails more interference with mineral resources than do alternatives 3 or 4, so long as the site chosen in those two alternatives is elsewhere than in the Delaware basin. However, the mineral resources of the Los Medanos site are comparatively well known; there can be no assurance that any alternative will be free of interference with mineral resources. In alternative 3, impacts at a specific site would be greater due to the combination of high-level-waste and TRU-waste disposal. However, these effects would be reduced on a national basis because of the economy gained by combining facilities.

Similar unavoidable adverse socioeconomic impacts, which are primarily related to the construction work force, would be induced by all of the alternatives.

Unavoidable transportation impacts would be induced by all alternatives. The impacts of normal accident-free transportation would differ from site to site, depending on each site's location in relation to the sources of waste.

Long-term unavoidable adverse impacts, consisting as they do only of long-term influences on the use of land and possibly of continued interference with access to mineral resources, would be induced in different degrees by all alternatives and by all choices of host rock.

Even though detailed information on the impacts of alternatives 3 and 4 is not available, evaluations related to commercially generated radioactive waste (DOE, 1979, 1980) provide assurance that minimal environmental impacts, comparable to those determined for alternative 2, would result from repositories at other sites. Thus, all alternatives, other than alternative 1 (no action), are predicted to have impacts that are small both in the short term (during construction and operation) and in the more-distant future. None of the action alternatives are so clearly superior environmentally to the others that they are preferred on the basis of lesser unavoidable adverse impacts.

REFERENCES FOR CHAPTER 10

DOE (U.S. Department of Energy), 1979. Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-D, Washington, D.C.

DOE (U.S. Department of Energy), 1980. Statement of Position of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (NRC Waste Confidence Rulemaking), DOE/NE-0007, Washington, D.C.

11 Irreversible and Irretrievable Commitments of Resources

11.1 LAND USE

If the WIPP is constructed at the Los Medanos site in southeastern New Mexico, approximately 224 acres of land will be occupied by surface facilities for the duration of operations. This land includes 30 acres for the surface storage of excess mined salt and approximately 112 acres for the roads and railroad. After plant decommissioning, most of this 224 acres will be restored to its original contours and permitted to revert to its natural state. Full recovery of the area is expected to require several decades.

These predictions of land-use commitments assume that the surface facilities will be razed during decommissioning. If instead they are mothballed, the land they occupy and the associated access roads will remain committed for an indefinite time thereafter.

11.2 DENIAL OF MINERAL RESOURCES

As discussed in Section 9.2.3, the development of the WIPP will deny access to portions of local deposits of hydrocarbons and potash minerals, at least temporarily. The most significant of these minerals is langbeinite, an ore that is rich in potassium and magnesium and has commercial value as a chemical fertilizer. In the United States langbeinite is found only in the Carlsbad Potash Mining District, where the resources will probably be depleted in less than 46 years. According to the U.S. Bureau of Mines, the langbeinite K_2O reserve at the Los Medanos site is 4.4 million tons; this is equivalent to 15 years' production of such ore at Carlsbad. Thus, the development of the WIPP will require an earlier transition to other chemical fertilizers. Studies performed to date indicate that the langbeinite reserves within control zone IV (73% of the total reserves at the site) could be mined by conventional techniques without affecting the integrity of the WIPP repository. Accordingly, the DOE may allow mining of this langbeinite. It is not clear, however, what the consequences of mining langbeinite from the inner control zones would be, although the matter is being studied.

The Los Medanos site overlies about 45 billion cubic feet of natural gas and 120,000 barrels of distillate. These amount to about 0.02% and 0.0003% of the U.S. reserves of natural gas and distillate, respectively. The existence of the WIPP does not necessarily preclude access to the underlying hydrocarbons permanently. The natural gas within control zone IV can be extracted without threatening the integrity of the repository; the DOE may allow drilling for natural gas in this area. The natural gas within the inner control zones can be recovered by slant-hole (deviated) drilling from control zone IV at an additional cost estimated at $21 million.

11.3 RESOURCES FOR WIPP CONSTRUCTION

As discussed in Section 9.2.2, the following resources will be required over the 4.5-year construction period of the WIPP:

Resource	Site and preliminary-design validation	Full-construction total
Concrete (portland cement), barrels	5,000	125,000
Steel, tons	220	15,000
Copper, tons	None	150
Aluminum, tons	None	200
Lumber, board-feet	None	500,000
Water, million gallons	3.5	22
Electricity, million kilowatt-hours	1.5	4
Propane, gallons	None	140,000
Diesel fuel, million gallons	700,000	1.5
Gasoline, gallons	50,000	940,000

None of these amounts will exceed 1% of the U.S. production over the construction period.

11.4 RESOURCES FOR WIPP OPERATION

As discussed in Section 9.3.3, the following resources will be used by the plant during its operation:

Electrical power, kilowatts	20,000
Diesel fuel, gallons per day	400
Gasoline, gallons per day	140
Water	
Gallons per day	25,000
Acre-feet per year	20

These modest requirements will not significantly affect the local or regional availability of these resources.

In addition, the transportation of waste to the WIPP will use some fuel. According to Section 6.7.3, trucks will travel about 280,000 miles per year and railcars about 400,000 miles per year in moving this waste. This transportation will use about 100,000 gallons of diesel fuel per year.

11.5 RESOURCES USED AT THE IDAHO NATIONAL ENGINEERING LABORATORY

As discussed in Sections 9.8.2.2 and 9.8.3.2, the following resources will be used at the Idaho National Engineering Laboratory (INEL) in retrieving the TRU waste from its present storage and preparing it for shipping to the WIPP, assuming processing by slagging pyrolysis:

Resource	Retrieval	Processing
Construction period	9 months	10 years
Pieces of heavy equipment	10	30
Diesel fuel, gallons	54,000	360,000
Operational period	20 years	10 years
Electricity, kilowatt-hours per year	600,000	24,000,000
Diesel fuel, gallons per year	88,000	80,000
Coal, tons per year		4,000
Wood chips, tons per year		6,000

The use of these resources in Idaho will not affect their local or regional availability.

11.6 COMPARISON OF ALTERNATIVES

The resources needed are most clearly defined for alternative 2, the authorized alternative, because it is the only alternative that has been studied in detail and with a specific site in mind. Irreversible and irretrievable commitments of resources for the other two action alternatives are similar but not identical.

Land is a resource. Its use for alternative 2 amounts to 224 acres. This is a long-term commitment in the sense that the land occupied by the plant and the roads and railroad to it will not return to the condition they are in now for a very long time (decades). The amount of land used for alternative 4 should be about the same. Combining a TRU-waste repository with a high-level-waste repository in alternative 3 would mean an overall decrease in the amount of land used of about 40% because there would then be one repository rather than two.

The quantity of resources used for construction and operation in alternative 2 is tabulated in Sections 11.3 and 11.4. The quantity of resources used for alternative 4 should be about the same. The quantity of resources used for alternative 3, like that of the land needed, would be decreased for the combined repository.

The resources used in transporting waste to a repository other than one in southeastern New Mexico depend on where the repository is. For instance, the distance from the INEL to a basalt repository at Hanford is much smaller than the distance to the WIPP, but the distance to a dome-salt repository in Texas, Louisiana, or Mississippi is somewhat greater.

Finally, the quantity of resources used to retrieve the waste from storage at the INEL and prepare it for shipment to a repository is the same regardless of which action alternative is chosen.

12 Relation to Land-Use Plans, Policies, and Controls

12.1 EXISTING LAND-USE PLANS, POLICIES, AND CONTROLS

As described in Section 8.1, 17,200 acres of the site for the authorized alternative, the WIPP facility in southeastern New Mexico, are Federal land, 1760 acres are State land, and none is private land. All this land is presently leased for grazing, 25% is subject to potash leases, and 35% is subject to hydrocarbon leases, with some overlap (Table 8-2).

There are no State, county, or local land-use policies, plans, or controls on this land. There is a "State of New Mexico Policy on Nuclear Waste Disposal," but it does not explicitly refer to the use of the land itself.

The Federal land is administered by the Bureau of Land Management (BLM) of the U.S. Department of the Interior; the State land is administered by the Commissioner of Public Lands of the State of New Mexico. Other Federal and some State agencies have jurisdiction over certain of the resources in these lands. These include the U.S. Geological Survey, which administers the development of mineral resources by issuing drilling permits and approvals for exploration and mining, and the New Mexico Department of Game and Fish, which promulgates hunting regulations for all lands in the State, including Federal lands.

The proposed land-withdrawal area is within the BLM's East Eddy Planning Unit. The BLM manages land under its control by means of a formal land-use planning system. For this planning unit, the BLM has completed a Unit Resource Analysis, which identifies inventories, problems, conditions, use, and management potentials. This information is being used to develop a Management Framework Plan (MFP) indicating decisions on the coordinated management of resources and broad-based functional guidelines for the entire planning unit. The tentative MFP guidelines state that the BLM will

1. Encourage exploration for oil and gas and for potash.

2. Restrict or control other surface uses that conflict with oil and gas or potash development.

3. Manage intensively for recreational uses.

4. Encourage livestock use and management, developing Allotment Management Plans (AMPs) for the unit. (The James Ranch, encompassing the southern 65% of the proposed withdrawal area, is already party to an AMP; the Crawford Ranch is not.)

The National Historic Preservation Act of 1966 (16 USC Section 470-70n), Executive Order No. 11593 (Federal Register, Vol. 36, p. 8921, 1971), and Public Law 93-291 (May 24, 1974) are related to the preservation of cultural, historic, archaeological, and architectural resources. There will be no conflict with these requirements, because all construction and other activities that will disturb the surface are preceded by archaeological surveys that guide the preservation of these resources.

As stated in detail in Chapter 14, the activities of the WIPP project will comply with all applicable Federal, State, and local requirements for protecting the environment.

12.2 COMPATIBILITY OF THE WIPP PROJECT WITH EXISTING LAND-USE PLANS

The BLM policies and plans encourage exploration for hydrocarbons and potash and also encourage recreation and well-managed grazing to the extent that they do not conflict with mineral exploration.

Section 9.2.3 describes the oil and gas resources of the WIPP site and the extent to which the authorized alternative conflicts with their exploration. It is clear that the withdrawal of the Los Medanos site from mineral exploration and development is incompatible with the goal of encouraging exploration for oil and gas. However, the existence of the WIPP does not necessarily preclude access to these resources permanently. The DOE may allow drilling for natural gas in control zone IV. Reserves in the inner control zones may eventually become available for exploitation through the use of such techniques as slant-hole drilling from control zone IV or by a future relaxation of the controls now thought prudent for the area.

The potash resources and the extent of conflict with them are also described in Section 9.2.3. The WIPP project conflicts with the BLM's goal of encouraging the exploration of these resources. It is possible, however, that mining of the potash, which is 300 feet above the waste-emplacement level, will eventually be found compatible with the WIPP project.

Because of site-exploration efforts, the road network in the area has already been expanded from about 8 miles of low-quality road by adding 30 miles of new caliche-surfaced road. The new roads are already allowing more recreational use, principally for hunting. In this respect, therefore, the WIPP project is compatible with BLM plans to encourage recreation.

Cattle grazing is now permitted by the BLM at an estimated six head per square mile on the Federal lands within the WIPP site. The U.S. Department of Energy (DOE) intends to allow grazing to continue at this stocking rate (or to adjust to BLM future practices) except for 670 acres devoted solely to the plant and an additional 390 acres required during construction. In this respect, the WIPP project is slightly incompatible with BLM plans for grazing.

12.3 COMPARISON OF ALTERNATIVES

In the lack of specific sites for use in alternatives 3 and 4, little can be said about the extent to which those alternatives will or will not be compatible with existing land-use plans, policies, and controls.

At this time the Hanford Site in the State of Washington and the Nevada Test Site are being considered as areas that might contain acceptable sites for high-level-waste repositories. At these two places, the question of land-use policy has already been decided: the land is to be used for DOE purposes. Thus the use of either place would be compatible with existing land-use plans, policies, and controls.

Salt domes are being investigated in Texas, Louisiana, and Mississippi. The land there is used much more intensively than the land in southeastern New Mexico, for the most part for farming and forestry. The use of land in these states could therefore be much less compatible with existing land-use plans, policies, and controls than the use of land in New Mexico.

13 Relationship Between Short-Term Uses and Long-Term Productivity

The WIPP will potentially provide a repository for isolating transuranic wastes from the biosphere for thousands of years. As such, it will afford long-term protection to the public from the radioactivity contained in transuranic waste generated in national defense programs. In the short term, the WIPP will offer an opportunity for experiments related to the disposal of high-level radioactive waste; the knowledge and experience gained from this opportunity will advance the state of the art of waste disposal in bedded salt. These missions support national defense and energy policies (IRG, 1979; OSTP, 1978).

Use of the Los Medanos site in southeastern New Mexico for a transuranic-waste repository would hinder the extraction of mineral resources. The types and quantities of these resources are discussed in Section 9.2.3 in the context of regional and national reserves. The underlying natural gas can be recovered by vertical and deviated drilling in control zone IV. It may eventually be possible to extract overlying potash minerals, but since studies of this prospect have not been completed, the recovery of these minerals cannot be assured.

Approximately 224 acres of land that is currently rangeland and wildlife habitat will be used for surface facilities, roads, a railroad, and the mined-rock pile. After decommissioning, which may take place several decades after the facility is built, most of this area will be graded to help it return to its natural state. However, the time required for the disturbed area to recover is expected to be several decades.

The impacts on long-term productivity of the other two action alternatives would depend on the site that is chosen. At Hanford and the Nevada Test Site the land is not farmed or grazed by domestic animals. Areas being considered for bedded-salt repositories are in arid regions generally used for grazing. Land in the southeastern United States is often considerably more productive than land in the West. A dome-salt repository would disturb less land than a basalt or granite repository and as much land as a shale repository (DOE, 1979, p. 3.1.107). However, the land in areas considered for a dome-salt repository is more intensively used. Thus, the net impact on productivity of a dome-salt repository could be greater than that of a repository in the other media. Impacts on long-term productivity will be examined in other environmental documents if alternative 3 or 4 is selected.

REFERENCES FOR CHAPTER 13

DOE (U.S. Department of Energy), 1979. Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste, DOE/EIS-0046-D, Washington, D.C.

IRG, 1979. Report to the President by the Interagency Review Group on Nuclear Waste Management, TID-29442, U.S. Department of Energy, Washington, D.C.

OSTP (Office of Science and Technology Policy), 1978. Isolation of Radioactive Wastes in Geologic Repositories: Status of Scientific and Technological Knowledge (draft), Executive Office of the President, Washington, D.C.

14 Environmental Permits, Approvals, Consultations, and Compliances

14.1 INTRODUCTION

This chapter examines the permits, certifications, licenses, and other approvals that may be required by the Federal Government or by the State of New Mexico for the Waste Isolation Pilot Plant (WIPP). The emphasis is on the environmental-quality-control requirements of laws and regulations in the areas of air quality, water quality, the disposal of solid and hazardous wastes, the protection of critical wildlife habitats, and the preservation of cultural resources.

The health and safety aspects of the handling of radioactive materials, the transport of radioactive materials, and associated activities governed by the Atomic Energy Act of 1954 as amended (40 USC 2011 et seq.) and related legislation are outside the scope of this chapter and are covered elsewhere in this document. However, the radiation-protection requirements of the State of New Mexico are discussed here.

This discussion does not explicitly address the environmental permit requirements for the remaining two action alternatives. The Federal permit requirements would be nearly identical in any case, except that the repository constructed under alternative 3 would be licensed by the U.S. Nuclear Regulatory Commission. The specific state permit requirements would vary, depending on the location of the site. The environmental documentation for alternative 3 would be prepared in accordance with the strategy set forth in the U.S. Department of Energy (DOE) statement of position on the Nuclear Regulatory Commission's Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (DOE, 1980).

The legislative and regulatory requirements directed at protecting the quality of the environment almost always address particular components of the environment: air, water, land, wildlife, and the like. A number of actions attendant on the WIPP project are governed by more than one set of regulations. For example, a sanitary landfill or a mined-rock pile must meet certain requirements of the Resources Conservation and Recovery Act, the Clean Water Act, the Clean Air Act, the Endangered Species Act, and the Historic Preservation Act, among others, at the Federal level. There are often parallel requirements at the State level.

The DOE, as a Federal agency, is required to comply with a number of environmental requirements under various Federal laws. The Federal requirements include, but are not limited to, those under the seven laws and one executive order discussed next.

<u>National Environmental Policy Act (NEPA) (42 USC 4321 et seq.)</u>. This Act requires "all agencies of the Federal Government" to prepare a detailed statement on the environmental effects of proposed "major Federal actions significantly affecting the quality of the human environment." In compliance with NEPA, the DOE filed with the Environmental Protection Agency (EPA) and circulated to the public in April 1979 a draft environmental impact statement

(DEIS) on the Waste Isolation Pilot Plant. It is now filing and circulating a final environmental impact statement (FEIS) for this proposed Federal action. The draft statement was issued before the Council on Environmental Quality (CEQ) Regulations on Implementing National Environmental Policy Act Procedures (40 CFR 1500-1508) became effective on July 30, 1979. Therefore, the DEIS was prepared, submitted, and circulated in compliance with the preceding CEQ guidelines as implemented by regulations issued by the Energy Research and Development Administration, the predecessor of the DOE (10 CFR 711). The FEIS complies with the present CEQ regulations to the extent practicable.

Executive Order 12088 (October 13, 1978). This Executive Order of the President of the United States requires every Federal agency to comply with applicable pollution-control standards established by, but not limited to, the following Federal laws:

- Toxic Substances Control Act (15 USC 2601 et seq.)
- Federal Water Pollution Control Act (33 USC 1251 et seq.)
- Public Health Service Act, as amended by the Safe Drinking Water Act (42 USC 300(f) et seq.)
- Clean Air Act (42 USC 7401 et seq.)
- Noise Control Act (42 USC 4901 et seq.)
- Solid Waste Disposal Act (42 USC 6901 et seq.)

The Executive Order also requires Federal compliance with Section 2174(h) of the Atomic Energy Act of 1954 (42 USC 2021(h)).

Environmental Quality Improvement Act (42 USC 4371). The primary purpose of this Act is to authorize an Office of Environmental Quality to staff the Council on Environmental Quality (CEQ). Another purpose of the Act is "to assure that each Federal Department and Agency conducting or supporting public works activities which affect the environment shall implement the policies established under an existing law."

Clean Air Act (42 USC 7401 et seq.) as amended by the Clean Air Act Amendments of 1977 (PL 95-95). Section 118 provides for the control of air pollution by Federal facilities. It requires that each Federal agency, such as the DOE, having jurisdiction over any property or facility that may result in the discharge of air pollutants, comply with "all Federal, State, interstate, and local requirements" with regard to the control and abatement of air pollution. The DOE intends to comply with all such requirements and will not seek any exemptions that otherwise might be granted.

Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 USC 1251 et seq.). Section 313 governs the control of water pollution from Federal facilities. Like Section 118 of the Clean Air Act, it requires all branches of the Federal Government engaged in any activity that may result in a discharge or runoff of pollutants, defined to exclude materials regulated under the Atomic Energy Act of 1954, to comply with Federal, State, interstate, and local requirements.

Resource Conservation and Recovery Act of 1976 (42 USC 3251 et seq.). This Act governs the disposal of solid and hazardous wastes. It does not apply to any activity or substance that is regulated by the Atomic Energy Act of 1954 (42 USC 2011 et seq.). In other words, the disposal of radioactive waste is governed not by this legislation but by the Atomic Energy Act. Since there are no plans to treat, store, and dispose of hazardous waste (as will be defined by EPA regulations scheduled for mid-1980) at the WIPP, Subchapter C (Hazardous Waste Management) will not apply to the project. However, the DOE will comply with the solid-waste-disposal requirements of Federal, State, and local agencies.

Noise Control Act of 1972 (42 USC 4901 et seq.). Section 4 of this Act directs all Federal agencies "to the fullest extent within their authority" to carry out programs within their jurisdiction in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health or welfare. The DOE will comply with such requirements to the fullest extent possible.

Endangered Species Act of 1973 (16 USC 1531 et seq.). Action has been taken by the DOE to comply with this law by insuring that any action pertaining to the WIPP will not jeopardize the continued existence of any threatened or endangered species or their habitats.

The DOE will comply with the applicable State environmental-control requirements whether or not it is specifically directed to comply under Federal legislation.

In order to determine the environmental requirements with which the WIPP project must comply, representatives of the following Federal and New Mexico State agencies were interviewed in person or by telephone in May and June of 1979:

Federal

Bureau of Land Management
Environmental Protection Agency (Regions VI and VIII)
Fish and Wildlife Service
Heritage Conservation and Recreation Service
Advisory Council on Historic Preservation

State

Department of Energy and Minerals
Department of Game and Fish
Department of Natural Resources
Environmental Improvement Division, Department of Health and Environment
New Mexico Heritage Program
New Mexico Historic Preservation Program
Office of State Attorney General
Office of State Engineer
State Inspector of Mines
State Land Commission

The sections that follow summarize the Federal and New Mexico requirements with which the WIPP project will comply where the requirement is applicable to actions being undertaken by the project.

14.2 FEDERAL AND STATE PERMITS AND APPROVALS

14.2.1 Historic Preservation

No particular permits, certifications, or approvals are required relative to historic preservation. However, the DOE must provide an opportunity for comment and consultation with the Advisory Council on Historic Preservation as required by the Historic Preservation Act of 1966 (16 USC 470(f) et seq.). Section 106 of the Act requires Federal agencies with jurisdiction over a Federal "undertaking" to provide the Council an opportunity to comment on the effect that activity might have on properties included in, or eligible for nomination to, the National Register of Historic Places.

Executive Order 11593 of May 13, 1971, requires Federal agencies to locate, inventory, and nominate properties under their jurisdiction or control to the National Register if the properties qualify. Until this process is complete, the agency must provide the Advisory Council an opportunity to comment on the possible impacts of proposed activities on eligible properties.

The DOE is complying with the requirements of the National Historic Preservation Act. As a result, the New Mexico State Historic Preservation Officer on April 28, 1978, recommended to the Heritage Conservation and Recreation Service of the Department of the Interior that the central 4 square miles of the WIPP site with the 33 archaeological sites then known be considered eligible for nomination to the National Register as an "archaeological district." On May 24, 1978, the Secretary of the Interior determined that these 4 square miles were eligible for nomination to the National Register. (The correspondence is reproduced in Appendix I.) Thus the DOE is within the purview of recent regulations on the protection of historic and cultural properties (36 CFR 800; Federal Register, Vol. 44, p. 6068, January 30, 1979). Under the regulations, the DOE will be required to determine any possible adverse effects on the archaeological sites that are eligible for nomination to the National Register. The DOE will also continue to consult with the State Historic Preservation Officer and the Advisory Council in order to reach agreement on the measures to be employed to avoid, mitigate, or minimize any such possible adverse effects. For the site and preliminary-design validation (SPDV) phase of the WIPP project, the DOE has submitted detailed plans for mitigating impacts on archaeological sites. The New Mexico State Historic Preservation Officer has agreed that these procedures "are adequate to mitigate direct and indirect adverse effects . . . on significant cultural resources." (See letters of April 10, and May 8, 1980, in Appendix I.) Later submittals will be made for the total WIPP facility.

14.2.2 Hazardous-Waste Disposal

Subchapter C of the Resource Conservation and Recovery Act (RCRA) of 1976, cited above, provides for hazardous-waste management. As already pointed out, radioactive-waste management is governed by the Atomic Energy Act and the related regulatory framework.

The definition of a (nonradioactive) hazardous waste under the RCRA is as follows:

> The term "hazardous waste" means a solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may--
>
> (A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness; or
>
> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The EPA published guidelines and regulations for the disposal of hazardous wastes (40 CFR 250) in the Federal Register on May 19, 1980. It has not been absolutely determined from the regulations whether the proposed mined-rock pile might be considered a hazardous waste under some conditions. According to EPA's criteria for what constitutes a hazardous waste, this is unlikely.

If any disposal of solid waste or mining waste in the WIPP qualifies as a "hazardous waste management activity," the DOE will comply fully with the regulations promulgated by the EPA.

New Mexico enacted a Hazardous Waste Act (Sections 74-4-12 to 74-14-12, NMSA, 1978) and adopted hazardous-waste regulations in 1977. "Hazardous waste" is defined by the State as follows:

> Sulfuric acid or any mixture containing sulfuric acid or any chemical intended for disposal which is corrosive to living tissue, toxic, subject to bioconcentration in biological systems, carcinogenic, teratogenic, mutagenic, and which is listed in Section 102 of these regulations, or any chemical which may injure human health or property as a proximate result of disposal because of its quantity, concentration or chemical characteristics.
>
> The term "hazardous waste" does not include any radioactive components of any substance. (Emphasis added.)

The New Mexico Act does not apply to radioactive waste, mine-processing waste, or mill-processing waste, nor does it apply to any noncommercial disposal of any hazardous waste.

At present, it appears that there is only a slight possibility that any of the WIPP activities would be subject to either Federal or State regulations on hazardous-waste disposal. This will be clarified when the EPA issues its final guidelines and regulations.

14.2.3 Endangered Species

The Endangered Species Act does not require a permit, certification, license, or other formal approval. What it does require is a "Section 7 consultation." Section 7 of the 1978 Amendments to the Act requires the following:

> All. . .federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species. . . . Each federal agency shall, in consultation with and with assistance of the Secretary, insure that any action authorized, funded, or carried out by such agency. . .does not jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary, after consultation as appropriate with the affected States, to be critical. . . . (Emphasis added.)

In order to comply with the Section 7 consultation requirements, the DOE has asked the U.S. Fish and Wildlife Service for a list of endangered and threatened species so that it can be determined whether such species are known to have a critical habitat on or in the vicinity of the WIPP site. Five species have been identified as possibilities: two birds, a ferret, a fish, and a cactus. (See letter dated November 15, 1979, in Appendix I.) A biological assessment of impacts on these species has been prepared; it has been determined that none have the necessary habitat near the site.

The State of New Mexico has a "cooperative agreement" with the U.S. Fish and Wildlife Service that authorizes the State to assume management responsibilities for endangered species on the "Federal list." In addition, the New Mexico Wildlife Conservation Act of 1974 (Sections 17-2-37 through 17-2-46, NMSA, 1978) empowers the State Game and Fish Commission to draw up a State list of endangered species with appropriate regulations.

The New Mexico Heritage Program was started several years ago as an office within the Game and Fish Department. A major function of the Heritage Section is to maintain an up-to-date computerized listing of rare and endangered species of animals on a county-by-county basis. The Heritage Section has been consulted with regard to rare and endangered animals or plants on the New Mexico list that may be known to have a critical habitat on or near the site. Although there have been sightings of several rare or endangered bird and animal species on or near the site, the sightings either were before 1960 or, if later than 1960, are unverified records.

Consultation on possible rare or endangered species is continuing with both the U.S. Fish and Wildlife Service and the New Mexico Heritage Program.

14.2.4 Rights-of-Way

As discussed in Chapter 8, the WIPP site would occupy 18,960 acres. Approximately 17,200 acres of the land to be used are currently under the jurisdiction of the Bureau of Land Management (BLM); 1760 acres are State lands. Right-of-way permits must be obtained from the BLM for any rights-of-way required before the actual withdrawal and for any needed rights-of-way on BLM land outside the boundaries of the site.

Title V of the Federal Land Policy and Management Act of 1976 (43 USC 1761 et seq.) governs rights-of-way for private and governmental entities across, under, or over BLM lands. Right-of-way permits would be needed for pipelines, electric transmission lines, telephone lines, and access roads. The regulations pertaining to rights-of-way are contained in 43 CFR 2800.

The DOE is also consulting closely with the BLM on other aspects of the WIPP project and its potential environmental consequences.

14.2.5 Water Quality

Section 402 of the Clean Water Act is the basis for regulations controlling discharges of pollutants into navigable waters of the United States: the National Pollutant Discharge Elimination System (NPDES). The discharges regulated by the NPDES are those described as point sources.

There will be no discharges from point sources into navigable waters under any of the definitions of that term. It is highly improbable that any discharge could result from a 10-year-recurrence rain. If such a possibility exists, then "best management practices" will be employed to eliminate such a possibility.

Consultation with respect to any possible need for an NPDES permit will continue with Region VI of the EPA.

Water quality in New Mexico is regulated by the Water Quality Division of the Environmental Improvement Division within the Department of Health and Environment. The authority for the regulatory program is contained in the New Mexico Water Quality Act (Sections 74-6-1 to 74-6-4, 74-6-6 to 74-6-13, NMSA, 1978) and the Water Quality Control Commission Regulations, as amended in 1977.

The regulations require a Notice of Intent to Discharge to be filed with the Water Quality Division. The notice would apply to any quantity of a discharge unless it is from a sewage system receiving 2000 gallons or less of liquid wastes per day. A discharge plan must be prepared and approved if the discharge may move directly or indirectly into groundwater. Thus, the principal test is the effect of the discharge on groundwater.

A Notice of Intent to Discharge and additional information have been filed with the State to cover the WIPP SPDV program. Later submittals will be made for the complete WIPP repository. The Water Quality Division will be consulted to clarify all necessary compliances.

14.2.6 Air Quality

The purpose of the EPA regulations for the prevention of significant deterioration (PSD) is to protect the clean-air areas of the nation from the degradation of air quality. The PSD requirements are based on the 1977 Amendments to the Clean Air Act. The Act establishes a classification system for areas where air quality is better than that required by the national ambient air-quality standards and limits the permitted incremental increases in pollutant concentrations.

In regard to the WIPP, the only regulated pollutant that could be of concern with respect to PSD requirements is total suspended particulates (TSP). However, the potential emissions of particulates from the WIPP are estimated at about 100 tons per year (Section 8.7.5). Thus the WIPP would not qualify as a "major stationary source" for which a PSD permit would be required.

Not all of the WIPP site is a clean-air area with respect to total suspended particulates. A portion of Air Quality Control Region 155, which intersects the WIPP site, has been designated by the State as a nonattainment area for particulates; that is, the particulate concentrations in this area are believed to exceed the national ambient air-quality standards. This designation was approved by EPA Region VI.

Information has been submitted to the State to establish that the WIPP site is not itself in a nonattainment area for TSP. Even if it should be determined, as is likely, that the WIPP project will be exempt from a PSD permit, the DOE is committed to employ the best available control technology for salt mining and storage so that it will not violate either the Class I or the Class II increment for particulates.

New sources of air pollution are governed by the New Mexico Air Quality Control Act (Sections 64-2-1 to 74-2-17 NMSA, 1978) and the New Mexico Air Quality Control Regulation 100, as amended. A New Source Permit must be obtained if it is demonstrated that a facility will emit an air contaminant that, uncontrolled, would result in emissions greater than 10 pounds per hour or 25 tons per year. Under the regulations, "air contaminant" includes particulate matter, dust, fumes, and radioactive material.

Under the 1979 amendments to the New Mexico Air Quality Control Act, a source that would require a permit is any air-contaminant-emitting structure, building, equipment, installation, operation, or combination thereof. The proposed construction of two shafts and an underground experimental facility (the SPDV program discussed in Section 8.2.1) qualifies as such a source, as hourly or annual particulate emissions would exceed the amount specified. A permit application has been filed with the State to cover the SPDV program. A later application will be filed to cover the total facility.

14.2.7 Radiation Protection

The New Mexico Radiation Protection Act (Sections 74-3-1 to 74-3-16, NMSA, 1978) is not aimed at disposal facilities for transuranic waste. Instead, the Act is intended to apply to the use and licensing of x-ray-generating devices, laboratories, medical facilities, pharmacies, industrial radiography, and well logging. The Act also includes uranium-mill licensing, since New Mexico is an Agreement State under Section 274 of the Atomic Energy Act of 1954.

As a disposal site for radioactive waste generated in national defense programs, the WIPP is exempt under Section 12-9-8, which provides--

> The Radiation Protection Act shall not apply to the transportation of any radioactive material in conformity with regulations of the Department of Transportation or other agency of the federal government having jurisdiction, or to any material or equipment owned by the United States and being used, stored or transported by or for the United States or any department, agency or instrumentality thereof, except to the extent required or permitted by the authority and control of such materials or equipment.

The Radioactive Waste Consultation Act (Chapter 377, Laws of 1979) was enacted at the first session of the New Mexico 1979 legislature. The Act establishes a Radioactive Waste Consultation Task Force and a joint interim legislative committee known as the Radioactive Waste Consultation Committee. The Act exempts weapons-grade material and other radioactive material that is incidental to research under the exclusive control of the United States.

However, the Radioactive Waste Consultation Task Force is empowered to negotiate for the State with the Federal Government in all areas relating to the siting, licensing, and operation of new Federal disposal facilities for high-level radioactive waste, transuranic waste, or low-level waste.

The 1979 session of the New Mexico legislature also enacted the Nuclear Waste Transport Act (Chapter 377, Laws of 1979), which preempts local governments in New Mexico from prescribing conditions for the transportation of radioactive waste on highways by giving exclusive jurisdiction to the Environmental Improvement Board. The Act specifically exempts "weapons grade material which is under exclusive control of the United States."

14.3 CONSULTATIONS

In addition to the regulatory agencies listed in Section 14.1, the DOE has contacted the following agencies in developing various portions of the environmental impact statement:

New Mexico Highway Department
Federal Aviation Administration
U.S. Department of Agriculture, Soil Conservation Service
U.S. Geological Survey
U.S. Army Corps of Engineers
Carlsbad, New Mexico, municipal authorities
Eddy County, New Mexico, authorities

The DOE has also consulted the following agencies, organizations, and officials about the construction and operation of the WIPP and its implications on the development of the area:

Organization or official

American Association of State Geologists and the Geological Review Group, U.S. Geological Survey
Toney Anaya, former New Mexico Attorney General
Jerry Apodaca, former New Mexico Governor
California Energy Resources Conservation and Development Commission
Pete Domenici, U.S. Senator, and staff
Robert Ferguson, former New Mexico Lt. Governor
Walter Gerrels, Mayor of Carlsbad
Bruce King (now Governor of New Mexico)
National Academy of Sciences
New Mexico Advisory Committee on the WIPP
New Mexico Energy Resources Board
New Mexico Governor's Technical Excellence Committee--Subcommittee on Radioactive Wastes
New Mexico Legislative Committee on Energy
New Mexico Senate Conservation Committee
Harrison Schmitt, U.S. Senator, and staff
Southeastern New Mexico Economic Development Division
U.S. Department of Justice
U.S. General Accounting Office
U.S. Nuclear Regulatory Commission
U.S. Office of Management and Budget
U.S. Office of Science and Technology Policy
Utilities Waste Management Group

In addition, a Federal-State-Local Review Group has been established and has met numerous times. This group consists of representatives of the following:

Federal Agencies

Army Corps of Engineers
Bureau of Land Management
Bureau of Mines
Department of the Interior
Environmental Protection Agency
Federal Aviation Administration
Federal Energy Administration
Federal Highway Administration
Federal Railroad Administration
Fish and Wildlife Service
Geological Survey
Mine Safety and Health Administration
National Park Service
Nuclear Regulatory Commission
Occupational Safety and Health Administration
Soil Conservation Service

State of New Mexico

Department of Health and Social Services
Energy Resources Board
Environmental Improvement Agency
New Mexico Energy Institute
Office of the State Geologist
Oil and Gas Conservation Commission
State Engineer's Office
State Highway Department
State Planning Office

State of Texas

Governor's Energy Advisory Council
Radiation Control Agency

Eddy County

Eddy County Commission
State Senator from Eddy County, Joseph Gant

City of Carlsbad

Department of Development

Other

Western Interstate Nuclear Board

The DOE has provided $2.6 million to the State of New Mexico for the Environmental Evaluation Group (EEG) to perform an independent technical review of the WIPP for the State of New Mexico. The group is studying health, safety, and environmental impacts, as well as mitigation methods. It is reporting its findings to the New Mexico Environmental Improvement Division, the Secretary of Health and Environment, the Governor, and the DOE. The State will use the EEG's findings as a major portion of its input to the State consultation and cooperation process and to guide its own judgment of the overall merits and desirability of the WIPP.

14.4 PUBLIC PARTICIPATION

The WIPP decisionmaking process has provided a number of opportunities for public comment and public involvement. The draft environmental impact statement of April 1979 was made available to numerous individuals and private organizations that requested an opportunity to comment on the statement. Notices of the availability of the statement were published in English and Spanish, and special efforts were made to notify individuals and organizations who, by their demonstrated interest or activity, could be expected to be interested in the WIPP. The time provided for comment on the draft statement was extended to 141 days.

Six public hearings on the proposal were held in Idaho, New Mexico, and Texas as follows:

Location	Date
Idaho Falls, Idaho	June 5, 1979
Albuquerque, New Mexico	June 7 and 8, 1979
Carlsbad, New Mexico	June 19, 1979
Odessa, Texas	October 1, 1979
Hobbs, New Mexico	October 2, 1979
Santa Fe, New Mexico	October 5, 1979

At these hearings, 167 persons presented oral statements. In addition, 97 letters were received as part of the record of public comment.

Chapter 15, "Public and Agency Comments," summarizes the issues raised in the comments received--whether in writing or in oral statements--from Federal, State, and local agencies and from the public. It also tells how this final environmental impact statement has been revised in response to these comments.

REFERENCE FOR CHAPTER 14

DOE (U.S. Department of Energy), 1980. Statement of Position of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (NRC Waste Confidence Rulemaking), DOE/NE-0007, Washington, D.C.

15 Public and Agency Comments

This chapter discusses the substantive comments made by private citizens and government reviewers on the WIPP draft environmental impact statement (DEIS). It also provides the decisionmakers with the information they need to consider responsible opposing viewpoints.

Comments on the DEIS were obtained from the public, citizens groups, and government agencies during 7 days of public hearings and a 141-day* written-comment period. Public hearings were held in Idaho Falls, Idaho; Albuquerque (two days), Santa Fe, Carlsbad, and Hobbs, New Mexico; and Odessa, Texas. A total of 167 persons presented oral statements on the WIPP project. Ninety-three letters, several longer than 50 pages, were received during the written-comment period. Table 15-1 (page 15-65) lists the persons who presented oral statements at the public hearings, and Table 15-2 (page 15-70) lists the persons, groups, and agencies that submitted written comments.

Various agencies of the New Mexico State government, particularly the Environmental Evaluation Group (EEG), provided comprehensive reviews of the DEIS. The EEG, funded by the U.S. Department of Energy (DOE), is part of the Environmental Improvement Division of the New Mexico Department of Health and Environment—the agency charged with the primary responsibility of protecting the health of the citizens of New Mexico. The mission of the EEG is to conduct an independent technical evaluation of the potential effects of the WIPP repository on public health and safety.

The Hearings Panel** at the last three public hearings held in Odessa, Hobbs, and Santa Fe submitted a report describing significant issues raised at those hearings. The panel commented on the major problem areas in the DEIS, summarized issues raised at the hearings, and made some substantive suggestions. This report has been included in the discussions in this chapter and is reproduced in full in Appendix Q.

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*The DOE notice of availability of the DEIS was published in the Federal Register on April 18, 1979 (Vol. 44, p. 23117). This notice allowed a 79-day written-comment period (through July 6, 1979). On July 2, 1979, the DOE published a supplemental notice that the written-comment period was extended to September 6, 1979 (Federal Register, Vol. 44, p. 38620) for a total of 141 days. However, all written comments received through the end of the public hearings (October 5, 1979) were considered in this final environmental impact statement (FEIS).

**The panel for the hearings consisted of Robert W. Hamilton, Vinson and Elkins Professor of Law at the University of Texas School of Law, the presiding officer; Dr. John Cumberland, Professor of Economics at the University of Maryland; and Dr. Irwin C. Remson, Professor of Applied Earth Sciences and Professor of Geology at Stanford University.

To put all the comments in an easily accessible form, each oral statement (recorded by a certified stenographer) and letter was analyzed in detail, and comments on specific issues were identified. Each distinct comment was categorized by up to three keywords (Table 15-3, page 15-75) and placed into a computerized indexing system to facilitate the rapid retrieval of all comments dealing with a specific topic (e.g., transportation accidents). This system allowed the preparers of this FEIS to consider all comments received on a topic while revising the parts of the document dealing with that topic.

To consolidate the voluminous response to the DEIS, the comments have been grouped into 30 major issues that cover all the substantive comments received. Each of these issues deals with one or more different topics, which are listed in this chapter as part of the discussions of the 30 issues. This chapter summarizes the issues and the responses of the DOE to the comments. The complete responses have been prepared as changes to the text of the DEIS; they therefore appear in the main text of the FEIS. For example, the State of New Mexico commented that emergency-response procedures during transportation accidents were not adequately addressed in the DEIS. In response to this comment, a new section (Section 6.11) has been prepared to discuss the current status of emergency preparedness and the DOE's commitments relative to the WIPP project.

This chapter is divided into 31 sections. Each section summarizes one issue; it describes the comments received on the issue, summarizes the DOE's response, and gives references to the sections of this FEIS in which the resolution is reflected. Sections 15.1 through 15.8 discuss the scope and the objectives of the WIPP project; the benefits, costs, and schedule alternatives; compliance with environmental regulations; the suitability of salt as a disposal medium; and the selection of the Los Medanos site.

Sections 15.9 through 15.13 discuss the geologic and hydrologic suitability of the Los Medanos site, including the related issues of conflicts with natural resources, borehole location and plugging, and long-term waste isolation. Sections 15.14 through 15.21 discuss the design and operation of the WIPP facility, including waste characteristics and processing, experimental programs, routine releases, the radiological effects of operational accidents, waste retrievability, and decommissioning and long-term monitoring. Sections 15.22 and 15.23 discuss the transportation of waste to the WIPP under normal and accident conditions. Issues attendant to the operation of the WIPP and the transportation of waste (i.e., emergency-response planning, security, insurance and liability, and the health effects of radiation exposure) are discussed in Sections 15.24 through 15.27.

Sections 15.28, 15.29, and 15.30 discuss socioeconomics, archaeological resources, and ecology and land use. Section 15.31 discusses the comments that dealt with topics considered to be outside the scope of the FEIS. For example, comments on the advantages and disadvantages of pursuing a license from the U.S. Nuclear Regulatory Commission (NRC), the advantages and disadvantages of the expanded use of nuclear energy, the preferred procedure for State involvement in the WIPP project, and similar topics are referenced in this chapter but are not treated elsewhere in the text. Comments dealing strictly with the previously proposed emplacement of spent fuel are discussed briefly in Section 15.31.7.

Table 15-4 (page 15-76) lists the substantive issues and the letters and oral statements providing comments.

Appendix P of this document reproduces in full the comments received from various Federal agencies and the cover letters from all official responses from the various states. Copies of all comments received, including the transcripts of the public hearings, are available for inspection at each of the DOE public reading rooms listed at the beginning of Appendix P.

15.1 SCOPE AND OBJECTIVES

The issue of the scope of the WIPP project, its programmatic objectives, and its relation to the recommendations of the Interagency Review Group (IRG) on Nuclear Waste Management was commented on in 11 letters and 4 oral statements. The comments are summarized below; a response to each issue is also provided.

1. Issue. The derivation of the programmatic objectives is not explained. The stated programmatic objectives have no clear policy basis.

- The Natural Resources Defense Council (NRDC) said that there is no logical derivation of the programmatic objectives in the DEIS, and the stated programmatic objectives are used to justify proceeding with the WIPP project at the Los Medanos site.
- The NRDC said further that programmatic objectives should be derived from the national waste-management policy, which will be established by the President on the basis of recommendations presented in the IRG report and other documents.
- The Southwest Research and Information Center (SWRIC) and the State of California said that the alternatives are based on programmatic objectives, which is unacceptable. The NRC does not accept the programmatic basis for a comparison of alternatives.

Response. The programmatic objectives outlined in Section 2.3 of the DEIS were derived primarily from the IRG report. This material has been eliminated from the FEIS as inappropriate in a document concerned with environmental matters. Programmatic considerations related to the WIPP project and the National Waste Terminal Storage (NWTS) program described in Chapter 2 reflect the President's program for the management of radioactive waste.

2. Issue. The U.S. Department of the Interior (DOI) asked that the impact statement explain the role of the WIPP project in relation to the national waste-management program. It said that the WIPP project should be evaluated in light of the IRG report.

Response. The WIPP project is not part of the NWTS program for the disposal of commercially generated high-level waste (HLW), but the NWTS program has provided information for evaluating the alternatives to the WIPP. The site and preliminary-design validation (SPDV) program for the WIPP facility and other WIPP experiments could provide useful data for the NWTS program. Without licensing and an intermediate-scale facility (ISF) for spent fuel, the authorized WIPP facility does not fulfill all the objectives for an early TRU-waste repository recommended by the IRG. If a TRU-waste repository is not constructed at the WIPP site, the site could be considered for a future licensed commercial-HLW repository.

3. Issue. The EIS should clearly state the relative importance of the programmatic objectives.

- The NRDC and the State of California said that the programmatic objectives should not be weighted equally but rather should stress environmental protection and safety. These objectives must recognize the uncertainties regarding disposal in geologic media.

Response. In the material eliminated, the overall goal "to isolate wastes safely" dominated. The programmatic objectives were not of equal weight.

4. Issue. The EIS should clearly define the scope of the WIPP project. The scope should be changed.

- The scope of the project without the intermediate-scale facility (ISF) for spent fuel should be defined. Governor King of New Mexico said that, without an ISF, the urgency of the WIPP diminishes. Similarly, the NRC stated that the programmatic advantages of WIPP diminish without an ISF.

- The development of the WIPP for TRU-waste disposal only will not facilitate the development of HLW repositories. The Environmental Protection Agency (EPA) said that data acquired from the WIPP may not be applicable to other media, although the WIPP should provide valuable generic data on waste disposal in salt.

- The Sierra Club said that the scope of the project as stated is too large for the status of present knowledge on radioactive-waste disposal.

- Several groups and persons said that the area of land occupied by the WIPP project seems suspiciously large for the scope of the project.

Response. The scope of the WIPP project, as now authorized, is given in Section 2.1. Not including an ISF reduces the programmatic and potential technical benefits of the project. The DOE agrees with the EPA that the WIPP program may not produce large quantities of data applicable to other media, but it could provide useful generic data on waste disposal in salt.

The FEIS describes the environmental impacts of the WIPP project as authorized. Any change in the plans described in this FEIS that would increase the magnitude, significance, or duration of adverse environmental consequences would require additional environmental evaluation.

5. Issue. Industry representatives said that successful waste disposal hinges on institutional issues and that the data acquired from the WIPP would be useful in the management of other hazardous waste, not necessarily radioactive.

Response. As discussed under items 2 and 3 above, the construction and operation of a TRU-waste repository would produce useful data for planning, designing, and operating geologic repositories for radioactive and nonradioactive waste (see Section 3.6.2).

15.2 BENEFITS, COSTS, AND SCHEDULE

The benefits, costs, and schedule for the WIPP project received attention in 23 letters and 19 oral statements. The substantive issues raised are summarized below and a response to each issue is provided.

1. Issue. The DEIS should compare the risks of the WIPP, and radioactive-waste-disposal in general, with other risks accepted by society. The Atomic Industrial Forum specifically asked for a comparison of radioactive-waste-disposal with the disposal of toxic and hazardous nonradioactive waste.

Response. The FEIS provides input to the decision on which of the alternatives developed in Chapter 3 is most appropriate. While a comparison of the risks entailed by the WIPP with other risks accepted by society could provide perspective, the risks of developing the WIPP, or other projects for the disposal of radioactive waste, are independent of these other risks accepted by society. Accordingly, a comparison of these risks is not included.

2. Issue. The Americans for Rational Energy Alternatives (AREA), the Southeastern New Mexico Economic Development District, and a few private citizens said that the DEIS concentrates on adverse environmental impacts and underestimates the socioeconomic and institutional benefits that may accrue from the development of the WIPP facility. AREA also said that the adverse effects of delaying the project are not addressed.

Response. The EIS generally concentrates on adverse impacts because they are the environmental cost of the WIPP project. Nevertheless, positive impacts on the local economies and institutional gains from each of the alternatives are addressed.

3. Issue. The cost of the WIPP is very high, especially in comparison with the much lower cost of leaving the waste at the Idaho National Engineering Laboratory (INEL).

- The NRDC requested consideration of the cost of proceeding prematurely with a project that may not be technically feasible.
- The Sierra Club, the State of California, and other groups and persons said that the cost of delay does not justify proceeding with the WIPP now. Using inflation to artificially increase future costs is not realistic; constant dollars must be used for meaningful cost comparisons.
- The NRC requested that the derivation of the cost of delay be reported.

Response. The DOE agrees that the monetary costs of proceeding with the WIPP facility would be high when compared with the costs of retaining the waste in surface storage at the INEL. However, the alternative of no action is unacceptable in the long term. The costs of disposal in the first HLW repository are less than those of disposal in a separate repository.

The majority of the technical community believes that the technology exists to proceed in a step-wise conservative fashion with isolating waste in a geologic repository. Proceeding with the SPDV program would reduce the risk of a premature expenditure of funds, whether alternative 2, 3, or 4 was implemented and the Los Medanos site was to be considered further.

The cost of stopping and restarting the WIPP project is given in the DEIS as $278 million; all but $25 million of this is due to inflation (at 8%).

4. Issue. The cost of a repository in an alternative geologic medium could be much lower.

The NRC requested that a quantitative cost-benefit analysis of all alternatives be included, noting that the alternative that combines a TRU-waste and an HLW repository (alternative 3 in the FEIS) would produce a large cost savings.

Response. Because bedded salt is a "soft" rock that can be mined by continuous-mining methods, the cost of a repository in an alternative medium like granite or basalt ("hard" rocks that must be blasted) may, in fact, be higher than the cost of a repository in salt. No savings would be expected from abandoning the WIPP project and proceeding with an alternative site for a dedicated TRU-waste repository. As indicated in Section 4.3, combining TRU-waste and HLW repositories could result in a construction-cost savings of 7% to 17% and in an operating-cost savings of 10% to 20%, in comparison with the costs of separate facilities.

5. Issue. The emphasis placed on removing waste from the INEL should be changed. The State of Idaho encouraged the DOE to minimize the delay in removing waste from the INEL, whereas the NRDC saw no urgency in removing the waste from Idaho.

Response. The impediments to removing waste from the INEL revolve around institutional and programmatic issues currently being resolved through comprehensive national program planning. It is not clear that the allocation of additional resources could effect an earlier removal of TRU waste from the INEL in a fashion consistent with national policy.

6. Issue. The WIPP should not proceed until the research for several candidate sites is completed.

Response. Alternatives 3 and 4 involve a delay in the demonstration of the disposal of defense TRU waste until several candidate sites are identified and characterized.

7. Issue. The New Mexico Department of Finance and Administration and several public-interest groups questioned the timing of the WIPP when compared with the timing of current research studies.

Response. The WIPP project is an extension of the ongoing research studies in salt. Because waste would not be received at the WIPP facility before 1986, the research studies critical to the WIPP operation (e.g., demonstration of retrievability) will be completed before the time their results would be needed. The research studies critical to long-term waste isolation (e.g., borehole plugging) can be expected to be completed before WIPP decommissioning (about the year 2010).

15.3 ALTERNATIVES

Among the issues that elicited the greatest response to the DEIS was the discussion of alternatives to the proposed action identified in that document (i.e., construction of the WIPP repository in southeastern New Mexico for the disposal of defense TRU waste, for the disposal of up to 1000 assemblies of spent fuel in an ISF in the WIPP, and for experiments with high-level waste). Since the DEIS was published, legislative action and Presidential policy have made the inclusion of an ISF as a part of the WIPP project infeasible as a near-term option (Section 15.31.7). Comments on the issue of alternatives appeared in 36 letters and 28 oral statements; they can be grouped into 6 categories and are summarized below. A response to each issue is also provided.

1. Issue. The DEIS does not adequately justify proceeding with the WIPP project now. Since alternative sites in other geologic media have not been examined to the same degree as the bedded salt of southeastern New Mexico, a rigorous examination of impacts, as required by the National Environmental Policy Act, has not been performed.

- The NRDC and several other groups and persons recommended research in candidate sites in other geologic media before proceeding with a radioactive-waste repository. Qualifications and selection criteria need to be established first so that a technically conservative course of action, including a comparison of media and sites, can be pursued.

- The Sierra Club said that studies of alternative media and sites are not sufficiently advanced to allow an adequate comparison of alternatives.

- The EPA said that insufficient alternatives for TRU-waste disposal in other media are presented to meet the requirements of the National Environmental Policy Act.

- The U.S. Department of Health, Education and Welfare recommended including a summary matrix of the environmental impacts of the alternatives. The State of New Mexico and the SWRIC said that the DEIS did not present a comparison of alternatives based on environmental considerations as required by the Act.

- The State of New Mexico requested an analysis and comparison of the impacts of transportation for alternative sites.

- The State of Colorado said that the WIPP project appears to be proceeding too quickly and that additional research is required before proceeding.

- The NRC staff, saying that the DEIS does not present the basic information needed for a reasonable comparative assessment of alternatives, recommended a rigorous comparative analysis. The NRC concluded that, without an urgent need for geologic disposal of the TRU waste at the INEL, the DEIS fails to make a strong case for proceeding with the WIPP before the analyses of alternative geologic media and alternative sites are completed.

- The DOI characterized the DEIS as inadequate because of the omission of a credible discussion of alternative geologic media.

- The SWRIC said that possible sites in dome salt, basalt, granite, tuff, shale, other rocks, deep ocean sediments, as well as other disposal technologies have not been adequately evaluated and that the FEIS should present a very thorough discussion of the problems and possibilities of various alternative disposal methods and sites.

Response. As indicated in the introduction to Chapter 4, the alternative of constructing and operating the WIPP at the Los Medanos site for demonstration disposal of defense TRU waste and for research and development with defense high-level waste is the most thoroughly studied of all the alternatives considered. While the NWTS program is advancing the state of knowledge on other sites in alternative media (Section 2.2.4), at present it is necessary to rely on generic information in evaluating the environmental impacts of alternatives 3 and 4. These generic data, particularly the DOE draft environmental impact statement on the management of commercially generated radioactive waste, form the basis for the comparison of environmental impacts of alternatives in Chapter 4.

Lacking identification and environmental analyses of specific alternative sites, the analyses of alternative 2 focus on the acceptability of the Los Medanos site for the WIPP mission rather than its comparison with other sites. Alternatives 3 and 4 both provide for a comparison of the Los Medanos site with two other sites at a future date. Implementation of either alternative would require new EISs for site banking and selection. Only sites with favorable characteristics, comparable to those of the Los Medanos site, would be considered for selection in either of the delay alternatives (3 or 4).

2. Issue. Until more research on the behavior of radioactive waste in geologic media can be performed, the WIPP should serve a research function only and not include the long-term disposal of radioactive waste.

- The State of Ohio recommended designing the WIPP only for contact-handled TRU waste, and, if results prove satisfactory, later adding the capability for disposing of remotely handled TRU waste.

- The State of Florida and several groups expressed their support for the WIPP as a research-and-development facility only. The Sierra Club added that the scope of the WIPP project is too large for the present state of the art.

- The NRDC, the State of California, and an industrial group recommended including the alternative for WIPP as a research-and-development facility only. The NRDC suggested further that an evaluation of alternative media for this facility also be included.

Response. A discussion of the options available for implementing the research-and-development mission of the WIPP has been added to the FEIS (Section 3.6.2). The greatest drawbacks of the stand-alone research-and-development facility are the failure to provide for the disposal of the TRU waste in Idaho and the high cost; surface facilities, shafts, and much of the underground area (i.e., main entries and drifts) would be required whether a permanent repository or a stand-alone experimental facility is constructed. Because the WIPP project includes initially retrievable storage for all TRU waste and only short-term experiments with defense high-level waste, the WIPP is a conservative step in the management of radioactive waste.

The question of developing research-and-development facilities in other geologic media is not covered in the WIPP FEIS. These facilities are being considered in the NWTS program.

3. Issue. The WIPP project should proceed as outlined in the DEIS. Less ambitious alternatives, such as the no-action alternative, are not acceptable because they will not serve to advance the state of the art for radioactive-waste management.

- The State of Alaska, the Atomic Industrial Forum, and another industrial group expressed support for the WIPP project as outlined in the DEIS because this alternative will advance the state of the art for radioactive-waste management.

- Other industrial groups said that the Los Medanos site is acceptable and the WIPP project should proceed.

Response. Alternative 2 is consistent with legislative authorization. Legislative action has eliminated from this alternative the near-term option of an intermediate-scale facility for spent fuel. The preferred alternative is to combine WIPP activities with the first available HLW repository, which is consistent with the President's program.

4. Issue. The WIPP project should proceed as a long-term repository for defense TRU waste and as a facility for experiments with defense high-level waste. The proposal for including up to 1000 assemblies of spent fuel from commercial reactors should be withdrawn, and no commercial waste should be emplaced in the repository.

- The Americans for Rational Energy Alternatives and an individual recommended replacing the spent fuel with defense high-level waste.

- The Southeastern New Mexico Economic Development District expressed support for the WIPP as a defense-waste repository and a small facility for experiments with commercial high-level waste.

- The State of California said that the operation of a TRU-waste repository in conjunction with a research-and-development facility would appear to provide useful design information and operating experience.

Response. The authorized WIPP mission includes the demonstration of the disposal of defense TRU waste and an experimental facility for high-level defense waste. A conservative step is being taken in that short-term experiments with defense high-level waste would be performed before developing a full HLW repository.

5. Issue. Several commentors argued that the DEIS failed to treat a number of reasonable alternatives.

- The SWRIC and the NRDC recommended examining alternatives for a stand-alone research-and-development facility (see item 2), for an unlicensed repository, and for an intermediate-scale facility for spent fuel in the first available HLW repository.

- The NRC recommended that the risk presented by the no-action alternative be clarified and that the merits of emplacing TRU waste in the first available HLW repository be reevaluated.

- The NRC and three persons requested further analysis and discussion of the alternatives to geologic disposal. Specific methods mentioned included ejection into space, disposal in deep ocean sediments, and controlled surface storage.

- Two commentors said that the alternative of using the Nevada Test Site as a repository site was not addressed.

Response. Chapters 2 and 3 of the DEIS have been restructured, and additional information is provided in the FEIS to define more clearly the available alternatives. Chapter 2 summarizes the process that led to the Los Medanos site in southeastern New Mexico. Chapter 3 includes discussions of alternative disposal methods (e.g., ejection into space, disposal in deep ocean sediments), alternative media, alternative sites in bedded salt, and alternative sites in the Delaware basin.

The Nevada Test Site is being considered as a potential repository site under the NWTS program.

The present authorizing legislation does not permit the consideration of licensing the WIPP.

6. Issue. The reasons for selecting the WIPP project as the preferred alternative in the DEIS are not clear.

- The NRC asked for an explanation of why DEIS alternative 6 (FEIS alternative 4), which involves delaying the construction of a TRU-waste repository while other site-qualification studies are conducted in alternative media, is not preferred.

- The NRC said that a repository site in basalt may be more attractive because of the greatly reduced probability of deep exploratory drilling in the future. Conversely, an industrial commentor suggested evaluating a long-term drilling-intrusion scenario for other media as well. One person said that, since the transportation routes from Idaho to Hanford, Washington, are much shorter than those to the WIPP, the Hanford site should be preferred.

Response. Alternative 2 is now termed the authorized alternative. Alternative 3 is the preferred alternative; it is the one that is consistent with the President's statement of February 12, 1980.

15.4 CONTINUED WASTE STORAGE AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Comments on the continued storage of defense TRU waste at the Idaho National Engineering Laboratory (INEL) were presented in 10 letters and 9 oral statements. These comments are summarized below. A response to each issue is also provided.

1. Issue. The NRDC said that there is no near-term need to build an ultimate disposal facility for the TRU waste stored at the INEL; the State of California agreed, stating that the risks of proceeding too quickly with permanent waste disposal without evaluating other alternatives far outweigh the risks of leaving the waste in Idaho for the time being.

The Sierra Club and two persons said that the INEL TRU waste should be left in interim storage because a considerable amount of money could be saved by leaving the wastes in Idaho and formulating a permanent solution.

Response. As discussed in Sections 1.4 and 4.1, and Appendix N, the environmental consequences of continued TRU-waste storage at the INEL are not significant in the short term. The radiological consequences of continued waste storage under routine and accident conditions are smaller than those of corresponding conditions during TRU-waste transportation and during WIPP operations (Sections 4.1 and 4.2), barring a natural catastrophe like a volcanic eruption at the INEL.

The total cost for any of the options for improving waste containment and continued waste storage at the INEL (Appendix N, Section N.3.5) is less than that of constructing and operating the WIPP facility (Section 9.4.1.1). However, these costs are for interim storage, whereas the cost of the WIPP is for demonstration disposal. Continued waste storage at the INEL presents unacceptable long-term risks.

2. Issue. Governor Kirk and U.S. Senator McClure of Idaho and three other persons said that the facilities at the INEL are inappropriate for long-term storage because of the proximity of important aquifer systems and the possibilities of natural (volcanic) events or intrusion by people.

- Of particular concern to these commentors is the disposal of the TRU waste that was buried at the INEL before 1970.
- The NRC and an industrial representative recommended that other scenarios for radioactivity-release mechanisms at the INEL be considered. All wastes, including the buried waste, should be removed.
- The State of Ohio said that leaving the waste in Idaho would contribute little to solving the problem of radioactive-waste management.
- An industry group recommended examining the effects of deteriorating waste containers at the INEL.

Response. In the long term, continued waste storage at the INEL presents unacceptable environmental risks, principally because of the potential for volcanic events and human intrusion (Section 4.1 and Appendix N). More detailed analyses of the consequences of the various alternatives are being performed by the DOE, to be included in an environmental impact statement for the long-term management of the TRU waste buried at the INEL.

In 1970, the Atomic Energy Commission, a predecessor of the DOE, stated its intention to remove the TRU waste at Idaho, and this remains one of the DOE's near-term objectives. The waste containers in storage at the INEL are deteriorating with time, and a long delay in retrieving these containers would create the need for repackaging more of the waste. No significant consequences of waste-container deterioration are seen in the near term.

3. Issue. The NRDC and the SWRIC recommended that the FEIS include a realistic evaluation of the time required for preparing the TRU waste stored in Idaho for shipment and how this time requirement relates to the various alternatives considered, particularly those involving delay.

Response. The time required for preparing the INEL TRU waste for shipment depends on the degree of waste processing. If the decision is made not to process TRU waste before shipment to the WIPP, the waste would be available almost immediately. DOE schedules show that waste-processing facilities could be constructed at the INEL by 1985; hence, processed waste would be available in 1986. It is not possible to predict delays, if any, in these schedules.

15.5 COMPLIANCE WITH THE NATIONAL ENVIRONMENTAL POLICY ACT

The compliance of the WIPP DEIS with the National Environmental Policy Act (NEPA) was commented on in 13 letters and 2 oral statements. The comments are summarized below. A response to each issue is also provided.

1. Issue. The DEIS does not comply with NEPA requirements because the alternatives are inadequately evaluated.

- The NRDC said that the DEIS does not meet NEPA requirements because it does not present consequence analyses for alternative sites.
- The DOI, the SWRIC, the Sierra Club, and the State of California said that alternatives are not evaluated on an environmental basis.
- The NRC said that a proper NEPA analysis requires a "rigorous comparison of the long-term impacts of TRU-waste repositories at alternative sites" and that the NRC does not accept the programmatic basis for selecting an alternative.

Response. The DOE recognizes that studies of the Los Medanos site are much further along than those of other sites. A comprehensive assessment of long-term waste isolation has been performed only for the WIPP at the Los Medanos site. A mathematically rigorous comparison of alternative sites is not available, and generic data must now be used. Selection of either of the delay alternatives (3 or 4) would allow this rigorous comparison, as site-specific long-term waste-isolation assessments would be performed for other sites.

The results of the WIPP long-term waste-isolation assessment demonstrate that the long-term radiological consequences of the WIPP repository at the Los Medanos site are insignificant. Since alternatives 3 and 4 are decisions not to select a site or define a specific facility at this time, the comparison of environmental impacts is based on generic estimates rather than specific evaluations. The draft EIS on the Management of Commercially Generated Radioactive Waste and the Statement of Position of the Department of Energy on Proposed Rulemaking on the Storage and Disposal of Nuclear Waste provide assurance that minimal environmental impacts, comparable to those determined for alternative 2, would result from repositories at other sites. The available alternatives to the authorized WIPP project are developed in Chapter 3, and their environmental impacts are examined in Chapter 4.

2. Issue. The DOI and a citizens group said that compliance with NEPA is questionable because the format of the DEIS is confusing and disorganized and the language is too technical. The DOI added that environmental impacts should be better identified and quantified.

Response. Many sections of the FEIS have been reorganized to clarify the information presented and to make the document more readable. A glossary is provided with definitions of technical and unfamiliar terms.

3. Issue. The DEIS does not comply with NEPA because it does not adequately address various impacts and mitigating measures for the proposed WIPP project.

- The State of New Mexico said that the discussions of transportation, emergency response, and socioeconomics were inadequate and stated that supplements to the DEIS should be prepared.

- The State of New Mexico and the EPA said that commitments to mitigation measures are inadequate.

Response. The specific areas of concern of the State of New Mexico have received added attention in preparing the FEIS. The analyses of the potential consequences of waste transportation and socioeconomic impacts have been refined and clarified in the FEIS (Chapter 6 and Section 9.4, respectively). Discussion of the issue of emergency-response planning has been added in Sections 6.11 and 8.12.

The DOE commitments to measures that will avoid or mitigate potential adverse impacts are detailed in Section 9.6. This section brings together in one place information reported in various sections of the DEIS.

15.6 REGULATIONS GOVERNING THE WIPP REPOSITORY

Comments on various regulatory aspects of the WIPP project were received in 11 letters and 7 oral statements. These comments are summarized below. A response to each issue is also provided. In addition, comments received in six of the written letters and six of the oral statements dealt with the regulations governing the transportation of radioactive waste. These comments are discussed in Section 15.22.

1. Issue. The DOI and several public-interest groups said that the development of the WIPP project must take into account EPA regulations for radioactive-waste repositories. Since the EPA regulations have not yet been promulgated, the WIPP project may need to be delayed until they become available.

Response. The design of the WIPP to date has been consistent with the EPA draft criteria for radioactive wastes published in the Federal Register on November 15, 1978. If alternative 2 is chosen, the WIPP design will be modified as necessary to comply with legally applicable EPA rules and regulations promulgated in the future.

2. Issue. The State of New Mexico said that the construction, operation, and decommissioning of the WIPP repository should be performed in compliance with all applicable environmental regulations of the State of New Mexico.

Response. As described in Chapter 14, the WIPP project would comply with all applicable State environmental regulations.

15.7 SALT-BED SUITABILITY

Eighteen letters and 16 oral statements raised the issue of the general suitability of any salt deposits for waste disposal, not specifically the salt at the Los Medanos site. The comments that referred specifically to the suitability of the Los Medanos site are discussed in Sections 15.9, 15.10, and 15.11.

1. Issue. Several commentors, including the States of New Mexico and California, the NRDC, and the SWRIC, raised questions about the suitability of salt as a host rock for radioactive waste. Some of these and other commentors said that salt has many disadvantages as a disposal medium: high solubility; low capacity for radionuclide sorption; uncertain ionic transport; loss of mechanical strength, particularly on exposure to heat; plasticity; corrosiveness; and the release of water on exposure to heat.

- The DOI pointed out that areas containing salt deposits often contain minerals and hydrocarbons, which may attract drilling or mining.
- Several groups and persons said that the suitability of salt has been questioned by the National Academy of Sciences, the U.S. Geological Survey (USGS), and the EPA.
- A few groups said that waste containers emplaced in the salt of the Asse repository in Germany show corrosion.

Response. The analyses in the DEIS and the FEIS address the effects of these general disadvantages at the Los Medanos site. Instead of relying on the generic properties of bedded salt, however, the analyses use the specific characteristics of the Los Medanos site and the surrounding area. The unfavorable properties cited by the commentors would be more serious if water entered the repository or if the heat and radiation emitted by the emplaced waste were to weaken the salt. Of these two possibilities, this impact statement treats only the first--water intrusion--in detail (Section 9.7.1) because TRU waste does not produce enough heat or radiation to weaken the salt bed. Section 9.7.2.1 describes the minor effects expected from heat; it reports calculations of upper bounds to those effects. Also, Section 9.7.3 discusses briefly some other effects that might be important in a repository for high-level waste.

The general objection that salt deposits are sometimes near mineral resources is evaluated in this document as it applies specifically to the Los Medanos site (Section 9.2.3).

The corrosion observed in the Asse repository is not severe enough to affect the retrievability of contact-handled waste over the period required for the WIPP repository. As explained in Section 9.7.3.3, retrievability is the principal reason for requiring that the waste containers resist corrosion after emplacement.

2. Issue. The NRC said that one advantage of salt as a disposal medium is its minability without explosives; mining in alternative geologic media, such

as shale, granite, and basalt, would require the use of explosives. Mining without explosives will produce less fracturing of the medium.

Response. The advantage that salt mining does not require the extensive use of explosives is recognized. As pointed out in Sections 8.2.1 and 8.2.2.2, electrically powered continuous-mining machines would develop most of the underground workings.

15.8 SITE SELECTION

Site-selection criteria and the site-selection process were addressed in 14 letters and 10 oral statements. These issues are summarized below. A response to each issue is also provided.

1. Issue. The NRC said that the site-selection criteria were derived after the site was selected. The Sierra Club and the SWRIC asserted that the site-selection criteria were formulated to fit the Los Medanos site after it was selected.

Response. The text describes the site-selection process as it happened (Section 2.2). There were no Federal regulations establishing criteria for selecting a site for a radioactive-waste repository, but there were informal criteria (Appendix D).

2. Issue. The SWRIC said that the site-selection criteria were modified during the selection process to fit the Los Medanos site.

Response. The required distance from deep drill holes was reduced from 2 miles to 1 mile midway in the process (Section 2.2.3). The 2-mile distance was originally established pending further study. When calculations became available on dissolution around an open borehole, it was found, as indicated in the text, that a much smaller distance would be sufficient.

3. Issue. Several commentors said that the site-selection criteria are inadequate.

- The NRC, the DOI, and the NRDC suggested that one of the criteria should be a comparison of alternative sites and media.
- The NRC suggested the following: criteria 2 and 9 (se Table 2-2) should consider future exploration, criterion 5 should consider future increases in dissolution rates as a result of changes in the climate, and criterion 9 should consider future growth as well as the present population. The NRC also suggested that NRC power-plant-siting criteria be considered.
- The DOI recommended reviewing the site-selection criteria by the systems approach.
- Two groups and one person said that political expediency is not a valid site-selection criterion.

Response. The NRC's suggestions are dealt with as follows: Future exploration for minerals at the site is discussed in Sections 9.2.3.7 and 9.6.5. The possible consequences of that exploration, if not done with care, are discussed in Section 9.7.1. As to changes in the rate of advance of the dissolution front, the present estimates in Section 7.4.4 are based on geologic evidence that spans several pluvial cycles and hence includes the effects of changes in climate. The suggestion that future as well as present populations be considered is valid, although extrapolation into the future is very uncertain; the subject is referred to in Appendix H, Section H.8.2. Finally, the NRC power-plant-siting criteria are only partly applicable; power plants and deep geologic waste repositories are not alike.

Comparison with alternative sites has been made insofar as present knowledge permits (Chapter 4). Demand for a more detailed comparison represents a preference for alternative 3 or 4 and a rejection of alternative 2.

4. Issue. The NRC asked for a better explanation of the site-selection process and especially of the site-elimination stage.

Response. The criteria and the process that led to the selection of the Los Medanos site are discussed in Section 2.2.

5. Issue. The NRDC and other commentors said that some of the site-selection criteria are not met by the Los Medanos site.

- The mineral potential at the site conflicts with the low-mineral-potential criterion. The NRC said that stage 3, site studies, should involve a comparison of alternative sites, which was not done.

- The Sierra Club suggested that three of the five IRG Subgroup report guidelines may not be satisfied: simple hydrologic system, high sorptive capacity in the host rock, and due consideration of mineral resources.

Response. Some of the criteria are not fully met, but these criteria are statements about desirable, rather than obligatory, factors. For example, one of the criteria that was not strictly followed was the avoidance of mineral resources. It is a purpose of this EIS to disclose this conflict fully, so that it can be considered in the decision of whether to proceed with the WIPP at the Los Medanos site. As to the two other IRG Subgroup guidelines, the DOE disagrees with the Sierra Club. The hydrologic system is as simple as any real hydrologic system is ever apt to be; indeed, the DOE considers the hydrologic system of the Los Medanos site one of its advantageous features. High sorptive capacity is desirable along the entire path of potential transport into the biosphere, the main part of which in this case is not salt; this guideline is well met by the Los Medanos site.

6. Issue. The State of New Mexico recommended that other agencies and experts comment on the site-selection criteria.

Response. Many groups and organizations have reviewed the site-selection criteria and have come up with similar lists. A detailed analysis of 8 such lists and 51 related papers has been prepared by the New Mexico Environmental Evaluation Group.

7. Issue. Several commentors, especially the EPA, requested that the FEIS clarify the adequacy of the site and the selection process.

- The EPA said that the low population density of the area is an advantage for the Los Medanos site.
- Two industrial representatives said that the Los Medanos site appears satisfactory for isolating waste.
- One person asserted that the DEIS does not support site suitability.

Response. The Los Medanos site has not been finally selected. This FEIS provides input to decisions on further investigation of the Los Medanos site by exploratory shafts and underground facilities to verify its adequacy.

15.9 GEOLOGIC SUITABILITY OF THE LOS MEDANOS SITE

Comments on the geologic characteristics of the Los Medanos site--such as faulting, seismicity, salt impurities, and climatic changes--were received in 24 letters and 9 oral statements. These issues are summarized below. A response to each issue is also provided.

1. Issue. Several commentors requested that the FEIS present more details on the geology and geochemistry of the salt deposits.

- The New Mexico Environmental Evaluation Group requested that the FEIS present a more detailed analysis of the effects of the presence of impurities like clay, anhydrite, and polyhalite on the physical, hydrologic, thermal, and strength characteristics of salt.
- The State of New Mexico also said that additional geochemical interactions must be considered if significant chemical and mineral impurities are present.
- The NRC recommended the inclusion of a map showing the salt mines in the area that were examined to check subsurface conditions.

Response. The geochemistry (including the effects of impurities) of salt deposits and the interaction of salt with waste (and the effects on repository properties) continue to be areas of investigation. The information given in the DEIS on these subjects has been updated in this FEIS (Section 9.7.3). These subjects are more important for heat-producing high-level waste, where the interactions are expected to be more significant than for TRU waste. A part of the WIPP program is the in-situ experimental investigation of these effects.

The general locations of potash mines within 10 miles of the center of the Los Medanos site are shown in Figure H-4 of Appendix H. Years of experience by potash companies and investigators in various agencies indicate the continuity and predictable gentle structure of the McNutt Potash Zone.

2. Issue. Several groups and persons requested that the presence of faulting and an anticline system at and near the site be more clearly discussed.

- The SWRIC said that the presence of faulting renders the site unsuitable for waste disposal.

- The NRDC said that faulting may provide pathways for brine intrusion.

Response. Section 7.3.5 discusses the previously inferred fault and anticline at the northern edge of control zone II and includes more recent data.

Hypotheses about salt dissolution by water penetrating through fractures are addressed in Section 7.4.4.

3. Issue. The NRC, the State of Florida, and several citizens groups and individuals suggested that tectonic stability may change with time; they requested a discussion of the effects of possible changes on the long-term integrity of the repository. In addition, the NRC requested that the FEIS address long-term effects of the maximum credible earthquake.

Response. The tectonic stability of the site is discussed in Sections 7.3.2 and 7.3.5 in terms of the nature and the age of tectonic and nontectonic structures at and around the site. The seismologic information presented in Section 7.3.6 indicates that the site is in an area of low seismicity. Expected changes at the Los Medanos site are outlined in Section H.8.4 of Appendix H.

4. Issue. Several commentors requested a clarification or reevaluation of the seismicity of the site.

- The NRC and several persons suggested that the region of the site may not be as seismically inactive as indicated; greater activity is suggested by the 1978 earthquakes in nearby areas of Texas.

- The NRC requested a discussion of the plate tectonics of the region.

- The NRC said that the FEIS should justify ignoring the assumption that minor shocks are associated with human activity.

- The EPA requested a discussion of the possibility of induced seismic activity from the Brantley Dam Reservoir.

- The NRC requested a more detailed discussion of how seismic survey lines were selected and data used.

- The State of New Mexico requested more information on several anomalous features identified during the seismic surveys.

- The NRC also suggested that a broader map of earthquake activity be presented to indicate the relative inactivity of the site region.

Response. The seismicity of the site is discussed in Section 7.3.6, including the historical and geologic record of earthquakes and displacements. The site is not completely aseismic; the network of seismic stations around the Los Medanos site has recently been enlarged in order to improve the data base for the slight activity in the Central Basin platform. Section 7.3.6 also discusses this implication in some detail, and the assumptions concerning it have been clarified. Any seismic activity induced by the development of the Brantley Dam project would probably be masked by seismicity induced in the region by water flooding for secondary oil recovery. Only barely detectable ground motion would be expected at the Los Medanos site.

5. Issue. The NRC requested more information on underground seismic effects and provisions for underground seismic instrumentation.

- The NRC said that an impact assessment is difficult without information on underground seismic effects, such as those expected in the mined shafts.

- Several commentors requested information on the effects of seismic rupture on groundwater, natural-gas deposits, and the integrity of the repository.

Response. Section 7.3.6 addresses the seismicity of the site, including a probabilistic analysis of the levels of ground surface motion. Section 9.5.3.1 presents an assessment of the potential seismic effects on both surface and underground structures. The details of the seismic monitoring system to be employed at the site are being developed; currently available information on seismic monitoring and expected underground instrumentation is given in Appendix J, Sections J.1.1 and J.2.1.

Section 7.3.5 reviews the geologic data that demonstrate the lack of surficial faulting within 5 miles of the Los Medanos site. The effects of hypothetical faults connecting aquifers and the repository are addressed in Section 9.7.1.

6. Issue. The NRC, the DOI, the States of New Mexico and California, and several groups and persons asked that the FEIS discuss and evaluate the effects of long-term climatic changes, such as future glaciations, global cooling, and carbon dioxide warming on geologic processes (e.g., salt-dissolution rates). The EPA said that the FEIS should indicate that Pleistocene Rocky Mountain ice sheets did not extend into New Mexico, and thus glaciation does not appear to threaten the integrity of the site.

Response. The geologic characteristics of the Gatuna Formation (Section 7.3.4) indicate the lack of glacial activity at the Los Medanos site during the Pleistocene, and Section 7.4.4 describes the effects of the Pleistocene (Gatuna time) climatic changes on the rate of dissolution.

7. Issue. The DOI requested that the FEIS discuss the possibility of discovering valuable fossils, especially in the Rustler Formation, and methods to preserve them. The National Paleontological Society suggested that, if fossils were found, a paleontologist be consulted and significant fossils collected.

Response. As discussed in Section 9.2.1, valuable fossils have been found in the lower Rustler Formation in Texas. Fossils are likely to be found only during the excavation of the shafts, if then. If any are found, paleontologists from State or regional institutions will be called in and consulted concerning possible salvage operations.

15.10 HYDROLOGIC SUITABILITY OF THE LOS MEDANOS SITE

The hydrologic characteristics of the Los Medanos site and the effects of certain hydrologic features on the suitability of the site were among the issues that elicited the greatest response. Comments were received in 24 letters and 21 public statements. The issues are summarized below. A response to each issue is also provided.

1. Issue. Numerous commentors, including the Hearings Panel, requested more information on the surface-water bodies in the region to allow an adequate evaluation of the impacts on local water resources.

- The State of New Mexico requested further evaluation of surface runoff and a description of existing and planned water-resource development in the area, including use downstream from Malaga Bend.

- The EPA suggested including a discussion of the potential for flash flooding and an evaluation of its effects on the repository.

Response. The area of the Los Medanos site contains no surface-water bodies that warrant investigation. A low-flow investigation of Hill Tank Draw, draining west into Nash Draw, is being conducted by the U.S. Geological Survey. To date, estimates of peak flows have not exceeded 2 cubic feet per second. Planned water-resource development downstream from Malaga Bend is very marginal because of the poor quality of water and the low groundwater levels. The effects of flash flooding are restricted to the Pecos River flood plain 14 miles from the site. Local sheet flooding is of minor concern because of the very permeable soils and the lack of significant drainage features. Additional protection to surface facilities could be provided by the construction of diversion channels or levees.

2. Issue. The DOI and several persons, particularly west Texas residents, said that the groundwater-monitoring system should be capable of monitoring the contamination of all potentially affected aquifers both during repository operation and after decommissioning. These same west Texas residents said that, if surface-water or groundwater systems are polluted by the WIPP through the releases of salt or radionuclides, the DOE must be responsible for the replacement of local water supplies.

Response. A monitoring program to observe changes in groundwater head and water quality would be part of repository operation and decommissioning. Observation holes would be located at strategic locations around the Los Medanos site and along the most likely flow path. A description of the hydrologic studies performed to date and an outline of further monitoring are presented in Appendix J.

3. Issue. The EPA requested that the FEIS address the potential for hydrologic changes and the transport of leached materials to Carlsbad Caverns.

Response. There is essentially no likelihood that leached materials will reach Carlsbad Caverns because of a groundwater barrier along the axis of the Pecos River and the direction of groundwater flow in shallow and deep aquifers. The data obtained to date show that the shallow-aquifer systems above the salt flow southwesterly toward Malaga Bend, where groundwater discharges along the Pecos River. The deep aquifers flow northeast toward the Capitan reef at very low flow rates.

4. Issue. The NRC, the EPA, the State of New Mexico, and other commentors said that the presence of high-pressure brine pockets in the formation immediately below the repository threatens the integrity of the repository. They requested a more complete discussion of the origin, evolution, occurrence, and potential hazards of the brine pockets.

Response. The discussion of brine pockets in Section 7.3.5 (there called brine reservoirs) has been expanded. Brine pockets have been encountered in a number of borings near the Los Medanos site. These brine pockets have all occurred in the Castile Formation below the proposed repository horizons. There are various theories about their origin and evolution. Generally, the controlling factors are the composition and the previous sedimentation rate of the overburden as well as the age and the geologic history of the affected formations. The brine pockets encountered in the Delaware basin have been associated with geologic structures in the Castile Formation and are concentrated in a belt of deformation along the Capitan reef. The Castile Formation at the Los Medanos site is essentially flat-lying, so that the probability of a pressurized Castile brine pocket at the site appears small. Even if such a brine pocket were to be present, the 700-foot layer of evaporites between the repository level and the Castile indicates that the brine pocket would have no effect on the repository.

The maximum pressure in such pockets is the overburden pressure; more usually the pressures are 80% to 90% of overburden pressure. Drilling through brine pockets at these types of pressures would produce difficult problems, but these problems can be managed through carefully planned engineering practices. Techniques for predicting encounters with reservoirs are being evaluated and tested; they include the use of seismic, geophysical, geochemical, and geologic data.

5. Issue. The EPA, the NRC, the State of New Mexico, and other commentors said that one of the major problems with the Los Medanos site is salt dissolution and its potential effects on the integrity of the repository. The comments requested that the FEIS include the following:

- More information on the processes and the rates of deep dissolution, indicating the uncertainties regarding salt-dissolution rates and in particular discussing salt dissolution below the site.

- The potential effects of boreholes (particularly old, forgotten, and possible improperly plugged hydrocarbon-exploration holes), wells, changes in hydrologic conditions, and mineral-exploration activities on salt-dissolution rates in the vicinity of the site.

Response. The discussion of dissolution in Section 7.4.4 has been extensively revised and updated. The effects of boreholes are addressed in Sections 8.11.3 and 9.7.1. Section 7.4.2 describes the potentiometric heads and other hydrologic data used to assess the effects.

6. Issue. The State of New Mexico, the Sierra Club, the SWRIC, and other commentors said that breccia pipes in the area may be deep-dissolution features that may provide pathways into the repository. These commentors requested more data on the origin, evolution, occurrence, and potential hazards of breccia pipes.

Response. Breccia pipes are reviewed in Section 7.4.4. Studies of the hydrologic characteristics of breccia pipes are continuing.

7. Issue. The State of New Mexico, the NRC, and numerous other commentors requested an assessment of the effects of climatic changes on the hydrologic characteristics of the site because climatic changes are probable during the very long time required for waste isolation. These changes could affect the hydrologic conditions, such as salt-dissolution rates, at the Los Medanos site, thus threatening the repository.

Response. Recharge areas for groundwater systems pertinent to the site are thought to be located northwest of the Capitan reef and southwest over the Capitan reef. Climatic changes that would increase the current annual precipitation twofold or threefold would not appreciably affect the present transport in aquifers unless the physical makeup of the geologic strata is also drastically changed. The aquifer systems are artesian (under pressure) and separated from each other by large thicknesses of impermeable rock. The incremental increase in head resulting from climatic changes would not change appreciably the hydrologic conditions beneath the repository. The possible effects of future climatic changes on the hydrology will be investigated further when recharge and discharge areas are verified and the hydrologic regime is more fully characterized.

8. Issue. Many specific comments made by the State of New Mexico, the EPA, the DOI, the NRC, and others suggested that the discussion of regional and site groundwater hydrology for aquifers above and below the bedded salt is inadequate for assessing the impacts of potential releases of radioactivity. Examples include the following:

- The hydrologic modeling appears to have large uncertainties.
- The FEIS should describe the regional extent of the Dewey Lake Red Beds, which are said to function as a confining feature.
- The potential effects of the Brantley Dam on groundwater systems should be evaluated.
- The FEIS should tell how the information on porosity and hydraulic conductivity was quantified and describe these terms quantitatively for various formations.
- A more detailed analysis of the Bell Canyon and the Rustler aquifers is needed to determine the potential for well-water contamination.
- The calculated water velocities in the Rustler Formation should be checked.
- More information is needed to support the assessment that groundwater is derived from rainwater; the age of the groundwater should be established.
- The hydrology should be characterized more completely to answer the question of radionuclide retardation.

Response. The hydrologic models used to characterize the Los Medanos site are based on data derived from in-situ borehole testing in over 70 wells that penetrate the aquifers of concern. The hydraulic potential, hydraulic conductivity, and storage capacity of the Magenta and Culebra aquifers of the Rustler Formation and the Rustler-Salado interface have been determined at 21 locations around the center of the site. These parameters were determined using conventional production and slug-test methods. The current estimate for porosity is based on tracer tests performed at the Gnome site near ERDA-10; this estimate will be updated as results become available from two-well tracer tests being conducted at four locations around the WIPP site (H2, H4, H5, and H6). Natural boundary conditions for the Magenta and Culebra aquifers include the Pecos River to the west and southwest, an east-west groundwater divide north of the Hobbs highway (U.S. Highway 62/180), and a southeast-northwest divide paralleling a natural ridge southeast of the site. These boundaries do not allow effects on west Texas groundwater, although west Texas surface water (the Pecos River) could be affected by releases at the Los Medanos site.

The Dewey Lake Formation is indeed a confining bed (Section 7.4.2). The formation is present throughout the region and has been found in every borehole drilled in the Los Medanos area.

The effects of the Brantley Dam on the groundwater systems beneath the site will be negligible because of its location upstream of Carlsbad, New Mexico, and outside the Capitan reef. Groundwater gradients near the dam site are southeast toward the edge of the Capitan reef shelf, then to the east from the Los Medanos site. The consequences of tectonic movement due to filling and emptying the dam will be minor and probably will be masked by seismicity induced by water flooding for secondary oil recovery.

The Bell Canyon aquifer is difficult to characterize because of the small number of boreholes that have been drilled to these depths for hydrologic investigations. The basis for quantifying the properties of the Bell Canyon aquifer has been the work of Hiss (1975); results from holes that have been tested since are in agreement with Hiss' results. In summary, flow in the Bell Canyon is to the northeast away from the Los Medanos site, with groundwater velocities of about 0.1 foot per year. The Bell Canyon brines have a potential surface throughout the Delaware basin that approximates the Rustler-Salado interface, prohibiting water-well contamination above these levels. There are no known boreholes that penetrate into the Bell Canyon or below for domestic, agricultural, or livestock use. The aquifers in the Rustler Formation have been extensively investigated in and near the site because of their role as the most likely pathway to the biosphere if there were a breach of the repository. The data discussed in Sections 7.4.2 and 7.4.3 show a large variation from place to place, as is to be expected. However, calculations using a nonadsorbing-particle tracking model indicate a path length of 15 to 20 miles and a travel time of approximately 40,000 years if the mean porosity is 10%. The particle velocities could be larger if the mean porosity were smaller, owing to substantial fracture permeability. The completion of the two-well tracer tests will answer some of the questions about the degree of fracture permeability.

Stable-isotope analyses (Lambert, 1978) show that the groundwater in the Santa Rosa, the Rustler, and the Capitan Formations comes from rainfall. The only age dating of groundwaters has been from the Capitan reef (Section 7.4.2). The ages of other formation waters are being measured.

9. Issue. Several residents of Texas asked that the region studied in the groundwater-hydrology analyses be extended to include aquifers used for water supply in west Texas.

Response. The response in item 8 above indicates that nuclide migration from the WIPP, even if the repository were breached, would not affect the aquifers important in west Texas.

15.11 RESOURCE CONFLICT

The issue of resource conflict at the Los Medanos site elicited comments in 21 letters and 12 oral statements. The comments are summarized below. A response to each issue is also provided.

1. Issue. The NRC, the DOI, the Sierra Club, and several other commentors said that conflict with resources should be considered at the site-selection level. Generic problems concerning the presence of resources may be limited to salt deposits; for example, basalt sites are not likely to be explored for oil and gas. Salt is also a resource that may be used in the future.

Response. Resources, especially potash and hydrocarbons, were considered at an early stage of site selection. The repository was located between possible trends for hydrocarbon production and outside the Known Potash District. Subsequent evaluation for both resources has resulted in the estimates given in Sections 7.3.7 and 9.2.3. If permitted by the DOE, drilling and mining in control zone IV would allow 53% of the natural gas to be produced and 85% of the potash reserve to be mined (100% of the sylvite and 73% of the langbeinite—Table 9-19). The scenarios in Section 9.7.1.6 indicate that drilling for gas and mining for potash by unsuspecting people in the future would present little or no radiation hazard to the surrounding population. Although the potential for breaching a repository by drilling may be greater in sedimentary basins than in other geologic settings, no location is immune to such hazards, and all sites must be evaluated for such breaching possibilities. Even basalt flows have been drilled to explore the sediments beneath them. The potential for the salt itself becoming an exploited resource was considered and dismissed. There are vast quantities of salt in this country that are closer to markets. The salt at the Los Medanos site has no nearby market and cannot compete economically with salt from other regions.

2. Issue. The Sierra Club, the NRDC, and numerous other groups and persons said that the denial of resources, in particular hydrocarbons and potash, is of major concern, and a waste-repository site should be located in an area where this problem does not arise.

Response. No gas and very little potash need be denied by the presence of the WIPP. The amount of resources so denied has no national significance; the impacts of such denial are discussed in Section 9.2.3. A salt repository is considered desirable because of the favorable characteristics of salt; the Los Medanos site minimizes the conflict with mineral resources while satisfying other site-selection criteria of higher priority. The long-term radiological effects of human intrusion into the WIPP repository are addressed in Section 9.7.1; these effects are seen to be insignificant when compared to radiation doses received from natural background sources.

3. Issue. The amounts of hydrocarbon and potash reserves at the Los Medanos site should be clarified. The values used for reserves and resources should be explained. Reserves should be estimated, assuming changes in price structure. The NRC and the DOI in particular made many specific comments concerning the inadequate and inconsistent presentation of information on resources and reserves.

- The uncertainties in the hydrocarbon study should be clarified. More data are needed on the hydrocarbon resources in the Pennsylvanian system.

- The FEIS should indicate that oil-and-gas companies are interested in drilling in the southwestern part of the site, as indicated by the leases in the area.

- The Gulf Oil Company said that the hydrocarbon resources were underestimated.

- The NRC made many additional specific comments on hydrocarbon estimates. It requested a precise definition of hydrocarbon reserves and resources, an evaluation of the potential for hydrocarbon reserves in the stratigraphy of the Los Medanos site and in combination stratigraphic-structural traps, an explanation of why the quantity of natural gas per well is estimated to be 1.33 to 2.09 billion cubic feet when the New Mexico Bureau of Mines and Mineral Resources estimates a range of 3.2 to 7.2 billion cubic feet, a justification of per-well reserve estimates in light of unequal well spacing, data on other hydrocarbon resource zones (as in the 1976 Sipes, Williamson, and Aycock study), and a clarification of the long-term relative importance of the hydrocarbon resources at the Los Medanos site.

- The potash reserves should be described according to standard definitions, such as the resource criteria of the U.S. Geological Survey or the U.S. Bureau of Mines.

- The langbeinite-reserve estimate should be revised to reflect recent USGS estimates (made after the open-file report used as a reference in the DEIS), which suggest that the WIPP area may represent 20% of the total U.S. langbeinite reserves, not 11.6%.

- The DOI said that the Carlsbad Potash District contains 1.4 billion tons of langbeinite resources at 6.6% K_2O weighted-average grade.

- The FEIS should describe how Agricultural and Industrial Minerals, Inc., defines the langbeinite resource and reserve values presented in its report, which is cited in the DEIS.

Response. The discussions of hydrocarbon and potash reserves in Sections 7.3.7 and 9.2.3 have been updated and rewritten. New estimates of the value of the hydrocarbon potential have been prepared; they reflect the present and expected price structure and, in particular, address the revenues lost by the State of New Mexico.

4. Issue. Several commentors, specifically the State of New Mexico and the DOI, asked that the FEIS clarify the duration of resource denial in all control zones at the Los Medanos site. In which control zones will resource

denial be temporary or permanent? If potash mining is allowed in zone IV, more than one-quarter of the langbeinite may be denied by leaving pillars to control subsidence.

Response. Drilling for oil and gas may be permitted with the approval of the DOE in control zone IV. Deviated drilling to tap the deep gas potential under zones I, II, and III may also be permitted, provided the hole is deeper than the Castile Formation before crossing into the vertical projection of zone III. The mining of potash may be permitted in zone IV using mining techniques presently employed in the Carlsbad Potash District. If allowed, there would be no restriction on the secondary mining of pillars in this zone. Future studies may indicate that the mining of potash in the inner zones represents no hazard to the repository. Since that cannot be insured a priori, at present no potash mining is to be allowed in the inner zones.

5. Issue. The State of New México and other commentors requested information on the present and projected economic (dollar) values of the mineral resources and reserves at the Los Medanos site. They said that the DEIS downplays the loss of revenues from present reserves; the FEIS should include a cost-benefit analysis comparing the WIPP and the lost resources.

- The revenues lost by mineral-lease condemnation should be estimated.
- Included in this analysis should be losses in State and local tax revenues (production taxes and corporate income taxes), losses in employment, and losses in business income from business in the State with connections to the mineral and oil industries.
- The State of New Mexico requested repayment for State revenues lost by resource denial.
- The cost differences resulting from changes in economic and social structures or improved mining methods should be evaluated.

Response. Estimates of mineral-resource economics have been prepared by knowledgeable consultants. Hydrocarbon values have been updated to consider present and future price schedules. An estimate of the revenues that might be lost to the State of New Mexico by resource denial has been added to Section 9.2.3.

6. Issue. The FEIS should consider the socioeconomic impacts of resource denial in the area; for example, if the construction and operation of the WIPP could shorten the life of langbeinite production in the Carlsbad area by about 5 years, the ramifications on the socioeconomics of the area must be evaluated.

Response. The denial of the langbeinite contained in zones I, II, and III would possibly result in adverse socioeconomic impacts more than 20 years in the future. These impacts, if they occur, would be more than offset by the beneficial socioeconomic effects of the repository.

7. Issue. The Americans for Rational Energy Alternatives and a potash-company representative said that the DEIS overestimates the impacts of resource denial and requested descriptions of alternative mineral resources. The development of improved mining techniques could allow the recovery of more minerals.

Response. Estimating future needs and extraction techniques is a difficult and imperfect art. The FEIS intentionally presents a view that tends to overemphasize the resource conflict. The United States has other potash resources, which, if developed by solution-mining techniques, will far exceed the resources present in the Carlsbad Potash District.

8. Issue. The presence of mineral resources at the Los Medanos site is a threat to the long-term integrity of the repository. EPA's draft criteria for radioactive-waste disposal say that institutional controls over the site should not be relied on for more than 100 years. These comments suggest that the FEIS should

- Consider the impacts of exploration and recovery in the future, when institutional repository controls are lost but the waste remains hazardous.

- Detail DOE restrictions and standards for continuous or drill-and-blast mining and oil-and-gas production in control zone IV.

- Describe the nature, scope, and schedule for evaluating the possibility of mineral exploitation in control zones I, II, and III.

Response. These concerns have been partly addressed in the answers to items 2 and 5. The issue of possible hazards due to human actions in the future is addressed in Section 9.7.1. A lack of resources does not protect a repository from human intrusion in the future. In fact, the duration of isolation may depend more on the effectiveness of active and passive institutional controls than on the incentive to explore a particular area at depth. A system of such institutional controls is included in the WIPP design (Section 8.11.4).

9. Issue. The FEIS should consider the effects of underground mining operations such as secondary hydrocarbon recovery, saltwater disposal, and solution mining outside control zone IV (and thus outside DOE control) on the long-term integrity of the repository.

Response. It is not considered likely that secondary recovery will be attractive for hydrocarbons near the Los Medanos site. Even if such methods were employed, the only significant effect would be the possible induction of seismic events of small magnitude. The design and operation of the repository are such that small seismic shocks will not present a hazard, and no long-term jeopardy to the repository is likely. No long-term hazards will result from the disposal of saltwater or from solution mining if they are conducted outside control zone IV.

15.12 BOREHOLE LOCATION AND PLUGGING

Five comments were received on borehole location and plugging. They are summarized below. A response to each issue is also provided.

1. Issue. The EPA and the NRC said that the problem of inadequate borehole detection is not addressed; a detailed description of a procedure to locate all boreholes should be presented.

Response. As discussed in Section 2.2.3 and Appendix D, one of the criteria governing the selection of the Los Medanos site was the absence of nearby drill holes into the salt. Part of the site-selection process was therefore a thorough search for boreholes over the New Mexico portion of the Delaware basin. Exploratory drilling in the basin began only a few decades ago, after government agencies had begun careful recordkeeping based on strict requirements for the registration of drill holes. For this reason, accurate, complete records of drilling in the Delaware basin were available for the site-selection process. These records were easy to verify because the revegetation of drill sites is slow in the arid climate of southeastern New Mexico; simple aerial surveys reveal the locations of boreholes dating back to the earliest drilling in the area. Searches of official records and actual field surveys have located all the boreholes near the Los Medanos site.

2. Issue. The Sierra Club and another group noted that no specific program for borehole plugging is given. The NRC suggested that the potential hazards be minimized by an adequate sealing program.

Response. A program for improving the methods of sealing boreholes is under way (Section 8.11.3). If the WIPP is constructed, the holes and shafts will be sealed by the techniques developed in that program when the facility is decommissioned. The DOE intends to seal all nearby deep drill holes.

3. Issue. The EPA requested a discussion of the effects of subsidence on borehole and shaft sealings.

Response. The total subsidence that will occur over the WIPP repository will range from less than 1.6 feet to zero over an area of less than 1000 acres (Section 9.7.2.2). This gentle variation in elevation is not expected to open sealed boreholes in the area, as the design of such seals would have to accommodate these types of displacement. According to the analysis of scenario 2 in Section 9.7.1, however, even fully open boreholes, which are not likely to result from either seal failure or subsidence, would not breach the repository severely enough to deliver serious radiation doses to people.

15.13 LONG-TERM WASTE ISOLATION

The long-term isolation of radioactive wastes in the WIPP repository raised comments in 18 letters and 13 oral statements. The New Mexico Environmental Evaluation Group and the NRC each forwarded numerous substantive comments. The comments have been categorized below. A response to each issue is also provided.

1. Issue. Not all credible mechanisms and events by which the emplaced waste could reach the biosphere have been examined in the DEIS; further analyses are required.

- Two commentors said that the salt itself is a resource that is likely to be extracted by solution mining after the loss of institutional controls. (One commentor, in response, said that such a scenario in southeastern New Mexico is unreasonable.)

- The NRC recommended the examination of a scenario in which salt dissolution and other events would lead to massive subsidence at the WIPP site.

- The NRC said that the maximum credible earthquake at the Los Medanos site should be examined for the possibility of its causing a release of radionuclides from the emplaced waste.

- The EPA suggested a scenario that causes changes in groundwater flow patterns resulting in radionuclide releases to Carlsbad Caverns.

- The New Mexico Environmental Evaluation Group, the Governor's Advisory Committee on the WIPP, the EPA, and a public-interest group all said that the WIPP long-term safety assessment should include a scenario in which a pressurized brine pocket in the repository dissolves wastes and is then connected to the surface through a drilled borehole or the massive fracturing of overburden rock.

- The New Mexico Governor's Advisory Committee on the WIPP recommended including a scenario in which the collapse of a breccia pipe developing through the repository results in massive fracturing and releases of radioactivity.

Response. The discussion of credible mechanisms by which emplaced waste could reach the biosphere has been somewhat expanded in the FEIS. The reasons for believing that solution mining is either unlikely or will not affect the repository are detailed in Section 9.7.1.6; a partial analysis of a brine-pocket scenario is presented in Section 9.7.1.3. The brine-pocket scenario proposed by the commentors was judged to be highly unlikely, based on the patterns of occurrence of brine pockets and the small chance of accidentally establishing a connection between the repository and the surface. All known artesian brine pockets are below the Salado.

Some results of parametric studies with the hydrologic models have been included to show that flow through the repository after a liquid-breach event is limited by the transmissivity of the aquifer to which the flow is directed; these studies support the belief that the liquid-breach scenarios typify the consequences of many different breaches caused by geologic phenomena and human activities (Appendix K, Section K.2.2). It is believed that the consequences of massive subsidence at the site are bounded by the consequences of scenario 4 (Sections 9.7.1.3 and 9.7.1.4) and that the consequences of a breccia-pipe intrusion are similar to the consequences of scenario 1 (Sections 9.7.1.3 and 9.7.1.4), in which a hydraulic communication is assumed between the Bell Canyon aquifer and the Rustler aquifers. The hydraulic head of the Bell Canyon aquifer is too small to allow direct releases of brine to the surface under the present hydrologic regime.

The underground effects of earthquakes would be less severe than surface effects during the operational phase (Section 9.5.3.1); the effects on a backfilled and closed mine would be even less severe.

The transport of radionuclides to Carlsbad Caverns by groundwater flowing through the WIPP repository is physically impossible under the present hydrologic regime. The establishment of such a flow would require a vertical displacement of the site relative to the Caverns by more than 1000 feet. Typical times for regional uplifts of this size are on the order of 100,000 years.

2. Issue. The scenarios examined in the DEIS do not account for all credible interfaces between the geosphere and the biosphere and radiation-dose pathways.

- The NRC, the EPA, and the New Mexico Environmental Evaluation Group suggested analyzing the radiation doses that would be incurred if a water well downstream of the WIPP repository should extract waters from the Rustler Formation after a breach in the repository.

- The NRC and the New Mexico Environmental Evaluation Group both recommended that the evaluation of dose pathways from releases at Malaga Bend be based on the assumptions that the contaminated water in the Pecos River is used for irrigation and the released nuclides accumulate in the sediments of the river and along the shore.

- The NRC and the New Mexico Environmental Evaluation Group recommended that population doses from the modeled scenarios be reported.

Response. Two recommendations of the commentors are being adopted: The radiation doses incurred by the use of well water taken downstream from a breached repository are being analyzed, and the consequences of using contaminated Pecos River water below Malaga Bend for irrigation are being studied. These scenarios involve a second unlikely event (e.g., the use of saline water for domestic purposes) in addition to the very conservative breaching events postulated. For this reason, they do not represent what are considered potential impacts for purposes of the FEIS. Continuing evaluation of all aspects of the long-term integrity of the WIPP facility is an integral part of the WIPP project. Accordingly, calculations for these events are under way and will be included in amendments to the WIPP Safety Analysis Report.

The NRC recommendation that the population doses resulting from all scenarios be reported has not been fully adopted for the following reason: There is no credible basis for estimating the population doses that would result from the use of contaminated resources when there is a large uncertainty in future demand and use patterns. Resources like water, air, and certain minerals are of this nature. The best that can be done is to estimate the dose delivered to a local, maximally exposed individual. Certain food crops intended solely for human consumption may, on the other hand, be used as a vehicle for estimating population doses independently of demographic assumptions. Population doses are being estimated in the two new scenarios mentioned above to the extent possible, but it is not feasible to make population-dose estimates for all scenarios.

3. Issue. The computer codes and data used in the WIPP long-term safety assessment have not been validated and may be inappropriate.

- The State of New Mexico recommended an independent analysis of the scenarios for liquid breach and transport. One commentor said that his analyses support the WIPP assessment.

- The State of California noted that the radionuclide-transport codes used have not been verified with field data. The NRC said that the code used by Intera Environmental Consultants has not been formally approved by that agency, and the EPA asserted that the Intera model, as used, was inappropriate.

- The State of New Mexico recommended that the FEIS be more explicit about the hydrologic data used in the modeling, stating that the reexamination of several parameters may be appropriate. Similarly, the EPA suggested that the FEIS explain the errors inherent in the hydrologic modeling.

- A commentor from the SWRIC suggested using the data from underground nuclear-weapons detonations in salt for the WIPP long-term waste-isolation assessment.

Response. The computer codes used to calculate the release of radionuclides from the WIPP repository and the code used to calculate nuclide transport in the saturated zone have not been validated by comparisons with field experiments; neither have these codes (or any others for this purpose) received formal approval in regulatory guides. The codes used to estimate the radiation doses to human organs, given radionuclide exposure levels, are current industry standards and appear to be generally accepted. Further documentation is given in a 1978 report by Torres and Balestri (see References for Chapter 9).

The errors inherent in hydrologic modeling with the Intera codes are potentially of three kinds: (1) conceptual errors in model formulation, leading to incorrect or incomplete descriptions of the physical phenomena being modeled; (2) coding and typographical errors arising in the model's implementation; and (3) a choice of model parameters that is biased or otherwise inappropriate for the actual phenomena being modeled. Regarding errors of type 1, the regional hydrologic model and the radionuclide-transport model are described in Appendix K (see in particular Sections K.1 and K.2 and the references cited therein). One possible conceptual error might be the assumption of porous-media flow in the Rustler aquifers, as opposed to fractured-media flow in whole or in part. The hydrologic evidence as of January 1978 generally supports the assumption of porous-media flow.

It is possible but unlikely that errors of type 2--coding and typographical errors--were involved in the calculations for the WIPP long-term safety assessment. Before accepting any results, the model calculations were all checked against order-of-magnitude estimates made by two independent analysts in order to catch implementation errors. Only one such error (arising from a mislabeled data tape) turned up. In addition, the staff of the New Mexico Environmental Evaluation Group made a partial analysis of the scenarios for liquid breach and transport, using simple approximations to the equations of the Intera models and to the hydrologic parameters taken from the DEIS. The results of this independent study were in satisfactory agreement with the results of the calculations supplied in the DEIS.

In regard to errors of type 3, it is believed that data from field measurements have adequately characterized the ranges of the relevant hydrologic parameters (see Table K-2, Appendix K) and that values on the conservative side of these ranges have been used for the radionuclide-transport calculations. The effects of uncertainty in hydrologic parameters on the radionuclide-transport predictions have been addressed in Section 9.7.1.

The available data from the Gnome site, the site of an underground nuclear detonation in a salt bed, have not proved useful for assessments of long-term waste isolation. The borehole and cavity at that site have recently been filled, and further studies there are not expected.

4. Issue. The duration of isolation before direct access to the repository by exploratory drilling must be reassessed in conjunction with the long-term institutional controls to be used at the site.

Response. In the scenario for direct access to the waste by exploratory drilling (scenario 5, Section 9.7.1.5), the earliest penetration is assumed to occur 100 years after closure. A 100-year penetration time is consistent with draft regulations for the disposal of spent fuel and of high-level and transuranic wastes that are currently under review by the EPA.

The mineral resources at the Los Medanos site could make future human intrusion somewhat more likely. The direct and indirect consequences of the most likely form of human intrusion, exploratory drilling, are nevertheless small. These consequences are discussed in Section 9.7.1.5.

5. Issue. The waste form, waste composition, and expected leaching rates must be clarified and possibly reassessed.

- The EPA suggested addressing how the expected release rates in the long-term scenarios differ with the various waste forms being considered.

- The NRC noted that leakage from experimental wastes in the short term could affect the TRU-waste leaching and nuclide-transport rates in the long term. Such effects need to be factored into the analyses.

- The NRC and other commentors asked that the selection of nuclides used in the modeling be clarified in the EIS.

- The EPA said that the oxidation-reduction state of the groundwater could make the actinides much more mobile, thereby resulting in larger nuclide releases to the biosphere.

- The NRC recommended examining the selective leaching of nuclides when the emplaced wastes come into contact with water.

- The State of New Mexico and an individual both said that the waste containers will not present an effective waste-release barrier in the long term. The State further questioned the effects on other containers and the salt if some waste escapes.

Response. The form and the composition of the TRU waste to be emplaced in the WIPP repository are described in Section 2.3 and Appendix E of the FEIS. The assumptions made about waste forms and leaching rates for the purpose of modeling long-term impacts are stated in Section 9.7.1.3. The radionuclides used in the long-term safety assessment are listed in Table 9-59. The bases for choosing these nuclides are given in Appendix E: in Table E-1 for contact-handled TRU waste and in Table E-3 for remotely handled TRU waste under "expected average" conditions. The WIPP repository will contain no high-level waste over the long term.

Data on the rates at which radionuclides might be leached from the assumed waste forms are not available--a fact that forced the use of the "as-rapid-as-salt" leaching hypothesis for all nuclides considered in the scenario analyses for the DEIS. This conservative hypothesis has been retained in calculations for the FEIS. The most recent calculations of the rates of radioactivity release in each scenario account for the solubility limits of the different nuclides in brine, but not their leach rates, which remain unknown. The latter calculations were not finished in time for publication in the FEIS.

The waste containers are intended to facilitate handling and storage and are not intended as long-term barriers to the release of waste. Accidents involving waste containers are analyzed in Section 9.5.1 of the FEIS. The effects of such accidents on undisturbed containers and the surrounding salt are not analyzed there, but it is believed that the effects can be minimized by decontaminating and repackaging damaged material. In this regard, certain decontamination fluids are known to accelerate the mobilization of radionuclides and would have to be used carefully in cleaning up after an accident. Although some localized mobilization of nuclides might be possible, it would require enormous volumes of decontamination fluid to significantly change the average leach rates throughout the repository or to modify the adsorptivity of nuclides on the surrounding host rocks.

The influence of the oxidation-reduction state of groundwater on the distribution coefficients of the several important nuclides is believed to be incorporated in the coefficients chosen in Table K-3 of Appendix K. A number of these coefficients have been measured at Sandia National Laboratories, using site-specific rock materials and brines.

6. Issue. Several commentors, particularly private persons and public-interest groups, expressed the opinion that the uncertainties in predicting conditions over many thousands of years are so great that a long-term waste-isolation assessment is not meaningful. Similarly, many persons and groups expressed the opinion that the WIPP long-term assessment underestimates (some said overestimates) the long-term risks presented by the repository.

- The NRC recommended expanding the discussions of the scenarios to make them more easily understood. It also asked for information on the derivation of the scenarios and on their uncertainties.

- Some persons living in west Texas were particularly concerned that radionuclides from the WIPP repository might eventually pollute their groundwater supply.

Response. The long-term waste-isolation assessments performed for the WIPP repository in both the DEIS and the FEIS analyzed a spectrum of accident scenarios only to establish some perspective on the likely future impacts of the proposed action. The consequences attending each scenario should be regarded as being typical of future impacts should these accidents occur; they are not intended as predictions of everything that will or will not happen. Accordingly, the scenario analysis is useful and meaningful only to the extent that it contributes to decisions concerning the means of impact mitigation and to decisions on alternatives. The scenario analyses say nothing about the long-term risk (probability times consequences) of the WIPP project. The analyses presented in Section 9.7.1 postulate events that represent very conservative estimates of what could happen in the long term. Thus, a probability of 1 is implicitly assumed. An analysis of expected probabilities would most likely reduce the radiation exposure risks fom the radiation exposure consequences reported.

The discussion of scenarios in Sections 9.7.1.3, 9.7.1.4, and 9.7.1.5 of the FEIS has been simplified in some cases and expanded in others in order to increase clarity. Documentation of the hydrologic models used in the four liquid-breach scenarios and a study of uncertainties involved in the WIPP-site-specific modeling of hydrology were not completed at the publication of the FEIS.

Radionuclides from the WIPP repository could pollute Texas groundwater supplies only if they are released to the aquifers of the Delaware Mountain Group below the repository. The natural water velocities in these aquifers are so low (less than 0.1 foot per year) that it would take at least 25,000 years for the nuclides to reach the Capitan Formation northeast of the site. Beyond the Capitan, potential routes for the migration of groundwater are not certain, but some routes appear to connect with aquifers in Texas. The most likely releases would be into the Magenta or the Culebra aquifers in the Rustler Formation above the repository. Under the present hydrologic regime, flow in the Rustler aquifers is generally to the southwest and into the Pecos River near Malaga Bend.

15.14 PLANT DESIGN AND OPERATIONS

Comments on various design and operational aspects of the WIPP facility were received in 11 letters and 4 oral statements. Most of the comments came from the EPA, the NRC, and the State of New Mexico. The comments are summarized below. A response to each issue is also provided.

1. Issue. The DEIS lacks commitments to design measures and operating procedures that would reduce or eliminate adverse environmental impacts. This was a primary comment of the EPA.

- The State of New Mexico requested that the design of the salt-storage pile incorporate features to mitigate its potential adverse effects on air quality, water quality, and soils and vegetation.

- Several commentors requested design information and commitments for long-term institutional controls (i.e., site markers, record maintenance, groundwater monitoring) after WIPP decommissioning. This issue is discussed in Section 15.21.

- To minimize effects on vegetation and wildlife, the State of New Mexico and an industrial commentor suggested that only the minimum area required for construction be cleared and that all water impoundments be fenced.

- The NRC requested an examination of alternatives to the proposed rights-of-way.

Response. The discussion of the various design features and construction practices incorporated into the WIPP design to mitigate adverse environmental impacts has been reorganized and brought together in Section 9.6. This section contains the DOE commitments to mitigating measures, including those related to protecting and restoring disturbed areas, reducing pollution, protecting archaeological resources, minimizing the denial of resources, minimizing adverse sociocultural effects, and minimizing the consequences of transportation and operational accidents.

2. <u>Issue</u>. The NRC, the State of New Mexico, and an industrial representative said that the FEIS should clarify the WIPP design bases with regard to natural events like earthquakes, tornadoes, dust storms, and floods.

<u>Response</u>. General information on the effects of natural events is given in Sections 7.3.6 and 9.5.3. The WIPP design bases with respect to earthquakes, tornadoes, dust storms, and floods are discussed at length in the Safety Analysis Report.

3. <u>Issue</u>. The NRC, the State of New Mexico, and several persons requested that the FEIS clarify the amounts of waste to be received, its sources, and the relation of these waste volumes to the underground repository area and to the surface facilities.

<u>Response</u>. Information on the sources and quantities of waste to be received by the WIPP has been clarified in Section 2.3. The waste volumes and types planned for the WIPP are consistent with an underground repository of about 100 acres and with the planned surface facilities.

4. <u>Issue</u>. The NRC said that the design of the WIPP facility does not use the "multiple-barrier concept" as currently interpreted by that agency.

<u>Response</u>. The WIPP relies on the total geologic system to provide a series of barriers against breaching and the release of radionuclides. These barriers include the thick, hydrologically isolated salt beds; the tectonically stable area; the extremely low hydrologic-transport capabilities of the water-bearing strata; and the sorptive capacities of the Rustler dolomites.

5. <u>Issue</u>. The State of New Mexico and an industrial commentor said that the air-quality and noise impacts of construction and operation need to be clarified.

<u>Response</u>. Additional information on the air-quality and noise impacts during construction and operation is provided in Sections 9.2.1 and 9.3.1.

6. <u>Issue</u>. The NRC and the New Mexico Environmental Evaluation Group requested more information on the occupational safety of workers, especially with regard to radiation exposures.

<u>Response</u>. The occupational safety of the workers under both normal and accident conditions is discussed in Sections 9.3.2.2 and 9.5.1, respectively. This information is a summary of that provided in the Safety Analysis Report.

7. <u>Issue</u>. The NRC and one person asked for a discussion of the local impacts of resources (lumber, water, electricity, and fuel) consumed during the construction and operation of the WIPP, saying that the water consumption reported in DEIS Section 9.1.2.1 appeared to be underestimated.

<u>Response</u>. As discussed in Sections 9.2.2 and 9.3.3, the consumption of building materials, water, fuel, and electricity during WIPP construction and operation is not expected to cause significant local impacts.

15.15 WASTE FORM

Comments concerning the waste-form and waste-acceptance criteria were presented in 10 oral statements and 19 letters. Most commentors were primarily concerned with the lack of final waste-acceptance criteria and the effects of final criteria on the accident scenarios. The comments are summarized below. A response to each issue is also provided.

1. Issue. Many commentors said that the FEIS must include the final waste-acceptance criteria and describe the TRU-waste forms more fully.

- The NRC requested that the FEIS provide more details on waste packaging and engineered barriers. Waste packaging during transportation is discussed in Section 15.22.

- The NRC and the New Mexico Governor's Advisory Committee on the WIPP said that the waste-acceptance criteria assumed in estimating the environmental impacts of shipping and handling TRU waste are not conservative because there is a possibility that TRU waste will not conform to the assumed criteria.

- The NRC said that the waste should be nondispersible and should include no combustible matter.

Response. The final waste-acceptance criteria for the WIPP were formulated after the DEIS was issued; they are discussed in Section 5.1 of the FEIS. These criteria have not changed significantly from the interim criteria reported in the DEIS, but more precise definitions can now be given. The definitions of the WIPP waste-acceptance criteria in the FEIS are technically correct; they have been rewritten in simpler language to clarify them for the lay reader.

The quality-assurance system to insure that the shippers of waste to the WIPP strictly comply with the waste-acceptance criteria will be available before the start of WIPP operations. TRU-waste processing is being considered as a method to insure that the criteria are met.

2. Issue. The State of New Mexico requested that the FEIS report the results of the gas-generation studies and more clearly define gas-generating waste.

Response. The studies of gas generation in contact-handled waste have been markedly advanced since the DEIS was published. These later results are discussed in Section 9.7.3.1 of the FEIS. The conclusion of these analyses is that there is little probability of repository failure from overpressurization at the gas-generation rates allowed by the waste-acceptance criteria.

3. Issue. The NRC, the DOI, and the State of New Mexico said that the FEIS should say what waste forms will be used in the experimental programs.

Response. The source and the characteristics of the high-level waste to be used for the WIPP experiments have not yet been defined. Section 5.1.3 describes a reference defense high-level waste from the Savannah River Plant, spiked with cesium-137 to increase its radioactivity and heat output. This waste, as described, is believed to be representative of the high-level waste to be employed in the WIPP experiments. Once the high-level-waste source(s) and characteristics are established, additional analyses will be performed. If significant new information is developed that is relevant to the environmental concerns, the FEIS will be supplemented.

4. Issue. The EPA requested that the FEIS address waste-form changes with time and the effects of these changes on the long-term impacts.

Response. Because of the conservative bounding assumptions made in the long-term analyses (Section 9.7.1.3), the specific waste form and its changes over time will not increase the consequences reported in Sections 9.7.1.4, 9.7.1.5, and 9.7.1.7. In other words, no credit is taken in the analyses for the resistance to release provided by the waste form; it is assumed that the waste dissolves with the salt and that the only limitations on solubility are those related specifically to the salt.

15.16 SLAGGING PYROLYSIS AND OTHER WASTE-PROCESSING METHODS

Five oral statements and five letters raised the issue of waste-processing methods, particularly slagging pyrolysis. These comments are summarized below. A response to each issue is also provided.

1. Issue. Several persons said that slagging pyrolysis results in adverse environmental impacts, including the release of radioactive materials (plutonium may escape from the HEPA filters) with consequent health effects, thermal pollution, and psychological stress on local residents.

Response. The environmental impacts of a slagging-pyrolysis facility are currently being analyzed. Any proposal to construct such a facility would have to meet the requirements of the National Environmental Policy Act, including review by government agencies and the public.

Any method for processing the stored TRU waste before shipment to the WIPP would result in the release of radioactive materials (including plutonium) during normal operations. However, the magnitude of the release must be considered in order to put this subject into perspective. Section 9.8 of the FEIS discusses the projected releases from the slagging-pyrolysis facility. The contribution of slagging-pyrolysis emissions to the radiation exposure of the surrounding population is expected to be negligible.

The heat released to the environment by the slagging-pyrolysis operation could range from about 15 million to 40 million British thermal units per hour, depending on the waste-processing rate and the operating parameters. The total heat flow would be equivalent to that produced by the engines of about 60 automobiles traveling at 55 miles per hour. No appreciable environmental effects (e.g., local weather effects, impacts on flora) would be expected from thermal emissions this small.

The closest residence would be about 11 miles away. As already mentioned, operational emissions would be minimal. Even for the worst-case accident examined, the maximum individual dose commitment for a member of the public is 0.1 rem. This dose commitment is less than that received annually from natural background radiation. All of these factors should minimize any psychological stress on local residents.

2. Issue. A few persons said that the slagging-pyrolysis facilities should be located near the waste source; unstabilized waste should not be transported. Conversely, others recommended that these facilities be located at the WIPP site.

Response. The location of a slagging-pyrolysis facility is being evaluated, and, if a proposal to construct such a plant is made, alternative locations will be evaluated in an environmental impact statement.

An environmental impact statement on the long-term management of buried TRU waste at the INEL is being prepared. (For a discussion of the TRU waste that is buried or stored at the INEL, see Section 2.3.) One of the decisions being addressed in that document is whether a slagging-pyrolysis facility for the INEL waste should be located at the INEL or at a repository site (e.g., the WIPP). Such factors as environmental effects, shipping safety, logistics, and cost are being evaluated. Some minimal processing (e.g., overpacking or repackaging) of the stored waste before shipment might be necessary if the slagging-pyrolysis facility were located at the repository. Also, waste processed by slagging pyrolysis would be safer than unprocessed waste in the event of a shipping accident.

3. Issue. The NRC requested that the FEIS compare slagging pyrolysis with other waste-processing methods and provide more information on waste incineration and immobilization processes and the properties of their products in an appendix.

Response. Appendix F of the FEIS provides information on each of the processing techniques considered for TRU waste. The document referred to there provides more detailed information.

4. Issue. The EPA recommended using soil contaminated with TRU waste in the slagging-pyrolysis process (in which soil must be added to waste in a ratio of 1.5:1).

Response. Soil contaminated with TRU waste is being considered for makeup material in the slagging-pyrolysis process.

5. Issue. The State of California said that the DEIS incorrectly stated the volume of INEL buried TRU waste that will result from slagging pyrolysis. The volume-reduction ratio from the incineration process is assumed to be 2:1. This ratio is not true for materials like soil, which constitute 3.75 million of the 6.25 million cubic feet of waste and contaminated soil that would require processing if a decision is made to retrieve the buried waste at the INEL. Thus, about 5 million cubic feet of waste will result from slagging pyrolysis, not the 3 million cubic feet reported in the DEIS.

Response. The overall volume-reduction factor for the slagging pyrolysis of the INEL buried waste is 2.6:1 (Table 2-3). The volume-reduction ratio for the process was not assumed to be 2:1. Rather, the overall volume-reduction ratio was calculated from the ratios estimated for various components of the feed stream.

An estimated 3.75 million cubic feet of contaminated soil lie around the buried INEL TRU waste. The present analysis of stored-waste processing is not based on using 3.75 million cubic feet of contaminated soil as makeup soil; the estimated amount of makeup soil for processing the stored waste is only 1.35 million cubic feet.

Furthermore, the makeup soil will undergo a significant volume reduction in slagging pyrolysis. The estimated density of the soil used in the process is 80 pounds per cubic foot. The slag product, which comes primarily from the soil, has a measured density of 175 pounds per cubic foot. Thus, the makeup soil itself would undergo a volume reduction of about 2.2:1.

15.17 PLANNED EXPERIMENTAL PROGRAMS

Fifteen letters and 11 oral statements commented on the experimental programs planned at the WIPP repository. These comments are summarized below. A response to each issue is also provided.

1. Issue. The State of Florida said that the inclusion of experimental programs contradicts the claim that the techniques necessary for radioactive-waste disposal at the Los Medanos site are available.

Response. The in-situ experiments will resolve some remaining technical issues on high-level waste, many of which have been raised by public and institutional concern. The bounding assessments in Section 9.7.1 show that, even with the worst of the uncertainties that remain, the TRU waste in the repository will not threaten the safety of the public.

2. Issue. Two groups expressed the opinion that the experimental programs are too dangerous and should not be included; one suggested that the results of West German experiments at the Asse repository be used rather than risk further experimentation at the WIPP.

Response. The planned experiments present no greater risk or consequences than those routinely encountered in the defense industry, which produces the waste to be used in the experiments. The German program does not address, either in scope or in scale, the requirements of defense-waste isolation.

3. Issue. The State of New Mexico and other commentors requested that the objectives, nature, and duration of the experimental programs be clarified. The NRC, the State of Alaska, and others requested that the FEIS discuss the long-term use of experimental areas within the repository and the retrievability of experimental waste.

- The NRC recommended that the in-situ experiments on actinide mobility be at least as extensive as the laboratory experiments because the in-situ results will be more valuable.

- The EPA, the Atomic Industrial Forum, and U.S. Senator McClure of Idaho said that the experimental programs will provide valuable data for future waste-disposal programs, although some information will not be applicable to other sites or other media.

- The NRDC recommended comparing the experimental program with approaches described by the American Physical Society and the California Energy Commission.

- The NRC suggested including a summary of the results of the experiments in Project Salt Vault and a discussion of how those results will affect the programs at the WIPP.

Response. The description of the experiments in the FEIS has been expanded (Section 8.9), and subsequent documents will elaborate this description. Studies of actinide mobility now under way in the laboratory will be augmented by larger-scale laboratory studies in the near future and by later in-situ experiments. The large-scale laboratory work will be extensive enough to bound the results of the in-situ work; for this reason, it will not be necessary to repeat all the laboratory work in the underground experiments. The basic approach to the experiments outlined is compatible with the recommendations of the American Physical Society and the California Energy Commission.

4. Issue. The Hearings Panel, the New Mexico Environmental Evaluation Group, and the DOI indicated that the FEIS should provide more details on the waste to be used in the experimental programs. One group suggested using only high-level waste from the INEL, and not commercial spent fuel.

Response. The FEIS contains new details on the waste to be used in the experiments (Section 5.1.3 and Table E-4 in Appendix E). Spent fuel is no longer planned for use in the experiments.

5. Issue. The NRC requested that the FEIS provide justification for claiming that no environmental impacts will result from the experimental program.

- The State of New Mexico asked that the environmental effects of the experimental program be defined.

- The EPA said that not enough information was provided in the FEIS to allow an evaluation of the impacts of the experimental program.

- The NRC stated that the experiments may provide a pathway for water migration or may increase the risk of mechanical failure, particularly from thermal testing. Therefore, potential long-term effects on repository integrity should be considered.

- The NRC also requested that the FEIS consider accident scenarios involving the transportation of high-level waste.

Response. In discussing the environmental impacts of the experimental program, this FEIS analyzes the impacts that might arise from high-level waste during normal transportation to the plant (Section 6.7), from severe accidents during transportation (Section 6.8), and from severe accidents at the plant (Section 9.5.1). This waste will exert no long-term impacts because it will be removed before the plant is decommissioned. As explained in Section 8.9.5, each experiment with high-level waste will have its own safety plan; the monitoring that will be a necessary part of the studies will further insure that the experiments do not breach the repository.

15.18 ROUTINE OPERATIONAL RELEASES

Comments on the routine releases of radioactive and other materials from WIPP operations were received in nine letters and six oral statements. These comments are summarized below. A response to each issue is also provided.

1. Issue. Routine releases may be a long-term problem because of bioaccumulation. This concern was expressed by the New Mexico Environmental Evaluation Group, the EPA, and a citizens group.

Response. The significance of the bioaccumulation of radionuclides routinely released was assessed by analyzing a scenario in which 25 years of released nuclides accumulate in the vegetation around the WIPP and a range fire releases these isotopes (Section 9.5.3.4).

2. Issue. Several commentors asked for a clarification of the routine releases.

- The NRC recommended giving a numerical estimate and the basis of the estimate for the maximum routine releases.
- Several individuals and groups said that releases will occur even with the best filters and that routine releases of tritium and radon must be clarified.
- The New Mexico Environmental Evaluation Group requested clarification of the results of routine releases of hydrogen, helium, and hydrogen chloride gases.
- The NRC also said that the DEIS states in Appendix G that χ/Q values were calculated with the MESODIF model; therefore the description of the AIRDOS-II χ/Q routine should be replaced with a summary of MESODIF.

Response. The comments asking for a clarification of the routine releases have been addressed in Sections 8.6, 8.7.5, and 9.3.2 and in Appendix G. The χ/Q values calculated with MESODIF are among the inputs to AIRDOS-II. MESODIF is described in Appendix H, Section H.4.4.

3. Issue. The NRC requested that the FEIS discuss releases via liquid pathways.

Response. No waterborne discharges are expected from the WIPP repository. Furthermore, because of (1) the high net water loss (precipitation minus evaporation), (2) the impermeability of the rock strata, and (3) the depth of the uppermost water-bearing stratum (more than 500 feet), there is no significant probability of contaminating groundwater from any other routine releases from the WIPP. The repository itself is isolated from any water-bearing rocks by more than 1300 feet of impermeable evaporite strata. There is no surface water in the site area; the nearest perennial surface-water stream, the Pecos River, is 14 miles from the site, and no integrated drainage system connects the site with the river. Thus there is essentially no likelihood that routine releases from the WIPP repository will affect surface waters, and releases via liquid pathways were therefore not examined.

4. Issue. The DOI said that a discussion of the impacts of routine releases on the biosphere (i.e., wildlife, plants, soil, and water) is required.

- The State of New Mexico said that routine releases of radioactivity will adversely affect future radiocarbon dating of archaeological artifacts.

Response. The analysis of impacts of routine releases from the WIPP repository (Section 9.3.2) concentrates on the effects on human populations. In this case, the releases are so low and the calculated exposures so small that, by extrapolation, no significant impacts on the biosphere are expected. The results of the analyses in Section 9.5.3.4 suggest that, at the release rates expected, significant bioaccumulation will not occur. The problem of radionuclide contamination of archaeological sites will be addressed in the specific plans to mitigate effects on archaeological resources to be submitted to the State Historic Preservation Officer and the Federal Advisory Council on Historic Preservation.

5. Issue. Commentors also requested that the FEIS clarify the systems that will be used to monitor routine releases.

- The Department of Health, Education and Welfare requested information on the routine monitoring of drinking water and food. Several commentors, particularly Texas residents, requested a more complete system to monitor releases in the groundwater systems.

- The department also requested a discussion of the radiation-protection criteria, including a discussion of the range of acceptable doses.

Response. The operational radiation-monitoring system to be employed for the WIPP repository is described in Appendix J, Section J.2.6. This monitoring system includes measurements of the radiation levels in drinking water, food, and other environmental indicators (e.g., soil, wildlife). The details of this monitoring program are reported in the WIPP Safety Analysis Report.

It may not be possible or reasonable to satisfy the specific requests for monitoring expressed by the residents of west Texas. There are no groundwater flow paths to the southeast into Texas and, even if there were, the groundwater velocities in the water-bearing strata are such that no contaminants would be seen for tens of thousands of years.

The FEIS reports the radiation doses expected under normal and accident conditions in relation to background exposure and health effects. The radiation-protection criteria, which in part account for these expected doses, are discussed at length in the Safety Analysis Report.

15.19 OPERATIONAL ACCIDENTS AT THE WIPP FACILITY

Seventeen letters and six oral statements commented on the analyses of environmental impacts from accidents occurring during plant operations. These comments are summarized below. A response to each issue is also provided.

1. Issue. The accidents selected for analysis may not represent the worst-case events, and additional accidents should be evaluated.

- The EPA and the NRC both suggested that the FEIS examine the radiological impacts of a range fire after the bioaccumulation of radionuclides routinely released during plant operations.

- The EPA also recommended examining the effects of a seismic event on waste containers stored underground.

- The NRC further recommended analyzing a large fire in which the HEPA filters catch fire and emit radiation.

Response. The DOE is continuing the evaluation of potential accidents during operations, particularly in the course of developing the Safety Analysis Report. In that report, accidents are classified as (1) those of "moderate frequency," which may occur once per year; (2) those that are "infrequent," which may occur once during the total operating lifetime; and (3) "limiting" events, which are not expected to occur but are included in order to estimate the worst possible consequences. This work was reevaluated for the FEIS.

The DOE has analyzed a range fire that releases radionuclides that had become biologically accumulated in plants around the repository. The analysis is reported in Section 9.5.3.4.

All experimental and empirical data reviewed to date indicate that earthquakes in the area of the Los Medanos site would not result in ground accelerations that could cause the rupturing of waste containers (Section 9.5.3.1). Accordingly, the seismic scenario suggested by the EPA is considered incredible and is not included.

An event in which the HEPA filters burn and emit radiation is also not credible for the WIPP repository, because the HEPA filters are not located near any areas in which a credible fire from another source could occur and the required maintenance schedule will preclude the buildup of particulate matter on the filters.

2. Issue. Some assumptions made in the accident analyses are not conservative and should be reassessed. The EPA recommended that the postulated surface fire in the contact-handled-waste area be assumed to last longer than 1 hour.

Response. The potential sources and durations of surface fires were assessed in developing the Safety Analysis Report. The result is that a fire lasting for no more than 1 hour still appears to be the best estimate. More conservative, worst-case events are evaluated in that report.

3. Issue. Numerous additional calculations are needed to fully assess the impacts of operational accidents on the operational work force. The New Mexico Environmental Evaluation Group listed numerous radiation doses that should be calculated and reported in the FEIS.

Response. The worker-dose calculations requested by the New Mexico Environmental Evaluation Group were considered in developing the Safety Analysis Report; a summary of the information presented in that report is presented in Sections 9.3 and 9.5 for normal and accident conditions, respectively.

15.20 WASTE RETRIEVABILITY

Comments on the issue of waste retrievability were received in 17 letters and 9 oral statements. Several of these comments related to the retrievability of spent fuel for reprocessing; because the disposal of spent fuel is no longer a part of the WIPP mission, these comments are not discussed here. The issue of emplacing spent fuel in the WIPP is discussed in Section 15.31.7. The comments are summarized below. A response to each issue is also provided.

1. Issue. The NRDC and other groups and persons said that certain characteristics of salt, such as plasticity, corrosivity, and loss of strength, which may make it undesirable for permanent disposal, will inhibit waste retrievability.

Response. Various properties of salt would complicate retrieval; specific provisions are being made in the planning and design of the retrievability feature to account for them (Section 8.10).

2. Issue. Several commentors said that the time period during which retrieval is to be possible should be reevaluated.

- The DOI, the Atomic Industrial Forum, and other commentors said that the retrieval period for the TRU and experimental high-level waste must be clarified.

- The NRC said that the waste should be maintained in a retrievable mode for the life of the repository and for 50 years after it is closed and decommissioned.

- The State of Alaska and several groups and persons said that the waste should be maintained in as retrievable a mode as possible because better means of waste disposal may become available in the future.

Response. The planned time periods for waste retrievability from the WIPP repository are as follows: Within 5 years after the first emplacement of each kind of TRU waste (contact and remotely handled), separate decisions will be made about the retrieval of each kind of waste. If the decision is made to retrieve it, 5 to 10 additional years would be required for the actual removal operation. These time periods have been clarified throughout the FEIS. Even after this planned retrieval period, the emplaced waste could be retrieved by existing techniques. Retrieval after the facility is closed would be much more expensive, but the decision to decommission would not be made until there would be reasonable assurances that the facility was suitable for a permanent repository. The NRC staff position (draft of 10 CFR 60) that high-level waste should be retrievable for a period of 50 years after a geologic repository is closed has not been clarified in terms of specific requirements. All high-level waste to be used in the WIPP experiments will be retrieved at the end of the experiments.

3. Issue. The New Mexico Environmental Evaluation Group, the NRC, the New Mexico Governor's Advisory Committee on the WIPP, the SWRIC, the Sierra Club, and others requested that the FEIS further clarify the details of retrievability, including the costs of alternative disposal methods for retrieved wastes, criteria, procedures, logistics, and hazards.

Response. The discussion of waste retrievability has been expanded in the FEIS (Section 8.10) to show more clearly the methods and equipment to be used. This discussion includes the DOE commitment to demonstrate retrievability before any waste is emplaced in the WIPP.

15.21 DECOMMISSIONING AND LONG-TERM MONITORING

Comments on the decommissioning of the WIPP repository and the long-term institutional control programs to monitor potential releases and prevent intrusion were made in 22 letters and 10 oral statements. These statements are summarized below. A response to each issue is also provided.

1. Issue. The State of Ohio and other commentors said that the discussion of decommissioning is too vague and should be rewritten to include more specific plans; decommissioning under a variety of circumstances should be addressed.

- The State of New Mexico requested that the FEIS clarify what will be done with the salt pile after decommissioning, saying that all disturbed areas should be reclaimed and revegetated.

- The State of New Mexico requested a discussion of the possible uses of the WIPP site after decommissioning.

Response. The discussion of decommissioning in Sections 8.11.1 and 8.11.2 has been expanded and clarified. At this time in the development of the WIPP project, it is not possible to define the specific procedures to be employed in decommissioning the repository. All decommissioning activities will be carried out in compliance with the applicable environmental regulations in force at that future time. It would be expected that the site-restoration program would include regrading and perhaps include revegetating.

2. Issue. The NRC requested a discussion of the ultimate disposal of retrievable experimental waste and contaminated materials.

Response. See item 1 above.

3. Issue. Because the greatest uncertainties concerning repository performance come after decommissioning, several commentors, including the Hearings Panel, the NRC, the New Mexico Environmental Evaluation Group, the DOI, the EPA, and the NRDC, said that the FEIS should discuss the long-term controls, including active and passive institutional controls, and clarify the time period and the area over which institutional controls will be maintained.

- The DOI said that radioactive waste must be isolated for periods of up to 250,000 years and that the DEIS did not present a credible discussion of the expertise necessary to characterize site integrity for such a long period.

- The State of New Mexico requested a discussion of institutional controls beyond 100 years.

- The NRDC requested clarification of the means to prevent intrusion, and the NRC asked about provisions to mitigate accidental intrusions. In addition, the FEIS should clarify which agency is responsible for control and how damages will be compensated for if there should be an accidental intrusion.

- The EPA suggested that the intrusion scenarios discussed in Section 9.7.1.5 should consider that controls can fail as well as be lost and that, although knowledge of the repository may not be lost, intrusion could occur because of complacency or avarice.

Response. A new Section 8.11.4 discusses the conceptual design of the active and passive institutional controls that would aid in reducing the probability of accidental human intrusion. Such controls include site marker systems and long-term record-maintenance systems. The integrated institutional control system would probably remain effective for a time period of 100 to 400 years.

4. Issue. The DOI said that the probability of intrusion, and therefore a problem with long-term control, is particularly great at the Los Medanos site because of the hydrocarbon, potash, and salt resources at the site. The potential for intrusion because of resource demand is high.

Response. The DOE has analyzed the effectiveness of an institutional-control system in precluding accidental human intrusion. The conclusion is that the likelihood of human intrusion is principally related to the effectiveness of site markers and record maintenance, not to the incentive to exploit the resources of an area. Physical and written evidence of a geologic repository will deter uncontrolled exploitation of mineral resources for a long time. Accordingly, well-conceived institutional-control systems at the Los Medanos site would be expected to reduce the probability of accidental intrusion to levels like those in basalt and other media.

5. Issue. The DOI requested an assessment of the Los Medanos site and all other alternative disposal media and methods in terms of the possibility of intrusion and the maintenance of long-term controls.

Response. See item 4 above.

6. Issue. The SWRIC and other commentors said that, as part of the institutional controls, a long-term monitoring system should be set up to monitor the integrity of the geologic media and the waste-storage containers. Several Texas citizens and government officials particularly requested effective monitoring of groundwater systems to detect any radioactive contamination.

Response. The details of the active institutional controls at the Los Medanos site have not yet been established. It is reasonable to assume, however, that these institutional controls will include the monitoring of repository performance with respect to waste isolation.

15.22 TRANSPORTATION

One of the issues provoking many comments on the WIPP DEIS was the transportion of radioactive materials to the WIPP repository. The transportation issue was raised in 36 letters and 36 oral statements. The public expressed great concern about transportation safety, the probability and severity of transportation accidents, and the transportation routes. The State of New

Mexico requested a supplement to the DEIS that would discuss State-specific transportation issues. Questions regarding transportation accidents are discussed in Section 15.23. General comments on transportation are listed below. A response to each issue is also provided.

1. Issue. Twenty commentors noted that the impacts of waste transportation are not analyzed for specific transportation routes.

- The States of New Mexico and Texas, the EPA, the SWRIC, and other commentors asked that waste-transportation routes be specified and suggested that analyses of the impacts of transportation be based on these specific routes.

- The Hearings Panel urged that the FEIS contain all available new data on transportation routes.

- The Hearings Panel and the New Mexico Governor's Advisory Committee on the WIPP recommended that a cost-benefit analysis of the various potential routes be performed.

Response. The safety of radioactive materials is insured by the packaging used to transport them. Design criteria for these packagings are not dependent on specific road conditions; safety is insured for any road condition. Average road conditions are therefore suitable for analysis. The analyses given in the FEIS use average data, but the discussion of probable routes in the vicinity (within 200 miles) of the site has been expanded (Section 6.4). In developing operational plans for the WIPP the costs and benefits of potential specific routes will be examined, either explicitly or implicitly, by the DOE and the waste carrier.

2. Issue. The DOI, the NRC, the EPA, and the SWRIC said that the EIS should discuss the probability and potential impacts of intentional destructive acts.

- The EPA said that the impacts of an intentional destructive act are potentially severe and may be more serious than the impacts calculated for the accident scenarios described in the DEIS.

- The Hearings Panel requested support for the statement that waste packages do not make attractive targets for sabotage.

Response. It is not possible to predict the probability of an intentional destructive act. Impacts calculated for such acts are presented in Section 6.10.

3. Issue. Several commentors, including the SWRIC, stated their belief that existing transportation regulations are inadequate to insure public safety.

- The State of New Mexico requested that the transportation regulations governing waste shipments to the WIPP be more clearly defined in the FEIS.

- The Hearings Panel requested analyses of accident consequences when transportation regulations are not followed.

Response. The DOE believes that the current transportation regulations are adequate to insure public safety. In shipping waste from the Rocky Flats

Plant to the Idaho National Engineering Laboratory (the waste to be eventually delivered to the WIPP), there has been no release to the environment from any abnormal occurrence during shipment. Such a proved record supports the adequacy of the regulations.

4. Issue. Several persons and groups, particularly the SWRIC, said that transportation packagings are inadequate to protect public health and safety. The SWRIC and others asserted that the Super Tiger was not able to pass the regulatory tests. The SWRIC and several persons also said that the transportation impacts calculated in the DEIS are not acceptable because they are calculated for packagings that do not yet exist.

Response. The assertion that the Super Tiger has not passed the regulatory tests is not correct. A description of the tests used to certify the Super Tiger and a rebuttal of the assertion are given in Section 6.3. The packagings that will probably be used for transporting waste to the WIPP are being designed at this time. Consequently, the analysis for the FEIS assumes that the packagings will be no better than the minimum regulatory requirements. This assumption is conservative because the packagings will undoubtedly exceed the minimum requirements.

5. Issue. The State of New Mexico and many groups and persons requested that the FEIS address radiation doses and subsequent health effects for transportation workers and for the people who live along transportation routes. Several New Mexico residents requested that the analyses consider the effects of psychological stress on the people living along transportation routes.

Response. Doses were calculated for transportation crews and for the public as well as for a worst-case individual who would be very close to all the shipment paths and exposed to all shipments to the WIPP (Section 6.8). A limited survey of residents in the vicinity of the WIPP site revealed concern about the safety of repository operations and transportation (Section 9.4.3.1). It is, however, not possible to quantify such psychological stress in terms of health effects in a regional population.

6. Issue. The State of New Mexico and several residents of the site region said that the roads that may be potential routes to the site are in poor condition, particularly those near the site.

Response. Some roads in the Los Medanos area that could be used as routes for transporting waste are in poor condition and upgrading of these roads may be desirable. As discussed in Item 1 above, the road conditions do not affect the safety assessment for waste transport; safety is insured through the design of waste packagings.

7. Issue. Several states (New Mexico, Nevada, Colorado, Utah, Missouri, and Texas) expressed concern over waste transported through them and said they would like to participate in deciding which transportation routes are selected for transporting waste to the WIPP.

Response. Under proposed DOT regulations for the highway routing of radioactive materials, states have the prerogative of specifying preferred routes through their jurisdictions. The IRG has also recommended to the President that rail-routing policies be reviewed. Routing is discussed in Section 6.4. See also item 1 above.

8. <u>Issue</u>. The State of New Mexico, the NRC, and the Hearings Panel requested that the transportation analyses consider special measures for transportation, such as DOE convoys or escorts.

<u>Response</u>. Special measures like convoys or escorts are not required at present; the DOE does not believe they are necessary to insure public safety.

9. <u>Issue</u>. The State of New Mexico and several groups said that the FEIS should discuss transportation costs.

<u>Response</u>. The costs of shipping contact-handled TRU waste to the WIPP and the costs of cleaning up after accidents are estimated in Sections 6.6 and 6.8.5, respectively.

10. <u>Issue</u>. A few groups said that the transportation distance should be one of the site-selection criteria; the total transportation distance should be minimized.

<u>Response</u>. Routes to the WIPP cannot be specified by the DOE; however, decisions about routing should certainly consider minimizing transport distances. See Sections 6.1 and 6.4.

11. <u>Issue</u>. The New Mexico Environmental Evaluation Group requested that the FEIS define the responsibilities of shippers, carriers, and government agencies.

<u>Response</u>. The responsibilities of shippers, carriers, and government regulatory agencies are described in Section 6.2.

15.23 TRANSPORTATION ACCIDENTS

Issues about transportation accidents were raised in 14 oral statements and 14 letters. The probability of accidents and their consequences were of particular concern. Other general issues concerning the transportation of waste are discussed in Sections 15.24, 15.25, and 15.26. Comments on accidents are discussed and summarized here. A response to each issue is also provided.

1. <u>Issue</u>. Several commentors, including the State of New Mexico and the SWRIC, said that the transportation-accident probabilities used are inadequate because they do not account for the specific highway and railbed conditions that might be encountered on potential routes to the WIPP repository.

- Several groups and persons asserted that the probabilities of transportation accidents were underestimated.

- The Hearings Panel strongly recommended that the FEIS clarify the probabilities of transportation accidents and the probabilities of the consequences estimated for these accidents.

- The State of New Mexico recommended that specific routes be examined to identify potential problem areas in transporting waste to the WIPP repository.

Response. The safety of radioactive-material transport is primarily insured by the packagings in which the materials are shipped. The regulations of the U.S. Department of Transportation provide specific design criteria for packagings; these regulations are very stringent and make no assumptions about specific road or railbed conditions. Consequently, an environmental-impact analysis can be performed on a generic basis with national accident statistics. Furthermore, the probabilities of accidents that, like those analyzed in the FEIS, have severe consequences and low probabilities change very little from region to region. Thus, the predictions of impacts would not change much if the analyses were performed for specific routes. A discussion of waste transport within 200 miles of the Los Medanos site has been added (Section 6.4).

The section discussing the impacts of transportation accidents was reorganized to emphasize the probabilities of the scenarios described. The discussions of accident probabilities were expanded and clarified (See Section 6.8).

2. Issue. The assumptions used to evaluate the impacts of transportation accidents are not conservative and must be revised to reflect worst-case conditions. Other accident scenarios should also be evaluated.

- The EPA suggested that the atmospheric diffusion conditions assumed in the accident scenarios are not worst-case conditions.

- The EPA further noted that the "large population center" used to assess population doses during transportation accidents is not as large as some urban centers that lie along probable transportation routes (e.g., Denver or Dallas).

- The NRC recommended that the waste generated in dismantling and decommissioning be included in the transportation impact analyses to enhance conservatism.

Response. The assumptions used in the transportation-accident analysis of the DEIS were conservative, and they have now been made more conservative by treating the source of radioactive-material release not as a point source at a fixed distance above the ground, as in the DEIS, but rather as a dispersed source that extends from the ground up to the height of the point source in the DEIS. The effect of this change is to increase the maximum ground-level exposure of the public and the maximum dose that an individual person could receive. Calculations were also made for intentional destructive acts and for the exposure of emergency workers.

The largest city for which a transportation accident was calculated was Albuquerque, which is as big as any city along the routes from the INEL to the WIPP except Denver and Salt Lake City. Calculations for one of these would have given a larger population dose, but not proportionately larger because the additional people exposed would be in the fringes of the field. Doses to maximally exposed individuals would remain the same.

3. Issue. Radiological pathways other than inhalation should be evaluated. Both the EPA and the NRC suggested that the radiation doses received by eating contaminated food and drinking contaminated water should be examined.

Response. Should an accident as severe as those postulated in the FEIS occur, the DOE will take action to insure that contaminated water or crops are not ingested by the public. This action might include confiscating crops, quarantining cropland, or monitoring water supplies. The precedent for considering such action, discussed in Section 6.8, is established in the NRC's final environmental impact statement on the transportation of radioactive material by air and other modes (NUREG-0170).

15.24 EMERGENCY-RESPONSE PLANNING

Comments concerning the lack of an emergency-response plan in the DEIS were received in nine letters and seven oral statements.

1. Issue. All of the 16 commentors said that the evacuation plans and emergency medical procedures to be followed in transportation or operational accidents should be delineated. Governor King of New Mexico requested a supplement to the DEIS on this issue.

- The States of New Mexico and Texas, the Department of Health, Education and Welfare, the SWRIC, the Americans for Rational Energy Alternatives, and other groups and persons said that the FEIS should clarify State and Federal jurisdictions and responsibilities, coordination between State and Federal agencies and local medical facilities, training programs for emergency-response personnel, provisions for necessary equipment, and the capability of State hospitals to handle problems related to accidents.

- The clarification should cover the area near the Los Medanos site and areas along transportation routes.

Response. Discussions of the status of emergency-response plans for both transportation and plant-operation accidents have been included in the FEIS as Sections 6.11 and 8.12.1, respectively. At this stage of the WIPP project, these specific emergency-response plans have not yet been established, and therefore only general information and the DOE's commitments to complete these plans are included. The Safety Analysis Report discusses site emergency-response plans in greater detail and will include the final specific procedures when they are developed. The transportation and operation plan will describe detailed emergency-response plans for transportation accidents.

15.25 SECURITY AND SAFEGUARDS

Comments on the security of the WIPP site and the transportation of wastes were received in 12 letters and 4 oral statements. The comments are summarized below. A response to each issue is also provided.

1. Issue. Several persons and groups, including the SWRIC, said that the EIS should address the risks and consequences of sabotage, hijacking, and terrorism during the transportation of wastes and the security provisions to prevent such acts.

- The EPA, the DOI, and the New Mexico Environmental Evaluation Group said that the hazards resulting from an act of sabotage or terrorism are potentially severe and could create more serious situations than conceivable truck or train wrecks.

- The NRC said that Section 6.8 of the DEIS does not accurately describe the results of the 1978 Ducharme study on the transportation of radionuclides in urban environs. Sabotage consequences are underestimated.

Response. The concern expressed over the risks and consequences of intentionally destructive acts during the transportation of wastes to the WIPP has resulted in the DOE's reevaluation of the topic. The discussions and analyses in Section 6.10 respond directly to the comments raised.

2. Issue. Several persons and groups requested that the EIS discuss the safeguard requirements for the WIPP repository and the impacts of such safeguards, especially in light of the poor record of the nuclear industry.

Response. Similarly, information on the security and safeguards provided at the WIPP site has been added as Section 8.12.2 of the FEIS. The WIPP-site security plan is still in the development stage; the information provided in Section 8.12 is general in nature but will be updated in the Safety Analysis Report. For obvious reasons the detailed site security plan will remain confidential.

15.26 INSURANCE AND LIABILITY

Eight letters and nine oral statements raised the issue of insurance coverage and liability in operational or transportation accidents. This issue is summarized below. Responses also are provided.

1. Issue. The FEIS should address the liability resulting from the loss of life or property as a result of accidents at the WIPP site or during transportation. It should discuss the extent of Federal and State liability and evaluate the adequacy of the Price-Anderson Act.

Insurance coverage under the Price-Anderson Act is inadequate. The New Mexico Attorney General's office maintains that the Act leaves gaps in the protection afforded New Mexico citizens and the State of New Mexico and identifies four key issues: (1) the potential liability of the State of New Mexico, (2) the availability to the State of Federal indemnification for any such liability, (3) the types of nuclear accidents for which Federal indemnification would be available, and (4) obstacles to financial redress for an injured party.

- The FEIS should identify all the costs that will be incurred by the State for insurance coverage. The FEIS should discuss the State's liability responsibility.

- Information should be provided on liability for the contamination of regional hydrologic systems by WIPP operations.

- Liability issues in relation to transportation should be clarified.

Response. The Price-Anderson Act is designed to insure that the public will be protected in the event of a nuclear accident connected with a facility operated or licensed by the Government. The WIPP facility would therefore be covered by the provisions of the Act. The provisions of the Act are very broad, and considered with its "omnibus provisions," the Act appears to cover transportation accidents that occur on the way to or from indemnified facilities like the WIPP, as well as operational accidents not related to the WIPP. The exact coverage provided by the Act is open to legal interpretation. Section 6.12 has been added to this FEIS to give the opinion of the DOE legal staff on this matter.

15.27 HEALTH EFFECTS OF LOW-LEVEL RADIATION

The question of the health effects of low-level radiation, in the WIPP project and in the nuclear industry in general, received a great deal of attention in the comments on the DEIS. A total of 23 oral statements and 17 letters included comments on this issue. The comments are summarized below. Responses also are provided.

1. Issue. The DEIS does not reflect the risks involved in exposure to radiation, tending to avoid the issue entirely.

- Many commentors, particularly several physicians, said that the DEIS distorts the health ramifications of developing the WIPP project by comparing radiation doses with annual average background exposures or 50-year dose commitments from background exposure. The description of exposure to radiation as a percentage of background, while technically accurate and generally accepted, tends to mask the harmful effects of background radiation. Such dose-related data should be translated into expected health effects, the total number of incremental cancers, work-days lost, hospital days, and shortening of life. Comments on this issue were also made by the New Mexico Environmental Evaluation Group, Governor Bruce King, the Hearings Panel, the EPA, and others. The EPA suggested using the EPA conversion factor of health effects per million man-rem. The Environmental Evaluation Group suggested using models of risk coefficients developed by various standards-setting organizations.

- The Environmental Evaluation Group, the NRC, and several individuals said that, in making comparisons with doses delivered by natural background radiation, similar time periods should be used; for example, doses in which radiation is absorbed over 1 year should only be compared with the dose received from natural background radiation in 1 year, not 50 years.

- Several other persons and groups said that radiation exposure should not be converted to health effects or cancers.

Response. There is a great deal of technical controversy over the health effects of low-level radiation, primarily because the effects of radiation at low doses are almost impossible to separate from similar effects exerted by other agents in the environment. No universally accepted epidemiological studies of populations exposed to low-level radiation have been successfully completed. In response to this concern, Appendix O has been added to discuss the current knowledge of the health effects of exposure to low levels of radiation. The radiation doses reported in the FEIS are compared with the doses received from natural background radiation, and the reader is referred to Appendix O for information on health effects.

2. Issue. The DEIS ignores the fact that large quantities of radioactive waste would be transported to, and emplaced in, the WIPP repository, thereby presenting a significant increase in the risk of cancer mortality and morbidity along transportation routes and in the vicinity of the WIPP site.

- The total radiation exposure of the U.S. population from waste transportation and emplacement should be stated.

- The EPA, the NRC, and several persons requested clarification of the radiation doses received by transportation workers under normal and accident conditions.

Response. Evaluations of the potential consequences of handling large quantities of radioactive materials must consider not only the "source term" (material quantity and radioactivity) but also the pathways by which such material could reach people. Radiation exposures of the public under both normal and accident conditions have been examined in the FEIS (transportation: Sections 6.7 and 6.8; plant operations: Sections 9.3 and 9.5; long-term safety: Section 9.7.1). These analyses take into account the source terms for the various wastes and the pathways through which radiation doses are received by people. Further analyses of radiation-dose consequences are included in the Safety Analysis Report.

15.28 SOCIOECONOMICS

The socioeconomic impact of the WIPP project evoked considerable response. Many persons, including some in the immediate area, expressed concern over the possibility of a boom-and-bust cycle and the potential effects on employment, housing, population, social services, cultural aspects, and the quality of life in the area. The comments made in 17 letters and 31 oral statements are summarized below. A response to each issue is also provided.

1. Issue. The analysis of potential socioeconomic effects should include a review of the statewide and national impacts attributable to the proposed project. The EPA, the Resource Economics Group of the University of New Mexico, and the State of New Mexico all commented on this issue. The State of New Mexico requested a complete presentation of the costs and benefits of the WIPP repository on a statewide basis.

Response. The FEIS contains a short statewide economic-impact analysis (Section 9.4.1.5). This analysis shows that some statewide impacts will be felt beyond Eddy and Lea Counties. In the total statewide economy, however, these effects will be minimal.

In terms of effects on the national economy, the economic impacts of the construction and operation of the WIPP are generally too small to be analyzed. Although the national program for the management of commercial radioactive waste (Section 2.2.4) will have a larger national impact, its effects are outside the scope of the FEIS.

2. Issue. Some commentors, including the State of New Mexico, the SWRIC, and several groups and persons, felt that employment and population impacts were underestimated. A smaller number, including the Americans for Rational Energy Alternatives, felt that the impacts had been overestimated. Most comments

pertained to a boom-and-bust cycle, the in-migration projections, and the low unemployment rate in the primary area of impact--Eddy and Lea Counties.

The Resource Economics Group of the University of New Mexico and the State of New Mexico said that in-migration was severely underestimated, resulting in incorrect estimates of its effects. Because the local labor market is relatively tight, less than 50% of the jobs will be filled by local labor instead of the 50% assumed in the DEIS. Housing-construction workers are not included in the population estimates.

Response. Since the DEIS was issued, significant changes have been made in the schedule and the scope of the WIPP (Section 2.1.2). These changes have reduced the peak level of employment during the construction phase of the project. New impact calculations show no boom-and-bust cycle.

A review of the presently available occupations in the area in relation to future needs and a review of the effects of past projects on labor-force availability and in-migration were also performed for the FEIS. The FEIS contains the same migration coefficients used in the DEIS, as the reviews showed them to be reasonable for similar large construction projects in the Rocky Mountains and the Southwestern United States.

3. Issue. Several commentors, particularly residents of the area near the site, were concerned about the possibility of a boom-and-bust cycle during the construction of the project. There were several closely related comments, particularly by the State of New Mexico, that short-term inflation, tighter housing, and a strain on community social services were not given proper attention in the DEIS.

Response. The question of the effect of inflation during large construction projects needs a substantial amount of research. It is apparent that a large construction project in a very sparsely populated area produces some local inflation. The amount of inflation in the economic areas in which inflation occurs depends on several factors, including population density, the size and the type of the project, transportation facilities, manufacturing facilities for products, reaction of the local economy, etc. The FEIS does not contain answers to all these questions. The DOE has issued to the State of New Mexico and the University of New Mexico a grant for a socioeconomic analysis that will include a review of potential impacts due to inflation.

4. Issue. Several commentors, including the SWRIC and the State of New Mexico, disagreed with the input-output procedure used in calculating the socioeconomic impacts of the WIPP project. Some technical comments concerned the treatment of the government sector in the input-output model, the unsophisticated methods used in analyzing fiscal and infrastructure impacts, and the inherent weaknesses in the use of input-output models. The EPA said that the primary area of impact covered by the input-output procedure was too small.

Response. Several changes were requested in the economic modeling processes. Some of the requested changes, however, would lead to spurious results. One comment, concerning the inclusion of the government sector in the modeling process, was accommodated (see Appendix L). The techniques used to measure fiscal effects on communities were somewhat modified for the FEIS, even though the methods used in the DEIS were more sophisticated than the methods contained in most FEISs.

In this FEIS, no attempt was made to split the modeled economic system into the very small economic entities suggested in several comments. The smallness of the economy in the two-county area would not allow further disaggregation to the degree needed to satisfy the requests.

5. Issue. The issue eliciting the most comments on socioeconomics was the lack of sociocultural analysis in the DEIS. A number of commentors, including the State of New Mexico, the SWRIC, and several persons, felt that the impacts on certain cultural aspects, such as community and services and the quality of life in the area, had not been properly analyzed and were potentially severe. Many of these comments specifically mentioned the small towns (Loving, Jal, and Malaga) within 40 miles of the site.

Several commentors requested a discussion of the psychological stress of the WIPP project on area residents and those along transportation routes.

Response. A sociocultural analysis was undertaken for the FEIS that included discussions with approximately 200 residents in the general area of impact (portions of Eddy and Lea Counties). The results of the sociocultural analysis are reported in Section 9.4.3.1 and in Appendix H, Section H.2.2.

6. Issue. According to the Resource Economics Group, the State of New Mexico, the SWRIC, and others, the current housing situation in the area and the potential impact on housing were not given proper attention. No mitigating action was suggested for relieving the housing shortages expected during WIPP construction.

The Colorado Division of Planning said that new growth should be planned to be energy efficient.

Response. The housing situation in the general area of impact has changed significantly during the last 2 years, mainly because of high interest rates and the rising costs of materials. The housing description was completely reviewed and updated for the FEIS (Section 9.4.5 and Appendix H, Section H.3.3).

7. Issue. The SWRIC, the State of New Mexico, and several persons felt that the potential effects of the WIPP project on tourism were not properly analyzed.

- The storage of radioactive materials could have a potentially serious effect on tourism, which represents a substantial portion of the economic base in the area.

- Moreover, crowded conditions during the construction of the WIPP could result in a short-term decline in tourist traffic within the area, thus hurting certain tourist-related businesses.

Response. Tourism is a vital part of the economic base of the Carlsbad area. Most of it is attracted by the Carlsbad Caverns National Park southwest of the City of Carlsbad. It is difficult to determine how the WIPP project would affect tourism in the area, but past experience in New Mexico has shown that the existence of nuclear weapons laboratories and atomic energy research establishments has not hindered tourism. Although an accident with radioactive materials has the potential for damaging tourism in the area, the distance from the site to the national park (more than 50 highway miles) makes a long-term effect unlikely.

8. Issue. The State of New Mexico, the Resource Economics Group, the SWRIC, and others said that the socioeconomic-impact analysis contained in the DEIS did not present enough detail. These comments mentioned such issues as the increasing demand deposits and savings deposits from businesses and employees, the potential effect on small businesses in the area, and the costs of developing a subdivision.

Response. The socioeconomic analysis contains a degree of detail appropriate to the expected degree of impact. Small details of the effects on savings deposits, individual small businesses, costs of developing subdivisions, etc., are not warranted.

9. Issue. The DOI and several persons were concerned with the availability of, and the impact of the WIPP project on, recreational facilities in the area. The DEIS did not contain plans for the expansion of recreational facilities or associated costs. It was said that the increased population would strain existing regional facilities such as Lake McMillan, Laguna Grande de la Sal, and Carlsbad Caverns.

Response. The impact of the WIPP project on recreational facilities is expected to be minimal. Except for swimming pools in Carlsbad and campsites, the recreational facilities currently available in the area are considered to be adequate, and a new State park in Hobbs will alleviate the shortage of campsites. Detailed planning of new facilities is outside the scope of the FEIS.

10. Issue. The DEIS did not estimate the effects of the WIPP project on property values near the site or along the transportation routes. Dr. Cumberland of the Hearings Panel suggested that the Government should consider compensating those people along transportation routes or near the site who wished to move because of fear of the WIPP project.

Response. The FEIS does not contain an analysis of the effects on property values near the site or along transportation routes. Most of the property in the immediate area of the proposed site is administered by the Bureau of Land Management. The nearest center of commercial activity and residential population is Loving, more than 23 highway miles from the site. The DOE has issued a grant to the State of New Mexico and the University of New Mexico for a study that will address some aspects of this subject.

11. Issue. Although two cities, Carlsbad and Hobbs, were analyzed for impacts from the project, the community closest to the site, Loving, was not analyzed. The SWRIC and several persons commented on this issue.

Response. The FEIS discusses both the existing conditions in the community of Loving and the predicted impacts there. The analysis was completed to the same level of detail as that provided for Hobbs and Carlsbad, the two cities that will receive the primary impact (Section 9.4 and Appendix H, Section H.3).

15.29 ARCHAEOLOGY

Comments on the archaeological resources at the Los Medanos site were submitted in four letters and one oral statement. They are summarized below. A response to each issue is also provided.

1. Issue. The States of New Mexico and Vermont said that the DEIS does not contain sufficient archaeological information to permit an evaluation of the significance of the archaeological sites.

The State of New Mexico made the most substantive comments on this issue. It requested that the following be included: a discussion of the cultural history of the region; more detail in the site descriptions to permit other reviewers to evaluate the significance of the archaeological sites, a specific discussion and evaluation of the significance of each site, and the inclusion of all inventory reports in an appendix.

Response. The discussion of the archaeology of the Los Medanos site has been expanded, updated, and moved to Appendix H, Section H.1.5. Because inclusion of the archaeology survey reports would add considerable volume to the FEIS, the results have been summarized in Appendix H. Copies of the survey reports are available on request from the DOE. A map (Figure H-2) showing the locations of the archaeological sites has been added.

The DOE has complied with the requirements of Section 106 of the National Historic Preservation Act in determining the eligibility of archaeological sites for inclusion in the Historic Register and has consulted with the Keeper of the Historic Register and the New Mexico State Historic Preservation Officer. The correspondence with these agencies is reproduced in Appendix I. The DOE will continue to comply with the National Historic Preservation Act by identifying any additional eligible properties and requesting and implementing a consultation process to mitigate or minimize any adverse impacts. Both of the officers above will be involved in this process.

2. Issue. The State of New Mexico and the DOI requested that other surveys be conducted to further delineate the areas previously surveyed and to provide data on sites in control zones III and IV.

Response. Further archaeological surveys will be conducted throughout the Los Medanos site, including sample surveys in the outer zones III and IV. Mitigation measures for affected sites discovered during previous surveys or in future surveys will be developed in cooperation with the State Historic Preservation Officer and the Advisory Council on Historic Preservation. Mitigating measures to be employed will address the problem of the effects of radionuclide contamination on radiocarbon dating of archaeological sites.

3. Issue. The State of New Mexico, the DOI, and an individual asked that mitigation measures be clearly defined for the archaeological sites discovered at the Los Medanos site. The mitigation measures should include the protection of existing sites; further detailed studies of the existing sites, including excavation and accurate dating; further surveys of the entire site; and the development of a regional cultural history.

Response. See items 1 and 2 above.

4. Issue. The State of New Mexico indicated that a release of radionuclides can contaminate archaeological sites and render radioactive dating methods useless.

Response. See item 2 above.

5. Issue. The NRC requested a discussion of unavoidable adverse impacts and irretrievable and irreversible commitments of archaeological resources.

Response. The potential impacts on archaeological resources will be avoided or mitigated through consultation with the State Historic Preservation Officer and the Advisory Council on Historic Preservation and the performance of an accepted impact-mitigation program (Section 9.6.4). No unavoidable adverse impacts on these resources will occur.

15.30 ECOLOGY AND LAND USE

Comments on ecology and land use at the Los Medanos site were made in eight letters and six oral statements. In particular, the State of New Mexico made extensive specific comments. The comments are summarized below. A response to each issue is also provided.

1. Issue. Two commentors requested a clarification of minor inconsistencies (e.g., number of cattle supported) in land-use data and the minimal impacts on land use.

Response. The inconsistencies in land-use data have been corrected, and the discussion of the significance of land-use impacts has been expanded.

2. Issue. The State of New Mexico and the DOI said that the presentation of baseline ecological data (vegetation and wildlife) is inadequate. There are inconsistencies between some tables and several statements. The discussion of endangered and threatened species (designated by the Federal Government or the State of New Mexico) should be clarified.

The State of New Mexico suggested numerous specific changes in Appendix H pertaining to additions and deletions in tables of plant and animal species (e.g., game birds, abundance estimates, and the potential occurrence of certain species).

Response. Similarly, the presentation of baseline ecological data (Appendix H, Section H.5) has been reevaluated and updated with more recent field data. The section on ecology in Chapter 7 (Section 7.1) has also been expanded. Technical comments made by the State of New Mexico were resolved in the text and Appendix H of the FEIS (Section 7.1 and Section H.5).

3. Issue. The DOI, the NRC, the State of Florida, and several persons said that the impacts section is fragmented and overlooks some important impacts. Ecological impacts resulting from such actions as construction, salt-dust emissions, fencing, roadways, rights-of-way, and power-line construction should be more fully reported.

For example, the DOI suggested that roadway impacts should include the loss of habitat, increased accidental deaths, and the inhibition on movement for certain species. The DOI also said that benefits of new vegetation communities along roadways should not be overemphasized and requested that the relation of impacts to potential BLM wilderness areas be discussed.

Response. The discussion of environmental impacts has been restructured to avoid fragmentation. Section 9.1 has been added to identify the actions that may lead to environmental impacts. All impacts exerted on the biophysical environment during construction and operation are discussed in Sections 9.2 and 9.3.

4. Issue. The NRC, the DOI, and the State of New Mexico requested that mitigation measures be more fully specified. Some examples given were revegetation, measures taken in power-line construction to reduce raptor deaths, and the fencing of water impoundments to protect wildlife.

Response. In restructuring the presentation of impact analyses, a separate section (Section 9.6) on the mitigation of impacts has been prepared. It evaluates and discusses most of the mitigation measures suggested in the comments.

15.31 ISSUES OUTSIDE THE SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT

15.31.1 Approval, Disapproval, No Comment

Some letters and statements did not discuss any specific issues in the DEIS but expressed general approval or disapproval of the project. Three letters and 20 statements expressed general disapproval of the WIPP project but raised no issues with the DEIS. Nine written letters and 27 oral statements expressed approval of the WIPP project, and many of these complimented the completeness of the DEIS.

Some of the commentors expressed disapproval of the nuclear-weapons and the nuclear-power industries in general. Conversely, other commentors expressed approval of the nuclear industry and indicated the need for nuclear weapons for national defense.

Letters received from 15 State (other than New Mexico) Planning and Clearinghouse Agencies and one Federal agency expressed neither approval nor disapproval of the DEIS but merely acknowledged its receipt and requested a copy of the FEIS.

These comments have been recorded but require no formal response by the DOE in the FEIS. Copies of the FEIS will be sent to the agencies and individuals requesting them.

15.31.2 Bias

The issue of bias in the WIPP DEIS was raised in 9 written letters and 10 oral statements. These comments can be summarized as follows:

1. The DEIS reflects a bias in favor of nuclear power and radioactive-waste isolation and does not present the facts in an objective manner. The document lacks candor concerning the issues and problems associated with the WIPP.

2. The DEIS overemphasizes negative effects and is overconservative in its presentation of environmental effects.

3. The proposed WIPP site in New Mexico was selected on the basis of political expediencies.

4. The DOE should not have written the WIPP DEIS because the choice of a radioactive-waste-disposal site involves a conflict of interest for the DOE, which is a promoter of nuclear energy.

The DOE and its contractors have made every effort to be objective in the preparation and writing of the EIS. Responsible opposing viewpoints have been carefully considered in the analyses and resolutions of comments made on the DEIS. In preparing the DEIS and this FEIS, the DOE responded to the requirements of the National Environmental Policy Act, which states that the agency proposing a major Federal action is the one responsible for the preparation of the attendant EIS.

15.31.3 Translation into Spanish and Indian Languages

The translation of the DEIS into Spanish and Indian languages was an issue raised in 5 written letters and 11 oral statements. Because approximately 56% of the New Mexico population speaks Spanish or one of the Indian languages, the DEIS should have been published in Spanish and several Indian languages in order to allow participation by all New Mexico residents. Governor Bruce King of New Mexico requested a summary of the FEIS in Spanish and Indian languages.

State officials and sociological consultants indicated that the great majority of the people in New Mexico who are literate are literate in English. Consequently, this FEIS has been published only in English. A summary of the FEIS, however, is being published in Spanish and will be distributed by the DOE. Notice of its availability will be published in the Federal Register and in local newspapers, both in English and in Spanish. The summary describes the authorized WIPP project and alternatives, the site and environmental interfaces, the transportation of waste to the site, environmental impacts, public participation, and interagency coordination.

In addition, the DOE provided a Spanish translator at the public hearings conducted at Odessa, Texas, and Hobbs and Santa Fe, New Mexico.

15.31.4 Licensing

Thirteen letters and 12 oral statements raised the issue of NRC licensing for the proposed WIPP. These comments are summarized as follows:

1. NRC licensing should be required for the WIPP regardless of the scope of the project.

   Governor Bruce King and the State of New Mexico strongly favor the licensing of the repository for health and safety reasons despite congressional objections to the NRC licensing of defense facilities. Others requesting licensing included several citizens and public-interest groups.

2. A nonlicensed facility represents a major change in the scope of the project as presented, and a new DEIS should be prepared.

3. NRC licensing is not necessary for the WIPP.

4. The WIPP Hearings Panel recommended that the DOE consider establishing an independent review board for the WIPP project if NRC licensing is not performed.

The authorizing legislation requires that the proposed WIPP be developed without licensing by the NRC. President Carter, in his February 12, 1980 message, recommends that all facilities for the permanent disposal of highly radioactive material be licensed. Alternative 3, the preferred alternative, provides for the disposal of defense-program waste in an NRC-licensed repository. The absence of NRC licensing, however, does not mean that the design and operation of the WIPP will not be subjected to review by independent groups within the DOE--review, that will insure that all WIPP safety-related features are designed, constructed, and operated in accordance with DOE safety regulations. Independent reviews of various aspects of the WIPP project are also being performed by the State of New Mexico and the National Academy of Sciences. The DOE is funding the State review.

Finally, it should be noted that licensing by the NRC does not change the environmental impacts of the WIPP.

15.31.5 Public Participation

The issue of public participation was raised in 9 letters and 23 oral statements. Most of these comments came from public-interest groups and private persons, but the State of New Mexico also was concerned about the adequacy of the time allotted for public involvement. These comments are summarized as follows:

1. The time allowed for the public to review a document as complicated as the WIPP DEIS was inadequate.

2. The public hearings were inadequate and were arranged and conducted in a manner that inhibited public participation: Not enough time was allowed for review before the hearings; in order to comment, a summary statement had to be submitted within a very short time period; the public was not adequately notified about the hearings; the timing and scheduling discouraged public participation; and more hearings in other locations were necessary, particularly in locations close to the site, in west Texas, and along transportation routes. This issue received by far the most comments.

3. Public hearings were conducted well and the opportunity for public participation was appreciated.

4. Supporting as well as opposing comments should be considered.

5. The DOE is minimizing publicity about the WIPP.

6. How will the DOE respond to the public comments?

Early in the public review process for the WIPP DEIS, the DOE recognized that the time allotted for this review was not sufficient. Accordingly, the written-comment period was extended by two months to September 6, 1979, and all written comments received through October 5, 1979, were considered in the preparation of the FEIS. Furthermore, the DOE held additional public hearings in Texas and New Mexico nearly six months after the release of the DEIS to insure that interested persons had adequate time to review the document and voice their concerns. Procedures for the conduct of the hearings were modified to permit oral statements without advance requests or the preparation of a written summary statement.

15.31.6 State Consultation

The issue of State consultation and cooperation for the WIPP project and waste transportation was raised in 5 letters and 14 oral statements. These comments can be summarized as follows:

1. Review and concurrence by the State of New Mexico is necessary in all aspects of the WIPP project. Most of the comments on this issue were made by New Mexico State officials. In addition, the representative of U.S. Senator McClure of Idaho expressed the view that State consultation should be required for any project similar to the WIPP.

2. Many persons and public interest groups said that either the State of New Mexico should have veto power over WIPP or public referenda should be held in New Mexico to allow the public to voice its opinions on the WIPP.

3. Several States (Utah, Missouri, and Texas) requested State consultation on the transportation of radioactive waste.

4. The Hearings Panel asked that the FEIS define the role of the State in the WIPP project.

   Recent legislation directs the Secretary of Energy to enter into a memorandum of understanding with appropriate officials of the State of New Mexico regarding the procedures for "consultation and cooperation" on the WIPP project. This agreement is to be entered into by September 30, 1980, and submitted to Congress within 15 days thereafter.

15.31.7 Emplacement of Spent Fuel in the WIPP Repository

Comments dealing specifically with the ramifications of emplacing up to 1000 spent-fuel assemblies in an intermediate-scale facility (ISF) in the WIPP repository were submitted in 24 letters and 14 oral statements. The comments can be summarized as follows:

1. An ISF is vitally needed and should be included in the WIPP repository. Without an ISF the WIPP program appears less important.

   - The U.S. Arms Control and Disarmament Agency stressed the importance of the proposed ISF to the nonproliferation of nuclear weapons.

- The State of Maryland and other commentors emphasized the need of an ISF for the continued use of nuclear power.

- Governor King of New Mexico said that, without an ISF, the urgency of the WIPP diminishes. Similarly, the NRC stated that the program advantages of the WIPP are diminished without an ISF.

2. In contrast, many commentors, including U.S. Senator McClure of Idaho and several industrial groups, said that spent fuel is too valuable to be disposed of in a geologic repository. At a minimum, the retrievability of spent fuel must be maintained or, preferably, defense high-level waste alone should be used.

3. Several commentors (including the State of California, the NRDC, and several other public-interest groups), expressed the opinion that the ISF would be premature in the WIPP; more research into radioactive-waste disposal in salt is required before an ISF can be considered. An ISF may be more appropriate in an HLW repository.

4. The advantages and disadvantages of the colocation of facilities need to be more fully investigated. The EPA explicitly included this comment as a major issue for the DEIS.

   - The State of Ohio expressed support for colocation, whereas the State of California expressed opposition.

   - The NRC stated that the DEIS failed to distinguish adequately between the impacts of a colocated TRU-waste repository and ISF and those of a TRU-waste repository alone.

5. The SWRIC and other public-interest groups expressed concern that the inclusion of an ISF would lead to the eventual construction of a reprocessing plant at the WIPP site.

6. The NRDC and private citizens expressed the opinion that the only reason for including an ISF in the WIPP was to help the nuclear-power industry, which is being affected by state moratoriums prohibiting plant construction until the waste problem is solved.

In addition, the NRC and others forwarded detailed comments on the long-term interaction of spent fuel with the geologic host medium.

Authorizing legislation limits alternative 2 to radioactive waste resulting from defense activities and programs. Consequently, comments on commercial-spent-fuel disposal are no longer relevant to the potential use of the Los Medanos site for the WIPP project; the inclusion of an ISF in the WIPP facility is not a reasonable alternative. If the Los Medanos site is proposed as the site of a repository for commercial high-level waste, further environmental evaluation will be required.

Table 15-1. Index of Commentors at the WIPP DEIS Hearings

Statement index number[a]	Name	Affiliation	Hearing location[b]
9000	Hall, Mr. Kirk	Governor Evans of Idaho	ID
9001	Field, Mr. Mike	U. S. Senator McClure of Idaho	ID
9002	Merkley, Ms. Ann	Nuclear Counterbalance	ID
9003	Barraclough, Mr. J. T.	U.S. Geological Survey	ID
9004	Ritter, Gerald	Atomic Industrial Forum	ID
9005	Squire, Mr. Al	Westinghouse Electric Corporation	ID
9006	Donnelly, Mr. Dennis	Nuclear Counterbalance	ID
9007	Hill, Ms. Hazel A.		ID
9008	Courtney, Mr. Jack		ID
9009	Lash, Dr. Terry	Natural Resources Defense Council	AL
9010	Goldstein, Dr. George	Governor King of New Mexico	AL
9011	Williams, Mr. Kelly	Americans for Rational Energy Alternatives	AL
9012	Ouelletto, Mr. Will	New Mexico Wildlife Federation	AL
9013	McDaniel, Ms. Judith		AL
9014	Kinney, Mr. Harry		AL
9015	Williams, Dr. David C.	Americans for Rational Energy Alternatives	AL
9016	Rodgers, Ms. Sally	Friends of the Earth	AL
9017	Romero, Ms. Ann	Nuclear Women of New Mexico	AL
9018	Gordon, Mr. John B.	Texas Energy Advisory Council	AL
9019	Hancock, Mr. Don	Southwest Research and Information Center	AL
9020	Turney, Ms. Evelyn		AL
9021	Dickerson, Ms. Storm		AL
9022	Toulouse, Ms. Charlotte		AL
9023	Clark, Mr. Ken III	Citizens Against Radio-active Dumping	AL
9024	Grand, Ms. Thora		AL
9025	Montague, Dr. Peter	Southwest Research and Information Center	AL
9026	Neill, Dr. Robert	New Mexico Environmental Evaluation Group	AL
9027	Hafer, Dr. Fritz	Nuclear Counterbalance	AL
9028	Keaveney, Mr. Barry	Taos Citizens Together	AL

Table 15-1. Index of Commentors at the WIPP DEIS Hearings (continued)

Statement index number[a]	Name	Affiliation	Hearing location[b]
9029	Kitts, Mr. Michael	Taos Citizens Together	AL
9030	Ahlen, Mr. Jack	New Mexicans for Jobs and Energy	AL
9031	Phillips, Mr. Richard Hayes	Citizens Against Nuclear Threats	AL
9032	Pratt, Ms. Judith	New Mexico State Representative	AL
9033	Eschen, Mr. Veryl	Atomic Industrial Forum	AL
9034	York, Mr. R. E.	El Paso Electric Company	AL
9035	Hyder, Dr. Charles	Southwest Research and Information Center	AL
9036	Salazar, Mr. Nacho	Energy Association of Taxpayers	AL
9037	Williams, Dr. David C.	Americans for Rational Energy Alternatives	AL
9038	Lambert, Mr. Ray W.	General Electric Corporation	AL
9039	Grado, Ms. Rosa		AL
9040	Philbin, Dr. Jeffrey S.		AL
9041	Biggs, Dr. Frank		AL
9042	Guinn, Ms. Thora	Citizens' Against Nuclear Threats	AL
9043	Lareau, Mr. Jim		AL
9044	Logan, Dr. Stanley		AL
9045	Earnest, Mr. Elbert		AL
9046	Stoy, Mr. Michael		AL
9047	Watt, Dr. Bob E.		AL
9048	Schneider, Dr. Kathleen	Physicians for Social Responsibility	AL
9049	Briggs, Mr. Jack		AL
9050	Witkop, Mr. Carl		AL
9051	Zook, Mr. Kenneth	Citizens Against Nuclear Threats	AL
9052	Sherson, Mr. Marc		AL
9053	Carver, Ms. Melanie		AL
9054	McDaniel, Dr. Patrick J.	Americans for Rational Energy Alternatives	AL
9055	Fox, Mr. Steven		AL
9056	Silva, Mr. Lauro		AL
9057	Cobb, Ms. Sandra O.		AL
9058	Priester, Mr. David	Texas Attorney General	AL
9060	White, Mr. P. L.		AL
9061	Romine, Mr. Robert		AL
9062	Hazelrigg, Ms. Deidre	Concerned Citizens of Cerrillos	AL
9063	Davis, Dr. Theodore	Physicians for Social Responsibility	AL

Table 15-1. Index of Commentors at the WIPP DEIS Hearings (continued)

Statement index number[a]	Name	Affiliation	Hearing location[b]
9064	Perkins, Mr. Dave	Atomic Industrial Forum	AL
9065	Dendahl, Mr. John		AL
9066	Melfi, Ms. Christa		AL
9067	Fleck, Dr. Martin		AL
9068	Williams, Dr. David C.	Americans for Rational Energy Alternatives	AL
9069	Braus, Dr. Anthony	Physicians for Social Responsibility	AL
9070	Deuel, Mr. J. K.		AL
9071	Sasmor, Ms. Betty P.		AL
9072	Ray, Ms. Tracy	Taos Citizens Together	AL
9073	Nathanson, Mr. Jeffrey	Southwest Research and Information Center	AL
9074	Mulcahy, Mr. Terrence		AL
9075	Simpson, Mr. Craig	War Resisters League	AL
9076	Foster, Mr. D. Graham		AL
9077	Baker, Dr. Louis		AL
9078	Acuff, Mr. Mark		AL
9079	Harrington, Dr. Eldred R.		AL
9080	Turrietta, Mr. James		AL
9081	Saucier, Ms. Evelyn	Americans for Rational Energy Alternatives	AL
9082	Wallentinsen, Mr. Derek	Sierra Club	AL
9083	Montenegro, Mr.		AL
9084	Melfi, Mr. Bill	Americans for Rational Energy Alternatives	AL
9085	Naylor, Ms. June	Ector County, Texas, League of Women Voters	AL
9086	Dennis, Mr. Martin		AL
9087	Arenson, Mr. Michael		AL
9088	Williams, Mr. Joe		AL
9089	Redus, Mr. Michael		AL
9090	Mr. Julian Riveria-deVargas		AL
9091	Lapzzynski, Ms. Sally		AL
9092	Matilda		AL
9093	Law, Mr. Tom		AL
9094	Jensen, Mr. John		AL
9095	Kleen, Mr. Reno		AL
9096	Gerrells, Mr. Walter	Mayor of Carlsbad	CB
9097	Gervers, Mr. John	New Mexico Radioactive Waste Consultation Task Force	CB
9098	Stone, Ms. Nancy		CB
9099	Lyon, Mr. E. P.	Carlsbad Industrial Action, Department of Development	CB
9100	McNabb, Mr. Dan	Lea County Industrial Development Corporation	CB

Table 15-1. Index of Commentors at the WIPP DEIS Hearings (continued)

Statement index number[a]	Name	Affiliation	Hearing location[b]
9101	Cobble, Mr. Steven B.		CB
9102	Smith, Ms. Molly	Citizens Opposed to Nuclear Waste Disposal in New Mexico	CB
9103	Ceniceros, Mr. Leonel	Southern New Mexico Legal Services	CB
9104	Watts, Mr. Marvin	AMAX Chemical Corporation	CB
9105	Stages, Ms. Nancy		CB
9106	Carrasco, Mr. Anthony		CB
9107	Frank, Ms. Teresa F.		CB
9108	Bruno, Ms. Patricia		CB
9109	Ross, Ms. Teresa		CB
9110	Quitberg, Mr. Leo V.	New Mexico Wildlife Federation	CB
9111	Kurent, Mr. Michael		CB
9112	Burns, Mr. E. B.		CB
9113	Fountain, Mr. Arthur H.		CB
9114	Burns, Ms. Isabelle	Sierra Club	CB
9115	Thompson, Ms. Geneva	American Indian Environmental Council	CB
9116	Van Dolsen, Mr. Charles	United Steelworkers Local 183	CB
9117	Kartchner, Ms. Roxanne		CB
9118	Fox, Mr. Steven		CB
9119	Stages, Mr. Andrew		CB
9120	Silva, Mr. Lauro		CB
9121	Martinez, Mr. J. A.	Carlsbad Neighborhood Association	CB
9122	Hoellwarth, Mr. Lee W.		CB
9123	Taylor, Ms. Lynda		CB
9124	Best, Ms. Alynda		OD
9125	Lyon, Mr. E. P.	Carlsbad Industrial Action, Department of Development	OD
9126	O'Chesky, Mr. Fred	New Mexico Radioactive Waste Consultation Task Force	OD
9127	Priester, Mr. David	Texas Attorney General	OD
9128	Meadows, Mr. Steve		OD
9129	Erskine, Ms. Midge		OD
9130	Perrine, Ms. Catherine	Ector County, Texas, League of Woman Voters	OD
9131	Hickerson, Mr. A. L.		OD
9132	Byerly, Ms. Olivia		OD
9133	Roberts, Ms. Jewel		OD
9134	Hilton, Mr. Wayne A.		OD
9135	Aldridge, Mr. Stephen		HO
9136	Miller, Mr. Forrest		HO

Table 15-1. Index of Commentors at the WIPP DEIS Hearings (continued)

Statement index number[a]	Name	Affiliation	Hearing location[b]
9137	Lyon, Mr. E. P.	Carlsbad Industrial Action, Department of Development	HO
9138	Levine, Ms. Carol		HO
9139	Gervers, Mr. John	New Mexico Radioactive Waste Consultation Task Force	HO
9140	Verchinski, Mr. Steve	American Society Against Nuclear Power	HO
9141	Gerrells, Mr. Walter	Mayor of Carlsbad	HO
9142	Richardson, Mr. William		SF
9143	Geiger, Mr. Eric		SF
9144	Harmon, Ms. Naomi		SF
9145	Dowds, Mr. Charles		SF
9146	Williams, Dr. David C.	Americans for Rational Energy Alternatives	SF
9147	Bernhardt, Mr.		SF
9148	Brahe, Mr. Joseph		SF
9149	Vondruska, Mr. Thomas		SF
9150	McGeorge, Ms. Ruth	Lama Foundation	SF
9151	Gutshall, Ms. Shawn		SF
9152	Reese, Ms. Bonnie	Lama Foundation	SF
9153	Reese, Mr. Ron	Lama Foundation	SF
9154	Kilbridge, Mr. Jamil	Lama Foundation	SF
9155	Pinkston, Mr. John		SF
9156	Wellman, Ms. Latifa	Lama Foundation	SF
9157	Breslin, Ms. Carina	Lama Foundation	SF
9158	Dendahl, Mr. John		SF
9159	Kitts, Mr. Michael	Taos Citizens Together	SF
9160	Fox, Mr. Steven		SF
9161	Miller, Mr. Forrest		SF
9162	Keaveney, Mr. Barry	Taos Citizens Together	SF
9163	Gervers, Mr. John	New Mexico Radioactive Waste Consultation Task Force	SF
9164	Lyon, Mr. E. P.	Carlsbad Industrial Action, Department of Development	SF
9165	Stoy, Mr. Michael		SF
9166	Warshawar, Mr.		SF
9167	Hill, Ms. Laura	Concerned Citizens of Santa Fe	SF

[a]Number code used in computer indexing of comments received.

[b]Key to hearing location: ID = Idaho Falls, Idaho, June 5, 1979; AL = Albuquerque, New Mexico, June 7 and 8, 1979; CB = Carlsbad, New Mexico, June 9, 1979; OD = Odessa, Texas, October 1, 1979; HO = Hobbs, New Mexico, October 2, 1979; SF = Santa Fe, New Mexico, October 5, 1979.

Table 15-2. Index of Commentors Submitting Written Comments on the WIPP DEIS

Letter index number[a]	Name or Organization
0001	The Paleontological Society, National Museum of Natural History, Mr. Richard E. Grant
0002	State of North Dakota, Planning Division
0003	AI Nuclear Energy Services, Inc.
0004	R. Seitz, Ward County Judge
0005	Environmental Coalition on Nuclear Power
0006	State of Oregon, Executive Department, Intergovernmental Relations Division
0007	State of Illinois, Executive Office of the Governor, Bureau of the Budget
0008	Mr. Karl Thomas Feldman, Jr.
0009	New Mexico Section, Society of Range Management
0010	State of North Carolina, Department of Administration
0011	U.S. Water Resources Council
0012	Congress of the United States, House of Representatives, Rep. Kent Hance
0013	State of South Dakota, Office of Executive Management, State Planning Bureau
0014	Mr. Robert Jones
0015	Pennsylvania State Clearinghouse
0016	CITE, Citizens for Total Energy
0017	U.S. Arms Control and Disarmament Agency
0018	CE Power Systems, Combustion Engineering, Inc.
0019	State of Delaware, Executive Department, Office of Management, Budget and Planning
0020	Ms. Elizabeth M. Cooley
0021	Ms. Leslie A. Thomas

Table 15-2. Index of Commentors Submitting Written Comments on the WIPP DEIS (continued)

Letter index number[a]	Name or Organization
0022	Mr. Paul and Ms. Mildred Lusk
0023	State of Utah, Division of Policy and Planning Coordination
0024	State of Alaska, Office of the Governor, Division of Policy Development and Planning
0025	Nuclear Counterbalance
0026	E. W. Mitchell
0027	TRIAD and Associates, Inc.
0028	State of Florida, Department of Administration, Division of State Planning
0029	Ms. Hazel Hill
0030	State of Missouri, Office of Administration
0031	State of Indiana, State Board of Health
0032	Ohio State Clearinghouse
0033	State of Vermont, Office of the Governor, State Planning Office
0034	Ms. Cathy Moser
0036[b]	Yates County (New York) Planning Board
0037	Mr. Joseph L. Gendron
0038	State of Rhode Island and Providence Plantations, Department of Administration, Statewide Planning Program
0040[c]	Arizona State Clearinghouse
0041	Mr. Phillip L. Boucher
0042	State of Nevada, Governor's Office of Planning Coordination
0043	State of Florida, Department of Environmental Regulation
0044	Mr. Michael Stoy
0045	Lynn R. Chong

Table 15-2. Index of Commentors Submitting Written Comments on the WIPP DEIS (continued)

Letter index number[a]	Name or Organization
0047[c]	State of Maryland, Department of State Planning
0048	State of Texas, Office of the Governor
0049	Americans for Rational Energy Alternatives, Inc., Nuclear Division
0050	The Izaak Walton League of America, Land of Enchantment Chapter
0051	PLENTY
0052	State of Kansas, Department of Administration, Division of State Planning and Research
0054[c]	Mr. Mark Johns
0055	Mr. John B. Griffiths
0056	Ms. Gladys R. Winblad
0057	Mr. John Camp
0058	Ms. Barbara Honors
0059	Natural Resources Defense Council, Inc.
0060	Westinghouse Electric Corporation, Power Systems Company
0061	A.P.
0062	Penberthy Electromelt International, Inc.
0063	State of Colorado, Department of Local Affairs, Division of Planning
0064	C. E. Davis
0065	Ms. Laura H. Connolly
0066	Lowenstein, Newman, Reis, Axelrad, & Toll
0067	New Mexico Bureau of Mines and Mineral Resources
0068	Southeastern New Mexico Economic Development District
0069	New York Federation for Safe Energy
0070	For a Habitable World

Table 15-2. Index of Commentors Submitting Written Comments on the WIPP DEIS (continued)

Letter index number[a]	Name or Organization
0071	Sierra Club, Rio Grande Chapter
0072	Sierra Club
0073	Atomic Industrial Forum, Inc.
0074	Americans for Rational Energy Alternatives, Nuclear Division
0075	State of New Mexico, Office of the Attorney General, Department of Justice
0076	State of California, Energy Resources Conservation and Development Commission
0077	Dr. Charles L. Hyder
0078	Southwest Research and Information Center
0079	State of New Mexico, Department of Finance and Administration, Planning Division
0080	State of New Mexico, Environmental Evaluation Group
0081	Mr. A. L. Hickerson
0082	Mr. Mike Rodriguez
0083	The Honorable Bruce King, Governor of New Mexico
0084	State of New Mexico, Governor's Advisory Committee on WIPP
0086	State of Mississippi, Office of the Governor, Planning and Coordination
0087	Community for Nonviolent Action
0088	U.S. Environmental Protection Agency
0089	Women's Health Service
0090	State of Georgia, Executive Department, Office of Planning and Budget
0091	U.S. Department of Health, Education and Welfare

Table 15-2. Index of Commentors Submitting Written Comments on the WIPP DEIS (continued)

Letter index number[a]	Name or Organization
0092	U.S. Nuclear Regulatory Commission
0093	U.S. Department of the Interior
0094	State of California, Department of Conservation, Division of Mines and Geology
0095	Gulf Oil Exploration and Production Company
0096	Commonwealth of Kentucky, Department of Natural Resources and Environmental Protection
0097	Report of the Public Hearing Panel, WIPP DEIS, Hearings conducted at Odessa, Texas (October 1, 1979); Hobbs, New Mexico (October 2, 1979); and Santa Fe, New Mexico (October 5, 1979)
0098	Dr. William F. Pike

[a]Number designator used in computer indexing program for classifying WIPP DEIS comments.

[b]Letter number 0035 was a draft of the U.S. Department of Health, Education and Welfare comments later superseded by final comments in letter number 0091.

[c]Letters numbers 0039, 0046, and 0053 were initially assigned in error.

Table 15-3. Keywords for Classifying Comments on the WIPP DEIS

Accidents
Alternatives
Approval (project)
Archaeology
Bacterial degradation
Benefits
Bias
Boom-bust cycle
Borehole plugging
Brine pockets
Climate
Containers
Cost
Decommissioning
Delay
Design
Disapproval (project)
Dissolution
Earth science
Ecology
Editorial changes
Emergency plan
Employment
Experimental programs
Faulting
Geodisposal suitability
Groundwater
Health effects
Housing
INEL (Idaho National Engineering Laboratory)
IRG (Interagency Review Group on Nuclear Waste Management)
ISF (ntermediate-scale facility)
Institutional issues
Insurance
Land use
Language translation
Licensing
Long-term isolation
Monitoring
NEPA compliance
No comments
Nuclide migration
Objectives (programmatic)
Operations
Other media
Public participation
Radiation
Regulations
Releases (routine)
Research
Resources
Retrievability
Routes
Salt-bed suitability
Schedules
Scope (project)
Security
Seismicity
Site selection
Slagging pyrolysis
Socioeconomics
Spent fuel
State consultation/cooperation
Stress
Supporting analyses
Surface water
TRU waste
Transportation
Waste form

Table 15-4. Matrix Identifying Issues Raised by Commentors on the WIPP DEIS

Issue	Type of comment	Commentors		
		Federal	State and local	Individuals and groups
Scope and objectives	Oral		9126	9004, 9012, 9035
	Written	0088, 0092, 0093	0024, 0040, 0076, 0083	0059, 0060, 0071, 0078
Benefits, costs, and schedule	Oral		9000, 9125, 9141, 9018, 9126, 9139	9005, 9009, 9027, 9028, 9031, 9045, 9047, 9066, 9068, 9071, 9086, 9140, 9103
	Written	0092	0079, 0083, 0024, 0063, 0068 0085, 0043, 0048, 0076	0037, 0041, 0054, 0059, 0062, 0078, 0060, 0069, 0071, 0072, 0073, 0074, 0049
Alternatives	Oral		9000, 9126	9162, 9005, 9027, 9040, 9043, 9045, 9046, 9047, 9050, 9142, 9159, 9077, 9124, 9140, 9002, 9054, 9064, 9082, 9158, 9006, 9009, 9019, 9023, 9025, 9031, 9075
	Written	0088, 0091, 0092, 0093	0094, 0047, 0083, 0079 0024, 0032, 0042, 0043, 0063, 0076, 0084, 0068	0009, 0018, 0022, 0037, 0044, 0049, 0058, 0059, 0060, 0062, 0065, 0066, 0069, 0070, 0071, 0072, 0073, 0078, 0087, 0097
Continued waste storage at INEL	Oral	9001	9000	9002, 9006, 9007, 9019, 9027, 9028, 9045
	Written	0088, 0092	0032, 0076	0014, 0059, 0060, 0062, 0070, 0072
NEPA compliance	Oral			9039, 9140
	Written	0088, 0092, 0093	0028, 0076, 0079, 0083	0005, 0059, 0071, 0072, 0078, 0087
Regulations governing WIPP	Oral			9004, 9019, 9031, 9053, 9107, 9128, 9142
	Written	0092, 0093	0043, 0048, 0079, 0080, 0084	0051, 0071, 0078, 0087
Salt-bed suitability	Oral			9009, 9031, 9035, 9062, 9075, 9080, 9098, 9029, 9101, 9103, 9105, 9142, 9149, 9155, 9052, 9037
	Written	0088, 0092, 0093	0076, 0079, 0080	0034, 0037, 0041, 0050, 0051, 0056, 0058, 0059, 0069, 0072, 0077, 0078
Site selection	Oral			9009, 9035, 9042, 9045, 9051, 9057, 9082, 9142, 9158, 9162
	Written	0088, 0092, 0093	0032, 0080, 0094	0005, 0058, 0059, 0060, 0071, 0072, 0073, 0078

Table 15-4. Matrix Identifying Issues Raised by Commentors on the WIPP DEIS (continued)

Issue	Type of comment	Commentors		
		Federal	State and local	Individuals and groups
Geologic site suitability	Oral			9009, 9031, 9035, 9051, 9053 9057, 9105, 9130, 9142
	Written	0012, 0088, 0092, 0093	0004, 0084, 0079, 0040 0043, 0067, 0076	0054, 0069, 0077, 0078, 0044, 0001, 0034, 0059, 0050, 0097, 0087, 0089, 0097
Hydrologic site suitability	Oral		9058, 9127, 9139	9031, 9124, 9136, 9142, 9105, 9077, 9075, 9130, 9027, 9025, 9149, 9042, 9057, 9155, 9052, 9085, 9135, 9002
	Written	0012, 0088, 0092, 0093	0004, 0043, 0048, 0079, 0085, 0076, 0080, 0094, 0067,	0069, 0059, 0046, 0054, 0073, 0078, 0058, 0072, 0012, 0014, 0097
Resource conflict	Oral		9139	9015, 9019, 9023, 9031, 9047, 9073, 9084, 9098, 9102, 9107, 9124
	Written	0088, 0092, 0093	0004, 0012, 0032, 0067, 0076, 0079, 0084	0037, 0049, 0050, 0059, 0060, 0065, 0072, 0073, 0074, 0078, 0095
Borehole location and plugging	Oral			9159
	Written	0088, 0092		0005, 0072
Long-term waste isolation	Oral			9006, 9019, 9031, 9042, 9035, 9038, 9015, 9027, 9044, 9047, 9114, 9146, 9159
	Written	0088, 0092	0043, 0076, 0004, 0079, 0084, 0080	0059, 0074, 0012, 0044, 0049, 0054, 0072, 0073, 0078, 0045
Plant design and operations	Oral			9007, 9025, 9027, 9040
	Written	0088, 0091, 0092, 0093	0048, 0063, 0079, 0084, 0094	0060, 0073
Waste form	Oral			9002, 9009, 9016, 9019, 9025, 9027, 9031, 9060, 9082, 9112
	Written	0088, 0092, 0093	0032, 0043, 0079, 0080	0049, 0050, 0059, 0060, 0071, 0073, 0074, 0078, 9024, 9026, 9097, 9122
Slagging pyrolysis and other waste-processing methods	Oral			9002, 9006, 9007, 9031, 9045
	Written	0088, 0092	0094	0014, 0037
Planned experimental programs	Oral	9001	9126	9002, 9004, 9009, 9031, 9033, 9038, 9052, 9053, 9082
	Written	0088, 0092, 0093	0024, 0043, 0079, 0080, 0084	0005, 0051, 0059, 0060, 0069, 0078, 0097

Table 15-4. Matrix Identifying Issues Raised by Commentors on the WIPP DEIS (continued)

Issue	Type of comment	Commentors: Federal	Commentors: State and local	Commentors: Individuals and groups
Health effects of low-level radiation	Oral		9010,9139	9002, 9027, 9031, 9037, 9039, 9042, 9045, 9047, 9048, 9050, 9063, 9069, 9070, 9091, 9105, 9138, 9140, 9144, 9146, 9152, 9162
	Written	0088, 0091, 0093	0079, 0080	0005, 0041, 0049, 0050, 0054, 0057, 0058, 0069, 0072, 0074, 0089, 0097
Socioeconomics	Oral		9032, 9126, 9139, 9141	9019, 9023, 9027, 9031, 9039, 9040, 9045, 9050, 9052, 9062, 9069, 9074, 9075, 9086, 9087, 9090, 9091, 9094, 9098, 9099, 9102, 9103, 9106, 9135, 9142, 9145, 9159
	Written	0088, 0092, 0093	0043, 0048, 0063, 0068, 0079, 0083, 0084	0014, 0049, 0054, 0070, 0077, 0078, 0097
Archaeology	Oral			9027
	Written	0092, 0093	0033, 0079	
Ecology and land use	Oral			9028, 9029, 9031, 9140, 9012, 9150
	Written	0092, 0093	0043, 0079, 0084	0060, 0073, 0097
Approval, disapproval, and/or no comment	Oral		9096, 9158	9154, 9156, 9157, 9160, 9162, 9166, 9159, 9167, 9149, 9118, 9121, 9132, 9133, 9142, 9147, 9150, 9151, 9152, 9029, 9049, 9055, 9056, 9063, 9072, 9083, 9089, 9113, 9034, 9036, 9054, 9064, 9065, 9067, 9078, 9079, 9081, 9011, 9012, 9013, 9014, 9017, 9020, 9021, 9022, 9033
	Written	0011	0086, 0090, 0030, 0019, 0052, 0002, 0007, 0006, 0024, 0047, 0010, 0013, 0015, 0038, 0096	0061, 0082, 0003, 0016, 0008, 0009, 0018, 0026, 0066, 0081, 0027
Bias	Oral			9016, 9019, 9035, 9051, 9062, 9073, 9086, 9091, 9135, 9159
	Written		0043	0041, 0051, 0054, 0059, 0070, 0071, 0078, 0087
Language translation	Oral			9035, 9039, 9051, 9053, 9062, 9073, 9086, 9090, 9106, 9120, 9123
	Written		0083	0058, 0077, 0078, 0087

Table 15-4. Matrix Identifying Issues Raised by Commentors on the WIPP DEIS (continued)

Issue	Type of comment	Commentors: Federal	State and local	Individuals and groups
Routine releases	Oral		9010	9027, 9031, 9045, 9047, 9130
	Written	0088, 0091, 0092, 0093	0079, 0080	0005, 0037, 0060
Plant operational accidents	Oral		9010	9002, 9030, 9031, 9038, 9040
	Written	0088, 0092, 0093	0040, 0076, 0079, 0080, 0084	0041, 0050, 0060, 0071, 0073, 0074, 0078
Waste retrievability	Oral			9019, 9028, 9031, 9041, 9050, 9093, 9101, 9128, 9145
	Written	0092, 0093	0004, 0023, 0024, 0032, 0080, 0084	0005, 0012, 0037, 0051, 0059, 0060, 0069, 0072, 0073
Decommissioning and long-term monitoring	Oral		9139	9006, 9075, 9017, 9019, 9029, 9085, 9130, 9138, 9146
	Written	0012, 0088, 0092, 0093	0032, 0076, 0079, 0080, 0084, 0004, 0043, 0048, 0067	0041, 0051, 0054, 0059, 0060, 0078, 0073, 0097
Transportation	Oral		9010, 9127, 9139, 9126, 9018	9151, 9108, 9114, 9128, 9142, 9145, 9149, 9159, 9068, 9123, 9144, 9069, 9019, 9035, 9052, 9038, 9047, 9053, 9098, 9107, 9134, 9002, 9031, 9042, 9102, 9135, 9016, 9048, 9050, 9086, 9091
	Written	0088, 0092, 0093	0004, 0012, 0023, 0030, 0040, 0042, 0048, 0063, 0079, 0080, 0083, 0084 0094	0014, 0034, 0037, 0041, 0049, 0050, 0054, 0055, 0057, 0060, 0065, 0069, 0072, 0073, 0074, 0077, 0078, 0087, 0089, 0097, 0098
Transportation accidents	Oral		9010	9016, 9019, 9027, 9031, 9048, 9053, 9086, 9091, 9107, 9142, 9019, 9159, 9042
	Written	0088, 0092	0079, 0080, 0084	0034, 0049, 0054, 0057, 0060, 0069, 0074, 0078, 0097
Emergency-response planning	Oral		9126, 9139	9048, 9091, 9107, 9123, 9142
	Written	0091	0023, 0048, 0079, 0083	0057, 0074, 0078, 0087
Security and safeguards	Oral			9108, 9138, 9142, 9159
	Written	0012, 0088, 0092, 0093	0004	0022, 0041, 0054, 0060, 0078, 0087, 0097
Insurance and liability	Oral		9126	9019, 9027, 9085, 9101, 9102, 9107, 9116, 9138
	Written		0048, 0075, 0079, 0083	0022, 0074, 0078, 0097

Table 15-4. Matrix Identifying Issues Raised by Commentors on the WIPP DEIS (continued)

Issue	Type of comment	Commentors		
		Federal	State and local	Individuals and groups
Licensing	Oral		9126, 9139	9004, 9009, 9016, 9025, 9028, 9033, 9107, 9130, 9136, 9146
	Written	0092	0079, 0080, 0083, 0084	0049, 0059, 0071, 0073, 0076, 0078, 0087, 0097
Public participation	Oral		9010, 9032, 9058	9002, 9006, 9009, 9016, 9019, 9023, 9025, 9027, 9028, 9050, 9051, 9062, 9073, 9082, 9086, 9095, 9106, 9123, 9135, 9035
	Written			0020, 0021, 0025, 0034, 0071, 0074, 0077, 0078, 0089
State consultation	Oral	9001	9010, 9018, 9126, 9139, 9163	9091, 9107, 9109, 9116, 9117, 9119, 9123, 9142
	Written		0030, 0052, 0075	0071, 0097
Inclusion of spent fuel	Oral	9001		9143, 9031, 9033, 9136, 9002, 9009, 9040, 9041, 9130, 9035, 9042
	Written	0017, 0092, 0088	0023, 0032, 0047, 0076, 0094, 0083, 0043	0018, 0058, 0060, 0062, 0072, 0073, 0009, 0027, 0051, 0059, 0016, 0046, 0077, 0097

Glossary

actinide	An element in the series beginning with element 90 and continuing through element 103. All the transuranic nuclides considered in this document are actinides.
activity	A measure of the rate at which a material emits nuclear radiation, usually given in terms of the number of nuclear disintegrations occurring in a given length of time. The unit of activity used in this document is the curie (Ci).
alpha particle	A positively charged particle emitted in the radioactive decay of certain nuclides. Made up of two protons and two neutrons bound together, it is identical to the nucleus of a helium atom. It is the least penetrating of the three common types of radiation--alpha, beta, and gamma radiation.
anhydrite	A mineral consisting of anhydrous calcium sulfate: $CaSO_4$. It is gypsum without its water of hydration and is denser, harder, and less soluble than gypsum.
annealing	Originally, to heat and cool again slowly to soften glasses or metals. In this document, to heat to the point where imperfections disappear.
anticline	A fold of rocks whose core contains the stratigraphically older rocks; it is convex upward.
aquifer	A body of rock that contains enough saturated permeable material to transmit groundwater and to yield significant quantities of groundwater to wells and springs. The opposite of an aquiclude.
argillaceous rocks	Rocks containing appreciable amounts of clay, especially shale.
artesian	Refers to water confined underground under pressure so that it will rise in a well. Sometimes the word is used to mean that the water flows out at the surface, but that, strictly speaking, is "flowing artesian."
B (shipment type)	A classification (10 CFR 71) of shipments of radioactive material depending on the amount of radioactivity contained; broadly characterized, type B shipments contain more radioactivity than type A shipments of similar radioactivity and potential hazard. Federal regulations also specify standards for the packaging of shipments according to type.
background (radiation)	Radiation in the human environment from naturally occurring elements, from cosmic radiation, and from fallout.
banking	A step in the screening process leading to the selection of a site for an HLW repository. A site is banked when, after regional and area studies, the participants in the siting process reach a consensus on the adequacy of the site relative to established criteria. In banking, the DOE acquires

an interest in the land sufficient to maintain the integrity of the site through the remainder of the site selection process. When several sites have been banked, one will be selected for a license application to the NRC. Banking requires that an EIS be prepared.

bare waste	High-level waste that is not enclosed in a canister; such waste will be used in some experiments in the WIPP.
basalt	A dark igneous rock usually formed as lava flows.
bedded salt	Consolidated layered salt separated from other layers by distinguishable planes of separation.
Bell Canyon Formation	A sequence of rock strata that forms the topmost unit of the Delaware Mountain Group.
beta particle	A negatively charged particle emitted in the radioactive decay of certain nuclides; a free electron.
biosphere transport (biotransport)	In this document, movement of radionuclides through food chains. Used in contrast to geotransport.
biological half-life	The time required for an organism to eliminate half the amount of a radionuclide ingested or inhaled.
brine aquifer	Same as shallow-dissolution zone.
brine inclusion	A small opening in a rock mass (salt) containing brine; also, the brine included in such an opening. Some gas is often present.
caliche	A limy material commonly found in layers on or within the surface of stoney soils of arid or semiarid regions. It occurs as gravels, sands, silts, and clays cemented together by calcium carbonate (lime) or as crusts at the surface of the soil.
canister	As used in this document, a container, usually cylindrical, for remotely handled waste, spent fuel, or high-level waste. The waste will remain in this canister during and after burial. A canister affords physical containment but not shielding; shielding is provided during shipment by a cask.
Capitan Reef	A buried fossil limestone reef of Permian age that rings the Delaware Basin except in the south.
Carlsbad Potash District	The area east of Carlsbad and north and west of the Los Medanos site formally designated by the U.S. Geological Survey as having potentially economic grades of potash mineralization.
cask	A massive shipping container providing shielding for highly radioactive materials and holding one or more canisters.

Castile Formation	A formation of evaporite rocks (interbedded halite and anhydrite) of Permian age that immediately underlies the Salado Formation in which the WIPP disposal level may be built.
chain reaction	A reaction that stimulates its own repetition. In a fission chain reaction, a fissionable nucleus absorbs a neutron and splits, releasing additional neutrons. A fission chain reaction is self-sustaining when the number of neutrons released equals or exceeds the number of neutrons lost by escape from the system or by non-fission absorption.
characterization, site	The process of making geologic and environmental studies to identify potential sites for mined geologic repositories. Detailed site characterization goes further: all additional data are collected that would be necessary if a license application is to be submitted.
clastic rock	Rock made up of broken fragments of preexisting rocks.
climax community	The final and most stable of a series of biotic communities in a succession. It will remain relatively unchanged as long as climate and physiographic factors remain constant, assuming no human interference.
commercial waste	Nuclear waste deriving from commercial sources. These are principally power reactors, but also include research laboratories and medical facilities.
conductivity, hydraulic	See hydraulic conductivity.
conservative	When used with predictions or estimates, leaning on the side of pessimism. A conservative estimate is one in which the uncertain inputs are used in the way that maximizes the impact.
contact-handled waste	Waste that does not require shielding other than that provided by its container.
containment	The retention of radioactivity within prescribed boundaries, such as within a waste package. In this document, usually retention within a system to the exclusion of its release to the biosphere in unacceptable quantities or concentrations.
contamination	Undesirable radioactive material present on outside surfaces. This contamination can be either transferable or fixed. Radiation penetrating the walls of a waste package from within is not contamination.
control zone	At the WIPP, one of four areas of land whose use is governed by controls and restrictions.

creep closure	Closure of underground openings, especially openings in salt, by plastic flow of the surrounding rock under lithostatic pressure.
criticality	The state of a mass of fissionable material when it is sustaining a chain reaction.
critical mass	The smallest mass of fissionable material that will support a self-sustaining chain reaction. The critical mass depends on its shape and the nature of the surrounding material because these influence the ease with which neutrons can escape and the likelihood that they will be reflected back in the mass.
crystalline rock	Rock designated as being either igneous or metamorphic, not sedimentary; rock consisting wholly of mineral crystals or fragments of crystals.
Culebra dolomite	The lower of two layers of dolomite within the Rustler Formation that are locally water bearing.
daughter product	A nuclide that results from radioactive decay. Thus radium-226 decays to radon-220, which in turn decays to polonium-216. The radon is the daughter of the radium, and polonium is its daughter.
decay, radioactive	The decrease in the number of radioactive nuclei present in a radioactive material due to their spontaneous transmutation. Also, the transmutation of a radionuclide into another nuclide by the emission of a charged particle.
decommissioning	The process of removing a facility from operation. It is then mothballed, entombed, decontaminated, and dismantled or converted to another use.
decontamination	The removal of unwanted material (especially radioactive material) from the surface or from within another material.
decontamination factor (DF)	The reduction in radionuclide concentration or surface level activity resulting from filtering or cleaning, measured as the ratio of activity before and after filtering or cleaning.
defense waste	Nuclear waste deriving from the manufacture of nuclear weapons and the operation of naval reactors. Associated activities such as the research carried on in the weapons laboratories also produce defense waste.
Delaware basin	An area in southeastern New Mexico and adjacent parts of Texas where a sea deposited large thicknesses of evaporites some 200 million years ago. It is partially surrounded by the Capitan Reef.
Delaware Mountain Group	A set of three formations that underlie the Castile Formation at the Los Medanos site. The uppermost of these is the water-bearing Bell Canyon Formation.

diapir — A geologic flow structure, either a dome or an anticline, in which overlying rocks have been ruptured by the flow upwards of a plastic core material such as salt.

diffusion, atmospheric — Movement of a contaminant due to the cumulative effect of the random motions of the air. Equivalent to eddy diffusion.

diffusion, mass — Same as molecular diffusion.

diffusion, molecular — Movement of a contaminant due to the cumulative effect of the random motions of molecules.

direct-access scenario — A postulated sequence of events in which radionuclides are carried directly to the surface, such as by means of drilling.

discharge point (or area) — In groundwater hydraulics, the point (or area) where water comes out of an aquifer onto the surface.

disposal — In this document, permanent disposition of waste in a repository. Use of the word "disposal" implies that no need for later retrieval is expected. It also implies a minimal need for surveillance.

dissolution — The process whereby a space or cavity in or between rocks is formed by the solution of part of the rock material.

dissolution front — The boundary of a geologic region within which rock is dissolving. In this document, the term particularly refers to the wedge-like leading edge of salt dissolution at the interface between the Rustler and the Salado Formations.

distribution coefficient — In an aquifer, the ratio of the concentration of a substance sorbed by the rock to the concentration of the substance remaining in solution. A large distribution coefficient implies that the substance moves much more slowly than the groundwater. It is measured in units of cm^3/g or equivalent.

dolomite — A sedimentary rock consisting mostly of the mineral dolomite: $CaMg(CO_3)_2$. It is commonly found with limestone.

dome (breccia pipe) — A type of hill found near the Los Medanos site; under at least some of these hills lies a roughly cylindrical volume of breccia (rock reconstituted from coarse rock fragments).

dome, salt — A diapiric or piercement structure with a central, nearly circular salt plug, generally one to two kilometers in diameter, that has risen through the enclosing sediments from a deep mother bed of salt.

dose (radiation) — A general term indicating the amount of energy absorbed per unit mass from incident radiation.

dose commitment — In this document, a less formal expression meaning dose equivalent commitment.

dose conversion factor — A numerical factor used in converting radionuclide uptake (curies) in the body to the resultant radiation dose or dose commitment (rem or man-rem).

dose equivalent — The product of absorbed dose and modifying factors that take into account the biological effect of the absorbed dose. While dose includes only physical factors, dose equivalent includes both physical and biological factors and provides a radiation-protection scale applicable to all types of radiation. Units are rem for an individual and man-rem for a population group.

dose equivalent commitment — The total dose equivalent that results from an intake of radioactive materials during all the time from the intake to the death of the organism. For people, the dose is usually evaluated for a period of 50 years from the intake. Units are man-rem.

dose rate — The rate at which dose is delivered.

drift — A horizontal mine passageway.

emplacement medium — The material in which a repository is built and into which the waste will be placed.

evaporite — A sedimentary rock composed primarily of minerals produced by precipitation from a solution that has become concentrated by the evaporation of a solvent, especially salts deposited from a restricted or enclosed body of seawater or from the water of a salt lake. In addition to halite (NaCl) these salts include potassium, calcium, and magnesium chlorides and sulfates.

exclosure — A biological study site from which grazing and browsing animals are excluded.

fault — A surface or zone of rock fracture along which there has been displacement.

fault tree — A tree-like cause-and-effect diagram of hypothetical events. Analysis of fault trees is used to investigate failures in a system or concept.

fertile — Describes a nuclide that can be transmuted into a fissile nuclide by absorption of a neutron and subsequent decay.

filter bank — An arrangement of air filters in series and/or parallel.

fissile — Describes a nuclide that undergoes fission on absorption of neutrons of any energy.

fission	The splitting of a heavy nucleus into two approximately equal parts, each the nucleus of a lighter element, accompanied by the release of a large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but it usually follows the absorption of neutrons.
fissionable	Describes a nuclide that undergoes fission on absorption of a neutron of energy over some threshold energy.
fluid inclusion	Brine inclusion. A small opening in a rock mass (salt) containing brine; also the brine included in such an opening. Some gas is often also present.
forb	A non-woody plant that is not grass or grass-like.
forced convection	Movement of a contaminant under an external influence such as a difference in pressure or an unstable gradient of density. Used in contrast to molecular diffusion.
formation (geologic)	The basic rock-stratigraphic unit in the local classification of rocks. It consists of a body of rock (usually sedimentary) generally characterized by some degree of internal lithologic homogeneity or distinctive features.
gamma rays	Short-wavelength electromagnetic radiation emitted in the radioactive decay of certain nuclides. Gamma rays are the same as gammas or gamma particles.
gamma-spectrum isotopic analysis	Analysis of the radionuclides present in a sample by measurement of the energy spectrum of the gamma radiation emitted.
geothermal gradient	The rate of increase of temperature of the earth with depth. The approximate average value in the earth's crust is 25°C per kilometer or 1.4°F per hundred feet.
geotransport	In this document, movement of radionuclides through subsurface soils and rocks, especially movement with the groundwater. Used in contrast to biotransport.
getter	A material that selectively sorbs and holds particular nuclides.
glove box	A sealed box in which workers, remaining outside and using gloves attached to and passing through openings in the box, can safely handle and work with radioactive materials.
gradient, hydraulic	See hydraulic gradient.
gradient, thermal	See thermal gradient.
gross alpha	The total rate of alpha particle emission from a sample, without regard to energy distribution or source nuclides.

gross beta — The total rate of emission of beta particles from a sample, without regard to energy distributions or source nuclides.

Gulf interior salt-dome region — A region in northeastern Texas, northern Louisiana, and south-central Mississippi containing several hundred salt domes. Salt domes near or under the Gulf of Mexico are not included. (See map in Figure B-4.)

gypsum — A mineral consisting of hydrous calcium sulfate: $CaSO_4 \cdot 2H_2O$. It is soft and, when pure, white.

half-life — The time required for the activity of a group of identical radioactive nuclei to decay to half its initial value.

halite — The mineral rock salt: NaCl.

Hanford Site — A 580-mi^2 DOE reservation in south-central Washington near the Columbia River. The nearest city is Richland, Washington.

head, hydraulic — See hydraulic potential.

health physics — The science concerned with the recognition, evaluation, and control of health hazards from ionizing radiation.

high-level waste — Radioactive waste resulting from the reprocessing of spent fuel. Discarded, unreprocessed spent fuel is also high-level waste. It is characterized by intense, penetrating radiation and by high heat-generation rates. Even in protective canisters, high-level waste must be handled remotely.

horizon — In this document, an underground level. For instance the waste-emplacement horizon in the WIPP is the level about 2150 feet deep at which openings would be mined for waste disposal.

hundred-year storm — A storm that, on a statistical basis, is expected to recur only once every hundred years.

hydraulic conductivity — A quantity defined in the study of groundwater hydraulics that describes the rate at which water flows through an aquifer. It is measured in feet per day or equivalent units. It is equal to the hydraulic transmissivity divided by the thickness of the aquifer.

hydraulic gradient — A quantity defined in the study of groundwater hydraulics that describes the rate of change of head with distance of flow.

hydraulic potential (or hydraulic head) — Hydraulic pressure corrected for the potential energy of elevation. In an aquifer it is equivalent to the highest level of a column of water that the pressure in the aquifer will support. It is measured relative to a specified level, in this document sea level.

hydraulic transmissivity A quantity defined in the study of ground-water hydraulics that describes the rate at which water may be transmitted through an aquifer. It is measured in ft^2/day or equivalent units.

hydraulic transport The transport of dissolved substances by groundwater.

hydraulics, hydrology These two terms tend to be used interchangeably, but they don't mean quite the same thing. Hydraulics is an engineering discipline; hydrology is the related science. Hydraulics deals with the flow of water. Hydrology deals with water: its properties, circulation, and distribution, from the time it falls as rainwater until it is returned to the atmosphere through evapotranspiration or flows into the ocean.

hydrofracture A process of producing underground openings by injection of a fluid (usually water) at pressures greater than the weight of the overlying rock and soil.

hydrologic modeling The process of using a mathematical representation of a hydrologic system (as embodied in a computer code) to predict the flow of groundwater and the movement of dissolved substances.

in situ In the natural or original position. The phrase is used in this document to distinguish in-place experiments, rock properties, and so on, from those in the laboratory.

intensity, earthquake A measure of the effects of an earthquake on humans and structures at a particular place. Not to be confused with magnitude.

Intermediate Scale Facility (ISF) A kind of facility proposed by the IRG in which the disposal of up to 1000 spent fuel assemblies would be demonstrated. See the IRG's own words in Appendix C.

interstitial brine Brine distributed in very small openings throughout a salt mass.

ion exchange A phenomenon in which chemical species in one phase or material exchange with similar species in another phase. In this report, ion exchange usually refers to a particular process in an aquifer: the exchange of ions in the water for ions in or on the rocks.

irradiation Exposure to any form of radiant energy.

isotope A species of atom characterized by the number of protons and the number of neutrons in its nucleus. In most instances an element can exist as any of several isotopes, differing in the number of neutrons, but not the number of protons, in their nuclei. Isotopes can be either stable isotopes or radioactive isotopes (also called radioisotopes).

kelvin	A unit of temperature equal to what used to be called the degree Centigrade. Abbreviated K.
langbeinite	A mineral, $K_2Mg_2(SO_4)_3$, used in the fertilizer industry as a source of potassium sulfate.
leaching	The process of extracting a soluble component from a solid by the percolation of a solvent (in this report, water) through the solid.
Lemhi Range	Mountains at the northwest corner of the Idaho National Engineering Laboratory.
level-line survey	A cross-country survey in which changes in elevation above sea level are very carefully measured.
liquid-breach scenario	A postulated sequence of events in which radionuclides are carried by groundwater and released.
lithostatic pressure	Subsurface pressure due to the weight of overlying rock or soil.
Los Medanos	In this report, the area in southeastern New Mexico surrounding the site proposed for the WIPP repository of alternative 2. In Spanish it means "dune country," and has a tilde over the n: Los Medaños.
Magenta dolomite	The upper of two layers of dolomite within the Rustler Formation that are locally water-bearing.
magnitude, earthquake	A measure of the total energy released by an earthquake. Not to be confused with intensity.
Malaga Bend	A sharp bend in the Pecos River 20 miles southeast of Carlsbad, New Mexico, and directly east of the town of Malaga. The discharge points of the Rustler aquifers are a series of brine seeps and springs nearby.
man-rem	A unit of population dose.
matrix, waste	The material in which radioactive nuclear waste is encapsulated. As used frequently in this document, the term refers to the material, likely to be a glass, encapsulating reprocessed high-level waste and contained in a canister.
maximally exposed person	A hypothetical person who is exposed to a release of radioactivity in such a way that he receives the maximum possible individual dose or dose commitment. This, for instance, if the release is a puff of contaminated air, he is a person at the point of largest ground-level concentration who stays there during the whole time of cloud passage. The use of this term is not meant to imply that there really is such a person, but only that thought is being given to the maximum exposure a person could receive.

maximum individual dose	The highest dose delivered to the whole body or to an individual organ that a person can receive from a release of radioactivity. The hypothetical person who receives this dose, the maximally exposed person, is one whose location and activities maximize the dose. For instance, he may be at the point of maximum concentration of a radioactive cloud for the whole time it takes to pass.
Mercalli intensity	A scale of measurement of earthquake intensity.
mined materials	The rock salt and other natural materials brought up to the ground surface during mining.
modelling, hydrologic	See hydrologic modelling.
Nash Draw	A shallow 5-mile-wide valley open to the southwest located to the west of the WIPP reference site. See map in Figure 7-15.
natural background radiation	Radiation in the human environment from naturally occurring elements and from cosmic radiation.
Nevada Test Site (NTS)	An area in Clark and Nye Counties in southern Nevada dedicated to the underground testing of nuclear weapons. The nearest large city is Las Vegas, Nevada.
nuclide	Isotope.
nuclide inventory (radionuclide inventory)	A list of the kinds and amounts of radionuclides in a container or a source. Amounts are usually expressed in activity units: curies or curies per unit volume.
order of magnitude	A factor of ten. When a measurement is made with a result such as 3×10^7, the exponent of 10 (here 7) is the order of magnitude of that measurement. To say that this result is known to within an order of magnitude is to say that the true value lies between (in this example) 3×10^6 and 3×10^8.
overcoring	A process for removing waste from its burial in salt by extracting a cylinder of salt that surrounds and contains the waste.
overpack	A container put around another container. In the WIPP, overpacks would be used on damaged or otherwise contaminated drums, boxes, and canisters that it would not be practical to decontaminate.
packer	A device used in drilled holes to isolate geological strata from one another in order to carry out hydrologic studies of particular formations.

Paradox basin	A 10,000-square-mile area in southeastern Utah and southwestern Colorado underlain by a series of salt-core anticlines. See Figure B-3.
Pasquill Stability Category	Relates atmospheric stability to the dispersion of an effluent plume. These categories range from A (extremely unstable: a plume will disperse rapidly) to G (extremely stable: a plume will not appreciably disperse).
permeability	Equivalent to hydraulic conductivity.
Permian basin	A region in the Central United States where, during Permian times 280 to 225 million years ago, there were many shallow seas that laid down vast beds of evaporites. The Delaware basin is a part of the Permian basin. See Figure B-1.
point source	A source of effluents that is small enough in dimensions that it can be treated as if it were a point. The converse (not used in this document) is a diffuse source. A point source can be either a continuous source or a source that emits effluents only in puffs or for a short time.
polyhalite	An evaporite mineral: $K_2MgCa_2(SO_4)_4 \cdot 2H_2O$. It is a hard, poorly soluble mineral with no economic value.
population dose	The sum of the radiation doses received by the individual members of a population.
potash	In this document, a potassium compound, especially as used in agriculture or industry. See Section 7.3.7.
potential, hydraulic	See hydraulic potential
potentiometric surface	The surface of the hydraulic potentials of an aquifer. It is usually represented in figures as a contour map, each point in which tells how high the water would rise in a well tapping that aquifer at that point.
qualification, site	A process roughly equivalent to site characterization.
rad	A unit of absorbed dose. Related to, but not the same as "rem."
Radiation Protection Guides	The officially determined radiation doses that should not be exceeded without careful consideration. These standards, originally set forth by the ICRP and the NCRP are now part of EPA regulations. They are equivalent to what were formerly called Maximum Permissible Exposures.
radiolysis	Chemical decomposition by the action of radiation.
radwaste	Short for radioactive waste.

recharge point (or area)	In groundwater hydraulics, the point (or area) where surface water enters an aquifer.
regulatory guide	One of a series of official NRC guides prescribing standards for nuclear facilities. They cover a variety of subjects such as what constitutes acceptable meteorological data or acceptable methods for calculating radiation dose.
rem	A unit of individual dose equivalent.
remotely handled waste	Waste that requires shielding in addition to that provided by its container in order to protect people nearby.
repository	A facility for the storage or disposal of radioactive waste.
reprocessing	The process by which spent fuel from a reactor is separated into waste material and uranium and plutonium to be reused as nuclear fuel.
reserves	Mineral resources that can be extracted profitably by existing techniques and under present economic conditions.
resources	Mineralization that is concentrated enough, in large enough quantity, and in a physical and chemical forms such that its extraction is currently or potentially feasible and profitable.
retrievable	Describes storage of radioactive waste in a manner designed for recovery without loss of control or release of radioactivity.
risk	The product of probability and consequence. In this report, the radioactive risk of a scenario is the population dose resulting from that scenario multiplied by the probability that the scenario will actually occur.
Rustler Formation	The evaporite beds, including mudstones, of probable Permian age that immediately overlie the Salado formation in which the WIPP disposal levels may be built.
Salina region	A region in Michigan, Ontario, Ohio, West Virginia, Pennsylvania, and New York underlain by extensive bedded salt of Paleozoic age. The region is divided into the Michigan and Appalachian basins. See Figure B-2.
Salado Formation	The evaporite formation of Permian age within which wastes would be disposed of in the WIPP repository of alternative 2.
Salt Vault, Project	A field experiment carried out by ORNL between 1965 and 1967 in an abandoned salt mine at Lyons, Kansas. Its purpose was to demonstrate the feasibility and safety of the concept of emplacing high-level waste in salt, to demonstrate equipment and techniques for handling packages of highly radioactive solids, and to secure data for the de-

sign of an actual disposal facility. Its results are reported in Bradshaw and McClain (1971).

San Simon Sink — The central, most depressed area of San Simon Swale.

San Simon Swale — A broad depression about 15 miles east of the Los Medanos site, open to the southeast. See Figure 2-2.

scenario — A particular chain of hypothetical circumstances that could, in principle, release radioactivity from a repository.

selection, final site — The process of choosing one of several banked sites for an HLW repository. This will include a comparison of their environmental, technical, and institutional factors. The result will be a license application to be submitted to the NRC.

sector, economic — A distinctive part of the economy of a geographical region defined by a standard industrial classification scheme. One such scheme defines "major" sectors and divides them into subsectors; for example, the major sector "trade" contains the subsectors "wholesale trade" and "retail trade." Another classification scheme specifies "primary" and "secondary" sectors; the criterion for including a sector in the primary classification is that its level of activity generally not be controlled by the level of economic activity in the region; a primary industry, in other words, produces goods and services for export from the region.

Seismic Risk Zone — A designation of a geographic region expressing the maximum intensity of earthquakes that could be expected there.

shaft — A man-made hole, either vertical or steeply inclined, that connects the surface with the underground workings of a mine.

shaft pillar — The cylindrical volume of rock around a shaft from which major underground openings are excluded in order that they not weaken the shaft.

shallow-dissolution zone — Also called the brine aquifer. A zone of residual material at the interface of the Rustler and Salado formations left after dissolution of the original salt. It is highly permeable and contains much brine. See Figure 7.36.

sorption — The binding on a microscopic scale of one substance to another, such as by adsorption or ion exchange. In this document, the word is especially used in the sorption of solutes onto aquifer solids.

source term — The kinds and amounts of radionuclides that make up the source of a potential release of radioactivity. See nuclide inventory.

specific activity	Radioactivity per unit weight of radioactive material.
spent fuel	Nuclear-reactor fuel that, through nuclear reactions, has been sufficiently depleted of fissile material to require its removal from the reactor.
storage	Temporary disposition in a repository. Use of the word storage implies keeping open the possibility of retrieving the waste for reprocessing, for moving it elsewhere, etc. Storage usually implies the need for continued surveillance.
storage pool, spent fuel	A water-filled and cooled basin in which spent fuel is stored before being sent away for reprocessing or disposal.
study area	The region about the Los Medanos site studied in the evaluation of that site.
sylvite	A mineral, KCl, used as a fertilizer.
tectonic activity	Movement of the earth's crust such as uplift and subsidence and the associated folding, faulting, and seismicity.
thermal excursion	A transient change in temperature or in heat output.
thermal field	The field or set of temperatures throughout a volume. Use of the term usually connotes temperatures that differ from point to point.
thermal gradient	The rate of change of temperature in the direction of increasing temperature.
transmissivity, hydraulic	See hydraulic transmissivity.
transport, hydraulic	See hydraulic transport.
transuranic nuclide	A nuclide with an atomic number greater than that of uranium (92). All transuranic nuclides are produced artificially and are radioactive.
TRU waste	Waste with a specific transuranic alpha activity of 10 nCi/g or greater. This waste can vary greatly in its specific gamma activity.
tuff	A rock formed of compacted volcanic ash and dust. It is usually porous and often soft.
valance state	The combining power of an element as shown by the number of univalent elements, such as hydrogen or chlorine, with which it will combine. Some elements, including the actinides, have several possible valence states. When such an element moves to a higher valence state, it is said to have been oxidized; when it moves to a lower state, reduced.

waste form	The condition of the waste. This phrase is used to emphasize the physical and chemical properties of the waste.
waste matrix	The material that surrounds and contains the waste and to some extent protects it fom being released into the surrounding rock and groundwater. Only material within the canister (or drum or box) that contains the waste is considered part of the waste matrix.

Abbreviations and Acronyms

AACC	American Association for Contamination Control
ACGIH	American Congress of Government Industrial Hygienists
AEC	U.S. Atomic Energy Commission
AFR	Away from reactor (spent fuel storage)
AMAD	Aerodynamic mean activity diameter
AMP	Allotment Management Plan: a BLM term
AMS	Aerial measuring systems
ANSI	American National Standards Institute
AQCR	Air Quality Control Region (of EPA)
AREA	American for Rational Energy Alternatives
ARMS	Aerial radiological measurement surveys
ATMX	Atomic munitions transport car (a rail car used for transporting CH TRU waste)
AUM	Animal-unit month: a term used by the Bureau of Land Management
BBER	Bureau of Business and Economic Research, University of New Mexico
BLM	Bureau of Land Management, Department of the Interior
BOD	Biological oxygen demand
CAB	Civil Aeronautics Board
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CH	Contact handled; refers to low-level waste not requiring shielding or the facilities for handling
dBA	Decibel
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EAR	Environmental Analysis Record: a term used by the BLM
ECS	Environmental control system
EEG	Environmental Evaluation Group, New Mexico
EIS	Environmental Impact Statement
EMT	Emergency medical technician
ENMU	Eastern New Mexico University, Portales, N.M.
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
ESCNM	Employment Security Commission of New Mexico
ESSA	Environmental Science Services Administration (now replaced by the National Oceanic and Atmospheric Administration)
FEIS	Final Environmental Impact Statement
FHA	Federal Housing Authority
FR	Federal Register
FRA	Federal Railroad Administration
FWPCA	(U.S.) Federal Water Pollution Control Administration
FWS	Fish and Wildlife Service, Department of the Interior

GAO	General Accounting Office
GEIS	Generic Environmental Impact Statement
GESMO	GEIS on mixed oxide fuels
HEPA	High-efficiency particulate air; a type of filter
HEW	U.S. Department of Health, Education and Welfare
HIAP	Hobbs Industrial Air Park
HLW	High-level waste
HUD	U.S. Department of Housing and Urban Development
ICRP	International Council on Radiological Protection
IMCC	International Minerals and Chemical Corporation
INEL	Idaho National Engineering Laboratory
IRG	Interagency Review Group on Nuclear Waste Management
ISF	Intermediate Scale Facility
LASL	Los Alamos Scientific Laboratory, New Mexico
L_{eq}	Probable sound energy average
MFP	Management Framework Plan; a term used by the BLM
mgd	Million gallons per day
MM	Modified Mercalli (scale of earthquake intensity)
MTU	Metric tons of uranium
NAAQS	National ambient air quality standards
NAS-NRC	National Academy of Sciences-National Research Council
NCC	National Climatic Center
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act of 1969
NMBM&MR	New Mexico Bureau of Mines and Mineral Resources
NMDFA	New Mexico Department of Finance and Administration
NMDGF	New Mexico Department of Game and Fish
NMEI	New Mexico Environmental Institute
NMEID	New Mexico Environmental Improvement Division
NMHD	New Mexico Highway Department
NOAA	National Oceanic and Atmospheric Administration
NOS	National Oceanic Survey
NPDES	National Pollution Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council
NTS	Nevada Test Site
NUREG	Identifier on NRC documents
NWS	National Weather Service; formerly U.S. Weather Bureau
NWTSP	National Waste Terminal Storage Program
ONWI	Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio
ORNL	Oak Ridge National Laboratory, Tennessee
OSTP	Office of Science and Technology Policy
OWI	Office of Waste Isolation, Union Carbide Corporation, Oak Ridge, Tennessee
PSD	Prevention of Significant Deterioration (of air quality)
PL	Public Law
ppm	Parts per million
PWR	Pressurized-water reactor

RCRA	Resource Conservation and Recovery Act of 1976
RH	Remotely handled; refers to waste requiring shielding or of waste containers or waste-handling facilities
RFP	Rocky Flats Plant, Denver, Colo.
RMA	Recreational market area
RPG	Radiation Protection Guide
RWMC	Radioactive Waste Management Complex at the Idaho National Engineering Laboratory
SAR	Safety Analysis Report
scfm	Standard cubic feet per minute
SCS	Soil Conservation Service, Department of Agriculture
SPI	Slagging-pyrolysis incinerator or incineration
SPL	Sound-pressure level
SPDV	Site and Preliminary Design Validation
SPSC	Southwestern Public Service Company
SRP	Savannah River Plant, South Carolina
SWRIC	Southwest Research and Information Center, Albuquerque, N.M.
TDS	Total dissolved solids
TLD	Thermoluminescent dosimeter
TRU	Transuranic; refers to nuclides beyond uranium in the periodic table
TSA	Transuranic Storage Area at Idaho National Engineering Laboratory
T22S, R31E	Township 22 South, Range 31 East
URA	Unit Resource Analysis; a term used by BLM
USAEC	United States Atomic Energy Commission
USBM	United States Bureau of Mines
USC	United States Code (of laws)
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USERDA	United States Energy Research and Development Administration
USGS	United States Geological Survey
USNRC	United States Nuclear Regulatory Commission
WACSC	Waste Acceptance Criteria Steering Committee
WIPP	Waste Isolation Pilot Plant
WISAP	Waste Isolation Safety Assessment Program

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FINAL
ENVIRONMENTAL IMPACT STATEMENT

Waste Isolation Pilot Plant

Volume 2 of 2

October 1980

U.S. DEPARTMENT OF ENERGY
Assistant Secretary of Defense Programs
Washington, D.C. 20585

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Appendix A

ALTERNATIVE GEOLOGIC ENVIRONMENTS

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Appendix A

ALTERNATIVE GEOLOGIC ENVIRONMENTS

For the near future (10 to 15 years), the only method available for the permanent disposal of transuranic (TRU) and high-level wastes is emplacement in cavities mined in a geologic formation. Several types of geologic formations show promise as burial environments--salt, crystalline rock, argillaceous rock, and tuff. Which of these is to be used for a repository depends on when the choice among them is to be made; the longer one waits to make this decision, the greater the number of choices that are open. The time scales for these choices are summarized in Chapter 3 of this document.

As background material for the discussions in the main text of this document, this appendix briefly describes the properties of the four candidate types of rock. The U.S. Department of Energy (DOE) is investigating these four media for possible use with high-level waste as well as the TRU waste to be received at the WIPP. Reflecting the investigations, this appendix includes some discussion of properties like thermal conductivity that are critical to the design of repositories for high-level waste, but are not of major importance to the WIPP.

The current investigations of alternative geologic media are extensive, and this brief review is not intended to cover them thoroughly. A comprehensive review of the candidate geologic media appears in the draft generic environmental impact statement (GEIS) for the management of commercially generated radioactive waste (DOE, 1979). Another recent review has been made by the Interagency Review Group (IRG) on Nuclear Waste Management, whose reports (IRG, 1979; IRG Subgroup, 1978) contain recommendations about the choice of geologic media. References to other reviews and to detailed data appear in the GEIS and in the IRG reports.

After presenting background material that explains the bases for choosing a rock medium, this appendix reviews each of the four candidate media.

A.1 GENERAL BASIS FOR CHOOSING A ROCK MEDIUM

The selection of a specific medium depends on two major properties: geologic and hydrologic characteristics, which must resist forces that might expose the buried waste to the biosphere, and structural characteristics, which must permit the construction of a mined cavity without disturbing the geologic and hydrologic characteristics. A satisfactory rock medium must present little threat that its hydrologic and geologic characteristics could provide a mechanism or pathway by which the waste could return to the surface in harmful quantities.

The geologic characteristics are important because the purpose of a waste repository is to provide a place in which a solid material can be buried permanently. As long as the material remains solid, it has little chance of leaving its place of burial because it can do so only if some process opens the earth to the depth of the burial point or if the surface is removed to that depth. Therefore geologic formations that have been stable for long periods are sought for repository locations, on the assumption that the long-inactive disruptive forces in the earth there will remain inactive.

Material buried in solid form might return to the surface in another way: by being engulfed in a stream of water that dissolves the material and carries it to the surface. Because the forces that influence the flow of underground water are less catastrophic (and potentially more likely) than those that might uncover a deeply buried solid, the hydrologic characteristics of a medium may have greater influence on its selection than the geologic characteristics.

The structural characteristics of the rock are important because a repository must be designed, constructed, and operated in such a fashion that it will not upset the geologic and hydrologic characteristics. Because a repository is an engineered structure, its ability to isolate the waste will depend on the material in which it is constructed. Consequently, the selection of the geologic medium must facilitate the engineering design of a structure that will have a minimum probability of releasing its contents.

To be able to design the underground structure to minimize its impact on the hydraulic environment, the burial medium must be chosen with special attention to its mechanical, physical, and chemical properties. In repositories that contain heat-producing waste, the burial medium must be able to withstand the thermal stresses induced by that waste. Furthermore, establishing an effective design requires analytical models for the structure that take into account the properties of the geologic medium; without meeting this fundamental requirement, it would be extremely difficult to be confident that the design of the repository meets the fundamental requirements. The ability to conduct the engineering analysis depends strongly on a thorough knowledge of the properties of a proposed medium. For this reason, the preferred medium must have well-studied properties.

To decide in detail whether the properties of a geologic medium are satisfactory requires that several questions be answered, including the following:

- Will the subsurface structure be able to remain open and operable over the planned lifetime of the repository?

- Can the structure be used for waste disposal without adversely affecting the surrounding geologic and hydrologic environments?

- Can the structure be used without adversely affecting its own structural integrity?

- Will the structural material be adversely affected by heat, and will it react chemically with the waste?

- Will the surrounding geologic material react chemically with the waste?

By reviewing these questions along with others, it is possible to identify specifically the important properties of a geologic medium. Among the chemical properties, it is necessary to understand the solubility and chemical stability of the medium, its ability to resist chemical change during heating, and the corrosiveness of fluids it contains. Important mechanical properties include tensile and compressive strength and stress-strain relationships as expressed by elastic and bulk moduli. Important physical properties include thermal conductivity, thermal expansion, heat capacity, and decrepitation temperature. These properties are not known equally well for all the candidate media.

In addition to knowing these basic data, it is important to have a well-developed mathematical model for predicting the mechanical behavior of a repository in the chosen medium. This model must predict the stresses, deformations, and temperatures that the geologic medium will experience. It must model the mechanisms by which the structure or its surroundings can fail; it can then test the conditions (stress, temperature, etc.) under which failure could occur.

Each of the four sections that follow reviews a geologic medium in the context of this discussion. Table A-1 compares the three major geologic media according to a number of important properties.

A.2 SALT

When geologic media were first evaluated for the emplacement of radioactive waste, salt was judged to be the best choice for a number of reasons, including long-term geologic stability, spatial predictability, suitability for engineering analysis, thermal and mechanical properties, ease of repository construction, freedom from circulating groundwater, chemical stability, and the existence of extensive masses of uniform material. The original report of a committee established by the National Academy of Sciences-National Research Council (1957) recommended that salt be evaluated as a storage medium because it has excellent thermal and physical properties. The report pointed out that the existence of salt formations for several hundred million years demonstrates that they have been isolated from disturbing forces on the surface and from circulating groundwater; consequently, there is an extremely high probability that they will remain isolated in the future. Other desirable features of salt formations are their uniform consistency, simple geologic structure, and predictable stratigraphic character over large regions. Furthermore, the mechanical and physical properties of salt are known well enough to provide a good basis for the engineering analyses necessary for designing a repository.

Experiments to confirm the evaluation of salt as a suitable geologic medium began in 1965 under Project Salt Vault (Bradshaw and McClain, 1971), which operated for 2 years. Other experiments have been conducted over the past decade at the Asse experimental repository in the Federal Republic of Germany (Kuehn et al., 1976). The experiments have confirmed the basic understanding of the fundamental properties of salt and the engineering analysis required to design a repository in salt.

Project Salt Vault brought to the attention of repository designers the phenomenon of brine migration: small amounts of brine that occur in salt (usually less than 1% by weight) move toward emplaced heat sources. It has been asserted that accumulations of brine in salt can lower its mechanical strength. As long as the brine remains distributed, however, its impact on strength will be minimal. Migration phenomena and reduction in strength can be considered potential problems only when elevated temperatures with large

Table A-1. Comparison of Geologic Media

Property	Salt	Basalt or granite	Shale
		BASIC PROPERTIES	
Plasticity	High	None	Variable
Solubility	High	Very low	Very low
Sorptive capacity	Low (depends on impurities)	Fair	High
Compressive strength	Moderate	High	Moderate
Thermal diffusivity	High	Low	Low
Thermal stability against chemical decomposition	High	High; potential dewatering of clay in basalt	High; potential dewatering of clay
		IN-SITU PROPERTIES	
Porosity	0.5%, interstitial	1%, cracks	5-30%, cracks
Permeability	Essentially none	Decreases with depth	Very low
Water presence	Isolated from flowing groundwater	Present, open to flowing groundwater	Present, open to flowing groundwater
Corrosiveness of indigenous fluid	High	Low to moderate	Low to moderate
Tectonic stability	Very stable	Very stable areas can be found	Very stable areas can be found
Geologic structure	Relatively simple areas can be found	Fracture systems often complex	Like salt
Hydrology	Moderately difficult to characterize	Difficult to characterize	Difficult to characterize
		PRACTICAL MATTERS	
Availability	Good	Good	Good
Need to use explosives	No	Yes	Possibly
Understanding of medium for repository use	Well studied	Not well studied	Not well studied
Waste rock	Reuse some; pile needs protection from erosion and runoff	Reuse some; pile probably does not need protection	Reuse some; pile needs protection, but less than salt
Mathematical modeling	Relatively simple; well developed	Relatively complex; not fully developed	Relatively complex; not fully developed

thermal gradients are present. The migration of brine toward heat sources is being investigated to determine whether it can increase the water content of the salt near hot waste and affect the strength of the salt there.

In a TRU-waste repository, reduced strength of salt due to the presence of brine is of minimal significance because little heat-producing waste will be emplaced there. For centuries underground mines have been built in salt; the stability of these mines has not been measurably affected by the presence of brine. The TRU waste in the repository will not provide significant heat-induced perturbing forces on the structure or its surroundings.

The intrinsic properties that make salt an attractive medium include uniformly low permeability, high thermal conductivity, abundance in thick masses, and plasticity that enables fractures to heal themselves at feasible repository depths. However, the high solubility of salt requires that extensive knowledge of regional and site hydrology be obtained before a repository site is selected; it will be necessary to develop an understanding about possible future groundwater flow at a chosen site.

The solubility of rock salt in water is two orders of magnitude greater than that of any other candidate medium. If man-made or natural events caused a breach in the repository, circulating groundwater could release the radionuclides in the waste, although the sorptive capacity of the geologic materials along the flow paths would retard the release of these nuclides. A thorough knowledge of these sorption properties is required for the particular rocks and the particular groundwaters at a repository. Generally, the sorptive capacity of salt is low and dependent on the impurities in salt.

Extensive salt mining in many locations around the United States and abroad has resulted in a well-developed salt-mining technology. One particular advantage associated with salt mining is that, after shaft construction, explosives are not needed. Electrically powered continuous-mining machines can construct the storage rooms; diesel-powered carriers haul the mined salt to branch-corridor conveyors, which are frequently extended to keep the hauling distances as short as possible.

Salt differs from basalt and shale in the potential environmental impacts of the waste rock from mining that has to be stored at the surface. The surface-storage pile would have to be designed to limit wind erosion and precipitation runoff in order to minimize potential environmental impacts during and after repository operation.

In summary, salt is the best understood of all candidate geologic media with respect to its possible use as a waste-repository medium, and it offers advantages in thermal properties and plasticity. It is found in many places in the United States (Figure A-1).

A.3 CRYSTALLINE ROCKS

Basalt, granite, and other crystalline igneous and metamorphic rocks have been proposed as geologic media for a repository; extensive deposits that have been stable for millions of years exist in the United States. The evaluation of these media is in an early stage of data collection, and an effort is under

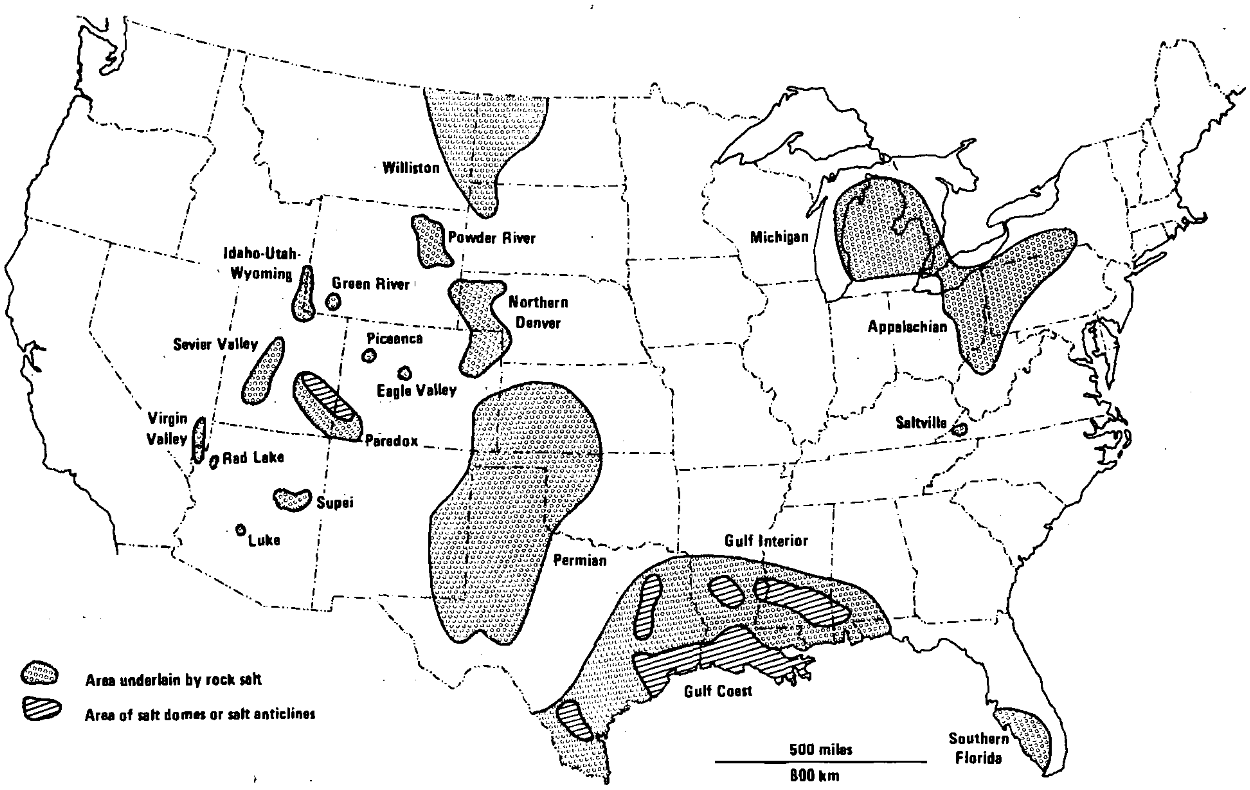


Figure A-1. Map of rock-salt deposits in the United States.

way to compile the information systematically. The basic mechanical properties (compressive strength, tensile strength, modulus of elasticity, etc.) of these rocks have been established through laboratory tests. The properties of the aggregate are, however, considered to be substantially different from those of the small samples of whole rock because crystalline rocks are fractured and cannot be reconstituted (unlike fractured salt, which will "weld" under lithostatic pressure). It is technically possible to build openings in crystalline rocks; still under development are analytical procedures that will completely evaluate the impact of thermal loads on mine structures in such rock or the surrounding rock formations.

Crystalline rocks do not dissipate heat as well as salt does; the thermal conductivities of crystalline rocks are about one-fourth that of salt. Each repository in crystalline rocks will be designed with heat loads adjusted to the thermal conductivity prevailing at the site. For some time heat transfer through crystalline rock has been considered a potential problem because the effects of cracks on thermal conductivity are not well known; heat dissipation in a medium with a random pattern of cracks is presently difficult to analyze. Experiments measuring heat conduction in granite are under way in Sweden and at the Nevada Test Site (NTS). The test at NTS showed that the cracks in NTS rocks affected the thermal conductivity by less than 10%. Tests conducted at both locations confirm that temperature distributions in hard rock can be calculated with a high level of accuracy.

Although large formations of salt, while soluble in water, are impervious to the flow of water, large formations of crystalline rocks are full of fractures that would provide convenient paths for water flow. In a backfilled, sealed repository built below the water table in crystalline rock, the cracks and void spaces may eventually fill with water. Because the cracks throughout the formation are mostly small, the ratio of water volume to rock volume is small. Nevertheless, a major drawback is that it is not yet possible to calculate the total flow and mass transport under the fracture-flow conditions. In addition, it is not yet possible to identify the effects that thermal loading will exert on the flow of water into or out of a sealed repository. Techniques for making these calculations are being developed.

Flow through a fractured medium will depend on the connectedness and size of the fractures. Their size is controlled to a large extent by the normal stresses acting across the fractures; since these stresses increase with depth, the permeability of crystalline rock usually decreases with depth. Although a model has not been established to accurately evaluate fracture flow, experience has shown that at depths of 1500 feet or more below the surface the fracture permeability is so low that it may not be a significant threat even when conservatively evaluated.

Because the water in crystalline rocks is more mobile than the water in salt, it may contribute to slow leaching of the radioactive nuclides from the waste. Although this condition might appear to be a problem, the magnitude of the problem is diminished because granite and basalt have sorptive properties that cause the radioactive elements in the water to be removed by chemical reactions with the rock. Furthermore, the typically low ionic strength of the water found in these formations reduces the possibility of adverse effects on these sorptive properties. Because of these favorable natural conditions, it appears that the corrosion of waste canisters stored in a crystalline-rock repository will be slow; the canister may maintain its integrity over many hundreds of years.

A major difference between repositories in crystalline rock and in salt will be in the methods of construction. While it will be possible in salt to use mining machines, crystalline rock will require drill-and-blast techniques whose impact on the integrity of a repository is still unknown. Such techniques might adversely affect the rock within a few meters around the mined openings. Since the rock beyond this affected volume will provide the required isolation, it is not clear that drill-and-blast construction will affect the long-term integrity of a repository. Experiments will be necessary to answer this question.

Major formations of granite and basalt exist in the United States; Figure A-2 shows their general locations. Reconnaissance studies have shown that the attractive granite formations include those in New England, the Rocky Mountain uplift, the Sierra Nevada Mountain Range, the Appalachian Mountains, and the Canadian Shield in northern Minnesota and Wisconsin. The basalt formations of interest are the Columbia Plateau Flood Basalts in Washington, Oregon, and Idaho. Because both the granite and the basalt formations are extensive, there is ample opportunity to find suitable sites. Field studies on the suitability of crystalline rocks are being conducted by the DOE at the Hanford Site, at the Nevada Test Site, and in Sweden. Sweden and Canada also have such programs.

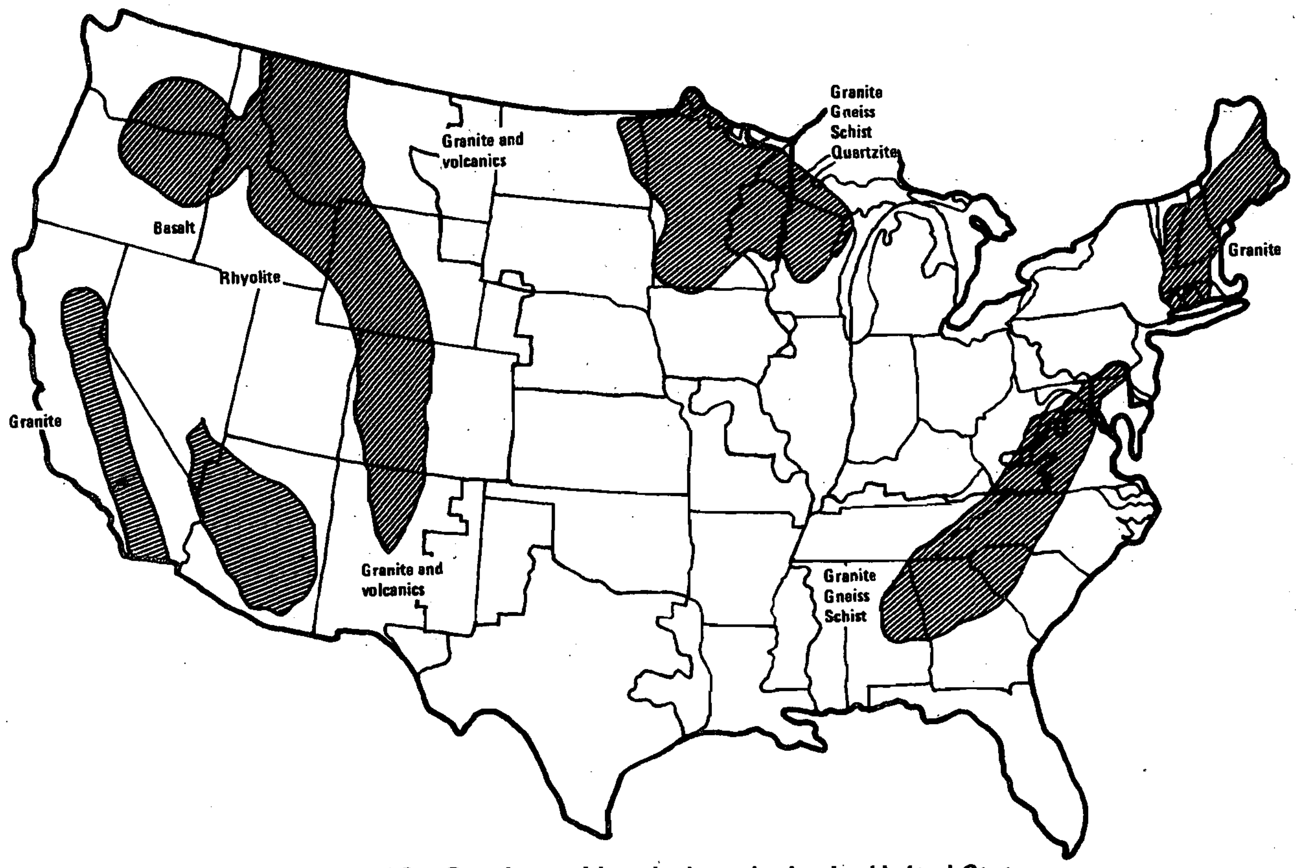


Figure A-2. Granite and basalt deposits in the United States.

A.4 ARGILLACEOUS ROCKS

Argillaceous rocks, especially shales, have also been proposed as geologic media for repositories. Argillaceous rocks vary widely in their characteristics: some shales are relatively plastic, with a high water content; others are relatively brittle, with a low water content. Because of the variation in their structure, these rocks vary widely in mechanical properties. Their strength in a direction perpendicular to the layers is often substantially different from their strength parallel to the layers. Shales exhibit good strength properties in compression but little or no strength under tensile load. Shales with a high water content may be highly plastic, deforming slowly under in-situ stresses; while good for closing cracks, this feature is poor for designing, constructing, and operating a mine that must remain open for 20 years. The anisotropy of shale and the possible variations in its properties make shale repositories difficult to model and analyze generically. Site-specific analyses and designs will be necessary for each proposed shale repository.

The ability of argillaceous rock to dissipate heat is comparable to that of crystalline rock. While facilitating uniform heat flow, the presence of substantial quantities of water in shale may set a relatively low upper limit on the temperature of the waste to avoid producing high-pressure gas through the conversion of water to steam. The design of a repository in shale will adjust the thermal output of the waste to avoid this possibility. Experiments with heaters have been conducted in two different types of shale. The results of tests in wet layered shale are consistent with the above picture. Tests in nonlayered low-water-content shale indicate heat-dissipation characteristics similar to those of granite and basalt. These tests confirm that temperature distributions in different types of shale can be calculated with an acceptable level of accuracy (Tyler et al., 1979).

Shale, a material of low in-situ permeability (Magara, 1971), is insoluble in water; it deforms under lithostatic loads, closing inherent joints. Because of these properties, water does not move easily through shale, even though shale may contain substantial quantities of formation water. Although heat could produce a major driving force to move the water, most of the waste to be received at a TRU-waste repository will not provide such a heat load.

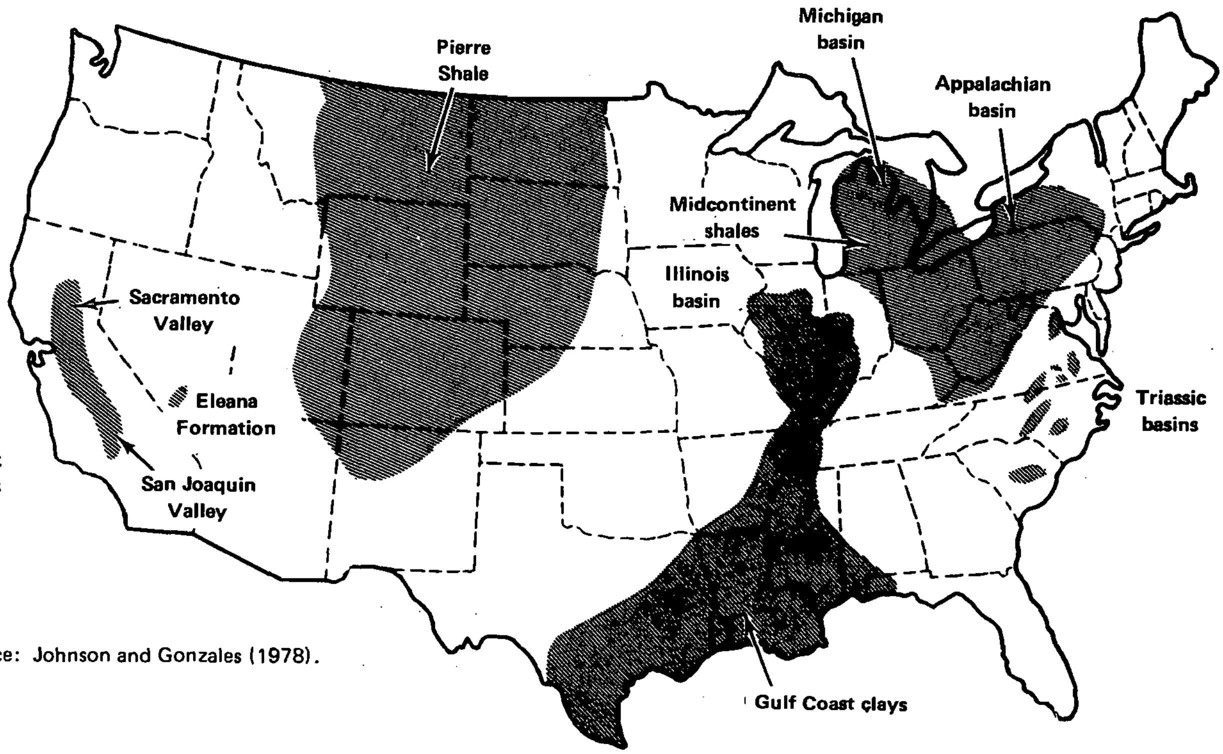
Argillaceous rocks, like crystalline rocks, may provide an aqueous environment conducive to slow corrosive attack on the encapsulated waste. Water entrapped in shale is of intermediate ionic strength, which moderately inhibits corrosive action on canisters. After a canister has been penetrated, the dissolution of the waste inside would also be slow because of the intermediate-level ionic strength of the water. The presence of radionuclides in the water will be mitigated by two major factors: the slow rate of water movement through the tight shale formations and the strong sorptive capacity of the shale minerals, which reduces the concentration of radionuclides in the water through chemical reactions.

The methods for constructing a repository in shale will vary: the soft layered type of shale could be mined with machines, while the harder argillites might require drill-and-blasting techniques. A major concern about the construction and operation of a repository in shale is the possible occurrence of squeezing zones: thin layers of unusually soft, plastic material that could be squeezed by lithostatic forces into mined openings. A study of the Eleana argillite at the Nevada Test Site showed that a repository in this type of formation would require substantial expenditures for necessary structural supports underground because of the presence of squeezing zones (Fenix and Scisson, 1978; Yaner and Owen, 1978).

Large formations of argillaceous material are located in the United States; the largest is the Pierre Shale, in portions of North Dakota, South Dakota, Colorado, Montana, and Wyoming. Figure A-3 shows the location of this and other major argillaceous formations in the United States.

A.5 TUFF

Tuff is composed of material ejected from volcanoes; some of the best tuff formations are located in volcano calderas. It has only recently been considered for repositories; data on its suitability have been gathered for approximately 1 year. Figure A-4 shows regions in the United States where tuff



Source: Johnson and Gonzales (1978).

Figure A-3. Deposits of argillaceous rock in the United States.

deposits are found. None of these regions are in the eastern part of the country; material originally ejected from volcanoes there has metamorphosed and is not classified as tuff.

There are two types of tuff to consider. Welded tuff has low porosity, low permeability, high strength, good thermal stability, and moderate chemical sorptivity. Nonwelded tuff has high porosity, low permeability, high water content, low strength, good thermal stability when dry, unusual thermal expansion properties, and extremely high chemical sorptivity. The first investigations of these materials suggest that they are promising media for the geologic disposal of waste.

Because of the process by which tuffs are deposited, the welded tuff is usually surrounded by at least a partial envelope of nonwelded tuff. If a repository were built in such a formation, the welded tuff would provide high mechanical strength and thermal stability while the surrounding nonwelded tuff would provide strong sorption of radionuclides. This arrangement could be a nearly ideal set of multiple barriers under the proper mineralogical and hydrologic conditions. Because the arrangement is complex, the engineering design of a repository in tuff will be difficult; however, the benefits could be significant.

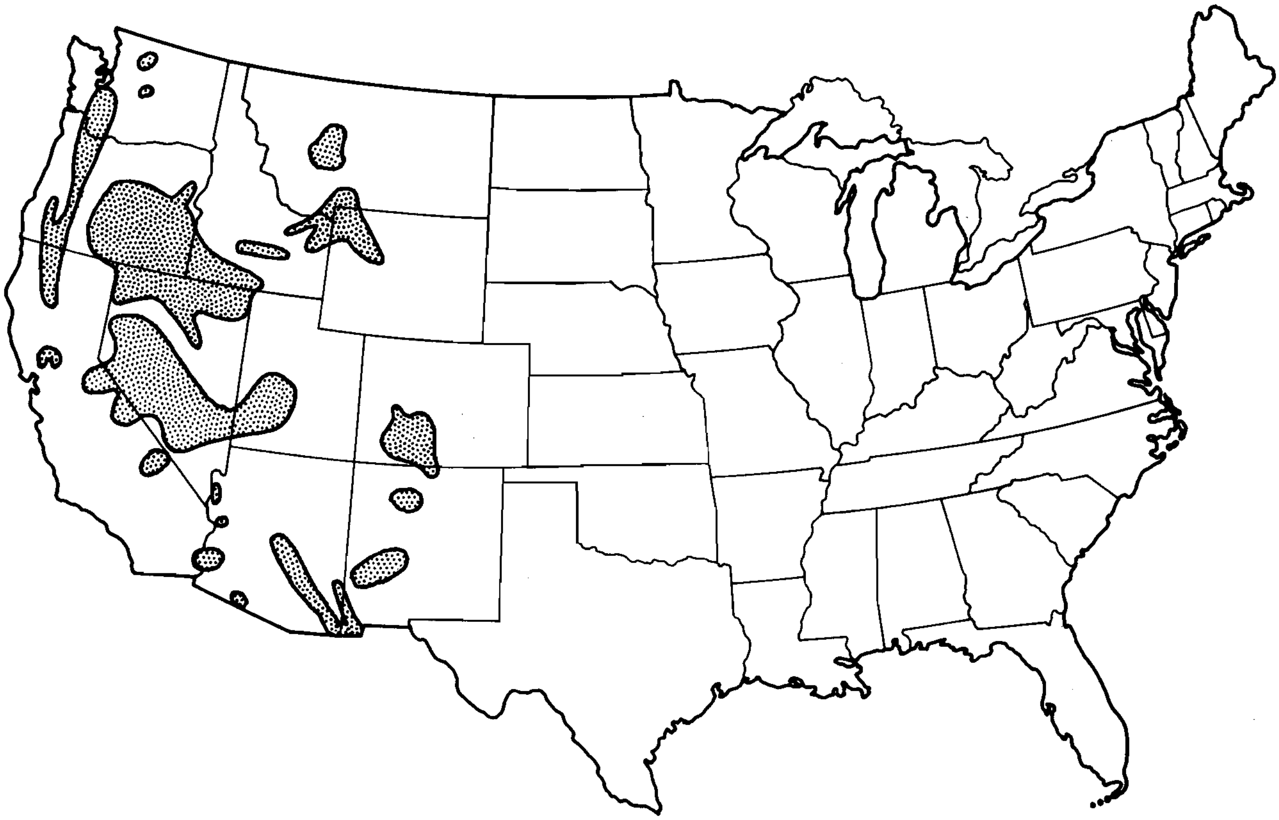


Figure A-4. Tuff deposits in the United States.

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Appendix B

THE NATIONAL WASTE TERMINAL STORAGE PROGRAM AND ALTERNATIVE GEOLOGIC REGIONS

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Appendix B

THE NATIONAL WASTE TERMINAL STORAGE PROGRAM AND ALTERNATIVE GEOLOGIC REGIONS

The National Waste Terminal Storage (NWTS) program of the U.S. Department of Energy (DOE, 1979) is directed at the development of facilities for the emplacement and disposal of high-level and transuranic (TRU) waste within deep geologic formations in order to provide safe, long-term isolation of the waste from human activities and from the environment. The program contains several elements:

1. Geologic studies to identify suitable geologic media and potential sites in various geographic regions.

2. Analysis of the behavior of radioactive waste in candidate geologic structures.

3. Engineering and design of operating repositories and associated specialized equipment.

4. Development of packaging and storage methods for unreprocessed spent fuel.

This appendix discusses the nature and status of the first program element listed above.

B.1 REGIONAL STUDIES

Site-evaluation activities include geologic investigations and supporting studies of the surface environment. These start on a broad national scale and subsequently narrow to candidate regions and then to investigations of areas within regions, finally resulting in work at specific sites. The confirmation of a potential repository site requires a detailed study of the geologic, hydrologic, environmental, and socioeconomic characteristics of the site. For a site to be acceptable, it must be established, in the framework of licensing regulations, that no credible circumstances would be encountered that would result in releases of radionuclides from the emplaced waste to the biosphere in quantities that would constitute a hazard to the public.

Geologic media being studied include salt domes, bedded salt, granite, shale, and basalt. These are found in many parts of the United States. Other materials, such as tuff and carbonate rocks, may also meet the requirements for a candidate host rock.

Most investigations of geologic disposal to date have centered on salt formations, and the primary emphasis of the NWTS program remains on salt domes and bedded-salt formations. Regional studies have been completed on the Permian basin of the Central United States, the Salina region (comprised of the Michigan and Appalachian basins) in the northeast, the Paradox basin of Utah, and the salt domes inland from the Gulf of Mexico. In addition, because they are DOE sites already committed to nuclear purposes, the Hanford Site in south-central Washington and the Nevada Test Site are being examined to determine whether suitable sites exist among the rocks they contain. The status of the site-selection studies is summarized in Section B.3. Sections B.4 through B.8 describe the regional studies and the work at the Hanford Site.

B.2 SAFETY STUDIES

A systematic evaluation of the safety and reliability of geologic disposal of radioactive waste is required in order to insure the viability of specific designs at specific sites being considered for repositories. In the NWTS program this evaluation is almost entirely in terms of the disposal of commercial high-level waste. These studies contain the following elements:

1. Models for analyzing disruptive events, both natural and man-induced.

2. Thermal analysis models.

3. Studies of interactions between the emplaced waste and the surrounding rock and groundwater.

4. Waste-migration models.

5. Borehole-plugging studies.

6. Systems analysis for linking all those effects together.

A basic program containing these elements, the Waste Isolation Safety Assessment Program (WISAP), is in progress. This program is independent of that used for the safety analysis reported in Chapter 9 of this document; one of its tasks, therefore, is to make analyses that parallel the Chapter 9 analyses. The principal purpose of the WISAP, however, is to aid in the site-selection and site-characterization activities of the NWTS program and eventually to enter into the environmental assessments required by the National Environmental Policy Act of 1969 for whatever sites are on the final list of alternative candidate sites.

B.3 STATUS OF SITE-SELECTION STUDIES

The earliest dates for the qualification of sites are as follows:

Geologic medium and location	Date
Bedded salt (other than Los Medanos)	1985
Dome salt (Gulf interior region)	1983
Basalt (Hanford)	1984
Nevada Test Site	1985
Other hard-rock sites	1985

B.3.1 Gulf Interior Salt Domes

The Gulf interior salt-dome region contains several hundred domes scattered across northeastern Texas, northern Louisiana, and central Mississippi. Picking a site in this region amounts to picking a particular dome, as they are discrete entities. At this point the main criteria are size, depth to top, and the nature of previous disturbances. Attention has been narrowed to eight domes, three each in Texas and Mississippi and two in Louisiana. Hydrologic characteristics, on the other hand, can be and are being studied regionally.

Most of the early knowledge of these domes has been obtained from the study and analysis of information from U.S. Geological Survey and state files and of drill-hole, seismic, and other geophysical data purchased from commercial interests. Indirect geophysical methods, such as aerial photogrammetry and infrared remote sensing, have also been used.

Early field evaluations resulted in the elimination of the Palestine Dome (Texas) in October 1979. Studies of the remaining seven domes are continuing. They include hydrologic studies of the three sedimentary basins in which the domes occur as well as dome-specific geologic and hydrologic studies. The understanding of dome locations is being further refined by gravity surveys, high-resolution seismic reflection and refraction surveys, and borehole evaluations. All of the seven domes being investigated are considered to be tectonically stable; no capable faults are known to exist in their vicinity. In late 1980, two or three domes will be recommended for further examination in the "location" study phase of the site-exploration process.

Salt domes appear to be viable alternatives to bedded-salt sites. Several European countries are considering salt domes seriously, and the Federal Republic of Germany has operated an experimental repository in a salt-flow structure for 13 years.

B.3.2 Hanford Basalt

The Columbia Plateau basalts cover a vast region of central Washington, northern Oregon, and western Idaho; much of it might in principle be of interest for waste disposal. For the practical reason that the Hanford Site in the State of Washington is already Federal land administered by the DOE for nuclear purposes, the detailed investigation of these basalts has centered on those of the Pasco basin, in which Hanford lies.

Geologic study of the area was begun more than a decade ago. Studies in the present context started in 1976; since then much mapping and geophysical work has been done, and 16 new holes have been drilled for cores, logging, and hydrologic tests.

The basic geologic structure consists of a series of lava flows separated by porous, water-bearing beds. There has been essentially no mineral exploration in these basalts, and there is little prospect for it. This, plus the extensiveness of the flows, implies that if any part of the structure proves satisfactory for waste disposal, there will probably be a great deal of choice in site selection.

The use of basalt can rely but little on experience and analysis made for salt. Therefore high on the program is the measurement of the physical, thermal, and chemical properties of the basalt, both alone and in the presence of groundwater. A Near-Surface Test Facility is being built in the northeastern portion of the Hanford Site for in-situ testing, especially with electrical heaters.

B.3.3 Nevada Test Site

The Nevada Test Site (NTS) is a large site, about 40 by 60 miles in size. It lies in the Basin and Range physiographic province and at the northern edge of the Mohave Desert ecosystem. Elevations range from 3000 to 7000 feet, and the climate and biological features vary greatly with elevation.

The primary mission of the NTS is the underground testing of nuclear weapons. Indeed, it is the only test site for this purpose now available to the United States. Because of the presence of residual fission products and transuranic nuclides on the surface and under the ground, the NTS is committed for the indefinite future to retention and care by the U.S. Government.

The NTS contains a variety of geologic environments that might be considered for waste disposal. However, potential interference with or by nuclear testing restricts areas that might be considered to those in the southwestern portion of the Site. Four such areas are under consideration; two are granite areas, one is shale, and one is tuff.

All four areas have been investigated by surface geologic mapping and geophysics, and two by drilling. Drilling into one of the granite areas was discouraging: the granite was encountered much deeper than aeromagnetic surveys had implied. The other area drilled was in tuff, and it continues to look promising.

At present only the Yucca Mountain location is being explored. This location is underlain by approximately 6000 feet of interbedded welded to nonwelded tuffs. An ideal geologic setting for a repository in tuff is a thermally conductive, mechanically strong, welded tuff enveloped by a low-permeability, highly sorptive, nonwelded zeolitized tuff. Field mapping, core drilling, and geophysical surveying are in progress to assess the extent to which these conditions exist at Yucca Mountain. A 6000-foot core and hydrologic test hole is being drilled into the study area; the results will be correlated with data from a 2500-foot hole drilled earlier. The water-bearing properties of inferred fracture zones in the Yucca Mountain area will be evaluated by hydrologic testing and geophysical surveys.

The NTS is in seismic risk zone 2, near zone 3. The Basin and Range province is well known to be seismically active. It is therefore necessary to find a block of material that has suitable properties and is sufficiently distant from active faults. Closely related is the question of volcanism; 12 to 13 miles southwest of the NTS there is evidence of volcanic activity as recently as 280,000 to 300,000 years ago.

The hydrologic characteristics of the NTS and its environs are well studied in the areas used or affected by nuclear testing but not in the southwestern area being considered for waste disposal.

B.3.4 Paradox Basin

Regional geology is still being studied in the Paradox basin in southeastern Utah and southwestern Colorado. In addition, three holes have been drilled in a structure called the Salt Valley anticline, one of the salt diapirs of the basin. The deepest of the three was continuously cored to a depth of about 4000 feet. Several types of geophysical logs have been run in these holes, and open-hole injection, pumping, and swabbing hydrologic tests have been conducted. The most recent activity has been vertical seismic profiling, in which a seismic source in one hole is detected in another hole.

In the near future, at least two deep holes, one in the Gibson dome area and one in the Oil Ridge area, will be cored, logged, and extensively tested. Preliminary results indicate that bedded-salt layers of sufficient volume are present at suitable depths in the Utah portions of the Paradox basin. The area is being investigated for historical evidence of earthquakes, especially in the basin itself. Studies of potential resource conflict and groundwater-flow systems are also in progress.

B.3.5 Permian Basin

Permian basin studies have concentrated on the Texas Panhandle. There is essentially no Federal land in the area, and access for drilling and other direct field work is difficult. Nevertheless a great deal of information is available from geophysical measurements and holes drilled by oil companies, and there have been a few holes drilled and logged by the NWTS program on the east edge of the Palo Duro basin.

B.3.6 Salina Region

The Salina bedded-salt region includes parts of Michigan, Ohio, Pennsylvania, New York, West Virginia, and Ontario. Regional studies for the New York and Ohio portions of the Salina basin have identified areas that appear to be geologically favorable to justify more detailed investigations. The Michigan portion of the Salina basin has not been studied in similar detail, but it is known that Michigan has salt beds of sufficient thickness and extent at suitable depths to meet general specifications for waste repositories. No field investigations have been carried out by the DOE in the Salina basin. Some field work in support of repository siting has been conducted in New York and Pennsylvania by the U.S. Geological Survey. Much additional information is needed before a potential repository site can be identified in the Salina basin. At present, no part of the basin has been investigated enough for a judgment of its acceptability as a repository site.

B.4 PERMIAN REGION*

B.4.1 Geology

The Permian region is located in portions of Texas, New Mexico, Oklahoma, Colorado, and Kansas, the entire region encompassing approximately 189,000 square miles (Figure B-1). The land surface consists predominantly of flat plains and tablelands, but some hilly and low mountainous areas exist east of the Midland basin in Texas and along the Wichita Mountains uplift in Oklahoma. Elevations range from 1500 to 2000 feet above the mean sea level in the eastern portion of the region to 5000 feet above the mean sea level in the west.

The Permian region has been tilted, warped, eroded, and invaded by at least one major sea since Permian time (280 to 220 million years ago). Rocks that predate the Permian period show local faulting and complex folding, but the Permian and younger strata are virtually free of deformation and in most areas have a dip of less than 0.5 degree. Most of the modern structures are probably of shallow origin and do not appear to reflect recurrent movement along Paleozoic or older structures.

The Permian region had a complex tectonic history during the Precambrian and Paleozoic Eras, culminating in the Wichita, Ouachita, and Arbuckle periods of mountain building, all of which occurred during the Pennsylvanian period (approximately 310 to 280 million years ago). It was in this tectonic framework that the region developed. A second period of mountain building, referred to as the Laramide orogeny, resulted in the uplifting of the Rocky Mountains just to the west of the Permian region about 65 million years ago, but this affected the region very little. In summary, the Pennsylvanian period of basin formation and crustal uplift is the only major tectonic activity that has affected the Permian region since Precambrian time, approximately 1 billion years ago. Structural readjustments since the Pennsylvanian have had little effect on the post-Permian rock units, including the extensive salt sequences.

The entire Permian region lies within seismic risk zone 1, which indicates that ground rupture should not be anticipated in the region. Recorded seismic activity is low compared with that of most other parts of the United States. Earthquakes with modified Mercalli intensities of V to VII are scattered sparsely over the region. Of the region underlain by salt, the only part that has undergone significant activity is the area on the flanks of the Amarillo uplift and along its west-northwesterly continuation across the Bravo dome and the Dalhart basin.

The Permian region has long been one of the major oil- and gas-producing regions of the United States. The hydrocarbon reservoirs of eastern New Mexico and west Texas range from Ordovician to Permian in age. Limestones deposited during Permian and Pennsylvanian time served as stratigraphic traps for hydrocarbons and have been the major producing strata in the Silurian, Devonian, and Ordovician systems. Future exploration is anticipated to the

*Data from Environmental Characterization of Bedded Salt Formation and Overlying Areas of the Permian Basin (NUS, 1979a).

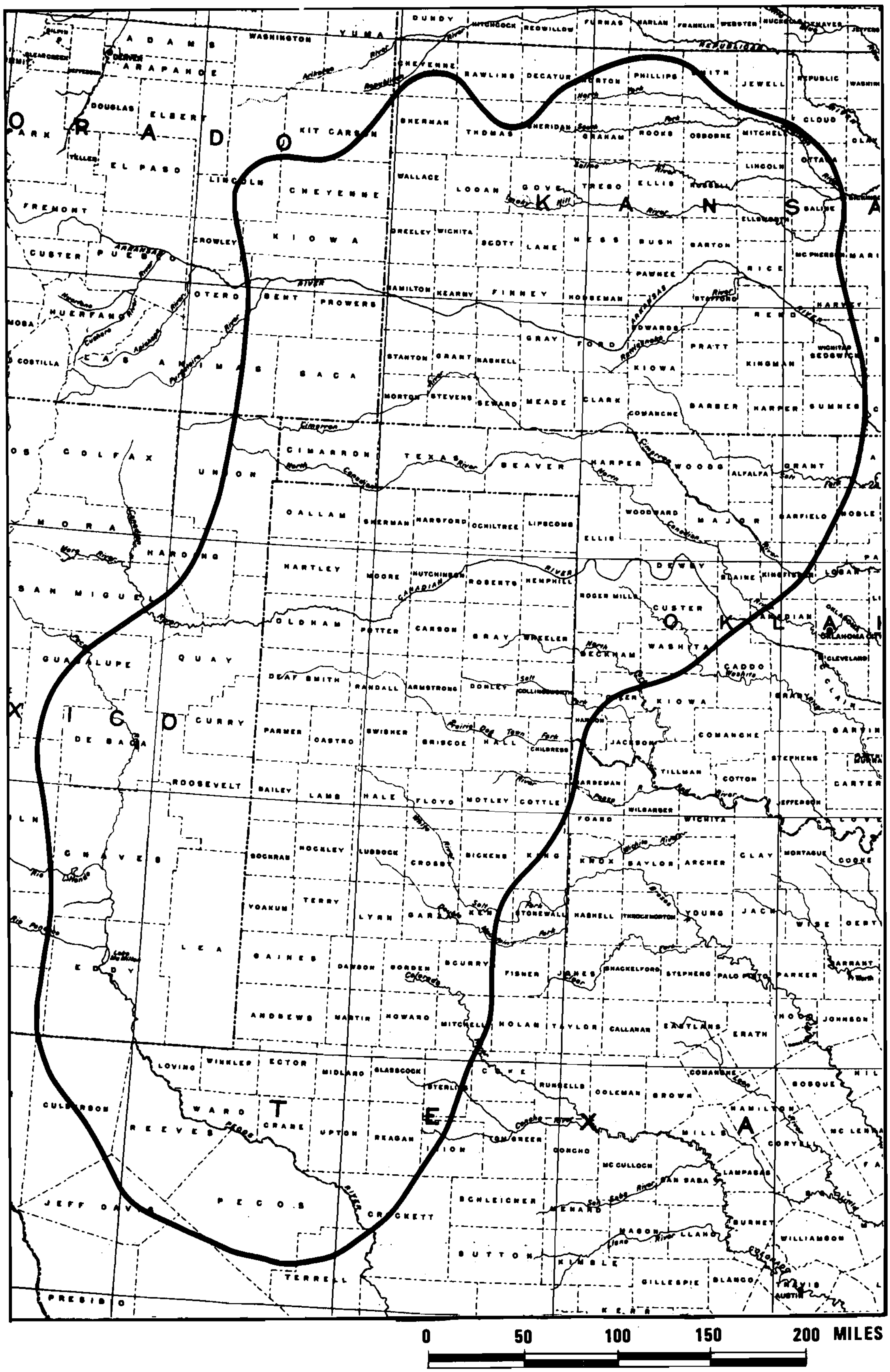

Figure B-1. The Permian bedded-salt basin.

north of the presently producing fields in southeastern New Mexico. In relation to the Upper Permian salt-bearing formations, most of the drilling for development and exploration will be at depths greater than those of the salt formations.

Major natural gas fields are present in western Oklahoma and the Texas Panhandle. There is some oil production in the area but far less than that of natural gas. The hydrocarbon-production zones in western Oklahoma and the Texas Panhandle are mainly lower Permian and Pennsylvanian strata. Most of the successful wildcat wells have found production horizons in Pennsylvanian and Mississippian strata, but deeper drilling is finding producing zones at depths of 25,000 feet in Silurian and Devonian systems. The principal oil-producing stratum is Pennsylvanian in age. Oil is also produced along the south side of the Palo Duro basin, along the crest of the Matador arch. Production is small from these basins. In addition to oil and gas, helium is produced at three localities, and carbon dioxide is produced from Permian rocks. On the basis of current leasing and drilling activity, it is anticipated that there will be exploration and development efforts for hydrocarbon zones below the Permian salt formations in western Oklahoma and the Texas Panhandle.

The southeastern Colorado portion of the Permian region supports oil and gas production that is small in comparison with that of the other producing provinces in the region. Principal hydrocarbon-production zones for this area are Pennsylvanian and Mississippian strata. Future drilling activity in southeastern Colorado will be in Pennsylvanian and Mississippian strata, which are stratigraphically below the Permian salt formations.

Major natural gas occurrences extend northward from western Oklahoma and the Texas Panhandle into Kansas. Hydrocarbon-production zones for the Kansas portion of the Permian region are in Cretaceous, Permian, Pennsylvanian, Mississippian, and Ordovician strata. It is expected that future drilling efforts for Paleozoic strata will continue at a high rate in southwestern Kansas. Helium is also produced in the Kansas portion of the region.

Lignite deposits occur in north-central Kansas, although production from this area is sparse. Lignite has also been mined from limited seams in Cimarron County, Oklahoma, for domestic heating purposes.

Uranium resources are scattered in small deposits across the south-central portion of the Permian region in eastern New Mexico, the Texas Panhandle, and western Oklahoma. A few local deposits are also present in the southeastern Colorado portion of the region. Production has been small because of the limited size of the deposits.

There are no known metal occurrences within the Permian region, though iron and titanium are found near its periphery in Kiowa County, Oklahoma.

The production of various nonmetals has been, and continues to be, one of the major industries in the Permian region. The nonmetallic mineral industry in the region includes construction materials (e.g., stone, sand and gravel, volcanic ash, and scoria). These nonmetals are extracted from depths of usually less than a few hundred feet, and thus extraction would not interact with the salt deposits under consideration. Evaporite (e.g., potash and anhydrite) deposits are also located extensively over much of the region.

B.4.2 Hydrology

The Permian region has a semiarid climate characterized by low rainfall and runoff, high evaporation, and frequent strong winds. The rivers in the region generally rise on the eastern slopes of the Rocky Mountains and flow southeastward across nearly flat plains, which slope eastward at 5 to 15 feet per mile. Rainfall and runoff increase and evaporation decreases to the east. The mean annual precipitation varies from less than 16 inches in the western part to about 30 inches in the eastern part. The mean annual runoff varies from less than 0.2 to about 4 inches from west to east. The quality of many streams in the region is poor because of natural contamination (salt, sulfates, silt) and man-made sources (oil-field brine, feedlot drainage, irrigation runoff, municipal and industrial discharges). In many areas, river water is unsuitable for most municipal, industrial, and agricultural water-supply purposes. Although major floods occur infrequently, localized flooding may occur as a result of intense local precipitation. In most areas, such floods are characterized by rapidly rising and falling peak discharges and high water velocities. Flooding is controlled or mitigated by reservoirs and flood-control dams on many streams in the region. Reservoirs are also used for minimum flow maintenance.

The largest single user of water in the region is agriculture (about 87% of the total consumption). Domestic uses, manufacturing, and steam-electricity generation account for most of the remaining water consumption.

Because of the limited availability and variable quality of surface water, groundwater has become the dominant water resource in the region. Sixty-three percent of the water withdrawn in the region comes from groundwater. Aquifer types include stream-valley alluvium; terrace alluvium; carbonate and gypsum; sand and sandstone; and undifferentiated sandstone, carbonate rock, shale, and basalt. The Ogallala aquifer is a terrace-alluvium aquifer extending from southwest Texas across parts of New Mexico and Colorado, and western Colorado, Oklahoma, and Kansas. It is the most important source of water in the region and is one of the most intensively developed in the United States. The zone of saturation ranges from a few feet to more than 250 feet, and the depth to water ranges from less than 50 to more than 300 feet. The yields of wells range up to 1500 gallons per minute (gpm), depending largely on the saturated thickness. The water is generally of good quality but can be hard locally. Virtually all of the withdrawal in the heavily pumped areas comes from storage (i.e., the water is being mined).

Alluvium and terrace deposits represent deposits of the major streams formed during the period of dissection of the High Plains and consist largely of reworked material derived from the Ogallala Formation. The alluvium and terrace deposits are nearly continuous along the major streams, although there are gaps along some of the streams where alluvial deposits are thin or absent. The zone of saturation ranges from 0 to 150 feet, and well yields range from less than 100 to 3500 gpm. The water ranges from fresh to highly saline.

The Edwards-Trinity (Plateau) aquifer is a sand and sandstone aquifer at the southern boundary of the Permian region. It consists of massively bedded limestone interbedded with shale. Although the yields of wells in most places average about 250 gpm, they can exceed 3000 gpm in places where the secondary permeability of the limestone is well developed. Water in the aquifer is generally fresh, although the concentrations of total dissolved solids can reach about 3500 mg/l.

The Rush Springs and Gerber-Wellington aquifers in Oklahoma and the Roswell artesian aquifer in New Mexico lie primarily outside the Permian region but do provide an important water resource to the portions of the region that they include.

B.4.3 Climate

The Permian region is in the Southern Plains and Lowlands climatic zone. In general, climatic changes are gradual across the zone because there are no significant climatic barriers. Differences in climatic conditions within this zone are controlled primarily by latitude, general air mass and other storm movements, elevation, and distance to sources of moisture.

The climate is predominantly continental, with cold winters and warm to hot summers. The western portion of the region has a dry climate because of the blocking effect of the mountains to the west. The modifying effect of the Gulf of Mexico results in a warm, humid, and rainy climate for the eastern portion of the region. The northern portions of the region are frequently affected by cold polar and arctic air masses during the winter and less frequently during the summer. Wind and precipitation patterns indicate a relatively high erosion potential.

Fundamental changes in the climate of the region have occurred over the last million years (the Pleistocene Epoch). During this period there have been four ice ages, the most recent of which ended about 10,000 years ago. Although glaciers did not extend to the Permian region, the climate was probably cooler, wetter, and stormier than at present. Flooding was probably more frequent. The current epoch (Holocene) is considered to be interglacial, and there are indications that a long-term global cooling trend is under way at present.

In the Permian region the 24-hour maximum rainfall with a 100-year recurrence interval ranges from 5 inches in the northwestern portion to 8 inches in the eastern portion. These values are typical for the contiguous United States. The frequency of tornadoes is noticeably greater in the central, northern, and eastern portions of the region. (Texas, Oklahoma, and Kansas are within an area of the United States that is associated with frequent occurrences of tornadoes.) Similarly, most of the northern and central portions of the region experience 100-year maximum winds with speeds of more than 90 mph, which is relatively high in comparison with typical values in the United States. Restrictive-dispersion conditions (inversions) are relatively infrequent in the region compared with the rest of the contiguous United States. The occurrence of restrictive-dispersion episodes increases from east to west across the region.

Air-quality statutes and regulations restrict development in areas that are not attaining the national ambient air-quality standards (unless certain offset criteria are satisfied) or where emissions would result in violations of the standards or would exceed increments established by the Clean Air Act Amendments of 1977. Data indicate that the national ambient air-quality secondary standards for particulates are being exceeded throughout the western half of the region and in some eastern areas. Furthermore, the particulate concentrations in the area between Amarillo and Midland, Texas, exceed the national primary ambient air-quality standards for particulates.

B.4.4 Background Radiation

Background radiation is ubiquitous, resulting from cosmic, terrestrial, and fallout sources. The limited data available for the Permian region reveal no anomalous areas.

B.4.5 Demographic, Socioeconomic, and Land-Use Systems

The Permian region is sparsely populated. Only three urban areas in the region support a population of more than 100,000 inhabitants: Wichita, Kansas (approximately 300,000), Lubbock, Texas (approximately 150,000), and Amarillo, Texas (less than 130,000). Odessa and Midland, Texas, have populations of just over 80,000 and 60,000, respectively. The largest urban area within 75 miles of the region is Oklahoma City, Oklahoma (approximately 580,000).

Total earnings for the Permian region in 1970 amounted to approximately 11 billion dollars; by the year 2000, earnings will be approximately 27 billion dollars. The dominant land use is agriculture. The livestock industry yields more earnings than all the field crops combined. Earnings from agriculture, forestry, and fisheries accounted for about 14% of all earnings; manufacturing accounted for approximately 13%. Mining and other extractive industries accounted for approximately 5% of the total earnings. Approximately 68% of the earnings was produced by retail and wholesale trade, government, and institutions. This percentage is expected to increase, whereas the percentages for agriculture and mining are expected to decrease in the coming decades.

Sensitive or conflicting commitments of land areas larger than 10,000 acres include 142,200 acres of Indian lands (trust areas) in Oklahoma. Also within the region are 2 national parks (93,720 acres), 5 national forests (639,321 acres), 3 wildlife refuges (64,606 acres), 11 recreation areas on Bureau of Reclamation projects (1,143,921 acres), 1 military installation (33,848 acres), and other military areas (primarily restricted air spaces), totaling 23,850,624 acres. The area committed to these activities is approximately 22.86% of the Permian region. The bulk of the land is range, agricultural, and open land, with some areas preempted for urban and residential development and for transportation networks.

The Permian region is traversed by a network of highways and rail lines. The highway system is the dominant mode of transportation throughout the region. Railroad trackage has been developed most intensively around major rail hubs within or near the northeastern portion of the region.

B.4.6 Terrestrial Ecosystems

The Permian region covers some 189,000 square miles and includes a variety of soil, topographic, and land-use patterns. About 98% of the region is classified as range or pasture (58%) or cropland (40%).

Most of the natural vegetation in the region is classified as grassland and shrubsteppe (97%), but forests (3%) are scattered along the major river drainages in Kansas, Oklahoma, and eastern Colorado and in the low mountains in the western portion of the region. Forests are not commercially valuable in the region because of their limited distribution. Nevertheless, they provide important wildlife habitats. Wetlands are scarce. However, six typical wetland areas are identified, one of which (the Great Salt Plains in Oklahoma) has been proposed for Registered National Landmark status. The region contains seven national wildlife refuges in wetland areas. The Society of American Foresters has identified two natural areas in Kansas that are set aside for scientific, educational, or recreational purposes. The Nature Conservancy has designated at least three natural areas in the Oklahoma portion of the region. Twenty-four plant species that are proposed for the Federal list of endangered species occur within the region.

Regional wildlife includes some 85 species of mammals, at least 350 species of birds, and more than 100 species of amphibians and reptiles. Forestland, shrubland, and openland species are well represented. Important wildlife includes game species, furbearers, and one species on the Federal list of endangered species, the black-footed ferret. At least 35 game birds and 26 game mammals are found in the region, and hunting and trapping are important. The white-tailed deer, mule deer, and pronghorn are important big-game animals. Cottontail, jackrabbit, and fox squirrel are important small-game mammals. Nonmigratory game birds include the turkey, ring-necked pheasant, lesser prairie chicken, bobwhite, and scaled quail; migratory game birds include waterfowl and the mourning dove. Birds on the Federal list of endangered species include the brown pelican, Mexican duck, bald eagle, peregrine falcon, whooping crane, and Eskimo curlew.

The major land uses in the Permian region are cropland and range and pasture. The major cropland areas are in Kansas and Texas; Texas and New Mexico have the largest amounts of range and pasture land. Important crops include winter wheat, sorghum, and cotton. Cattle, sheep, hogs, and milk cows are important livestock.

B.4.7 Aquatic Ecosystems

A large portion of the Permian region is semiarid, with intermittent streams as the only aquatic habitat. These streams, when flowing, are generally high in mineral content from natural sources (salt springs, brine seeps, or gypsum overburden) and from human activities (petroleum and natural gas production or irrigation return flows). As a result, the most suitable (often the only available) aquatic habitats are near the peripheral portions of the region.

In the northern portion of the region, streams of the Smoky Hill River system, which drain ultimately to the Missouri River, are turbid and moderately salty. During low-flow periods in summer months, particularly in the upper reaches, these streams become ephemeral. Near the northeastern boundary of the region and below the confluence of the Saline and Solomon Rivers, the Smoky Hill River system maintains adequate flow and supports a marginal recreational fishery for catfish and carp. The Topeka shiner, a threatened fish in Kansas, has been recorded from the Smoky Hill and Saline Rivers within the Permian region.

Rivers of the north-central Permian region, including the Arkansas, Cimarron, Canadian, and Red Rivers, have poor water quality as a result of natural and man-induced pollution. These streams (with a possible exception of the Arkansas River) have their origin in semiarid regions and frequently exhibit no flow or subsurface flow conditions. Consequently, suitable habitats for aquatic organisms are mainly outside or near the eastern periphery of the region. A few locally endangered or threatened species may occur in the north-central portion of the region but are expected primarily in the headwater areas of Colorado and New Mexico or near the eastern boundary of the region, where the streams become larger and flow continuously.

Much of the central Permian region, although within the watersheds of the Brazos and Colorado Rivers, consists of playa lakes and dry creeks and is essentially noncontributing. Aquatic habitats are therefore few in number and, when present, are generally not suitable for fish and aquatic invertebrates because of the naturally high salt content of surface waters. A few tributaries (e.g., the Concho River of the Colorado River system, which is essentially spring-fed) maintain flows and water quality that support exploitable fish populations. Such streams are generally near the eastern boundary of the region.

In the south and southwest portions of the Permian region, the Pecos River, although polluted from natural brines and irrigation return flows, supports a diverse fish fauna in tributaries to the main-stem river. Many of the species and subspecies of this region (particularly the several species of desert pupfish and gambusia) have been isolated by natural barriers and are restricted to specific habitats (often a single tributary or spring). Because of their highly restricted distributions and dependence on unique habitats for survival as a species or subspecies, many of these fishes are considered to be endangered.

B.5 SALINA REGION*

B.5.1 Geology

The Salina region includes portions of New York, Pennsylvania, Ohio, Michigan, West Virginia, and Ontario (Figure B-2). The entire region encompasses approximately 80,000 square miles of land area in the United States.

About half of the Salina region is in the Great Lakes section of the Central Lowland physiographic province. The lakes and terrain features, such

*Data from Environmental Characterization of Bedded Salt Formation and Overlying Areas of the Salina Basin (NUS, 1979b).

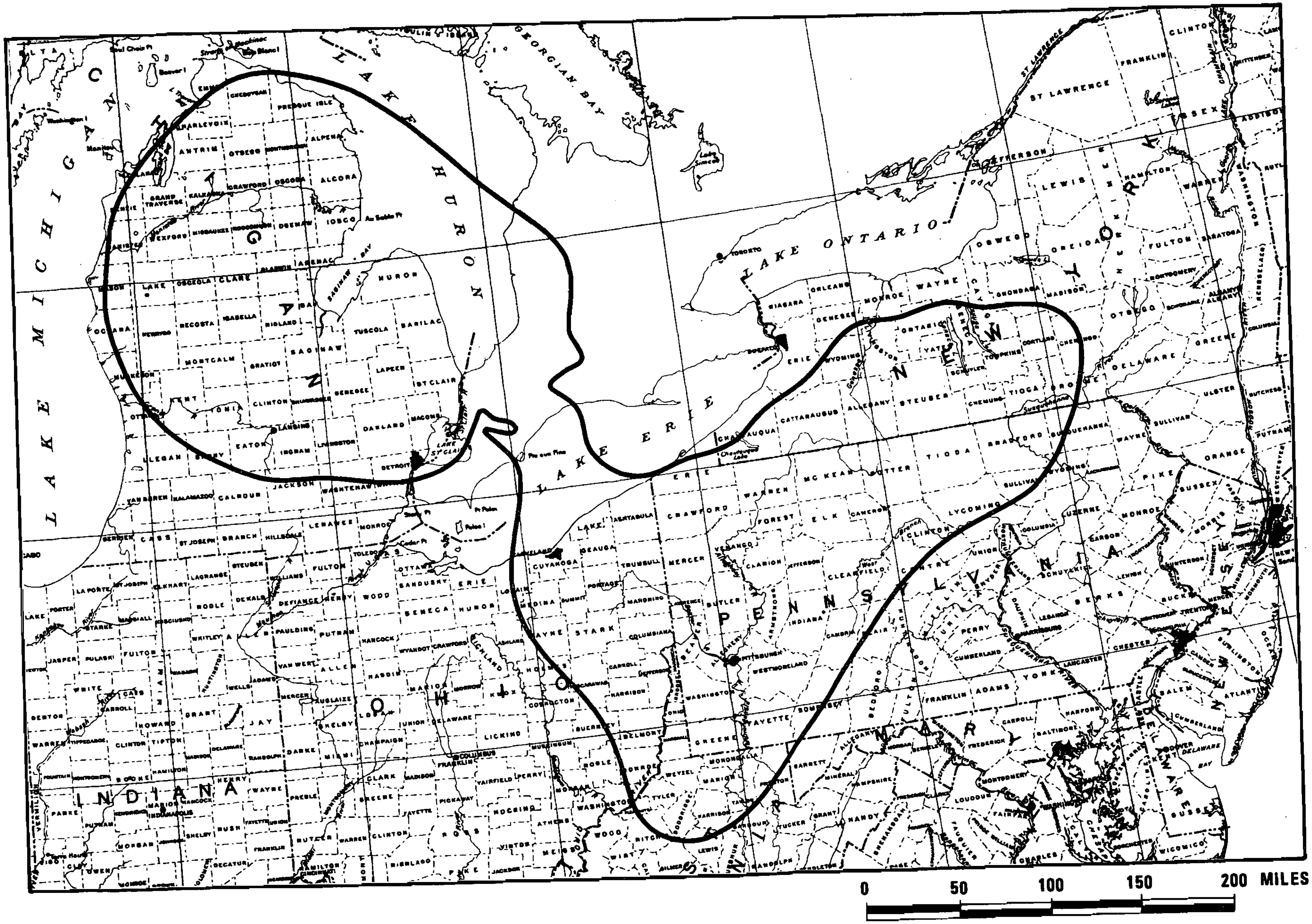

Figure B-2. The Salina bedded-salt region.

as moraines and drumlins, reflect the prominent effects of Pleistocene glaciation in this section. The remainder of the region is a part of the Appalachian Plateaus physiographic province. It is composed of shallow river valleys and broad ridges, with escarpments that provide abrupt changes in elevation. Local elevations generally vary by no more than 300 to 400 feet; however, the elevation increases in going from west to east from about 1000 feet above sea level in Ohio to about 2000 feet above sea level in New York.

The Salina region lies within two major tectonic divisions: the Central Stable region in the west and the orogenic belts of the Atlantic margin in the east. The Central Stable region is founded on Precambrian rocks that compose the stable interior of the North American continent. The eastern areas of the region contain mountainous areas uplifted and deformed during the Paleozoic Era. Separating the eastern and western portions of the region are a series of arches--areas that were stable or gently uplifted and deformed during the Paleozoic Era, when the Appalachian and Michigan basins were subsiding. It was during these periods of subsidence that salt beds were formed. All these structures are extremely old, with no major movements in the earth's crust for approximately 190 million years. Indeed, the Salina region has experienced no major internal tectonic activity since Precambrian time (1 billion years ago). Major structural features within the region are few, uncomplicated, and broad in extent. Minor structures within the region are also relatively few and simple.

The Salina region is one of low seismicity. Earthquakes in the eastern portion of the region are attributed to readjustment of the earth's crust after the most recent Ice Age. Major surface faulting is uncommon. Several seismic events have occurred in the vicinity of Attica in western New York. These earthquakes have been related to the Clarendon-Linden Fault, a north-south-trending tectonic feature. Several moderate earthquakes (modified Mercalli intensity of V) have occurred near Cleveland, Ohio. Portions of the Salina region in Michigan, Pennsylvania, and West Virginia have been virtually earthquake-free.

Oil and gas fields have been developed in all parts the Salina region. Primary, secondary, and tertiary recovery efforts, which include water flooding and fracturing, may have affected portions of the Silurian salt layers. The most abundant oil and gas fields are in Pennsylvania, West Virginia, and Ohio. Major bituminous coal reserves occur in Pennsylvania, West Virginia, Ohio, and Michigan. Much of the coal is within 300 feet of the surface, well above the salt beds. Metallic ores in the region are of low grade and of limited economic importance. Several nonmetallic minerals of economic importance are extracted in the region: salt, salt brines, silica, and construction materials (sand, gravel, gypsum, etc.). With the exception of salt brines, it is not expected that current or future recovery of these minerals would affect waste-repository siting.

B.5.2 Hydrology

The Salina region is subdivided into three Hydrologic Regions (HR): HR I, southeastern Great Lakes basin; HR II, Susquehanna River headwaters; and HR III, northeastern Ohio River basin.

Hydrologic Region I covers the drainage area of Lake Huron, Lake Erie, and Lake Ontario. The terrain is characterized by flat land, lakes, marshes, and peat bogs, reflecting the poor development of regional drainage systems. Streams are relatively short and follow the lows of the once-glaciated terrain. The terrain is therefore more conducive to infiltration than to direct, rapid surface runoff. Water available for withdrawal and use in HR I comes primarily from precipitation within the area. Annual precipitation ranges from 28 to 37 inches; approximately one-third, nearly 12 inches, becomes runoff. Water is generally nonsaline throughout HR I.

Major floods and most damaging floods are usually the result of rain and snowmelt on frozen or nearly saturated ground. Intense summer storms have created destructive floods, but these are ordinarily confined to local areas. Dams are used for flood control and for water-resource management. The largest single use of water in the region is for cooling steam-electricity generating plants. Manufacturing facilities and domestic consumption are also major water users.

Although water-bearing formations underlie all of HR I, the depth to the water table varies with the season, local geologic characteristics, and terrain. With the exception of the lower Michigan Peninsula, productive aquifers (yielding to a well at least 50 gpm of water containing not more than 2000 ppm of dissolved solids) are located only along some of the main watercourse alluvial valleys. Because of the abundance of surface-water supplies in HR I, groundwater usage has not been extensively developed and constitutes generally less than 10% of the total water use.

Hydrologic Region II is located in the headwaters area of the Susquehanna River, which flows southeasterly from south-central New York through Pennsylvania and Maryland. The two major tributaries of the Susquehanna River that flow through HR II are the West Branch of the Susquehanna River and the Chemung River. Hydrologic Region II is characterized by deeply eroded, steep-sided, flat-bottomed valleys and flat to gently rolling plateaus varying in relief from several hundred feet in New York to nearly 2000 feet in Pennsylvania. This type of landscape tends to shorten the time for precipitation to run off into streams and consequently promotes the possibility of flooding. Precipitation averaging nearly 38 inches annually in HR II is the major source of water supply. The mean annual runoff varies from about 15 to 25 inches, about half of this occurring during the 3-month period from March through May. Some tributaries of the West Branch of the Susquehanna River are heavily influenced by acid mine drainage. Nevertheless, the dissolved-solids concentration of most streams in HR II seldom exceeds 800 ppm. Generally, floods occur each year in HR II; major flooding can occur in all seasons. Flooding is, however, more frequent in early spring, usually in March. Major floods have been caused by heavy rainfall on top of heavy snowfall and by heavy rainfall on previously saturated ground. Occasionally, local flooding is caused by ice jams or from thunderstorms during the summer months. As in HR I, major water uses are for steam-electricity generation, manufacturing, and domestic consumption.

The abundant water in the Susquehanna River basin is looked to by communities outside the area as a supply source for the future. Currently significant quantities of water are piped to Chester, Pennsylvania, and Baltimore, Maryland. Rural water supply needs will also increase rapidly in the future. This includes rural domestic use, consumption by livestock, and irrigation.

The increases are not as dramatic as in the urban areas, but they are nevertheless substantial and must be planned for, particularly where they compete directly with urban needs.

Groundwater in HR II occurs in appreciable quantities in rock strata and is generally of good quality, except near coal mines below Tioga County, Pennsylvania. Deep aquifers in the region may be saline or brackish. Highly permeable glacial deposits along most of the valleys are significant sources of groundwater. These aquifers are very productive and readily recharged. Since most urban communities are situated on water-bearing glacial deposits in the valleys, groundwater has not been widely utilized. Although water-use data are not available for HR II, data for the entire Susquehanna River basin, which includes HR II, indicate that 17% of the total water consumption is supplied by groundwater. Total groundwater use is expected to increase as water demands grow in the region.

Hydrologic Region III lies in the northeastern section of the Ohio River basin. Major streams in this region are the Allegheny River, Monongahela River, Muskingum River, Beaver River, and the main stem of the Ohio River. Hydrologic Region III is located in the Appalachian Plateaus physiographic province, which is characterized by a rugged terrain resulting from the differing resistance of the rock to weathering and runoff. Extensive forest cover, poor-quality soils, narrow valleys, steep stream gradients, and flash floods during the dry seasons are characteristic of this area. Vegetation is generally sufficient to retard runoff and minimize erosion. Precipitation averages about 45 inches annually; runoff ranges from about 11 to 25 inches annually. Many minor tributary streams throughout the area normally cease flowing during the dry season, with drought periods adding to their number. Often during late summer and early fall, stream flow from precipitation is negligible, the only flow being from groundwater seepage. Waters of the region are nonsaline, although some tributaries have high concentrations of dissolved solids. In order of gross consumption, major water-usage categories are steam-electricity generation, manufacturing, and domestic use.

Valley-fill sediments, consisting both of glacial outwash and recent alluvium, are the most important source of groundwater in HR III. Highest yields occur generally in the valleys of the Ohio River and its north-side tributaries. Most bedrock systems in the area are relatively poor water bearers, although productive aquifers do occur in some limited rock strata that underlie portions of HR III. High iron concentrations are often found in these waters. Groundwater supplies have been developed in the valley-fill-sediment aquifers primarily for use at the point of need. Because of the large areas covered by these aquifers, most of the stored water has been untouched by current development.

B.5.3 Climate

The Salina region is located primarily within the Great Interior climatic zone. Differences in climate are controlled primarily by latitude, general air mass and storm movements, elevation, and distance to sources of moisture. Modifications to the climatic patterns are introduced by the Great Lakes and by the lifting effects of the Appalachian Mountains. The climate is generally characterized as cool in the northern section and warm temperate and rainy in the southern section. Wind and precipitation patterns indicate a very low erosion potential in the region.

Fundamental changes in the climate of the region have occurred over the last million years (the Pleistocene Epoch). In this period there have been four ice ages, during which glaciers covered much of the Salina region.

The most recent ice age (Wisconsin Glacial) ended about 10,000 years ago, although continuous ice sheets still exist in the polar regions. The current epoch (Holocene) is considered to be interglacial; however, there are indications that a long-term global cooling trend is under way at present.

In the Salina region, severe-weather conditions are rather typical of those occurring in most areas of the contiguous United States. The maximum 24-hour rainfall with a 100-year recurrence interval ranges from 4 to 6 inches. The frequency of tornadoes is noticeably greater in southern Michigan and eastern Ohio than in other sections of the region. However, the frequency is significantly lower than that in the Central United States. Most of the Salina Region experiences 100-year maximum winds of less than 90 mph, which is typical for most of the continental United States.

Restrictive dispersion conditions are relatively frequent in the extreme southern section of the Salina Region compared with the rest of the region and with the contiguous United States. Sections of the Salina Region experience less than 25 to nearly 40 episode-days in 5 years.

Air-quality statutes and regulations restrict development in areas that are not attaining the national ambient air-quality standards (unless certain offset criteria are satisfied) or where emissions would result in violations of the standards or would exceed increments established by the Clean Air Act Amendments of 1977. Data indicate that the national ambient air-quality secondary standards for particulates are being exceeded around all major cities and in eastern Ohio, southwestern Pennsylvania, and northern West Virginia.

B.5.4 Background Radiation

Background radiation is ubiquitous, resulting from cosmic, terrestrial, and fallout sources. Limited data available for the Salina region reveal no anomalous areas. Dose rates range from 68.8 mrem/yr at Charlevoix, Michigan, to 116.7 mrem/yr at Wheeling, West Virginia.

B.5.5 Demographic, Socioeconomic, and Land-Use Systems

Many areas within the Salina region are highly urbanized. The heaviest concentrations of urban areas (over 50,000 inhabitants) in the region occur in Ohio, southern Michigan, and western Pennsylvania. The largest urban areas in or near the region include Detroit (nearly 4 million inhabitants), Cleveland and Pittsburgh (nearly 2 million inhabitants each), and Buffalo (over 1 million inhabitants).

Total earnings for the Salina region in 1970 amounted to 66 billion dollars; by the year 2000 earnings will be about 181 billion dollars. Manufacturing accounted for approximately 41% of the total earnings in 1970. Although agriculture and forestry are the dominant land uses, they produce, together with fisheries, about 1% of the total earnings of the region. Mining and other extractive industries likewise account for about 1% of the regional earnings. Retail and wholesale trade, government, institutions, and other services account for approximately 56% of earnings. This percentage is expected to increase, and the percentage for manufacturing is expected to decrease, in the coming decades.

Sensitive or conflicting commitments of land areas larger than 10,000 acres consist of the Allegany Indian Reservation, 10 parks, 8 forests, 3 wildlife refuge, 8 recreation projects, 14 airports, 2 military reservations, and 4 military operations areas. The area committed to these activities totals less than 6% of the Salina region. The bulk of the remaining land is agricultural and open land, with some areas preempted for urban and residential development and for transportation networks.

The Salina region is traversed by a well-developed network of highways, rail lines, and waterways used for commercial transportation.

B.5.6 Terrestrial Ecosystems

The broad mosaic of land-use patterns in the Salina region has a significant influence on the distribution and abundance of terrestrial resources. Major land-use patterns in the region are forestland (44%), cropland (31%), pastureland (6%), and other rural land (6%).

Four ecoregion categories occur in the Salina region: Northern Hardwoods, Beech-Maple Forest, Appalachian Oak Forest, and Mixed Mesophytic Forest. Important natural vegetation includes commercially valuable timber, wetlands, natural areas, and proposed endangered plant species. Commercial forestland in the region is about 90% hardwoods and 10% softwoods. Forestland is about equally divided among sawtimber, poletimber, and seedling/sapling stands. Approximately 2% of the region is classified as wetlands with some importance to waterfowl. Some 28 representative wetland areas and 5 National Wildlife Refuges (predominantly in wetland areas) are located in the region. (Only three wildlife refuges are reported in Section B.5.5 as sensitive or conflicting commitments of land because of the size criterion--10,000 acres or more.) The Society of American Foresters has identified 10 natural areas in the region. Five plant species that are proposed for the Federal list of endangered species occur in the region.

Regional wildlife includes some 65 species of mammals, at least 400 species of birds, and 73 species of amphibians and reptiles. Forestland, shrubland, and openland species are well represented. Important wildlife includes game species, furbearers, and endangered species. At least 31 game birds and 23 game mammals are found in the region, and hunting and trapping are important. The white-tailed deer is the most important big-game animal; rabbits and tree squirrels are important small-game mammals. Nonmigratory game birds include the ring-necked pheasant, bobwhite, and ruffed grouse; migratory game birds include waterfowl and the mourning dove. Species on the

the Federal list of endangered species are the Indiana myotis, Kirtland's warbler, peregrine falcon, and bald eagle.

Farming is important in the Salina region. Major crops are corn, hay, winter wheat, and oats. Cattle, swine, and sheep are important livestock.

B.5.7 Aquatic Ecosystems

The Great Lakes provide the most extensive commercial fishery within the Salina region. Although shifts have occurred in the abundance of various species because of fishing pressures, introduction of predators, and pollution, commercial harvesting of fish remains a significant industry in the Great Lakes. The Ohio River drainage presents a more limited fishery resource. The commercial fish harvest in this drainage may be considered negligible, as are the present-day collections of mussels and clams. The Great Lakes and the Finger Lakes in upstate New York support a diverse sport fishery. Appalachian streams offer trout fishing; in many lower stretches of tributaries and in the main-stem rivers of the Salina region a warm-water fishery exists. Many streams and lakes are augmented with stocked species to enhance sport fishing. Only two fish species and one invertebrate on the Federal list of endangered species occur in the region.

B.6 PARADOX REGION*

B.6.1 Geology

The Paradox region (Figure B-3) is located in southeastern Utah and southwestern Colorado. The entire region encompasses roughly 10,000 square miles; about 60% of this land area is in Utah. The Paradox region is a tectonic unit (Paradox Fold and Fault Belt) of the Colorado Plateau and is also a feature of Thornbury's (1965) rugged Canyon Lands section of the Colorado Plateau. As such, it has a diverse and varied physiography and exhibits the landforms associated with tectonic and igneous activities as well as with extensive wind and water erosion. Most of the region is above 5000 feet in elevation, often with high relief and rugged terrain. The area contains some of the most spectacular scenery in the United States.

The rocks of the Paradox region consist of at least 15,000 feet of clastic and evaporitic sediments resting nonconformably on a basement complex of granitics and metasediments. The age of the basement rocks is Precambrian, while the sedimentary strata range in age from Cambrian to Cretaceous. Disconformities and hiatuses abound, some of very long duration. Ordovician and Silurian rocks, for example, are completely absent, and no marine deposition has occurred since the close of the Mesozoic Era. The only Tertiary rocks of significance are intrusive volcanics. The Quaternary is represented only by fluvial deposits, a substantial amount of wind-blown sediments, and minor amounts of gravel and till.

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*Data from Regional Characterization Report for the Paradox Bedded Salt Region and Surrounding Territory (Bechtel, 1978a).

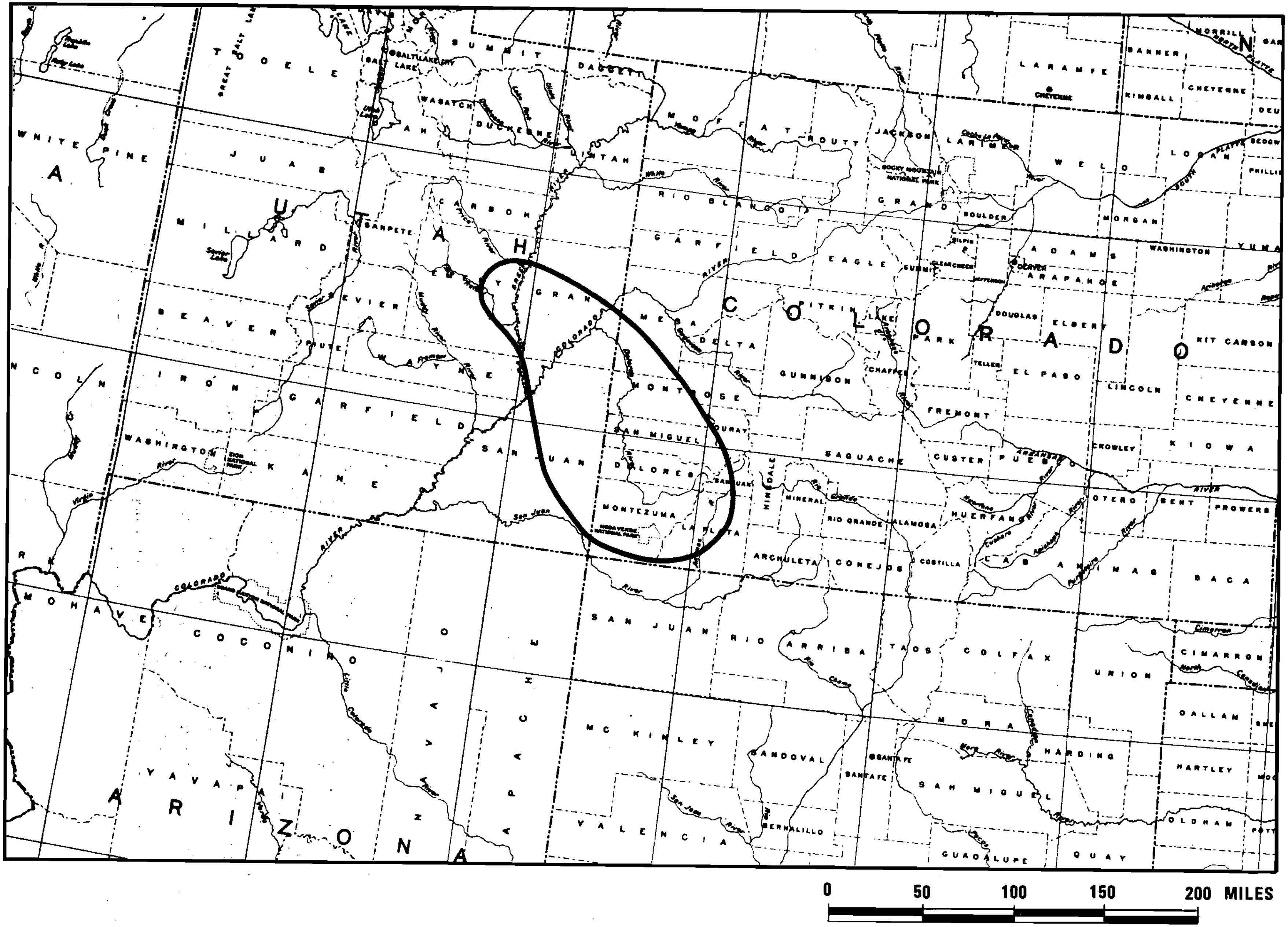

Figure B-3. The Paradox bedded-salt region.

The Colorado Plateau Province, of which the Paradox region is a part, is a mildly deformed platform surrounded by the more highly deformed Rocky Mountains. The principal tectonic elements of the Plateau include uplifts, monoclinal flexures, domes of igneous intrusion, platforms, slopes, saddles, and fold-and-fault belts. In addition, the region displays numerous igneous plugs, diatremes, caldron sinks, dikes, and multitudinous systems of joints and small faults.

The Paradox region is one of low seismic activity. Fifty-four earthquakes with a maximum intensity equal to or greater than V on the modified Mercalli scale of 1931 are known to have occurred in or within 100 miles of the Paradox region from 1853 to 1976.

The tectonic history of the region was eventful. Evidence indicates that the region was under water for a long period of time before the start of the Cambrian period. During the Paleozoic Era much activity occurred, with periods of uplift and erosion alternating with periods of inundation and sedimentation. The formation of the Paradox basin salt occurred during the latter part of this era. By comparison, the Mesozoic Era was relatively quiescent. No major mountain-building activity occurred in the region during the Triassic and Jurassic periods, but the shallow seas moved in and out to deposit occasional layers of marine sediments. The powerful uplifts that raised the Colorado Plateau province to its present elevation began in the last half of the Cretaceous. During the early Cenozoic Era the mountain building continued until the Rocky Mountains were formed. Volcanism was also widespread and frequent during the Cenozoic Era, when most of the prominent surface features of the region were formed.

The Paradox region and surrounding territory have supplied important energy resources for nearly three decades. Petroleum, natural gas, and uranium from this area have made substantial contributions to the nation's energy needs and have played an important role in the local economy. Energy and mineral production is still increasing. A few metals and industrial minerals are also present in the region, but they have been produced on a small scale compared to exploitation of the energy reserves.

B.6.2 Hydrology

Surface water is a valuable resource in the semiarid Paradox region. The principal rivers in the and surrounding territory of the Upper Colorado Water Resource Region (UCWRR) are the Colorado and the Green, and their major tributaries are the Price, San Rafael, Dolores, and San Juan Rivers. No large natural freshwater lakes or wetlands occur in the region. Precipitation is light and varies with ground elevation. Maximum stream flow occurs in late spring; it is due to snowmelt runoff from mountainous areas. Localized flooding can occur, especially when periods of snowmelt coincide with intense thunderstorms. Areas most prone to flooding are along the floodplains of rivers or streams. Most serious damage occurs in broad floodplains where agricultural or urban developments exist. Flood control is accomplished by watershed management and land-treatment programs in the UCWRR. Flood-control reservoirs are normally multipurpose and may provide power generation, irrigation, and recreational benefits. Surface-water quality is generally good, although high dissolved-solids concentrations pose a problem in some waterways of the UCWRR. Water availability is limited, and demand, especially for good-quality irrigation water, is growing.

Groundwater occurs in the Paradox region under both water-table and artesian conditions, and the quality of this water ranges from fresh to near-saturated brines (in excess of 350,000 mg/l of total dissolved solids). Water-table conditions commonly exist in the shallow alluvial aquifers, in recharge areas, and near the surface in relatively flat-lying rocks that are found over large portions of the region. Most of the groundwater underlying the region has dissolved-solids concentrations in excess of 3000 mg/l and is unsuitable for most uses. Usable fresh water is present only in near-surface aquifers and is seldom found at depths greater than 200 feet. The only source of fresh water is precipitation falling on the region; principal areas of recharge are the highlands of the region and other areas where aquifers crop out.

B.6.3 Climate

The Paradox region is largely a cool, semiarid, mid-latitude steppe with isolated areas classified as mid-latitude deserts or humid continental regimes. The region is very dry, with an average annual precipitation of approximately 8.3 inches. The dry conditions provide the region with a relatively high potential for wind erosion.

Fundamental changes in the climate of the region have occurred during the last million years, apparently resulting from changes in global temperature. Four major glaciations occurred during the Pleistocene Epoch, but the region is located more than 500 kilometers southwest of the southernmost limit of the ice cover and was not glaciated.

The region is relatively free from severe-weather hazards and can expect a maximum 100-year rainfall of only 3 inches in a 24-hour period. It is also in an area of low tornado activity; this part of Utah reported no tornadoes from 1955 to 1967. Similarly, high winds are not frequent; a maximum wind speed of about 85 mph has a 100-year mean recurrence interval. However, local channeling effects might alter the maximum speed at specific sites.

Inversions are relatively common in the Paradox region in comparison with the United States as a whole: the region has experienced about 180 episode-days in 5 years. These conditions are related to the terrain of the region, which is a complex system of valleys surrounded by high terrain. This type of terrain allows the formation of frequent temperature inversions that could pose a major problem for the dispersion of emissions from a waste repository. In addition, poor dispersion conditions occur during the frequent stagnation of large-scale high-pressure systems.

With regard to existing air quality (Prevention of Significant Deterioration), all national parks and wilderness areas within the Paradox region are classified as Class I areas. The remainder of the region is a Class II area. The law generally allows no or minimal industrial development in Class I areas and moderate development in Class II areas.

B.6.4 Background Radiation

Virtually no data specific to the Paradox region are available. In general, the mountain states are higher than the national average in both natural terrestrial and cosmic background radiation, although the regional variations appear to be of minor significance.

B.6.5 Demographic, Socioeconomic, and Land-Use Systems

The Paradox region is a rural area with many small towns of less than 1000 people scattered along highways. Farmington, New Mexico, and Grand Junction, Colorado, are the only two cities in the areas adjacent to the region with more than 20,000 inhabitants. There are no cities this large within the region. The total population of the region was approximately 240,000 in 1970. Most of the counties in the region showed a 10 to 20% increase in population between 1970 and 1975.

The economy of the region is dependent on the continued long-term development of extractive industries and the processing of petroleum, coal, molybdenum, vanadium, natural gas, and other mineral and energy resources. Growth in these and related support industries will, to a large extent, determine the rate of economic growth for the region, primarily because of their export value.

Agriculture is also important in the region, although productivity is limited by local climatic factors. The low annual rainfall, combined with areas of marginal soil productivity, limits agricultural activities to livestock grazing and local hay and grain production. Livestock is the only major agricultural product exported from the region. Other industries are of lesser importance.

Land uses of interest include Federal and state recreational and natural areas (which occupy 29% of the land area within the region), urban areas (less than 1%), and Indian lands (16%). The bulk of the remaining land is open range, with small areas preempted for transportation networks.

B.6.6 Terrestrial Ecosystems

The Paradox region contains vast areas of relatively undisturbed natural habitat. Fifteen natural vegetation systems occur in the region; these range from pine or fir forests to scrublands, steppes, and barrenlands. Six ecological reserves have been established or proposed for the region; these "natural areas" would insure the preservation of a typical or unusual vegetation type in as near an undisturbed condition as possible. A great variety of wildlife inhabits the region, including many furbearing species, numerous big- and small-game species, and several threatened or endangered species.

Major range types within the region include grasslands, three types of desert shrubs, and pinyon-juniper woodlands. This range is well utilized, and the market value of livestock is normally 50 to 60% of the value of all agricultural products in the region. Lands having good soil on moderate slopes are generally dry-farmed or irrigated. A variety of crops are grown; these typically account for 40 to 50% of the market value of all agricultural products. Although extensive forested areas occur in the region, forest products contribute less than 1% of the total value of all agricultural crops.

B.6.7 Aquatic Ecosystems

Most aquatic habitats in the Paradox region are cold-water trout streams, generally above 5000 feet in elevation. The native game fish, mainly cutthroat trout and whitefish, have been largely replaced by introduced game species, principally rainbow trout. Very little warm-water-stream habitat is found in the region; the warm-water habitats that do exist frequently contain both cold- and warm-water fish species. Although a considerable number of sport fish are taken annually, the fishery resource is relatively poor because of the high sediment load of many streams. Four threatened or endangered fish species have been identified in the region; all are found in the Colorado River or its tributaries.

B.7 GULF INTERIOR SALT-DOME REGION*

B.7.1 Geology

The Gulf interior region of Alabama, Mississippi, Louisiana, and Texas lies within the Gulf Coastal Plain physiographic province (Figure B-4). It includes parts of 11 major physiographic subdivisions.

The basement of the Gulf interior region consists of structurally deformed incipient or weakly metamorphic late Paleozoic and older rocks and crystalline materials of unknown age. These rocks are overlain by a great thickness of Mesozoic and Cenozoic that regionally thickens in successive wedges toward the Gulf. The top of the Paleozoic basement occurs at depths of about 13,000 feet at the northern boundary of the region and reaches almost 30,000 feet in depth at the southern limit. Local structure modifies this general trend.

The region lies within a large structural downwarp known as the Mississippi Embayment, which extends north into southern Illinois, east into Alabama, south to the vicinity of Baton Rouge, Louisiana, and as far west as eastern Texas. A variety of smaller structural elements modifies this general framework and defines the immediate structural parameters of the storage rock unit. These features include basins and domes or uplifts, flexures and faults, and salt domes.

The region is one of low seismicity. Within 100 miles of the Gulf interior region there were only 20 earthquakes between 1886 and 1974 whose maximum intensities were equal to or greater than V on the modified Mercalli scale of 1931.

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*Data from Regional Environmental Characterization Report for the Gulf Interior Region and Surrounding Territory (Bechtel, 1978b).

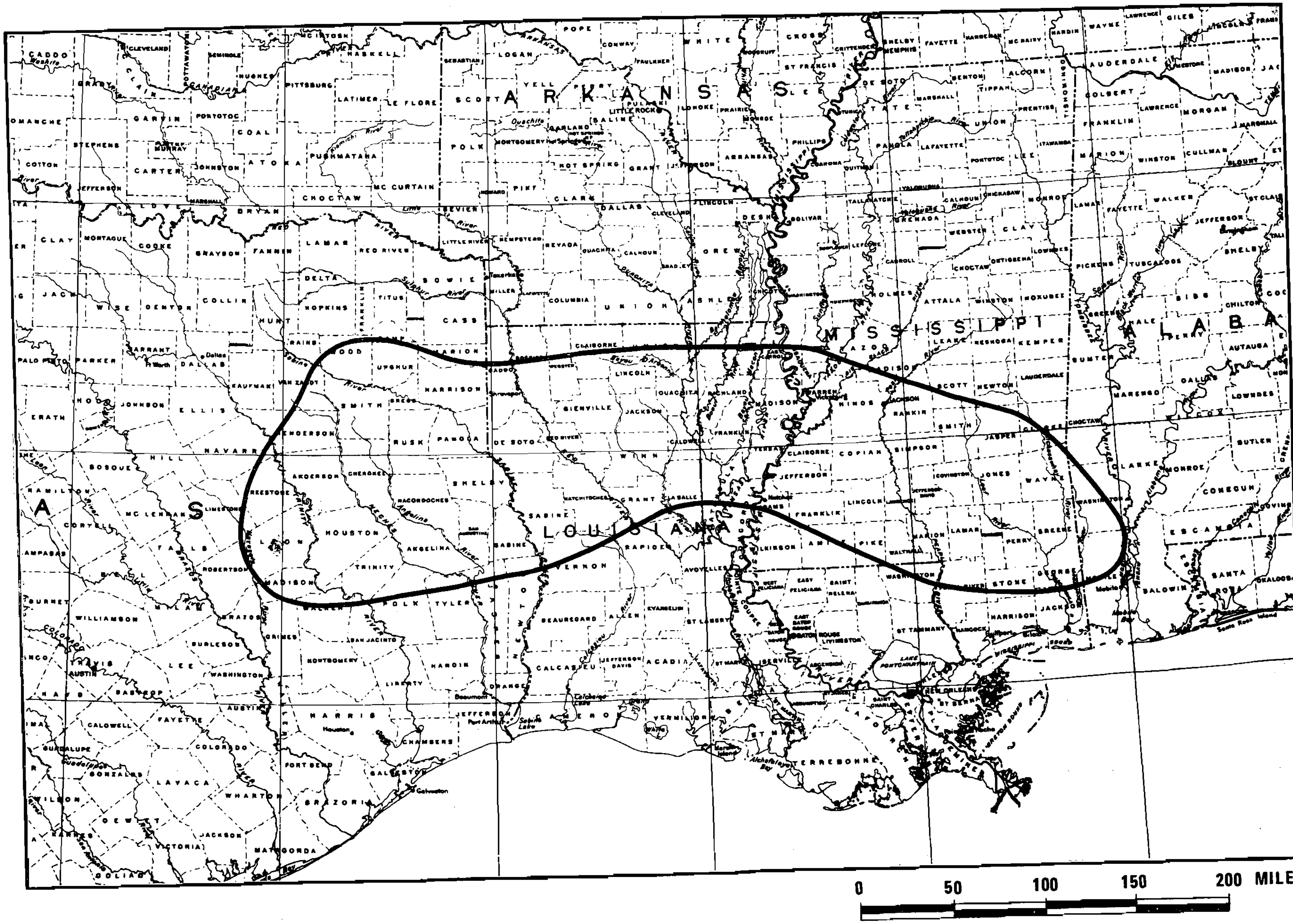

Figure B-4. The Gulf interior salt-dome region.

The early tectonic history of the Gulf Coastal area before Jurassic time is conjectural because of lack of data. Currently, there are two trends of thought concerning the origin of the Gulf. One theory holds that the Gulf in some form existed since late Precambrian; the more popular theory holds that the Gulf was initiated by plate tectonics (sea-floor spreading) during early Mesozoic. By early Jurassic time, marine water had entered the area from the west, and a major evaporite-deposition cycle was initiated. At this time the area was probably landlocked. By the late Cretaceous, the area was open to the sea, and the salt deposition had ceased. Various episodes of uplift prior to the Recent (Holocene) Epoch have resulted in the deposition of up to as much as 30,000 feet of material.

Oil and natural gas are the chief mineral industries of the area and have been for the past 50 years. However, other industries, based on processing such materials as ceramic and nonceramic clays, iron ore, and salt, are also well developed in relation to available markets.

B.7.2 Hydrology

The surface-water resources of the Gulf interior region can best be summarized by briefly reviewing the surface-water characteristics of each of four Water Resource Regions (WRRs): the Arkansas-White-Red, Texas Gulf, Lower Mississippi, and South Atlantic Gulf Regions. The various surface-water parameters described for each WRR--including precipitation, runoff, flood history, and surface-water quality, availability, and demand--may vary significantly between and within WRRs.

The Arkansas-White-Red Region (AWRR), which consists of 265,000 square miles in Oklahoma, Louisiana, Arkansas, Texas, Missouri, Kansas, New Mexico, and Colorado, intersects only a small midwestern portion of the Gulf interior region. Precipitation and runoff decrease greatly from the humid eastern areas to the semiarid western areas of the AWRR. The AWRR averages 3200 to 113,000 cfs of runoff, with the maximum stream flow generally occurring from April to June. Major rivers include the Arkansas, White, Red, and Canadian. Eastern lowlands of the AWRR are subject to severe rainstorms and recurrent flash flooding; flooding in the western and central portions results from intense and infrequent rainstorms of short duration. Flood-control problems have been reduced, particularly in eastern areas, by the construction of numerous reservoirs along major rivers. Surface-water quality in several major waterways of the AWRR is poor because of widespread natural and man-induced pollution, including natural mineralization, mine discharges, erosion, and municipal and industrial effluents. The availability of many AWRR surface waters for agricultural, municipal, industrial, and recreational uses is severely limited by the low quantities and qualities of surface waters in some parts of the AWRR. In general, most water supplies are derived from groundwater sources in the western and central AWRR.

The Texas Gulf Region (TGR), which consists of 173,000 square miles in Texas, Louisiana, and New Mexico, intersects roughly one-third of the western Gulf interior region. Precipitation and runoff decrease dramatically from the Texas Gulf Coast northwest to the central and western areas of the TGR. Average runoff is 30 million acre-ft/yr and is principally from the eastern one-fourth of the TGR. Major rivers in the TGR include the Sabine, Neches, Trinity, and Brazos. Flooding in the TGR typically results from tropical storms originating in the Gulf of Mexico; the largest floods have occurred in late summer and early fall from hurricanes. Total-dissolved-solids concentrations in the TGR vary from less than 100 to over 2500 mg/l, with the upper reaches of the Brazos River having the poorest water quality observed. Approximately half the TGR's water needs are met from surface-water sources, and surface-water use is expected to triple by the year 2020. Although the regional supply of surface water is expected to meet that demand, the unequal geographic distribution of surface-water supply and demand may pose problems.

The Lower Mississippi Region (LMR) consists of about 102,700 square miles in Louisiana, Mississippi, Arkansas, Missouri, Tennessee, and Kentucky; it intersects the central quarter of the Gulf interior region. Average annual precipitation varies from 64 inches along the Gulf Coast to 44 inches in southern Missouri. Runoff is rather uniform throughout the LMR, decreasing from 26 to 14 inches per year from coastal to central areas, respectively. Roughly 116,380 cfs of annual discharge is generated within the LMR. Major rivers include the Mississippi, St. Francis, White, Arkansas, and Yazoo. Flooding generally results during late winter or spring from heavy rains and rapid snowmelt throughout the Ohio and Mississippi River valleys or in late summer or early fall from tropical storms and hurricanes along the Gulf Coast. Areas subject to flooding are floodplains and adjacent areas of the Mississippi River, its major tributaries, and coastal areas. By 1970, LMR flood-control storage totaled 6,028,000 acre-feet, and over 3780 miles of levees and floodwalls were in place. Surface-water quality throughout the LMR is variable and dependent on location; in general, however, most streams have good natural quality. Varying degrees of man-induced pollution require selective use and some pretreatment of surface waters in some areas of the LMR. The LMR is one of the most water-rich WRRs in the United States, with 85 million acre-feet of runoff generated within the LMR and a total of 485 million acre-feet discharged annually from its waterways into the Gulf of Mexico. Large increases in surface-water demand are projected by the year 2020, and no shortages are expected.

The South Atlantic-Gulf Region (SAGR) consists of 276,000 square miles in South Carolina, Florida, Virginia, North Carolina, Georgia, Alabama, Louisiana, and Mississippi; it encompasses roughly the eastern third of the Gulf interior region. Precipitation is generally plentiful and uniformly distributed throughout the SAGR. Average runoff is 305,000 cfs. Seasonal highs in runoff occur from November to April and from June to October, resulting from broad cyclonic disturbances and tropical hurricanes, respectively. Major rivers in the SAGR include the Alabama, Tombigbee, Apalachicola, Santee, and Altamaha. Widespread, disastrous flooding is uncommon, although an estimated (in 1968) additional 3.3 million acres of land require flood protection by 1980. Seasonal flood potential is highest from December to April and from August to October. Areas most prone to flooding include the floodplains of major rivers and coastal areas. Numerous watershed and flood-control projects have been constructed throughout the SAGR for flood protection. Natural surface-water quality is generally excellent, with dissolved-solids concentrations averaging less than 100 mg/l. In some coastal plain streams, high turbidity and high sediment loads are not uncommon. In some localized areas, municipal, industrial, and agricultural sources of pollution have caused restricted use of surface waters and an increased reliance on upstream reservoir storage and groundwater for municipal water supplies. Because of abundant surface-water and groundwater supplies within the SAGR, no current or projected water shortages are expected.

Good-quality groundwater is present throughout the Gulf interior region, and it is used extensively for domestic, municipal, and industrial purposes. Several aquifers or hydrologic units are recognized in the post-Cretaceous coastal plain sediments. They comprise a thick sequence of interbedded sands, clays, and marls in which the more permeable materials provide aquifers confined between the less permeable clays and marls. Important water-bearing units or aquifers in the region include the Wilcox-Carrizo units, the Sparta (Kosciusko) Formation, Miocene sands, and Pleistocene to Recent alluvial valley deposits. The water-bearing formations receive recharge in their outcrop areas from precipitation and stream flow, although under present conditions the aquifers are full, and most of the water available for recharge is rejected, moving laterally and discharging to low stream valleys.

B.7.3 Climate

The Gulf interior region lies within a humid temperate zone with moderately high winter temperatures and moderate amounts of rainfall throughout the year. These conditions indicate a relatively low potential for wind erosion.

Although this area has experienced significant temperature decreases (9-28.8°F) in the recent geologic past, indications of glaciation within that period are absent. In fact, the previous glacial boundary appears to be more than 435 miles north of this region.

Severe-weather occurrences in the Gulf interior region generally take the form of high winds and precipitation associated with hurricanes that intrude inland from the Gulf of Mexico. The 100-year-recurrence events for these two meteorological phenomena are 11 inches of precipitation within a 24-hour period and winds of 90 mph. Another severe-weather phenomenon experienced in this region is the occasional tornado (ranging from 6 in a 12-year period on the Louisiana-Mississippi border to 43 or more in portions of northeast Texas during the same period).

Generally moderate mixing levels together with moderate wind speeds and rolling terrain make the Gulf interior region unlikely to experience inversions. Stations within and near this region have reported 13 to 28 episode-days of poor dispersion within a 5-year period.

The region, like most of the country, experiences periods when the national ambient air-quality standards (NAAQS) for particulates are exceeded. Trends in air quality, as evaluated by the Environmental Protection Agency (EPA), indicate a very gradual improvement in this condition in the Gulf interior region, primarily as a result of improved pollution-control technology. There are also a number of areas within this region that have been designated by the EPA as areas of concern for the control of photochemical oxidants. In most cases, these areas, consisting of large metropolitan sites and their immediate surroundings, are presently exceeding NAAQS for this pollutant.

With regard to the Prevention of Significant Deterioration, the region lies within a Class II area, which allows for moderate industrial development. The nearest (presently defined) Class I areas are more than 100 miles away.

B.7.4 Background Radiation

Data for approximately 38 locations in the Gulf interior region and surrounding territory indicate that the region is about average in natural terrestrial and cosmic background radiation. The highest reported background radiation values are in Texas, but regional variations appear to be insignificant.

B.7.5 Demographic, Socioeconomic, and Land-Use Systems

In eastern Texas, the Gulf interior region is a rural area with many small towns. The major cities within the area are Tyler and Longview, but large urban areas such as Dallas, Fort Worth, Waco, and Austin are adjacent to the region. Approximately 75% of the population is white; the remaining is black (except for the 0.7% that is Indian, Chinese, Japanese, or other). The total population of the area was 766,154 in 1970, and most of the counties showed a population-growth rate of more than 7% between 1970 and 1975. Per capita income for the region was $3119.

The Gulf interior region in Louisiana encompasses 298 parishes in the northern part of the State and includes the cities of Shreveport, Monroe, and Alexandria. The total population of this area was 1,062,685 in 1970. Population growth was slower in Louisiana than in Texas, and many parishes had a net decline of up to 10% between 1970 and 1975. Annual per capita income in 1974 for the region was $2788.

There are 35 counties in the Gulf interior region in Mississippi. The largest cities in the region are Jackson, Meridian, Hattiesburg, and Vicksburg. The total population for the area was 778,158 in 1970 and increased to 1,064,217 (estimated) in 1975. Six counties experienced a decline in population between 1970 and 1975, and counties other than those having the major cities mentioned above had a slower growth rate than the rest of the nation and the slowest for all states in the Gulf interior region. Nearly 66% of the 1970 population was white, 34% was black, and less than 1% was of other origin. Per capita income grew by 50 to 70% between 1969 and 1974, and the regional average annual per-capita income was $2826 in 1974.

The economy of the eastern Texas region is largely resource oriented. Extractive industries such as mining, petroleum, and natural gas extraction, manufacturing based on regional resources, and agriculture comprise the core of the export economic base. In rural counties in eastern Texas, tourism is an important element in the local economy. Mining and manufacturing activities account for 33% of the total employment. Eastern Texas is a producer of agricultural crops and livestock; some counties produce considerable amounts of livestock and poultry for export to other states.

Much of the region in Louisiana is rural and is used for agricultural crops, grazing, or forests. More than 64% of the total employment is located in the Shreveport, Monroe, or Alexandria urban areas. The State is one of the largest producers of natural gas and petroleum. Manufacturing is located near the larger urban areas, and industries based on lumber and wood products, food products, primary metal products, fabricated metal products and appliances, textiles and apparel, and chemicals all have notable employment. In 1970 the agricultural production of crops was centered in the lowland region along the Mississippi River; livestock production was concentrated in upland areas. Total agricultural income in 1974 was $445 million, up 114% from 1969, with approximately 70% attributed to crops and hay.

Manufacturing accounts for 31% of the total employment in the Mississippi portion of the Gulf interior region and represents the largest single employment sector. Extractive industries (natural gas and petroleum, sand and gravel, and other minerals) employ less than 20% of the labor force. Agriculture is also a significant contributor to the local economy. Lowland counties of the Mississippi River basin are intensively cultivated for field and row crops; upland counties are extensively used for livestock grazing.

The majority of the population in the eastern Texas Gulf interior region lies in the Tyler and Longview urban areas. As much as 10% of the area is in urban uses, and the average population density throughout the area is 0.02 person per acre. Vast expanses of woodlands and agricultural land characterize the area. Eastern Texas has three national forests totaling 507,012 acres: Angelina, Davy Crockett, and Sabine. Recreational uses of lakes and reservoirs and parks in the area are rapidly growing, and second-home development around some lakes (i.e., the Cedar Creek Reservoir) has occurred recently. The Federal Government maintains and is acquiring jurisdiction over sizable land areas to meet growing demands for various recreational uses. Airports are common throughout eastern Texas; restricted or prohibited airspaces with various altitude and aircraft-operation limitations are also present. Highway and rail systems are extensive throughout the area. One Indian reservation exists in Polk County, Texas.

In Louisiana most urban land in residential, commercial, and industrial uses is around the cities of Shreveport, Monroe, and Alexandria. Outside these urban areas, small towns are numerous, but rural areas are, for the most part, devoted to agriculture or forests. Upland parishes in northwestern Louisiana have less field and row crops and more livestock-grazing land than do lowland parishes along the Mississippi River. The Kisatchie National Forest is distributed in several parcels throughout Louisiana; the total acreage of all parcels is 500,302 acres, or 6.1% of the land in the area. State fish and wildlife management areas and state forests provide abundant recreational uses. Airports of varying size are found throughout the area; restricted and prohibited airspaces with varying limitations are also present. Rail and highway systems are well developed in all of Louisiana. One Indian reservation is located in the area.

The largest cities in the Gulf interior region in Mississippi are Jackson (166,572), Meridian (46,256), Hattiesburg (38,097), and Vicksburg (29,726). Like Louisiana, the area is largely rural, with agricultural lands predominating. Five national forests in the area cover 1.7 million acres, or 15% of the area. Many types of uses are provided, including recreation as well as timber harvesting. Airports of various sizes are found throughout the area, as are restricted airspaces. Rail and highway systems are well developed. One Indian reservation is located in Leake County, outside the Gulf interior region.

B.7.6 Terrestrial Ecosystems

In the Gulf interior region and surrounding territory in Texas there are nine potential vegetation types, ranging from mixed hardwood-softwood forests to open prairies and savannahs. No ecological reserves have been established in the basin, but a number of locally administered natural areas do insure preservation of habitats in as near an undisturbed condition as possible. Important animal species include approximately 9 furbearers, several game animals, and 20 protected, threatened, or endangered species.

Major range types in the Texas Gulf interior region include grasslands, shrublands and chaparral, and pinyon-juniper woodlands. The rangeland has a relatively high productivity compared to the typical western range, and livestock and livestock products accounted for the highest portion of all agricultural products sold in the Texas Gulf interior region in 1974 (47%). This was followed by poultry and poultry products (36%), crops and hay (12%), nursery and greenhouse products (3%), and forest products on farms (1%). Harvested hay, sorghum, and cotton were the crops covering the greatest land area in 1974. Commercial forests in counties within the east Texas Piney Woods region cover about 63% of the region. Forest types with the most coverage are loblolly-shortleaf pine, oak-pine, and oak-hickory.

Only four potential vegetation types occur within the Gulf interior region of Louisiana--prairie and three kinds of mixed hardwood-and-softwood forests. However, the variation within these vegetation types, due to man's activities as well as the natural soil and climatic variations, contributes to diverse wildlife habitats. In addition to one ecological reserve, the Bayou Boeuf Natural Area, there are several State, private, and Federal wildlife areas. Important animal species include approximately 13 furbearers, 11 game mammals, and 6 threatened or endangered species.

Livestock grazing occurs on cultivated pasture as well as in forested lands. Livestock and livestock products represented only 18% of the value of agricultural products sold in 1974. Principal livestock types produced in the area in 1974 were beef and dairy cattle. Livestock productivity varies throughout the area, as does the productivity of agricultural crops and timber resources, the most productive livestock parishes being De Soto, Caddo, Richland, Natchitoches, and Rapides. Agricultural crop production was largest in Morehouse, East Carrol, Madison, and Avoyelles Parishes; crops and hay represented 70% of all agricultural products sold in the Louisiana Gulf interior region in 1974. Cotton was the crop with the largest harvested area, followed by soybeans, rice, corn, sorghum, wheat, and sugarcane. There are three major forest types in Louisiana: southern pine, upland hardwood (oak-hickory), and bottomland hardwood. Commercial southern pine forests are mostly longleaf and slash pines in the southern half of the State and shortleaf and loblolly pines in the north. Bottomland hardwoods include such species as oak, gum, cypress, elm, ash, and cottonwood. The production of timber resources was highest in Ouachita, Caldwell, Winn, Natchitoches, Sabine, and Caddo Parishes.

In Mississippi, as in Louisiana, there are only four potential natural vegetation types, but one, the blackbelt, is limited to the Gulf interior region of Mississippi and Alabama. Six ecological natural areas have been established in the Gulf interior region of Mississippi for the preservation of vegetation types and wildlife habitat. Important animal species include approximately 11 furbearers, 11 game animals, and 13 species on the Federal list of threatened and endangered species.

In the Mississippi Gulf interior region, poultry and poultry products accounted for the highest portion of all agricultural products sold in 1974 (45%), followed by crops and hay (30%), and livestock and livestock products (22%). Rangeland and wooded pasture are extensively distributed throughout the area. Soybeans, hay, and cotton were the crops with the largest harvested area in 1974. Commercial forests are extensive, covering about 62% of the land area in Mississippi. Commercial forests with the largest areas are oak-hickory, loblolly-shortleaf pine, oak-pine, and oak-gum-cypress.

B.7.7 Aquatic Ecosystems

The Gulf interior region is noted for its extensive and valuable recreational and commercial warm-water stream and lake fisheries. Stream and lake habitats in the region can be divided into bottomland and upland habitat types. Bottomland habitats are generally in the larger, deeper, slow-moving, and turbid streams and rivers that meander through the interior region. Upland habitats are generally in the smaller, faster-moving creeks and streams that are the tributaries of the major waterways within the region. Six endangered fish species have been identified in the Gulf interior region; all six species are found in the State of Mississippi.

B.8 THE HANFORD SITE*

The Hanford Site is a 600-square-mile tract in the southeastern part of Washington State. It is semiarid, and the closest population center is Richland, 5 kilometers to the south.

B.8.1 Geology

The Hanford Site is in the Columbia Plateau physiographic province, which is characterized by the occurrence of a thick sequence of tholeiitic basalts and varies significantly in topographic expression as well as structure (Figure B-5). The Columbia basin section is a broad geologic and structural basin in the interior of the province; the Hanford Site is located in the Pasco basin, which is one of several subbasins.

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*Source: Private communication from K. R. Fecht, Rockwell Hanford Operations, December 1978.

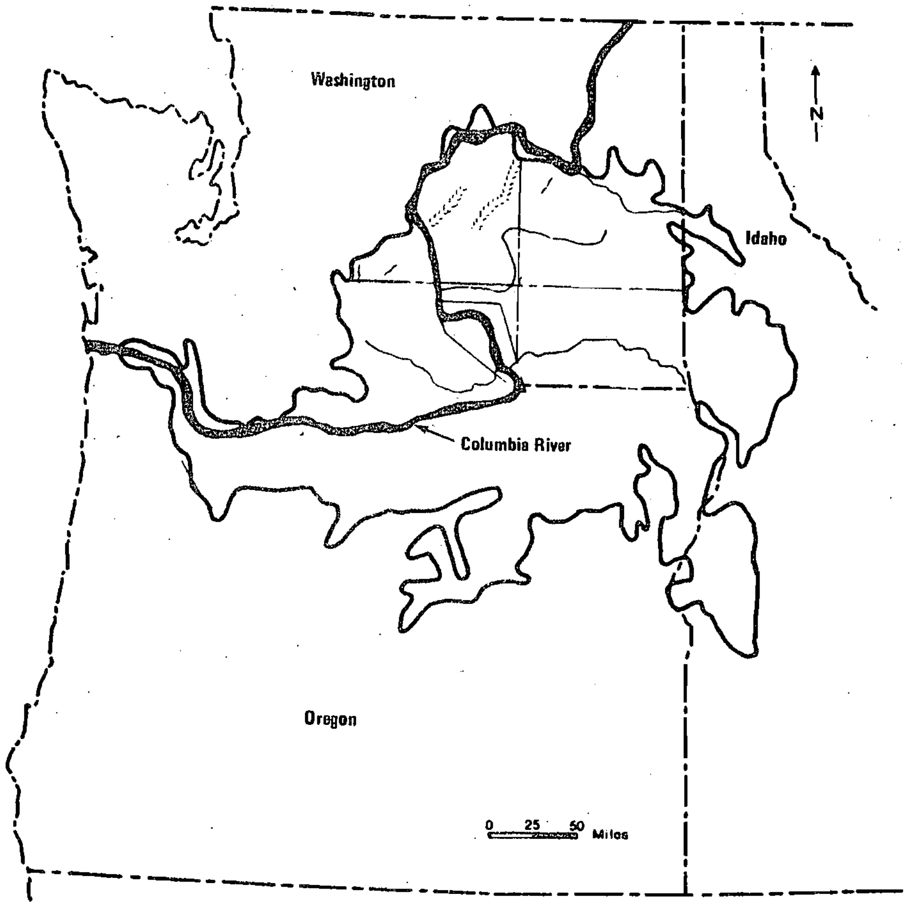

Figure B-5. Location of the Columbia Plateau basalts.

The Columbia basin contains the Channeled Scablands formed at the close of Pleistocene glaciation by multiple catastrophic floods. The floods occurred as ice-dammed lakes released torrents of water and ice when the ice dams were breached.

The regional geology is dominated by Cenozoic rocks and structures. During the Cenozoic Era, numerous basalt magma outpourings from extensive fissure systems flowed across the Columbia Plateau and into regional areas of subsidence, such as the Pasco basin, where thick sections of basalt accumulated. The thickness of the basalt sequence is an average of 1800 feet in the Columbia Plateau and is more than 10,000 feet in the Pasco basin. The frequency and size of the eruptions decreased and then ceased during the late Tertiary period (about 6 million years before the present).

Regional subsidence continued and was accompanied by regional north-south compression, which has resulted in folding of the basalt sequence and in the formation of a number of roughly east-west-trending anticlinal ridges in the central part of the Columbia Plateau. At the Hanford Site, this ridge system is represented by the Rattlesnake Mountains, the Yakima Ridge, and the Umtanum-Gable Mountain Ridge.

Within and on top of the basalt sequence are sedimentary deposits. The interbeds between basalt flows consist of tuffs, tuffaceous sediments, and, in some locations, stream-carried sediments. Interbeds are more prevalent in the upper part of the basalt sequence.

The top of the basalt sequence is covered with fluvial, glaciofluvial, and eolian deposits. In the Pasco basin, the basalt is covered by up to 1000 feet of fluvial sediments (the Ringold Formation) overlain with up to 300 feet of glaciofluvial sediments (informally named the Hanford Formation). Eolian deposits overlie the Ringold Formation in the western part of the Hanford Site. The basement rocks below the basalt sequence are of uncertain composition but are probably sandstones and shale. Granitic rocks are probably below that.

Mineral resources are sand and gravel, basalt, and possibly natural gas. Natural gas has not been detected in the recent drilling of deep boreholes.

The Columbia basin is a region of low seismicity in which moderate earthquakes have occurred. Microseismic activity at the Hanford Site indicates low levels of stress relief, generally shallow focal depths, and no obvious relationship to any geologic structure. The maximum known earthquake intensity in the vicinity of the site was less than IV on the modified Mercalli scale.

Faults in the region are associated with folds in the basalt and appear to reflect local adjustments to folding. They are relatively short in length (less than 30 miles), with generally small displacements (less than 500 feet).

B.8.2 Hydrology

The Pasco basin is a series of confined aquifers overlain by an unconfined aquifer. The area is bounded by ridges to the north, south, and west and by a broad regional monocline to the east.

The confined aquifers are primarily the permeable interbeds and interflow zones in the basalt sequence. The interflow zones are characterized by vesicular rock or by interconnected fracturing caused by rapid cooling of the basalt magma. There is very little hydraulic interconnection between aquifers since the central volume of the basalt flows is dense and has a very low permeability. Fractures in the basalt have been filled with secondary mineralization products such as montronite. The confined aquifers are recharged by precipitation, stream runoff, and infiltration from the overlying unconfined aquifer or distant recharge points. Discharge of the upper aquifer is to the Columbia River.

The unconfined aquifer occurs above the basalt sequence up to about the top of the Ringold Formation. The groundwater movement is distorted by local geologic structures and has been modified by waste-disposal activities at the Hanford Site.

Between the top of the unconfined aquifer and the land surface is the vadose zone. This unsaturated zone is up to about 300 feet thick and is extremely dry below about 30 feet. In this desiccated zone, there is nearly no downward movement of water.

B.8.3 Climate

The climate of the Columbia basin region is dominated by the Cascade Mountain Range to the west and by the prevalent direction of storm fronts from the Pacific Ocean. Summers are relatively hot and dry, most of the average 6 inches of precipitation falls during the winter, and there are occasional periods of high winds. Prevailing winds are from the northwest.

Tornadoes are infrequent. It has been estimated that the probability of a specific surface structure's being hit by a tornado is only 6 in one million.

Thunderstorm activity is low. The estimated annual lightning strike frequency is 0.022 for a typical Hanford building.

B.8.4 Demography

There are an estimated 250,000 people within 50 miles of the Hanford Site. The estimated mean growth rate to the year 2000 is 0.7%.

B.8.5 Historic and Archaeological Sites

There are five locations listed as historic sites or as natural landmarks within 50 miles of the Hanford Site. None are on the site. There are over 200 Indian archaeological sites in the Hanford area, and many of them are along the Columbia River where it passes through the Hanford Site.

B.8.6 Ecology

The ecological aspects of the Hanford Site are consistent with the semiarid climate. The principal plant community is the sagebrush-cheatgrass-bluegrass association; mammals include the coyote, the rabbit, mule deer, and small rodents; birds include the chukar partridge, western meadowlark, migratory ducks and geese, and several species of predatory birds. There are several thousand insect species and about 15 species of snakes and lizards. The aquatic ecosystem consists of the Columbia River and a few ponds and ditches.

Rare, threatened, and endangered species inhabiting the Hanford Site include three plant species and seven bird species. The status of some of the latter has not been determined.

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Appendix C

PRESIDENT CARTER'S MESSAGE TO CONGRESS ON THE MANAGEMENT OF RADIOACTIVE WASTE

AND

THE FINDINGS AND RECOMMENDATIONS OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

Appendix C

PRESIDENT CARTER'S MESSAGE TO CONGRESS ON THE MANAGEMENT OF RADIOACTIVE WASTE

AND

THE FINDINGS AND RECOMMENDATIONS OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

Two documents have been especially important in establishing a national policy for the management of radioactive waste: President Carter's message to Congress on February 12, 1980, and the 1979 report of the Interagency Review Group. This appendix contains the entire message and excerpts from the report.

C.1 PRESIDENT'S MESSAGE

On February 12, 1980, President Carter established a comprehensive program for the management of radioactive waste. His message to the Congress of the United States stated the objectives of that program and outlined the steps to be taken in carrying it out. The message specifically mentioned the WIPP project and the site near Carlsbad, New Mexico. The remainder of this section is a complete text of President Carter's message.

PRESIDENT CARTER'S MESSAGE TO CONGRESS

(February 12, 1980)

TO THE CONGRESS OF THE UNITED STATES:

Today I am establishing this Nation's first comprehensive radioactive waste management program. My paramount objective in managing nuclear wastes is to protect the health and safety of all Americans, both now and in the future. I share this responsibility with elected officials at all levels of our government. Our citizens have a deep concern that the beneficial uses of nuclear technology, including the generation of electricity, not be allowed to imperil public health or safety now or in the future.

For more than 30 years, radioactive wastes have been generated by programs for national defense, by the commercial nuclear power program, and by a variety of medical, industrial, and research activities. Yet, past governmental efforts to manage radioactive wastes have not been technically adequate. Moreover, they have failed to involve successfully the States, local governments, and the public in policy or program decisions. My actions today lay the foundation for both a technically superior program and a full cooperative Federal-State partnership to ensure public confidence in a waste management program.

My program is consistent with the broad consensus that has evolved from the efforts of the Interagency Review Group on Radioactive Waste Management (IRG) which I established. The IRG findings and analysis were comprehensive, thorough, and widely reviewed by public, industry and citizen groups, State and local governments, and members of the Congress. Evaluations of the scientific and technical analyses were obtained through a broad and rigorous peer review by the scientific community. The final recommendations benefited from and reflect this input.

My objective is to establish a comprehensive program for the management of all types of radioactive wastes. My policies and programs establish mechanisms to ensure that elected officials and the public fully participate in waste decisions, and direct Federal departments and agencies to implement a waste management strategy which is safe, technically sound, conservative, and open to continuous public review. This approach will help ensure that we will reach our objective--the safe storage and disposal of all forms of nuclear waste.

Our primary objective is to isolate existing and future radioactive waste from military and civilian activities from the biosphere and pose no significant threat to public health and safety. The responsibility for resolving military and civilian waste management problems shall not be deferred to future generations. The technical program must meet all relevant radiological protection criteria as well as all other applicable regulatory requirements. This effort must proceed regardless of future developments within the nuclear industry--its future size, and resolution of specific fuel cycle, and reactor design issues. The specific steps outlined below are each aimed at accomplishing this overall objective.

First, my Administration is committed to providing an effective role for State and local governments in the development and implementation of our nuclear waste management program. I am therefore taking the following actions:

- By Executive Order, I am establishing a State Planning Council which will strengthen our intergovernmental relationships and help fulfill our joint responsibility to protect public health and safety in radioactive waste matters. I have asked Governor Riley of South Carolina to serve as Chairman of the Council. The Council will have a total of 19 members: 15 who are Governors or other elected officials, and 4 from the Executive departments and agencies. It will advise the Executive Branch and work with the Congress to address radioactive waste management issues, such as planning and siting, construction, and operation of facilities. I will submit legislation during this session to make the Council permanent.

- In the past, States have not played an adequate part in the waste management planning process--for example, in the evaluation and location of potential waste disposal sites. The States need better access to information and expanded opportunity to guide waste management planning. Our relationship with the States will be based on the principle of consultation and concurrence in the siting of high level waste repositories. Under the framework of consultation and concurrence, a host State will have a continuing role in Federal decisionmaking on the siting, design, and construction of a high level waste repository. State consultation and concurrence, however, will lead to an acceptable solution to our waste disposal problem only if all the States participate as partners in the program I am putting forth. The safe disposal of radioactive waste, defense and commercial, is a national, not just a Federal, responsibility.

- I am directing the Secretary of Energy to provide financial and technical assistance to States and other jurisdictions to facilitate the full participation of State and local government in review and licensing proceedings.

Second, for disposal of high level radioactive waste, I am adopting an interim planning strategy focused on the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel. An interim strategy is needed since final decisions on many steps which need to be taken should be preceded by a full environmental review under the National Environmental Policy Act. In its search for suitable sites for high level waste repositories, the Department of Energy has mounted an expanded and diversified program of geologic investigations that recognizes the importance of the interaction among geologic setting, repository host rock, waste form, and other engineered barriers on a site-specific basis. Immediate attention will focus on research and development, and on locating and characterizing a number of potential repository sites in a variety of different geologic environments with diverse rock types. When four to five sites have been evaluated and found potentially suitable, one or more will be selected for further development as a licensed full-scale repository.

It is important to stress the following two points: First, because the suitability of a geologic disposal site can be verified only through detailed and time-consuming site specific evaluations, actual sites and their geologic environments must be carefully examined. Second, the development of a repository will proceed in a careful step-by-step manner. Experience and information gained at each phase will be reviewed and evaluated to determine if there is sufficient knowledge to proceed with the next stage of development. We should be ready to select the site for the first full-scale repository by about 1985 and have it operational by the mid-1990's. For reasons of economy, the first and subsequent repositories should accept both defense and commercial wastes.

Consistent with my decision to expand and diversify the Department of Energy's program of geologic investigation before selecting a specific site for repository development, I have decided that the Waste Isolation Pilot Plant project should be cancelled. This project is currently authorized for the unlicensed disposal of transuranic waste from our National defense program, and for research and development using high level defense waste. This project is inconsistent with my policy that all repositories for highly radioactive waste be licensed, and that they accept both defense and commercial wastes.

The site near Carlsbad, New Mexico, which was being considered for this project, will continue to be evaluated along with other sites in other parts of the country. If qualified, it will be reserved as one of several candidate sites for possible use as a licensed repository for defense and commercial high level wastes. My fiscal year 1981 budget contains funds in the commercial nuclear waste program for protection and continued investigation of the Carlsbad site. Finally, it is important that we take the time to compare the New Mexico site with other sites now under evaluation for the first waste repository.

Over the next five years, the Department of Energy will carry out an aggressive program of scientific and technical investigations to support waste solidification, packaging, and repository design and construction including several experimental, retrievable emplacements in test facilities. This supporting research and development program will call upon the knowledge and experience of the Nation's very best people in science, engineering, and other fields of learning, and will include participation of universities, industry, and the government departments, agencies, and national laboratories.

Third, during the interim period before a disposal facility is available, waste must and will continue to be cared for safely. Management of defense waste is a Federal responsibility; the Department of Energy will ensure close and meticulous control over defense waste facilities which are vital to our national security. I am committed to maintaining safe interim storage of these wastes as long as necessary and to making adequate funding available for that purpose. We will also proceed with research and development at the various defense sites that will lead the processing, packaging, and ultimate transfer to a permanent repository of the high level and transuranic wastes from defense programs.

In contrast, storage of commercial spent fuel is primarily a responsibility of the utilities. I want to stress that interim spent fuel storage capacity is not an alternative to permanent disposal. However, adequate storage is necessary until repositories are available. I urge the utility industry to continue to take all actions necessary to store spent fuel in a manner that will protect the public and ensure efficient and safe operation of power reactors. However, a limited amount of government storage capacity would provide flexibility to our national waste disposal program and an alternative for those utilities which are unable to expand their storage capabilities.

I reiterate the need for early enactment of my proposed spent nuclear fuel legislation. This proposal would authorize the Department of Energy to: (1) design, acquire or construct, and operate one or more away-from-reactor storage facilities, and (2) accept for storage, until permanent disposal facilities are available, domestic spent fuel, and a limited amount of foreign spent fuel in cases when such action would further our non-proliferation policy objectives. All costs of storage, including the cost of locating, constructing, and operating permanent geologic repositories, will be recovered through fees paid by utilities and other users of the services and will ultimately be borne by those who benefit from the activities generating the wastes.

Fourth, I have directed the Department of Energy to work jointly with states, other government agencies, industry and other organizations, and the public, in developing national plans to establish regional disposal sites for commercial low level waste. We must work together to resolve the serious near-term problem of low level waste disposal. While this task is not inherently difficult from the standpoint of safety, it requires better planning and coordination. I endorse the actions being taken by the Nation's governors to tackle this problem and direct the Secretary of Energy to work with them in support of their effort.

Fifth, the Federal programs for regulating radioactive waste storage, transportation, and disposal are a crucial component of our efforts to ensure the health and safety of Americans. Although the existing authorities and structures are basically sound, improvements must be made in several areas. The current authority of the Nuclear Regulatory Commission to license the disposal of high level waste and low level waste in commercial facilities should be extended to include spent fuel storage, and disposal of transuranic waste and non-defense low level waste in any new government facilities. I am directing the Environmental Protection Agency to consult with the Nuclear Regulatory Commission to resolve issues of overlapping jurisdiction and phasing of regulatory actions. They should also seek ways to speed up the promulgation of their safety regulations. I am also directing the Department of Transportation and the Environmental Protection Agency to improve both the efficiency of their regulatory activities and their relationships with other Federal agencies and state and local governments.

Sixth, it is essential that all aspects of the waste management program be conducted with the fullest possible disclosure to and participation by the public and the technical community. I am directing the departments and agencies to develop and improve mechanisms to ensure such participation and public involvement consistent with the need to protect national security information. The waste management program will be carried out in full compliance with the National Environmental Policy Act.

Seventh, because nuclear waste management is a problem shared by many other countries and decisions on waste management alternatives have nuclear proliferation implications, I will continue to encourage and support bilateral and multilateral efforts which advance both our technical capabilities and our understanding of spent fuel and waste management options, which are consistent with our non-proliferation policy.

In its role as lead agency for the management and disposal of radioactive wastes and with cooperation of the other relevant Federal agencies, the Department of Energy is preparing a detailed National Plan for Nuclear Waste Management to implement these policy guidelines and other recommendations of the IRG. This Plan will provide a clear road map for all parties and will give the public an opportunity to review the entirety of our program. It will include specific program goals and milestones for all aspects of nuclear waste management. A draft of the comprehensive National Plan will be distributed by the Secretary of Energy later this year for public and Congressional review. The State Planning Council will be directly involved in the development of this Plan.

The Nuclear Regulatory Commission now has underway an important proceeding to provide the Nation with its judgment on whether or not it has confidence that radioactive wastes produced by nuclear power reactors can and will be disposed of safely. I urge that the Nuclear Regulatory Commission do so in a thorough and timely manner and that it provide a full opportunity for public, technical, and government agency participation.

Over the past two years as I have reviewed various aspects of the radioactive waste problem, the complexities and difficulties of the issues have become evident--both from a technical and, more importantly, from an institutional and political perspective. However, based on the technical conclusions reached by the IRG, I am persuaded that the capability now exists to characterize and evaluate a number of geologic environments for use as repositories built with conventional mining technology. We have already made substantial progress and changes in our programs. With this comprehensive policy and its implementation through the FY 1981 budget and other actions, we will complete the task of reorienting our efforts in the right direction. Many citizens know and all must understand that this problem will be with us for many years. We must proceed steadily and with determination to resolve the remaining technical issues while ensuring full public participation and maintaining the full cooperation of all levels of government. We will act surely and without delay, but we will not compromise our technical or scientific standards out of haste. I look forward to working with the Congress and the states to implement this policy and build public confidence in the ability of the government to do what is required in this area to protect the health and safety of our citizens.

JIMMY CARTER

THE WHITE HOUSE

C.2 FINDINGS AND RECOMMENDATIONS OF THE INTERAGENCY REVIEW GROUP ON NUCLEAR WASTE MANAGEMENT

An important document in the development of the national waste-management program has been the report of the Interagency Review Group on Nuclear Waste Management (IRG, 1979). After a brief review of the purpose of this Group and its major technical findings, this section presents quotations taken from two parts of the Group's report: the sections dealing with the disposal of transuranic (TRU) waste and with the disposal of high-level waste (HLW). Although high-level waste would not be disposed of at the WIPP, the quotations dealing with high-level waste are included here as reference material supporting the discussion of alternatives in Chapters 3 and 4.

The Interagency Review Group was formed in order to guide the national waste-management program. President Carter called for a review of the waste-management program in his April 1977 National Energy Plan. In response to this request, the DOE established an internal task force and published a draft report in March 1978. The President then created the formal Interagency Review Group on Nuclear Waste Management and instructed it to make policy and program recommendations to him, using the draft report of the DOE task force as one input. This group, chaired by the DOE, comprised representatives of 14 agencies. It developed a draft report to the President that was published for public comment in October 1978 (IRG, 1978). After the review of public comment, the Interagency Review Group published a revised report (IRG, 1979).

The Interagency Review Group consulted extensively with the scientific and technical community, including independent geologic and environmental experts. The Group's summary of the major technical findings of this activity (IRG, 1979, p. 42) is quoted in full below.

> Present scientific and technological knowledge is adequate to identify potential repository sites for further investigation. No scientific or technical reason is known that would prevent identifying a site that is suitable for a repository provided that the system's view is utilized rigorously to evaluate the suitability of sites and designs, and in minimizing the influence of future human activities. A suitable site is one at which a repository would meet predetermined criteria and which would provide a high degree of assurance that radioactive waste can be successfully isolated from the biosphere for periods of thousands of years. For periods beyond a few thousand years, our capability to assess the performance of the repository diminishes and the degree of assurance is therefore reduced. The feasibility of safely disposing of high-level waste in mined repositories can only be assessed on the basis of specific investigations at and determinations of suitability of particular sites. Information obtained at each successive step of site selection and repository development will permit reevaluation of risks, uncertainties, and the ability of the site and repository to meet regulatory standards. Such reevaluations would lead either to abandonment of the site or a decision to proceed to the next step. Reliance on conservative engineering practices and multiple independent barriers can reduce some risks and compensate for some uncertainties. However, even at the time of decommissioning, some uncertainty about repository performance will still exist. Thus, in addition to technical evaluation, a societal judgment that considers the level of risk and the associated uncertainty will be necessary.

IRG Discussion of a Generic Approach to TRU-Waste Disposal

The Interagency Review Group raised an important issue about TRU waste disposal: should a dedicated TRU-waste repository be built if an opportunity exists to do so, or should TRU-waste disposal await the availability of high-level-waste repositories and take place there? The IRG report states (IRG, 1979, p. 73) that "the IRG still considers that proceeding with a dedicated TRU repository, if an opportunity is available, is consistent with a conservative and stepwise approach."

It should be noted, however, that the Interagency Review Group approached this question generically, as an appropriate interim strategic-planning basis until the environmental-review provisions of the National Environmental Policy Act (NEPA) have been carried out. The discussion by the Interagency Review Group (IRG, 1979, pp. 69-70) of strategies for TRU-waste disposal is reproduced in full below.

> As with choosing a strategy for HLW disposal, the choice of a TRU waste disposal strategy must await completion of an appropriate environmental impact statement and its adoption through the NEPA process. In the meantime, Federal actions regarding the management of TRU waste must not prejudice the choice of strategies for their disposal. Nevertheless, an interim strategic planning basis will be necessary to guide the TRU-waste management programs and R&D activities before that choice is made.
>
> In laying out the following technical strategies for TRU waste disposal, the IRG assumed that all TRU waste, whether generated by commercial or defense operations, would be disposed of in the same manner because no technical reason exists to treat them differently. The two strategies examined by the IRG are:
>
> Strategy 1. No special action would be taken to pursue TRU waste disposal prior to the opening of a high-level-waste repository. TRU waste would be disposed of in high-level-waste repositories whenever they become available.
>
> Strategy 2. If an opportunity can be found, the program would proceed with an early dedicated TRU repository as soon as a site could be appropriately qualified and NEPA requirements fulfilled.
>
> Enough TRU waste now exists stored above ground to warrant the opening of a repository dedicated to TRU. Such a facility could probably hold all the TRU waste to be generated through the end of this century. Of course, once a high-level-waste repository were available, decisions on the location for disposal of then existing TRU wastes could be made on a case by case basis to maximize convenience and minimize transportation. A second repository dedicated to TRU waste alone would seem to be unnecessary.
>
> Because of the presence in TRU waste of substantial quantities of transuranic radionuclides, issues related to long-term containment (such as the potential for groundwater transport, any possibilities of repository breachment, and concerns about mineral resources or tectonism) are identical for TRU and HLW repositories. However, the problems associated with heat generation and increases in temperature are absent and the TRU wastes are not as difficult to handle as HLW. The operational demands on a disposal system designed for TRU waste alone would be more modest than those associated with a HLW repository. In addition, because of the absence of heat-related considerations, the regulatory review of a dedicated TRU repository would be somewhat simplified compared with that for a HLW repository.
>
> Proceeding with an early, dedicated TRU repository would therefore be consistent with the previously recommended philosophy of [conservatism] and proceeding stepwise into the most difficult disposal problem and would signal the government's determination to proceed in a timely manner with disposal of nuclear wastes. There would, of course, be some additional costs associated with the opening of a dedicated TRU facility.
>
> Having considered these various matters, the IRG recommends adopting, as an interim strategic planning basis pending NEPA review, the concept of proceeding with an early TRU repository if an opportunity exists to do so.

IRG Discussion of High-Level-Waste Disposal

The Interagency Review Group defined four technical strategies for high-level-waste disposal (IRG, 1979, pp. 49-50):

- Strategy I provides that only mined repositories would be considered and that only geological environments with salt as the emplacement media would be considered for the first several repositories. As a result of past focusing on salt, there is a large volume of information available. In addition, one body of opinion holds that salt is the best, or at least an acceptable, emplacement medium and that suitable sites can be found where salt is the host rock.
- Strategy II provides that, for the first few facilities, only mined repositories would be considered. A choice of site for the first repository would be made from among whatever types of environments have been adequately characterized at the time of choice. Because generic understanding of engineering features of a salt repository are most advanced, the first choice is expected to be made from environments based on salt geology. Sites from a wider range of geologic environments would be available for selection somewhat later.
- Strategy III provides that, for the first facility only mined repositories would be considered. However, three to five geological environments possessing a wide variety of emplacement media would be examined before a selection was made. Other technological options would be contenders as soon as they had been shown to be technologically sound and economically feasible.
- Strategy IV provides that the choice of technical options and, if appropriate, geological environment be made only after information about a number of environments and other technical options has been obtained.

These strategies were intended to illustrate the range of possible strategic approaches. They were not intended to be a complete list of possible strategies or comprehensive descriptions of a strategic planning basis that might actually be adopted by the waste disposal program. For the latter purpose, they are admittedly incomplete.

IRG Discussion of Key Elements of Interim Strategic-Planning Basis for High-Level Waste

As a result of comments on its draft report, the IRG (1979, pp. 61-62) expanded and clarified its views on the interim strategic-planning basis for high-level waste, restating them as follows:

- The approach to permanent disposal of nuclear waste should proceed on a stepwise basis in a technically conservative manner....
- Near-term R&D and site characterization programs should be designed so that at the earliest date feasible, sites selected for location of a repository can be chosen from among a set with a variety of potential host rock and geohydrological characteristics. To accomplish this, R&D on several potential emplacement media and site characterization work on a variety of geologic environments should be increased promptly.
- A number of potential sites in a variety of geologic environments should be identified and early action should be taken to reserve the option to use them if needed at an appropriate time. In order to avoid working toward and ultimately having a single national repository, near-term options should create the option to have at least two (and possibly three) repositories become operational within this century, ideally and insofar as technical considerations permit, in different regions of the country. In pursuing a regional approach to siting, geologic, hydrologic, tectonic and other technical characteristics of sites must remain the primary basis for selection.

- Construction and operation of a repository should proceed on a stepwise basis and initial emplacement of waste in at least the first repository should be planned to proceed on a technically conservative basis and permit retrievability of the waste for some initial period of time. Further definition of the retrievability concept, the circumstances in which waste would be retrieved and the technical aspects (including development of waste packaging, containers and handling) is necessary.

All IRG members agreed with the above elements of the recommended interim strategic-planning basis for high-level waste. They asserted further (IRG, 1979, p. 63) that these elements

- do not prejudge the NEPA process
- require the Federal government to maintain a technically conservative approach
- call for resolution of uncertainties by increasing the technical and program breadth with respect to the near-term repository characterization program
- do not preclude subsequent adoption of longer term technologies inasmuch as they call for increased R&D to develop selected alternatives
- support a step-wise approach to the development of a HLW repository, while maintaining storage capacity for managing wastes until emplacement and disposal opportunities are available

The IRG did not come to a consensus on the basis for selecting the site for the first high-level-waste repository.

REFERENCES

IRG (Interagency Review Group), 1978. Report to the President by the Interagency Review Group on Nuclear Waste Management (draft), TID-28817, U.S. Department of Energy, Washington, D.C.

IRG (Interagency Review Group), 1979. Report to the President by the Interagency Review Group on Nuclear Waste Management, TID-29442, U.S. Department of Energy, Washington, D.C.

Appendix D

SELECTION CRITERIA FOR THE WIPP SITE

CONTENTS

Appendix D

SELECTION CRITERIA FOR THE WIPP SITE

This appendix briefly describes how the geologic, hydrologic, and other characteristics of the WIPP site in southeastern New Mexico meet site-selection criteria and factors. The criteria and factors given here are from the Geological Characterization Report (Powers et al., 1978, pp. 2-15ff) and are based on criteria suggested earlier by the Oak Ridge National Laboratory (ORNL, 1973), the International Atomic Energy Agency (1977), and Brunton and McClain (1977).

The site-selection criteria described here were originally formulated under the expectation that the WIPP would be a repository that would contain spent fuel from nuclear reactors. The heat emitted by spent fuel would have had important effects on the salt in which it was emplaced; for that reason, some of the criteria were specifically intended to insure the safety of spent-fuel emplacement. The WIPP mission no longer includes the disposal of spent fuel or any other high-level waste. Furthermore, the design of the WIPP no longer includes the separate mined cavity for high-level waste called the "lower repository" or the "lower horizon" in the criteria. Accordingly, not all the criteria presented here are applicable to the WIPP under its current mission and design. Because the site was, however, actually selected under these criteria, no effort has been made to revise them for this document.

D.1 GEOLOGIC CRITERION AND SITE-SELECTION FACTORS

The geology of the site will be such that the repository will not be breached by natural phenomena while the waste poses a significant hazard to man. The geology must also permit safe operation of the WIPP repository.

Topography. The terrain must permit access for transportation. The effect on inducing salt flow during excavation must be considered. Surface-water flow and the potential for flooding must be evaluated.

The maximum relief over the WIPP repository is 120 feet. The regional relief is low and easily accommodates the required transportation corridors. The location near a broad surface and groundwater divide will minimize the development of future relief. Differential stress in the salt due to surface relief is not a significant factor in causing deformation in the salt. (See Powers et al., 1978, Sections 3.2 and 4.2.)

Depth. Repository horizons should be deeper than 1000 feet to insure that erosion and consequences of surficial phenomena are not a major concern. The depth of suitable horizons will not exceed 3000 feet to limit the rate of salt deformation around the excavations.

The selected repository bed for heat-producing waste varies between depths of 2750 and 2250 feet over the potential excavation area. The bed for TRU waste ranges from 2200 to 1800 feet deep through the repository region. These depths are based on interpretations of seismic reflection data. (See Powers et al., 1978, Sections 3.3, 4.3, and 9.2.)

Thickness. The total thickness of the salt deposits should be several hundred feet to buffer thermal and mechanical effects. The desired thickness for the repository bed is 20 feet or more to mitigate the thermal and mechanical effects at nonhalite units.

The halite unit in which the heat-producing waste will be placed is about 100 feet thick. The total thickness of the evaporite section provides about a 1300-foot buffer above and below the repository horizons. This distance to the nearest potential aquifers insures that the thermal effects at these aquifers will be insignificant. (See Powers et al., 1978, Sections 4.3.2 and 9.2.)

Lateral extent. The distance to structural or dissolution boundaries must be adequate to provide for future site integrity. For the Los Medanos area a distance of 5 miles to the Capitan reef and 1 mile to regional Salado dissolution has been established.

From seismic data and drill-hole information, the selected horizons are believed to extend well beyond the repository site. The separations from the deformed salt belt parallel to the Capitan reef and from the natural dissolution fronts are adequate to insure the required site integrity. (See Powers et al., 1978, Sections 3.3, 4.3, and 6.3.)

Lithology. Purity of the salt beds is desirable. Brine in the salt could induce geochemical interactions; pending further investigations, 3% brine is established as a desirable upper limit for the heat-producing waste horizon. Additional geochemical interactions must be considered if significant chemical or mineral impurities are present.

The horizon within the lower Salado that will accommodate the heat-producing wastes averages more than 97% halite from the samples analyzed. Brine content averages less than 0.5%. (See Powers et al., 1978, Sections 4.3 and 7.2 through 7.6.)

Stratigraphy. Continuity of beds, character of interbedding, and nature of beds overlying and underlying the salt are important considerations in the construction of the facility; they are also important in insuring the long-term integrity of the repository.

There are no beds of clay or polyhalite near enough to the lower repository horizon to affect repository construction and operation or to affect the long-term performance of the repository. The significant nonhalite beds adjacent to the heat-producing-waste horizons are principally anhydrite, which has favorable thermal, mechanical, and chemical properties for bounding layers. The upper (TRU-waste) level of the repository can also be located to avoid rock-mechanics instabilities due to interbeds of nonhalite rock. (See Powers et al., 1978, Sections 3.3, 3.4, 4.3, and 4.4.)

Structure. Relatively flat bedding (less than 3 degrees) is desirable for operational purposes. Steep anticlines and major faults are to be avoided.

Seismic-reflection data and drill-hole information have been interpreted as showing relatively flat (less than 1 degree) bedding over most of the 3-square-mile repository horizon. Seismic data do show a small anticline at the northern edge of control zone II. Drilling on this anticline (WIPP-12) has shown that the elevation difference of the repository beds, from ERDA-9 at the center of the repository to WIPP-12, is less than 200 feet, an average of about 2 degrees. Photography, satellite imagery, surface mapping, geophysical techniques, and drilling have been used to search for indications of significant faulting. No post-Permian faults are known to exist in the site area. Seismic indications of faulting in older, deeper rocks do not extend through the Permian evaporite section.

The lack of severe structure and recent faulting satisfactorily meets the desired conditions for this factor. (See Powers et al., 1978, Sections 3.4 and 4.4.)

Erosion. While the depth of the repository reduces concern about erosion, it is desirable to avoid features that would tend to localize or accelerate erosion.

The site is located near a broad surface-water divide, and the local base level is at an elevation of about 2900 feet. Consequently, future erosion will proceed less rapidly over the site than in the established drainage channels. The expected erosion rates will not expose the Salado salt within the required lifetime of the repository. Future climatic changes will not alter this assessment, and glaciation is not expected to be a concern at this location. (See Powers et al., 1978, Sections 3.2.3, 3.6, 4.2, and 6.2.)

Dissolution. Regional and/or local dissolution must not breach the repository while the wastes represent a significant hazard to people. While there are various suggestions for the time a repository should remain isolated from the biosphere, a period of 250,000 years (10 half-lives of plutonium-239) is commonly used to represent the time over which the wastes are significantly hazardous.

Studies by the U.S. Geological Survey indicate that the maximum rate of horizontal progression of the salt-dissolution front in Nash Draw, averaged over the past 500,000 years, has been 6 to 8 miles per million years and less than 500 feet vertically per million years. The nearest active solution front is to the west, in Nash Draw. This is far enough from the site to provide repository isolation for more than 2 million years. (See Powers et al., 1978, Section 6.3.6.)

Subsidence. Subsidence due to dissolution of salt will be avoided when the subsidence adversely affects the repository beds or unduly accelerates the rate of dissolution to the jeopardy of the long-term integrity of the repository.

Subsidence has occurred over the western portion of the WIPP site area because of the natural removal of salt from the Rustler Formation. Hydrologic data from this region indicate that the major aquifers in the Rustler have different potential heads, and thus this regional subsidence has not caused them to be interconnected by permeable fractures. No sinks due to localized solutioning are present at the site.

D.2 HYDROLOGIC CRITERION AND SITE-SELECTION FACTORS

The hydrology of the site must provide high confidence that natural dissolution will not breach the site while the waste poses a significant hazard to man. Accidental penetrations should not result in undue hazards to mankind.

Surface water. Present and future runoff patterns, flooding potential, etc., should not endanger the penetrations into the repository while these openings are unplugged.

Because the site is near a broad surface-water divide, lacks established drainage, and is well above the Pecos River, simple construction techniques will prevent flooding of the repository. (See Powers et al., 1978, Section 6.2.)

Aquifers. For the WIPP, the overlying and underlying aquifers represent a secondary barrier if the salt is breached. Consequently, low permeability and transmissivity are desirable but not mandatory. Accurate knowledge of aquifer parameters is important to construction, decommissioning, and realistic calculation of the consequences of failure scenarios.

Aquifers above and below the repository have low transmissivity. Consequently, flooding of the repository during its operation through shafts or drill holes is not credible. These access points can readily be plugged to prevent water inflow after decommissioning.

The quantity of water carried by the major aquifers above and below the WIPP beds is too small to be useful. Furthermore, the water carries too many salts to be potable or otherwise useful.

The hydrologic parameters of the aquifers do not permit rapid flow of water. The low permeability would limit the flow even if heads were to be modified in future pluvial cycles. (See Powers et al., 1978, Section 6.3.)

Hydrologic transport. For the WIPP, this is a secondary factor that must be evaluated to allow quantitative calculations of the consequences of various failure scenarios. Slow transport of isotopes is acceptable if more critical factors have been satisfied.

Calculations based on various postulated failure scenarios show that the transport of radionuclides through the overlying and underlying aquifers would be so slow that a significant hazard to people would not exist even if the salt beds were breached. The nearest natural discharge point is near Malaga Bend on the Pecos River, over 14 miles away. At the maximum measured rate of water movement, it would take about 1700 years after a breach for the first trace of nonretarded nuclides (i.e., iodine-129) to appear at the Pecos. The long-lived transuranic nuclides would be retarded by the sorption of ions and would not begin to appear at Malaga Bend until 35,000 years after a postulated breach of the salt beds. The concentrations of radionuclides (or possible radiation doses) would never reach significant hazard levels in the Pecos River. (See Powers et al., 1978, Sections 6.3, 9.3, and 10.6.)

Climatic fluctuations. Possible pluvial cycles must be considered in estimating the effects of the hydrologic factors.

The dissolution and erosion rates established as averages over the past 500,000 years include the effects of several past pluvial cycles. It is expected that future cycles would also be shorter than the isolation time sought for the repository. Transport rates under different climates (rainfall) can be estimated by appropriate boundary conditions on the hydrologic model. The low permeability of the major aquifers above the site will not be significantly altered by the climatic changes expected for this area, and the resultant flow in the aquifers will not be grossly altered by changed climatic conditions. (See Powers et al., 1978, Sections 3.6 and 4.5, Chapter 6, and Section 10.3.)

Man-made penetrations. The effect of drill holes and mining operations must be included in evaluating the potential effects of dissolution.

The repository and control zone III are free of preexisting boreholes that extend through the salt, shafts, and mining activity. Any existing or future holes in any of the WIPP zones must be adequately plugged when abandoned.

D.3 TECTONIC STABILITY CRITERION AND SITE-SELECTION FACTORS

Natural tectonic processes must not result in a breach of the site while the wastes represent a significant hazard to people and should not require extreme precautions during the operational period of the repository.

Seismic activity. The frequency and magnitude of seismic activity impact facility design and safety of operation. Low levels of seismicity are desirable, but facility design can accommodate higher levels as well.

The WIPP site is in an area of relatively low seismic activity. The nearest seismic activity has been 10 or more miles north of the site and of small magnitude. It is not known whether the three nearest events were tectonic, related to salt dissolution, or a result of human activity. No faulting has been observed in the area of these seismic events. In any case, they and the potential future events pose no hazard for a properly constructed repository and are no threat to its long-term integrity. (See Powers et al., 1978, Chapter 5 and Section 10.5.)

Faulting and fracturing. While open faults, fractures, or joints are not expected in salt, the more brittle units within and surrounding the salt may support such features that can enhance dissolution and hydrologic transport. Major faults and pronounced linear structural trends should be avoided.

No major structural trends of recent geologic age are known to exist in the site area. The nearest recent faulting observed is on the west side of the Guadalupe Mountains, some 70 miles away. Seismic-reflection data have indicated small faults in deep, old rocks below the Salado Formation. There are no known tectonic faults in post-Permian rocks at the site area. Thousands of miles of drift in the potash mines in the Salado salt have not encountered any open fractures or faults through which groundwater had penetrated.

Salt-flow anticlines. Major deformation of salt beds by flow can fracture brittle rock and create porosity for brine accumulations. Major anticlines resulting from salt flow should be avoided or evaluated to check on brine presence and anhydrite fracturing.

The only anticlines within the site are relatively minor features. Both have been drilled, however, and the cores show little fracturing or porosity and no accumulation of fluids. These small anticlines will not hinder repository construction or jeopardize its long-term safety. (See Powers et al., 1978, Section 4.4.)

Diapirism. An extreme result of salt flow, this feature will be avoided for WIPP siting.

There are no known or indicated diapirs (salt domes) at the WIPP site. (See Powers et al., 1978, Section 4.4.)

Regional stability. Areas of pronounced regional uplift or subsidence should be avoided since such behavior makes prediction of future dissolution, erosion, and salt flow more uncertain.

Geologic mapping has failed to reveal any indicators of regional instability. Caliche formation and attitude indicate stable conditions in the site region over the last half-million years. The lack of scarps and the natural seismicity are consistent with regional stability. (See Powers et al., 1978, Sections 3.4, 4.4, and 10.3.2.)

Igneous activity. Areas of active or recent volcanism or igneous intrusion should be avoided to minimize these hazards to the repository.

No recent igneous activity is known in the region. Geophysical surveys, mining, and drill-hole intercepts have shown that an intrusive dike exists 9 miles northwest of the site. Radiometric dating shows it to be 35 million years old. No other intrusive features are known to exist in the region. (See Powers et al., 1978, Section 3.5.)

Geothermal gradient. Abnormally high geothermal gradients should be avoided to allow construction in salt at 3000 feet. High gradients may also be indicative of recent igneous or tectonic activity.

The geothermal gradient as determined in the AEC-8 drill hole shows a normal geothermal gradient averaging about 0.58°F per 100 feet. The heat flow is about one heat-flow unit. (See Powers et al., 1978, Section 4.4.1.)

D.4 PHYSICOCHEMICAL COMPATIBILITY CRITERION AND SITE-SELECTION FACTORS

The repository medium must not interact with the waste in ways that create unacceptable operational or long-term hazards.

Fluid content. The repository bed containing high-level waste should not contain more than 3% brine. The limit for TRU waste has not been established, but the value used for high-level waste is acceptable.

The average brine content of the lower repository is less than 0.5% by weight. The average brine content of the upper repository horizon beds is less than 1% by weight. (See Powers et al., 1978, Sections 7.5 and 10.7.8.)

Thermal properties. To avoid undesirable temperature rises, no major natural thermal barriers should exist closer than 20 feet of the repository horizons.

This is of significance to the lower horizon, where the halite unit of interest is about 100 feet thick. The adjoining beds are anhydrite, which, even though far enough away, has similar thermal conductivity and does not represent a thermal barrier in any case. (See Powers et al., 1978, Section 9.2.3.)

Mechanical properties. The medium must safely support excavation of openings even while thermally loaded. Clay seams and zones of unusual structural weakness should be avoided in the selection of the repository horizon.

The halite bed at the lower level is sufficiently thick and devoid of clay seams that stability of openings will not be a problem for repository operation. Clay seams and polyhalite beds are more common in the area selected for the upper repository level, but construction levels can be located to avoid significant structural stability problems from such nonhalite beds. (See Powers et al., 1978, Section 9.2.4.)

Chemical properties and mineralogy. Beds that are of unusual composition or contain minerals with bound water should not occur within 20 feet of the waste horizon. This will lessen the uncertainties with regard to thermally driven geochemical interactions.

The heat-producing waste horizon is quite pure halite, with more than 97% NaCl. No polyhalite, clay, or other water-bearing minerals occur near this horizon. The upper horizon beds are more than 92% NaCl, with impurities being mostly potassium and magnesium salts and clay. These impurities have no known negative implications for TRU-waste isolation and, in fact, have been shown to absorb radionuclides from brine. (See Powers et al., 1978, Sections 4.3 and 7.2 through 7.5.)

Radiation effects. While no unacceptably deleterious effects are postulated, these phenomena are best quantified in halite, and thus the purer rock salt beds are desired for high-level waste.

Samples of WIPP salt show no characteristics that would produce undesirable effects under irradiation. The low brine content will limit the amount and effects of radiolytic disassociation of water. (See Powers et al., 1978, Chapter 9.)

Permeability. Salt has a very low permeability. It is necessary to evaluate the permeability only of the interbeds and the surrounding media. Low permeability is desirable, but quantitative limits need not be specified for site selection. Salt permeability to gases may be important in establishing waste-acceptance criteria.

Laboratory measurements on cores show very low permeability. On a large scale, measurements at the WIPP horizons have not been made. Experience in other drill holes (absence of aquifers in salt and presence of small high-pressure gas pockets) would argue for very low in-situ permeability on larger scales. (See Powers et al., 1978, Section 9.2.3.)

Nuclide mobility. This is a secondary factor in siting since confinement by the salt and isolation from water are the basic isolation premises. Ion sorption must be determined to allow quantification of safety analyses and to indicate whether engineered barriers (clay) would be beneficial.

The distributed impurities in the rock salt provide significant ion-sorption capability for many radionuclides. The clay layers in higher salt beds will be still more sorptive. These properties will tend to minimize radionuclide migration due to such local mechanisms as brine migration in thermal gradients. (See Powers et al., 1978, Section 9.3.)

D.5 ECONOMIC AND SOCIAL COMPATIBILITY CRITERION AND SITE-SELECTION FACTORS

The site must be operable at reasonable economic cost and should not create unacceptable impacts on natural resources or the biological and social environment.

Natural resources. Unavoidable conflict of the repository with actual or potential resources will be minimized to the extent possible.

This factor is not well satisfied by the WIPP site. Both hydrocarbons and potash exist in potentially economic quantities within the site. While salt itself may be considered a valuable mineral, its economic potential at the site is very low. Since both potash and hydrocarbons may be recovered from control zone IV, the amounts that may be restricted from development within zones I, II, and III are the critical amounts. These quantities are not large in terms of national supply (even the langbeinite product is synthesized in quantity from brine lakes). These minerals may prove an enticement for future exploration and exploitation. For this reason, studies are under way to examine the effects of recovering the potash ore from above control zone III. Very little potash exists above the repository (zone II) itself. Similarly, once adequate borehole plugging is demonstrated, drilling in zone III could be permitted or the same zones developed from zone IV by slant drilling. The expectation, but one that cannot yet be guaranteed, is that these minerals may be recovered in the decades ahead should they be economically attractive. Certainly the time frame for their development would be within the next century, while the site is still under administrative control. The small amounts of either resource within zone III would not be of significant interest in the absence of other production in the area. (See Powers et al., 1978, Chapter 8.)

Man-made penetrations. Boreholes or shafts that penetrate through the salt into underlying aquifers will be avoided within 1 mile of the repository. Existing mining activity, unrelated to the repository, should not be present within 2 miles of the repository. Future, controlled mining will be allowable up to 1 mile from the repository. Future studies may permit still closer mining and drilling if properly controlled.

The present site adequately fulfills this present restriction on man-made penetrations. (See Powers et al., 1978, Section 2.3 and Chapter 4.)

Transportation. Transportation should be capable of ready development. Avoidance of population centers by transportation routes is not a factor in the siting of the repository.

The present site meets this requirement and would utilize a spur line of the Santa Fe Railroad now running to the Duval mine.

Accessibility. The site should be readily accessible for transportation and utilities.

The site presents no problems for access by road, railroad, or utility lines.

Land jurisdiction. Siting will be on Federal land to the extent possible.

Of the 18,960 acres to be withdrawn by the DOE if this site is approved, 17,200 are Federal land controlled by the Bureau of Land Management and 1760 acres belong to the State of New Mexico. There are no private lands within the site.

Population density. Proximity to population centers and rural habitats will be considered in siting. A low population density in the immediate site area is desirable.

There are 16 permanent residents within 10 miles of the site. There is a transient population at potash mines. The nearest town is Loving, New Mexico, with a population of 1600. Carlsbad is 26 miles west and has a population of 28,600. Low population is not necessary to siting but, all other factors being equal, is desirable.

Effects on ecology and cultural resources. Major impacts on ecology due to construction and operation should not occur. Archaeological and historic features of significance should be preserved.

No major or unusual impacts on the environment or the ecologic system are expected from the construction and the operation of the repository. No endangered species of plants or animals are known to occur at the site. No significant archaeological sites will be destroyed by repository construction.

Sociological impacts. Demographic and economic effects should not result in unacceptable sociological impacts.

There was no a priori reason to expect any severe or unacceptable socioeconomic impacts attributable to the site location. This assessment has been substantiated by the socioeconomic studies reported in Section 9.4 of this document.

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Appendix E

DESCRIPTIONS OF WASTE TYPES

CONTENTS

Appendix E

DESCRIPTIONS OF WASTE TYPES

This appendix contains four tables that describe the types of waste to be emplaced in the WIPP and the containers used for transportation and storage. Isotope inventories and maximum and average activity levels at the time of emplacement are included. Curves illustrating the radioactive decay of the contact-handled and remotely handled transuranic (TRU) wastes to be disposed of in the WIPP are also presented.

This appendix also includes a detailed report characterizing defense TRU waste now held in retrievable storage; it was compiled by James E. Dieckhoner of the U.S. Department of Energy. The report concludes with a description of the types of waste stored and the containers used at the Idaho National Engineering Laboratory (Annexes 1 and 2, respectively).

Table E-1. Defense Contact-Handled TRU Waste--Drum

Type of container	DOT-17C 55-gal steel drum	Rocky Flats Plant Standard SX-200
Liner (if used)	0.09-in.-thick rigid-polyethylene inner liners	Rocky Flats Plant Standard SX-202
Weight of container	840 lb (maximum gross)	
Volume of waste	Approximately 7.3 ft^3 (207 liters)	
Surface-dose rate	≤200 mrem/hr	Waste-acceptance criterion
Surface contamination	5% of limit in 49 CFR 173.397	Waste-acceptance criterion
Waste properties	Combustible: paper, cardboard boxes, wooden boxes, plastic bags, rubber scrap, rags, surgical gloves, clothing, etc. Noncombustible: residues from chemical processing, building rubble, metal, glassware and acids	

Radionuclide	Mass present[a] (grams)	Activity[b] Ci/drum	Activity[b] Ci/liter	Surface contamination (Ci/drum)
Pu-238	2.5-3[c]	4.2-2	2.0-4	7.0-10
Pu-239	7.5	4.6-1	2.2-3	7.5-9
Pu-240	5.0-1	1.1-1	5.3-4	1.8-9
Pu-241[d]	2.7-2	2.8	1.3-2	1.0-7
Pu-242	2.4-3	9.4-6	4.5-8	1.6-13
Am-241	1.5-3	5.2-3	2.5-5	8.5-11
Total	8	3.4	1.6-2	1.1-7
Total fissile content	7.5 g			
Total Pu	8 g			

[a]Average condition; maximum fissile content is 200 grams, based on transportation regulations.

[b]For activity of maximum container, multiply by 25 (200/8).

[c]2.5-3 = 2.5 x 10^{-3}.

[d]A beta emitter and hence not strictly speaking a TRU nuclide as defined in Section 5.1.2.

Table E-2. Defense Contact-Handled TRU Waste--Box

Type of container	DOT-7A 4 x 4 x 7-ft plywood box	Rocky Flats Plant Standard SX-211 (plywood box) and SX-207 (fiberglass-reinforced-polyester coating)
Weight of container	Maximum 5000 lb; typical 3000 lb	
Volume of waste	Approximately 100 ft^3 (2800 liters)	
Surface-dose rate	≤200 mrem/hr	Waste-acceptance criterion
Surface contamination	5% of limit in 49 CFR 173.397	Waste-acceptance criterion
Waste properties	Combustible: same as drums (see Table E-1) Noncombustible: same as drums (see Table E-1) Equipment and materials too large for 55-gal drums	

Radionuclide	Mass present[a] (grams)	Activity[b] Ci/box	Ci/liter	Surface contamination (Ci/box)
Pu-238	4.0-3[c]	6.8-2	2.4-5	4.5-9
Pu-239	1.2+1	7.5-1	2.7-4	5.0-8
Pu-240	8.1-1	1.8-1	6.5-5	1.2-8
Pu-241[d]	4.4-2	4.5	1.6-3	6.5-7
Pu-242	3.9-3	1.5-5	5.4-9	1.0-12
Am-241	2.5-3	8.4-3	3.0-6	5.5-10
Total	13	5.5	2.0-3	7.0-7
Total fissile content	12.2 g			
Total Pu	13 g			

[a]Average condition; maximum fissile content is 350 grams but not exceeding 5 grams in any cubic foot, based on transportation regulations.
[b]For activity of maximum container, multiply by approximately 27 (350/13).
[c]$4.0\text{-}3 = 4.0 \times 10^{-3}$.
[d]A beta emitter and hence not strictly speaking a TRU nuclide as defined in Section 5.1.2.

Table E-3. Defense Remotely Handled TRU Waste

Type of container	Carbon-steel canister, 10 feet long	
Weight of container	Maximum 7000 lb	
Volume of waste	Approximately 25 ft^3 (708 liters)	
Surface-dose rate	100 rem/hr	Waste-acceptance criterion
Surface contamination	5% of limit in 49 CFR 173.397	Waste-acceptance criterion
Waste properties	Primarily noncombustible: concrete, steel, dried process sludges, etc.	

Expected Average Conditions[a]

Radionuclide	Mass present (grams)	Activity		Surface contamination (Ci/canister)
		Ci/canister	Ci/liter	
Co-60	1.4-3[b]	1.6	2.2-3	2.0-8
Sr-90	1.8	2.5+2	3.5-1	3.1-6
Y-90	4.6-4	2.5+2	3.5-1	3.1-6
Rh-106	1.6-7	2.2	3.1-3	2.7-8
Ru-106	6.5-4	2.2	3.1-3	2.7-8
Cs-137	1.4-2	1.2	1.8-3	1.5-8
Ba-137m	2.4-9	1.2	1.8-4	1.5-8
Eu-152	1.7-3	3.1-1	4.4-4	3.9-9
Eu-154	8.6-3	1.2	1.8-3	1.5-8
Pu-238	3.7-3	6.5-2	9.1-5	4.1-8
Pu-239	1.2+1	7.5-1	1.1-3	4.8-7
Pu-240	7.9-1	1.8-1	2.5-4	1.1-7
Pu-241[c]	4.1-2	4.6	6.5-3	5.7-9
Am-241	3.8-3	1.2-2	1.8-5	7.7-9
Total	1.5+1	5.1+2	7.2-1	7.0-6

Table E-3. Defense Remotely Handled TRU Waste (continued)

Expected Maximum Conditions[d]

Radionuclide	Mass present (grams)	Activity		Surface contamination (Ci/canister)
		Ci/canister	Ci/liter	
Co-60	9.3-2	9.9+1	1.4-1	6.4-7
Sr-90	5.9+1	7.8+3	1.1+1	1.0-4
Y-90	1.5-2	7.8+3	1.1+1	1.0-4
Rh-106	2.1-8	6.8+1	9.6-2	9.2-7
Ru-106	2.2-2	6.8+1	9.6-2	9.2-7
Cs-137	5.0-1	3.9+1	5.5-2	5.2-7
Ba-137m	7.3-8	3.9+1	5.5-2	5.2-7
Eu-152	1.1-1	2.0+1	2.8-2	1.3-7
Eu-154	3.1-2	7.8+1	1.1-1	5.2-7
Pu-238	4.2-2	6.5-1	9.2-4	3.9-8
Pu-239	1.3+2	7.1	1.0-2	4.6-7
Pu-240	8.7	1.7	2.4-3	1.1-7
Pu-241[c]	4.6-1	4.3+1	6.1-2	1.9-6
Am-241	2.5-2	7.8-2	1.1-4	7.4-9
Total	2.0+2	1.6+4	2.3+1	2.1-4

[a]Expected average activity in canisters for use in analyses in which a large number of canisters are involved.

[b]1.4-3 = 1.4×10^{-3}.

[c]A beta emitter and hence not strictly speaking a TRU nuclide as defined in Section 5.1.2.

[d]Maximum activity in individual canister for calculating shielding requirements and the consequences of single-canister accidents.

Table E-4. Postulated Defense High-Level Waste for Experiments

Type of container	Steel canister
Weight of container	Maximum 1000 lb
Volume of waste	3.8 ft^3 (107 liters)
Surface-dose rate	>4500 rem/hr
Physical form	Glass (or calcine)

Radionuclide[a]	Mass present (grams)	Activity	
		Ci/canister	Ci/liter
Co-60	4.5-2[b]	5.0+1	4.7-1
Se-79	6.0-1	4.1-2	3.8-4
Rb-87	2.4+1	2.0-6	1.9-8
Sr-89	6.0-10	1.7-5	1.6-7
Sr-90	6.5+1	9.2+3	8.6+1
Y-90	1.7-2	9.2+3	8.6+1
Y-91	1.4-8	3.3-4	3.1-6
Zr-93	7.0+1	2.8-1	2.6-3
Zr-95	1.4-7	2.8-3	2.6-5
Nb-95	1.6-7	6.0-3	5.7-5
Nb-95m	9.3-11	3.6-5	3.3-7
Tc-99	4.4+1	7.3-1	7.0-3
Ru-106	1.6-1	5.3+2	5.0
Rh-106	1.5-7	5.3+2	5.0
Pd-107	6.3	3.3-3	3.0-5
Sn-121m	4.2-2	2.5	2.3-2
Ag-110	2.1-9	8.8	8.2-2
Sn-123	9.6-6	7.9-2	7.4-4
Sn-126	1.4-1	4.0-3	3.8-5
Sb-124	2.9-12	5.1-8	4.8-10
Sb-125	2.0-1	2.2+2	2.0
Sb-126	6.6-9	5.6-4	5.3-6
Sb-126m	5.2-11	4.0-3	3.8-5
Te-125m	2.9-3	5.3+1	5.0-1
Te-127	1.1-8	3.0-2	2.9-4
Te-127m	3.3-6	3.1-2	2.9-4
Cs-134	1.5	1.9+3	1.8+1
Cs-135	1.7+1	2.1-2	1.9-4
Cs-137	2.2+3	1.9+5	1.8+3
Ba-137m	3.3-4	1.9+5	1.8+3
Ce-142	1.2+2	2.9-6	2.7-8
Ce-144	1.1	3.4+3	3.2+1
Pr-144	4.4-5	3.4+3	3.2+1

Table E-4. Postulated Defense High-Level Waste for Experiments (continued)

Radionuclide[a]	Mass present (grams)	Activity	
		Ci/canister	Ci/liter
Pr-144m	2.2-8	4.1+1	3.8-1
Pm-147	7.2	6.7+3	6.3+1
Sm-147	2.0+1	4.6-7	4.3-7
Sm-151	1.7	4.2+1	3.9-1
Eu-152	2.4-3	7.5-1	7.0-3
Eu-154	9.3-1	2.7+2	2.5
Eu-155	2.4-1	1.1+2	1.1
Tb-160	5.3-11	6.0-7	5.6-9
U-232	6.0-5	1.3-3	1.2-5
Tl-208	1.8-12	5.3-4	4.9-6
U-233	2.1-5	1.9-7	1.8-9
U-234	2.4-1	1.5-3	1.4-5
U-235	9.0	1.9-5	1.8-7
U-236	6.0	3.7-4	3.4-6
U-238	1.5+2	5.1-5	4.8-7
Np-237	6.2	4.3-3	4.0-5
Pu-236	1.7-1	1.6-2	1.5-4
Pu-238	2.3+1	3.8+2	3.6
Pu-239	2.1+6	1.3+1	1.2-1
Pu-240	3.6+1	7.9	7.3-4
Pu-241	1.7+1	1.7+3	1.6+1
Pu-242	2.8	1.1-2	1.0-4
Am-241	4.6	1.6+1	1.5-1
Am-242	2.5-8	2.0-2	1.8-4
Am-242	2.1-3	2.0-2	1.8-4
Am-243	2.4-2	4.6-3	4.3-5
Cm-242	1.5-5	5.0-2	4.7-4
Cm-243	2.0-4	9.4-3	8.8-5
Cm-244	1.7-3	1.3-1	1.3-3
Cm-245	3.4-5	6.1-6	5.7-8
Cm-246	2.1-6	6.2-7	5.8-9
Total	3.0+3	4.3+5	4.0+3

[a]Only radionuclides with a specific activity greater than 10^{-10} Ci/liter are listed. The reason for deleting radionuclides with a lower concentration is twofold. First, their contribution to the total radioactivity of the mixture is minimal, and the product of their hazard index and concentration is small in comparison with the radionuclides listed.

[b]$4.5-2 = 4.5 \times 10^{-2}$.

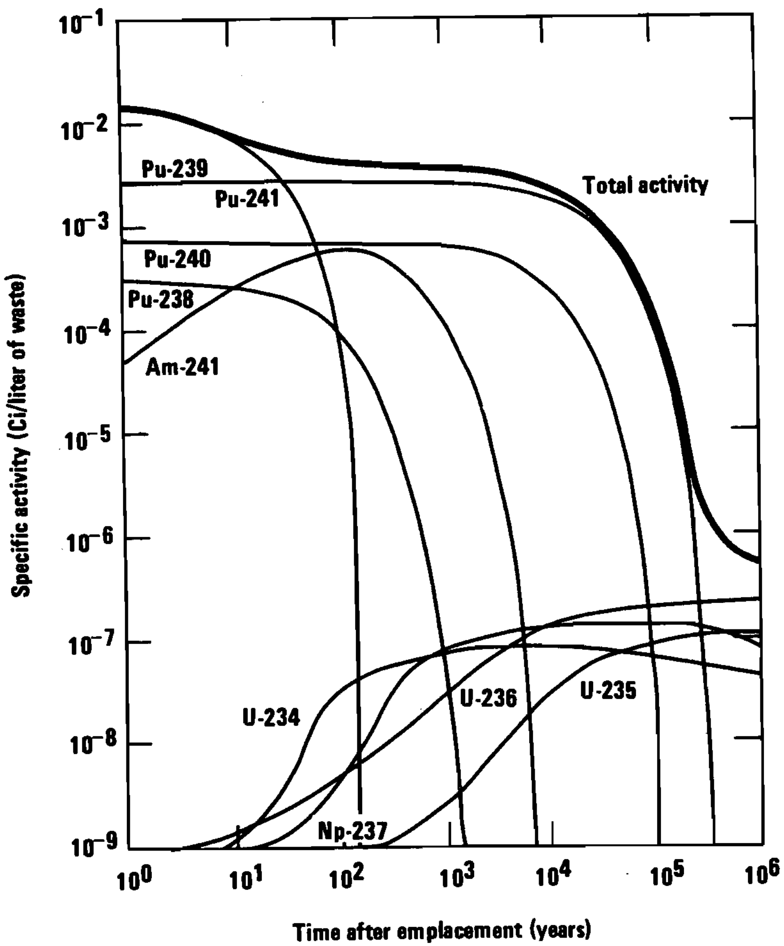


Figure E-1. Radioactive decay of contact-handled TRU waste. The activities shown are for a DOT-17C 55-gallon steel drum containing 8 grams of plutonium.

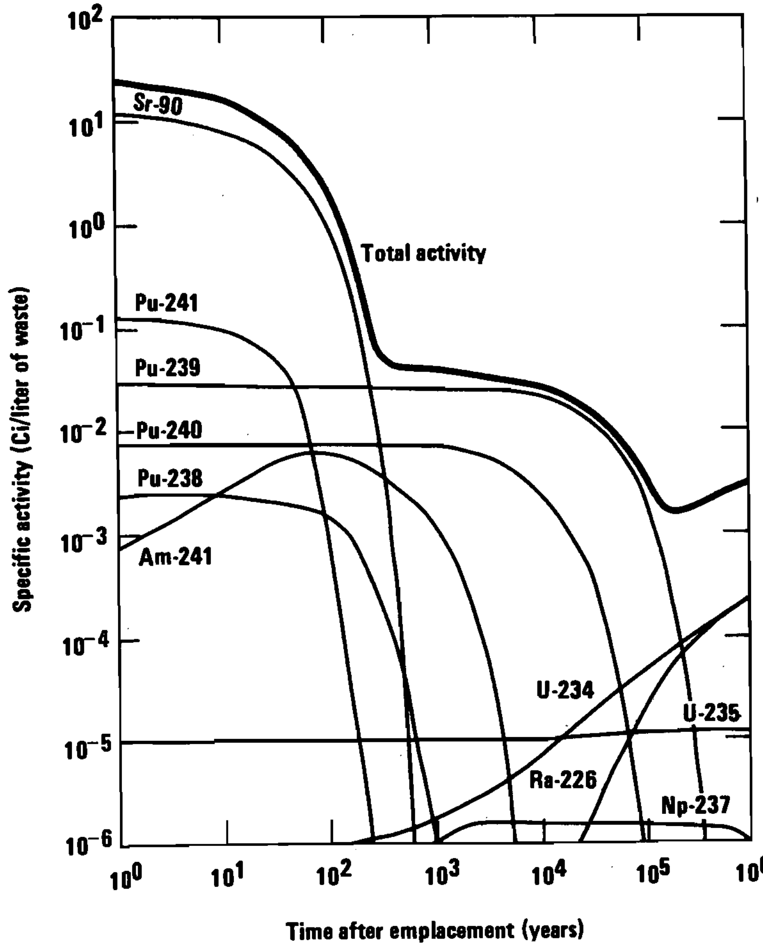


Figure E-2. Radioactive decay of remotely handled TRU waste.

REPORT FOR THE WIPP

WASTE ACCEPTANCE CRITERIA STEERING COMMITTEE

DETAILED CHARACTERIZATION

OF DOE STORED TRU WASTE

Compiled by James E. Dieckhoner

Office of Nuclear Waste Management
Division of Waste Products
Operations Branch

June 16, 1978

Introduction

This report was prepared in response to a request of the WIPP Waste Acceptance Criteria Steering Committee (WACSC) at their meeting on March 2. All DOE field offices conducting TRU retrievable storage operations were asked to provide the Operations Branch with certain specific information concerning the TRU waste currently on hand and projected for the future. A copy of the request for data is included as Appendix A. Copies of the data supplied are included as Appendices B through G. The remainder of this record is a condensation of these responses and a restructuring of the data into a format where the WACSC can obtain an overall perspective on the DOE-wide situation. The reader is encouraged to consult the individual replies or to contact the respective field offices for more detailed information.

NOTE: Only one of the appendices mentioned above (Appendix F) is included here: the data on wastes stored at the Idaho National Engineering Laboratory (see Annex 1, pp. E-23 through E-42).

Section I

Qualitative Description of Available Waste Characterization Information

A. Contact-Handled TRU Waste:

LASL - Waste generators are required to complete a form containing information on the radionuclide content (including error estimates and how the amount was determined), package construction, package radiation level, and waste type. The LASL lists 33 different waste types (see Appendix C [not included here] for details). In addition, the form also permits the inclusion of additional data. Examples of typically recorded information include the identification of equipment items or types, and of chemical contaminants on or in the waste.

Sandia Lab - The waste will be in the form of glassware, equipment, solidified liquids, ceramic waste, etc., and contains Np-239, Pu-238, Pu-239, Pu-241, Am-241, and Cm-244. All waste is packaged in DOT 17-C containers.

Pantex - Data currently available include: container size, volume, weight and type; chemical and physical form of the waste; isotopic composition and curie amount; and surface radiation reading.

ORNL - The computer system contains data by container: date received, source of waste, shipper, location in storage area, estimated amount of combustibles and noncombustibles, and estimated amount of U-233 and transuranics. Essentially all of this waste is from glovebox and hot cell operations. Since no assays were done, the isotopic composition data, if not reported by the generator, can be implied from the source (i.e., building). The package size and construction is well known, but the precise weight is not. No information on compactibility is available. Although some knowledge of the chemical and physical forms of the waste can be inferred from its source, no specific information has been recorded. No information is available on nonradioactive constituents.

Hanford - Each waste shipment is accompanied by a shipping ticket which physically describes the material content, the source of the waste, any special conditions, the type of radioactivity (specific radionuclides, etc.), quantity (curies or grams), and the radiation level. The TRU waste containers must also be identified as combustible or noncombustible. The locations of the TRU containers are also recorded.

INEL - The following information is recorded for each shipment: waste generator and building number, gross volume, gross weight, curie content, type and number of containers, unit container volume, waste description, nuclide identification and storage location. No data are currently available on nonradioactive toxic constituents in the TRU waste. Some may be obtained from a records search, although initial indications are that any such information would be very limited and superficial. Compilations of some of these data can be found in Appendix F [reproduced here as Annex 1, pp. E-23 through E-42].

NTS - For retrievably stored, contact-handled TRU waste the gram content, curie content, isotopic composition, package size with weight and construction, and combustibility information are available.

SR - Early records contain only waste volumes and activities. However, since July 1, 1974, combustibles and noncombustibles are segregated and placed in separate drums and marked accordingly. The material composition of the waste can only be inferred from sample observations of the waste packaging operations and estimation by the production personnel. Results of such a survey can be found in Appendix B [not included here].

B. Remote-Handled TRU Waste:

LASL - The same type of information will be available as previously indicated for contact-handled TRU waste.

Sandia Lab - The same type of information would be available as previously indicated for contact-handled TRU waste.

Pantex - No waste of this type is stored at Pantex.

ORNL - Essentially all of this type waste is from hot cells (90 percent from one facility) and gloveboxes. It includes plastics, paper wipes, various kinds of equipment, equipment racks, etc. No assays of waste to determine isotopic composition were made but the source and knowledge of the process may give some indication. The package size, weight, and construction are well-known. An estimate of the combustibility is available, but there is no information on its compactibility, nor on the presence of nonradioactive toxic constituents. The chemical form varies--nitrides, chlorides, oxides, and others.

Hanford - The same type of information is available as previously indicated for contact-handled TRU waste.

INEL - The same type of information is available as previously indicated for contact-handled TRU waste.

NTS - No waste of this type is stored at NTS.

SR - No waste of this type is stored at SR.

C. TRU Waste Disposed of by Shallow Land Burial:

LASL - Waste management personnel have kept logbook-type records on all waste disposed of since the late 1940's. Work is underway to convert the pre-1971 records into the current computer system. The major problem with these old records will be the actual identification of which wastes contain >10 nCi/gm. Where buried TRU wastes can be identified, information as to waste matrix, packaging, radiation level, TRU content, and burial location should be available.

Sandia Lab - The waste is in the form of glassware, equipment, paper products, contaminated experiments, etc., and contains about 1 gram of Pu-239.

Pantex - The same type of information is available as previously indicated for contact-handled TRU waste.

ORNL - Due to an accidental loss of records, no detailed information is available for the pre-1969 buried TRU waste, estimated to be about 200,000 ft^3 in volume. Since field separation of TRU waste began in 1970, about 63 containers of equipment were buried, in an essentially nonretrievable fashion, that were judged to be contaminated marginally above the 10 nCi/gm level. About 90 percent contained hoods and gloveboxes. No assays were made and the data is based on the judgment of the generator. The size and composition of the containers are known, the weights are estimates based on actual weights of a few. An estimate of the combustibility is available, but no information on the compactibility or on the presence of nonradioactive toxic constituents is available.

Hanford - The same general type of information is available as previously indicated for contact-handled TRU waste, except for knowledge of where the buried TRU-contaminated (>10 nCi/gm) waste is located among the non-TRU-contaminated waste.

INEL - The data available at the present time on the subsurface disposed TRU are limited to hand tabulations of quantities shipped from Rocky Flats Plant and estimates of Pu quantities.

NTS - No waste of this type is buried at NTS.

SR - Much of the waste sent to the burial ground was contained in cardboard cartons which were dumped into the waste trenches and covered with soil. Bulky waste was wrapped in plastic and buried, or wrapped waste was placed in wooden boxes. Test retrievals indicate that the waste package in plastic will be well preserved; however, the cellulosic materials in contact with the soil will be degraded. Because early records are lacking, activity content and volume of waste buried before 1961 can only be estimated.

NOTE: The preceding are only brief synopses of the lengthier information submitted by the field. The reader is encouraged to consult the Appendices [in the original report] for more details, and to directly contact the field organizations to resolve difficulties in interpretation or to obtain specific additional information.

Section II

Inventory Data

All of the field offices were asked to present estimates of the approximate volumes of TRU waste in the following three categories (i.e., retrievably stored, contact-handled, retrievably stored, remote-handled; and TRU waste disposed of by shallow land burial) as of the start of FY 1978 and expected to have been accumulated as of the start of FY 1986. Estimates of the accuracy of these data were also requested. A compilation of the site submitted data is presented in Table 1, and a summary of the DOE-wide situation in Table 2.

TABLE 1

APPROXIMATE VOLUMES OF DOE TRU WASTE AND ESTIMATES OF THEIR ACCURACY

Waste Category	Site	As of 10/1/77 Volume (ft³)	As of 10/1/77 Accuracy	As of 10/1/84 Volume (ft³)	As of 10/1/84 Accuracy
Stored, Contact-Handled TRU Waste	LASL	54,020	± 5%	200,000	± 25%
	SLA	0	-	3,500	± 30%
	Pantex	38	± 10%	57	± 15%
	ORNL	9,600	- 5% (4)	18,750 (4)	± 25% (4)
	Hanford	247,000	± 10%	770,000	± 30%
	INEL	1,201,917	± 10%	2,036,682	± 30%
	NTS	6,116	± 10% (3)	35,314	+200% - 50% (3)
	SRP	56,168	± 5% (1)	95,100	± 25% (1)
		1,574,859 ft³	± (5-10)%	3,195,403 ft³	± 30%
Stored, Remote-Handled TRU Waste	LASL	0	-	8,000	± 50%
	SLA	0	-	50	± 30%
	Pantex	0	-	0	-
	ORNL	26,550	± 5%	47,350 (4)	± 25% (4)
	Hanford	2,940	± 5%	7,900	+100% - 50%
	INEL	304	± 10%	14,442	± 50%
	NTS	0	-	0	-
	SRP	0	-	0	-
		29,794 ft³	± (5%)	77,742 ft³	± 50%
Buried TRU Waste	LASL	580,045	± 50%	580,045 (2)	± 50%
	SLA	60	± 50%	60	± 50%
	Pantex	1,143	± 10%	1,143	± 10%
	ORNL	200,000 (5)	± 50% (5)	200,000 (5)	± 50% (5)
		15,000	± 10% (4)	22,000	± 25% (4)
	Hanford	5,483,000	+200% - 50%	5,483,000	+200% - 50%
	INEL	2,102,000	± 30%	2,102,000	+200% - 50%
	NTS	0	-	- (3)	-
	SRP	1,084,740	± 5% (1)	1,084,740	± 5% (1)
		9,465,988 ft³	+125% - 40%	9,472,988 ft³	+125% - 40%

(1) Telecon with J. Covell, SR, 6/6/78.

(2) Telecon with J. Warren, LASL, 6/6/78. The figure in Appendix C was reduced since no burial of >10 nCi/gm is planned.

(3) Telecon with B. Church and P. Fitzsimmons, NV, 6/6/78. The figure in Appendix G was reduced since no burial of >10 nCi/gm waste is planned. The 1×10^4 m^3 referred to <10 nci/gm waste.

(4) Telecon with B. Brockelsby, OR, 6/6/78. The changes in Appendix D reflect re-estimates by ORNL for 1984 and the accuracy values. These buried TRU volumes refer to bulky equipment.

(5) This buried TRU volume refers to waste buried prior to the initiation of TRU retrievable storage operations at ORNL. Confirmed by telecon with B. Brockelsby, OR, 6/6/78.

Table 2

Summary of DOE TRU Waste Volumes

Waste Category	As of 10/1/77 Volume (ft^3)	Accuracy	As of 10/1/84 Volume (ft^3)	Accuracy
Stored Contact-Handled	1.6×10^6	± (5-10)%	3.2×10^6	± 30%
Stored Remote-Handled	3.0×10^4	± 5%	7.8×10^4	± 50%
Buried (1) (2)	9.5×10^6	+ 125% - 40%	9.5×10^6	+ 125% - 40%

(1) An unknown fraction of the buried TRU waste may be in concentrations less than the 10 nCi/gm level, and therefore may be incorrectly included as "TRU" waste.

(2) Due to the degradation of the original container, the total volume of material resulting from any operations to recover this material may be a factor of 2 to 3 larger than the original waste volume. In addition, such recovery operations would also generate an additional waste volume.

Section III

Obtaining More Detailed Waste Characterization Data

The estimated time and funding required at the TRU waste retrievable storage sites to obtain significantly better data varied from site to site. Following is a synopsis of the individual replies:

LASL - For the retrievably stored waste, very little, if anything, can be done to improve significantly the available data.

Pantex - It was estimated that it would require 80 man-days and $6,400 to obtain more detailed waste characterization data. This would not include opening of the containers, only verification with instruments. It would also not lead to the establishment of an actual weight of TRU material, since it is mixed with non-TRU materials and processing would be required.

ORNL - For the contact-handled TRU waste there might be two possible methods:

- The first would require the development of an instrument system that can detect and quantify a variety of radionuclides through the wall of a storage drum. Employment of such a system would cost about $100/drum. This method would not, however, give any additional information on percent combustibles, compactibility, the presence of nonradioactive toxic materials, etc.

- The second method would involve construction of a facility where the drums would be opened and the contents analyzed and repackaged. Construction cost would be about $1M and operating costs about $1K/drum.

For the remote-handled TRU waste, improvement of the isotopic composition data is essentially not possible. The waste is heavily shielded so it would have to be removed from the casks in hot cells for further study, after being excavated. Construction would cost about $2M, excavation about $0.6K/cask and operation about $3K/cask. It would take about two to four years.

Hanford - It is estimated that rough estimates for the missing data for 300 Area burial grounds could be obtained in about one year and cost about $75K. The cost to improve the quality of the available data would take about one to two years and cost $250-$500K.

INEL - If the timing of additional waste characterization studies could be arranged to coincide with the ongoing program, it is anticipated that it could be done in four months for about $375K. If the timing could not be arranged, it would take two more months and cost an additional $100-$125K. An additional $100K would be needed to characterize the Pu in the soil surrounding the buried waste.

NTS - Estimates of the funding and time required to obtain significantly more detailed waste characterization data appear to be minimal.

SR - A more detailed waste characterization study of retrievably stored waste would cost about $160K and take about one year. It would characterize, in detail, current waste as it is prepared for storage. Sampling waste now in storage would be more difficult and costly.

Section IV

References

The following published reports contain specific additional data on the DOE stored and buried TRU waste. Additional data is contained in internal memos, burial records and shipping records.

1. "History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas, A, B, C, D, E, F, G, and T). A Source Document," LA-6848-MS, Vol. I and II, Margaret Anne Rogers, June 1977.

2. "Radioactive Waste Management Site Plan, Los Alamos Scientific Laboratory," updated June 1977 (available from AL).

3. "Radioactive Waste Management Site Plan, Sandia Laboratories--Albuquerque," updated 1977 (available from AL).

4. "Radioactive Waste Management Site Plan, Pantex Plant, Amarillo, Texas," updated 1977 (available from AL).

5. "ORNL Solid Waste Disposal Log," ORNL Computer Report, PCS-0673.

6. "Radioactive Waste Management Site Plan - ORNL," updated 1977 (available from OR).

7. ERDA-1538, "Final Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington," December 1975.

8. BNWL-MA-88, "Resource Book - Disposition (D&D) of Retired Contaminated Facilities at Hanford," August 1975.

9. RHO-CD-27-3Q, "Summary of Radioactive Solid Waste Burials in the 200 Areas During the First Three Quarters of 1977," J. D. Anderson and B. E. Porcurba, December 7, 1977.

10. "Radioactive Waste Management Site Plan - Hanford," updated 1977 (available from RL).

11. ERDA-1536, "Final Environmental Statement, Waste Management Operations, Idaho National Engineering Laboratory, Idaho," September 1977.

12. IDO-10054(77), "Radioactive Waste Information 1977, Summary and Record to Date."

13. IDO-10055(77), "Radioactive Waste Management Information for 1977."

14. WMP-77-3, "History of Buried Transuranic Waste at INEL," D. H. Card, March 1977.

15. "Radioactive Waste Management Site Plan - INEL," updated 1977 (available from ID).

16. "Reports of the DOE Solid Waste Information Management System (SWIMS) (available from ID).

17. E. L. Albenesius, H. E. Hootman, "Characterize TRU Waste Inventories and Relate Characterization to Proposed Criteria," TRU Waste Form and Package Criteria Meeting, pp. 49-60, SAND 77-1178, August 1977.

18. E. L. Albenesius, W. C. Reinig, "Long Range Management of Transuranium-Contaminated Solid Wastes at Savannah River," Proceedings of the Seminar on the Management of Plutonium-Contaminated Solid Wastes, Marcoule, France, 1974, OECD, 1976.

19. M. O. Boersma, H. E. Hootman, P. H. Permar, "Development of an Integrated Facility for Processing TRU Wastes at the Savannah River Plant," paper presented at NEA-IAEA Technical Seminar on the Treatment, Conditioning and Storage of Solid Alpha-Bearing Wastes and Cladding Hulls, Paris, France, December 6-7, 1977.

20. J. W. Fenimore, R. L. Hooker, "The Assessment of Solid Low-Level Waste Management at the Savannah River Plant," DPST-77-300, August 1977.

21. J. H. Horton, J. C. Corey, "Storing Solid Radioactive Wastes at the Savannah River Plant," DP-1366, June 1976.

22. SRO-TWM-77-1, "Integrated Radioactive Defense Waste Management Plan," Savannah River Plant, Aiken, S.C., July 1977.

Annex 1

DATA ON WASTES STORED AT THE IDAHO NATIONAL ENGINEERING LABORATORY

April 23, 1978

Mr. J. B. Whitsett, Chief
Radioactive Waste Programs Branch
Idaho Operations Office - DOE
Idaho Falls, ID 83401

TRU WASTE DATA - Duf-73-78

Ref.: J. P. Hamric ltr to L. P. Duffy, same subject, Mar. 22, 1978

Dear Mr. Whitsett:

The referenced letter requested that TRU waste data be furnished for the WIPP Steering Committee. The following information and attached tables fulfill that request. The data are furnished in the same sequences as requested in the referenced letter.

(1) The information presently available on TRU waste is provided by the Waste Management Information System (WMIS) and the Transuranic Contaminated Waste Container Information System (TCWCIS). The start of the WMIS data file presently coincides with the initiation of retrievable storage at INEL (10/70) and the TCWCIS started in September 1971.

The WMIS data base includes the following data for each solid waste shipment: waste generator and building number, gross volume, gross weight, curie content, type and number of containers, unit container volume, waste description, nuclide identification and storage or disposal location. Routine monthly reports include disposed waste by nuclides, stored waste by nuclides, waste compaction data, number of stored or disposed containers, and detailed and summary reports by generator or disposal/storage location.

All retrievably stored waste, both contact and remote-handled, are included in the WMIS. The first year of data for retrievable storage is not available in the TCWCIS. The data available at the present time on the subsurface disposed TRU are limited to hand tabulations of quantities shipped from Rocky Flats plant and estimations of Plutonium quantities.

(2) Table I lists the quantities of TRU waste in each of the three requested categories. The retrievable storage data are derived from the WMIS data bank. The subsurface volume data are based on the information published in IDO-10055 (77) and have been modified to reflect the retrieval operations through 12-31-77. The quantity

listed for the Transuranic Disposal Area reflects the >10 nCi/gm TRU portion of the total waste disposed on Pad-A. Table II lists the volume projections for TRU waste through 10-1-84, based on the waste generator's forecasts. There is no projected subsurface disposal of TRU.

(3) The data for TRU waste presently in retrievable storage are the container volumes and are considered to be accurate within ± 10%. The projected container volumes for contact-handled TRU is ± 30% based on generator forecasts. For remote-handled TRU (ILTSF), the projected volume may vary ± 50%. This projection includes the first years waste from SAREF. The subsurface disposed TRU quantities are container volumes, based on tabulations of containers shipped, and do not reflect a review of waste shipment records. The disposed volume probably is accurate within ± 30%. However, due to container degradation, the mixing of waste with soil along with the TRU waste generation associated with retrieval operations; the total TRU retrieved volume may be a factor of 2 to 3 larger than the original waste volume.

(4) The WMIS data are published annually by DOE-ID. The documents are:
IDO-10054 (77) Radioactive Waste Management Information 1977 Summary and Record to Date.
IDO-10055 (77) Radioactive Waste Management Information for 1977.

The TCWCIS data are not published formally; however, several tabulations from this system are attached. Another information source is "History of Buried Transuranic Waste at INEL," WMP-77-3, March 1977, J.H. Card. A review of available past data records has been initiated with the objective of producing a WMIS type data base for all solid waste prior to October 1970. Also some additional Rocky Flats drum logs may allow the TCWCIS data base to be extended back to include the TRU waste of 1969-1971.

(5) The time and costs required to obtain significantly more detailed waste characterization data are dependent upon the scheduling of the project relative to the current waste retrieval operations. It is anticipated that upon completion of the Initial Drum Retrieval (IDR) project, the TSA-1 will be opened for a visual inspection of the exterior surfaces of the waste containers. This operation could also be the first step in obtaining retrievable containers for waste characterization. Also the Early Waste Retrieval (EWR) project, currently scheduled through December 1973 provides the basic containment structure and equipment for the characterization project. If the waste characterization project could be scheduled to operate concurrently with the final portion of the EWR project or directly afterwards, the costs of reactivating a mothballed EWR facility would be circumvented.

Utilizing the TSA-1 container inspection program to obtain the drums and an active EWR facility as a basic containment facility, it is anticipated that the costs of the waste characterization program would be 375,000 dollars and require 4 months of operation. A separate entry into the TSA to obtain the drums and reactivation of the EWR facility to conduct the waste characterization would add 2 months and 100-125,000 dollars to the program.

Another area of investigation which is very critical to the waste volume shipped to WIPP is the amount and degree of Plutonium soil contamination surrounding the subsurface waste. It is proposed that core samples be obtained in and around the early waste pits and trenches to better quantify the soil volume that will have to be processed. It is estimated that such a project could be accomplished for approximately 100,000 dollars.

The specifications for current waste packages are given in Appendix A. These specifications are applicable to drummed waste received after December 1972 and boxed waste received after June 1972. Consequently, it is estimated that TSA-1 and TSA-4 contain 1262 boxes which were not fiberglassed and 60,119 drums without liners.

Table III lists the isotopic composition by weight percent for the TRU nuclides in the contact-handled TRU waste. Table IV gives the average weight for the boxes and drums in the contact-handled TRU waste by year of storage. The increase in drum weight for the period of 1970-1977 is very significant and probably the result of better package utilization. Table V lists the combustibility and compactibility for the contact-handled TRU waste. Utilizing normal compaction and incinerating techniques, about 71% of the waste is not treatable. Table VI gives the plutonium loading in the Rocky Flats boxes and runs by year of storage. Again, the drums show a significant increase in Plutonium content in the latest waste (1970-1977).

A sampling of the contact-handled TRU waste by container content is given in Table VII. This table contains the data from several waste generators. Consequently, duplicate or near duplicate content descriptions may be encountered.

No data are currently available on nonradioactive toxic constituents in the TRU waste. Some information may be obtained from our record search.

However, the initial indications are that any information of this type will be very limited and superficial.

Very truly yours,

L. P. Duffy, Manager
Waste Management Program

HMB:lf

Attachment - Appendix A

cc: R. W. Kiehn, EG&G Idaho

TABLE I

TRU WASTE AT INEL
AS OF 12/31/77

Storage Area	Volume m^3	Volume Cu. ft.	Curies	Box	Barrel	Bin	Grams Pu	Grams Am-241	Grams U-233
Retrievably Stored - Contact-Handled TRU									
TSA #1 (1) 10/70-10/75	27,450	969,260	120,900	4,241	64,519	83	148,400	11,290	40,590
TSA #2 10/75-12/77	4,583	161,825	44,390	787	8,728	78	49,480	2,230	15,040
TSARI (2) 1/77-12/77	2,006	70,832	9,469	-	9,378	11	12,140	946	-
TOTALS	34,039	1,201,917	174,759	5,028	82,625	172	210,020	14,466	55,630
Retrievably Stored - Remote-Handled TRU									
11 TSF (3) 11/76-12/77	9	304	54	-	76	-	19	-	-
Subsurface Disposal TRU						Cartons			
SDA (4) 1954-10/70	59,522	2,102,000	191,000	6,042	182,250	12,783	344,000	-	-
TDA (5)	7,190	253,800	3,494	1,243	15,000	-	11	-	-

(1) Transuranic Storage Area - 20 year retrievable storage
(2) Transuranic Storage Area - Retrieved waste from subsurface disposal
(3) Intermediate Level Transuranic Storage Area - Intermediate gamma TRU waste
(4) Subsurface Disposal Area - Shallow land burial TRU wastes
(5) Transuranic Disposal Area - Pad disposal of >10 nCi/gm TRU

TABLE II

TRU WASTE AT INEL

As of 10/1/84

Retrievably Stored - Contact-Handled TRU			
As of 12/31/77	34,039 m^3	or	1,201,917 cu. ft.
Projection thru 1984	23,641 m^3	or	834,766 cu. ft.
Totals	57,680 m^3	or	2,036,682 cu. ft.
Retrievably Stored - Remote-Handled TRU			
As of 12/31/77	9 m^3	or	318 cu. ft.
Projection thru 1984	400 m^3	or	14,124 cu. ft.
Totals	409 m^3	or	14,442 cu. ft.
Subsurface Disposal TRU			
As of 12/31/77	59,522 m^3	or	2,102,000 cu. ft.
Projection thru 1984	0		0
Totals	59,522 m^3	or	2,102,000 cu. ft.

TABLE III

ISOTOPIC COMPOSITION OF TRU NUCLIDES IN TSA WASTE

Nuclide	Weight %
Am-241	5.15
Pu-238	0.34
Pu-239	69.57
Pu-240	4.36
Pu-241	0.30
Pu-242	0.01
U-233	20.27

TABLE IV

AVERAGE WEIGHT TRU WASTE CONTAINERS

Drums

	# Drums	Weight (lbs)	Average Weight
1970*	9,378	1,787,825	190.6
1971*	2,726	871,646	319.6
1972	15,690	5,641,154	363.2
1973	9,097	3,000,723	329.9
1974	6,860	2,444,782	356.9
1975	8,782	3,261,068	371.3
1976	4,279	1,596,536	372.4
1977	3,464	1,471,801	424.9
	60,266	19,975,565	331.5 (45 lbs/ft^3)

Boxes

	# Boxes	Weight (lbs)	Average Weight
1971*	562	1,205,060	2183.1
1972	975	3,063,110	3141.7
1973	944	2,813,612	2980.0
1974	774	2,006,220	2692.0
1975	613	1,316,289	2566.9
1976	492	1,359,950	2764.1
1977	514	1,415,634	2754.2
	4,764	13,179,875	2766.6 (25 lbs/ft^2)

*Partial year's data.

TABLE V

COMBUSTIBILITY AND COMPACTIBILITY - TSA WASTE

9/71 - 12/77*

Unit Count	Total	Comp Comb	Comp NComb	NComp Comb	NComp NComb
Drums	48,917	15,677	1,190	408	31,842
Boxes	4,766	404	423	205	3,734
Bins	161	160	1	-	-
Volume (m^2)					
Drums	10,374	3,325	252	87	6,710
Boxes	14,849	1,259	1,318	639	11,633
Bins	547	544	3	-	-
Total	25,770	5,128	1,573	726	18,343
%		19.9	6.1	2.8	71.2

*Does not include retrieved wastes.

TABLE VI

AVERAGE PLUTONIUM LOADING ROCKY FLATS WASTE

Drums

Year	# of Units	Weight (gms)	Gms Pu/ Container
1971*	2,726	2,555	0.94
1972	15,690	27,744	1.76
1973	8,978	12,705	1.42
1974	6,119	28,595	4.67
1975	3,556	30,894	8.69
1976	2,765	15,519	5.61
1977	2,660	27,198	10.2
TOTAL	48,494	145,210	3.42 (Ave.)

Boxes

Year	# of Units	Weight (gms)	Gms Pu/ Container
1971*	552	769	1.39
1972	975	5,383	5.52
1973	944	11,554	12.24
1974	776	6,612	8.39
1975	302	1,047	3.47
1976	492	1,858	3.78
1977	466	4,993	10.71
TOTAL	4,507	32,116	7.13 (Ave.)

*Partial year's data.

TABLE VII

TRANSURANIC STORAGE AREA DATA
9/71 thru 12/76
TABULATED BY CONTENT CODE

Content Description	Drums	Volume Cu. Ft.	Boxes	Volume Cu. Ft.	Weight lbs.	Pu Grams	AM Grams
Not Recorded - Unknown	1,903	21,088			392,805	3,241	32
First Stage Sludge	4,957	37,821			2,537,489	26,224	10,249
Second Stage Sludge	6,472	48,842			3,469,429	1,523	16
Organic Set Ups (Oil Solids)	3,366	27,581			1,784,055	1,837	0
Special Set Ups (Cement)	851	6,812			508,472	910	7
Evaporated Salts	12	107	1	112	10,692	6	7
Combustibles (Rags, Gloves, Poly)	865	6,623			164,845	-0-	-0-
Non-compressible, Non-combust.	777	5,762			184,474	-0-	-0-
Solidified Grinding Sludge, Etc.	41	305			9,880	-0-	-0-
Solid Binary Scrap Powder, Etc.	12	88			2,950	-0-	-0-
Dirt	135	993			83,535	-0-	-0-
Sludge	23	169			6,800	-0-	-0-
Alpha Hot Cell Waste	40	160			3,674	16	-0-
American Process Residue	120	897			43,997	150	-0-
Sludge, Filter	1	7			145	14	-0-
Cemented Sludge	73	537			19,072	1,061	-0-
Graphite	758	5,619			197,179	6,274	-0-
Graphite Cores	32	235			8,327	405	-0-
Benelex and Plexiglas	16	118	16	1,792	63,728	67	-0-
Graphite Scarfings	16	118			3,827	81	-0-
Graphite Heels	4	41	1	112	3,500	783	-0-
Tantalum	192	1,412			48,365	2,372	18
Paper and Rags - Dry	4,945	36,835	323	36,176	1,576,644	2,662	91
Filters, Absolute (8x8)	110	809			16,912	215	7
Paper and Rags - Moist	7,293	53,738	8	896	1,455,248	2,212	11
Plastics, Teflon, Hash, PVC	1,832	13,625	9	1,000	333,056	1,145	39
Insulation & CWS Filter Media	253	1,860	78	8,736	195,774	6,501	0
Leaded Rubber Gloves & Aprons	509	3,743			172,042	14,025	16
Insulation	239	1,761	1	112	36,138	217	0
Insulation Heel	1	11			411	199	0
Crucible, Lead	30	221			11,448	91	0
Brick, Fire	886	6,519	24	2,688	387,140	2,789	0
Grit	5	37			2,220	21	0
Blacktop Concrete Dirt and Sand	937	6,890	81	9,072	669,417	647	0

TABLE VII (Continued)

Content Description	Drums	Volume Cu. Ft.	Boxes	Volume Cu. Ft.	Weight lbs.	Pu Grams	AM Grams
Oil Dirt Residues From Incinerator	11	81			4,209	10	0
Cement Insul. & Filter Media	206	1,515	2	224	56,971	5,253	17
Crucible and Sand	1	7			282	35	0
Sand, Slag and Crucibles	6	67			2,700	1,164	0
Sand, Slag, and Crucible Heels	8	59			1,707	1,468	0
Electrorefining Salt	2	15			476	24	0
Ash, Incinerated (Virgin)	8	59			3,212	359	0
Soot	13	96			2,826	702	0
Resin, Ion Column Unleached	29	266			11,528	2,716	0
Resin, Leached	6	59			2,389	263	0
Resin, Leached and Cemented	139	1,022			40,500	2,964	21
Glass	761	5,881	1	112	190,594	3,841	16
Raschig Rings, Unleached	1,096	8,060			215,924	11,562	0
Raschig Rings, Leached	22	166			6,545	46	0
Washables, Rubber, Plastics	6	67			2,813	81	0
Gloves, Drybox	53	510			19,533	759	0
Plexiglass and Benelex	48	364			12,971	90	0
Metal Scrap (Non SS)	1,669	12,718	2,589	289,702	7,981,075	27,319	43
Metal, Leached (Non SS)	457	3,361	1	112	141,841	13,531	3
Filters CWS	58	460	466	52,192	886,546	5,548	13
Equipment Boxes			12	1,344	12,687	88	0
High Level Acid	235	1,728			75,815	17	0
High Level Caustic	691	5,081			229,878	20	0
High Level Sludge/Cement	1,998	14,692			1,260,952	7	0
16 nCi/gm Non-Combustible	1	7			335	0	0
Contaminated Soil			36	4,032	160,002	1	0
LSA 100 nCi/gm Combustible	103	757			23,168	0	0
LSA 100 nCi/gm Non-Combustible	110	609			22,782	0	0
LSA Paper, plastics, Etc.	352	2,611	6	672	82,244	1	0
LSA Metal, Glass, Etc.	110	809	334	37,492	918,936	68	0
Concrete, Asphalt, Etc.	704	5,233	171	10,426	1,022,373	326	0
Wood	24	176	54	6,055	123,892	467	0
Bldg. 776 Process Sludge	5	37	19	2,128	89,887	23	0
Laundry Sludge			11	1,232	46,980	43	0
Equipment	1	7			178	11	0
Dirt	470	3,456			255,463	0	0
Sludge	296	2,177	8	896	176,751	64	0
TOTALS	47,404	363,658	4,252	467,323	28,492,732	154,559	10,606

NUCLIDE DISTRIBUTION - TSA STORED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Ac-227	-0-	-0-	-0-	-0-	7.290E-02	-0-	-0-	7.290E-02	4.273E-07	-
Am-241	6.630E+03	1.193E+04	7.351E+03	4.574E+03	5.600E+03	3.722E+03	5.936E+03	4.574E+04	2.681E-01	26.8
Am-243	-0-	1.000E-04	-0-	-0-	9.250E-04	6.117E-05	-0-	1.086E-03	6.366E-09	-
Ce-144	-0-	-0-	-0-	-0-	-0-	4.200E-01	-0-	4.200E-01	2.462E-06	-
Cf-252	-0-	-0-	-0-	-0-	1.342E-04	-0-	-0-	1.342E-04	7.866E-10	-
Cm-244	-0-	6.000E-01	1.112E+03	-0-	4.854E-01	3.640E-02	-0-	1.113E+03	6.524E-03	.6
Co-58	-0-	-0-	8.300E-01	-0-	-0-	-0-	-0-	8.300E-01	4.865E-06	-
Co-60	-0-	-0-	6.200E+00	-0-	-0-	-0-	-0-	6.200E+00	3.634E-05	-
Cr-51	-0-	-0-	1.450E+00	-0-	-0-	-0-	-0-	1.450E+00	8.499E-06	-
Cs-137	2.468E+00	-0-	3.000E+00	-0-	1.882E-01	4.200E-01	-0-	6.076E+00	3.562E-05	-
Eu-152	-0-	-0-	-0-	-0-	1.690E-01	-0-	-0-	1.690E-01	9.906E-07	-
H-3	-0-	-0-	-0-	-0-	-0-	8.541E-06	-0-	8.541E-06	5.006E-11	-
HAP	-0-	-0-	8.495E-02	-0-	-0-	-0-	-0-	8.495E-02	4.979E-07	-
HFP	2.743E-01	1.000E-01	3.750E-01	2.160E+01	1.717E+01	1.897E+01	1.626E+01	7.475E+01	4.382E-04	-
Mn-54	-0-	-0-	1.400E-01	-0-	-0-	-0-	-0-	1.400E-01	8.206E-07	-
Np-237	-0-	6.445E-04	-0-	-0-	1.206E-04	-0-	7.050E-06	7.732E-04	4.532E-09	-
Pm-147	-0-	-0-	-0-	-0-	4.640E+02	-0-	-0-	4.640E+02	2.720E-03	-
Pu-238	2.334E+01	4.919E+01	5.030E+01	5.797E+01	2.462E+03	4.712E+02	1.301E+04	1.612E+04	9.449E-02	9.4
Pu-239	7.747E+02	1.641E+03	1.726E+03	1.921E+03	2.534E+03	8.985E+02	2.220E+03	1.172E+04	6.870E-02	6.9

NUCLIDE DISTRIBUTION - TSA STORED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Pu-240	1.902E+02	4.029E+02	4.252E+02	4.718E+02	6.185E+02	2.144E+02	5.331E+02	2.856E+03	1.674E-02	1.6
Pu-241	6.294E+03	1.367E+04	1.390E+04	1.639E+04	2.068E+04	5.611E+03	1.539E+04	9.194E+04	5.389E-01	53.9
Pu-242	1.075E-02	2.213E-02	2.341E-02	3.858E-02	4.702E-02	1.743E-02	4.643E-02	2.058E-01	1.206E-06	-
Ra-228	-0-	-0-	-0-	-0-	2.750E-01	-0-	-0-	2.750E-01	1.612E-06	-
Ru-106	-0-	-0-	-0-	8.000E-01	-0-	-0-	-0-	8.000E-01	4.689E-06	-
Sr-90	-0-	-0-	-0-	-0-	-0-	3.000E-01	-0-	3.000E-01	1.758E-06	-
Tc-99	-0-	-0-	-0-	-0-	1.390E-03	-0-	-0-	1.390E-03	8.148E-09	-
Th-232	-0-	-0-	1.202E-03	5.665E-02	6.123E-02	4.201E-02	5.886E-03	1.670E-01	9.789E-07	-
U-232	-0-	-0-	-0-	3.483E+00	3.537E+00	1.999E+00	2.604E-01	9.279E+00	5.439E-05	-
U-233	-0-	1.000E-02	2.562E+00	2.003E+02	1.959E+02	1.132E+02	1.475E+01	5.267E+02	3.037E-03	.3
U-234	-0-	-0-	1.098E-04	1.658E+00	1.674E+00	-0-	-0-	3.332E+00	1.953E-05	-
U-235	1.778E-05	-0-	2.390E-04	1.141E-04	1.076E-04	1.446E-04	5.902E-04	1.293E-03	7.579E-09	-
U-236	-0-	-0-	1.750E-06	2.639E-04	2.666E-04	-0-	-0-	5.323E-04	3.120E-09	-
U-238	1.332E-06	1.465E-05	4.040E-05	3.433E-05	1.363E-03	2.740E-04	2.423E-04	1.970E-03	1.155E-08	-
Un-Id-B & G	-0-	-0-	1.400E+00	-0-	-0-	-0-	-0-	1.400E+00	8.206E-06	-
TOTAL	1.392E+04	2.769E+04	2.458E+04	2.365E+04	3.258E+04	1.105E+04	3.712E+04	1.706E+05		

NUCLIDE DISTRIBUTION - DISPO_ WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Pu-240	9.000E-04	1.775E-03	6.975E-02	1.312E-01	9.430E-03	1.360E-03	1.026E-02	2.247E-01	1.148E-07	-
Pu-241	1.000E-04	6.062E-02	3.199E-01	4.646E+00	3.227E-01	3.564E-02	2.885E-02	5.414E+00	2.734E-06	-
Pu-242	-0-	9.777E-08	5.557E-07	1.088E-05	7.709E-07	1.065E-07	6.979E-08	1.248E-05	6.303E-12	-
Ra-226	5.576E+00	1.250E+00	2.299E-01	1.000E+00	3.382E-08	2.021E-01	-0-	8.258E+00	4.171E-06	-
Rb-86	-0-	4.210E+00	4.160E+00	6.322E+01	5.851E+00	-0-	-0-	7.744E+01	3.911E-05	-
Ru-103	2.670E-02	9.558E+03	1.076E+00	9.644E-02	2.033E+00	8.026E-02	2.980E-02	9.561E+03	4.829E-03	.5
Ru-106	8.307E+00	1.093E+01	1.989E+02	3.379E+02	2.614E+02	1.358E+02	1.530E+02	1.106E+03	5.506E-04	-
Sb-125	1.931E+01	1.915E+00	8.932E+01	1.074E+02	7.997E+01	6.260E+01	6.833E+01	4.288E+02	2.166E-04	-
Sc-46	4.948E+00	3.121E+00	-0-	-0-	-0-	-0-	-0-	8.069E+00	4.075E-06	-
Sm-153	-0-	-0-	-0-	-0-	-0-	3.302E+00	-0-	3.302E+00	1.677E-06	-
Sr-89	-0-	-0-	-0-	-0-	-0-	1.008E-01	-0-	1.008E-01	5.091E-08	-
Sr-90	1.670E+01	2.103E+01	1.872E+02	1.579E+03	1.764E+03	2.017E+02	2.546E+02	4.104E+03	2.073E-03	.2
Ta-182	-0-	-0-	-0-	-0-	-0-	7.310E-02	-0-	7.310E-02	3.692E-08	-
Tc-99	-0-	-0-	-0-	-0-	-0-	3.961E-07	3.200E-09	3.993E-07	2.017E-13	-
Th-230	-0-	-0-	-0-	-0-	5.405E-09	-0-	-0-	5.405E-09	2.730E-15	-
Th-232	2.180E-04	1.090E-07	5.450E-05	4.695E-05	1.091E-02	9.610E-08	3.646E-04	1.159E-02	5.854E-09	-
U-232	-0-	-0-	-0-	-0-	8.360E+00	-0-	-0-	8.360E+00	4.222E-06	-
U-233	-0-	6.000E-06	-0-	1.040E-08	-0-	9.527E-03	-0-	9.533E-03	4.815E-09	-
U-234	3.710E-04	-0-	1.857E-05	1.123E-05	1.760E-04	6.178E-04	2.782E-02	2.901E-02	1.465E-08	-

NUCLIDE DISTRIBUTION - DISPOSED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% >.1
U-235	1.018E-01	1.072E-01	6.434E-02	6.481E-02	7.012E-02	2.764E-02	4.606E-02	4.820E-01	2.434E-07	-
U-236	1.584E-06	-0-	-0-	-0-	2.280E-06	3.170E-05	2.049E-04	2.405E-04	1.215E-10	-
U-238	7.735E+00	8.274E+00	4.723E+00	4.875E+00	5.211E+00	1.768E+00	3.147E+00	3.575E+01	1.806E-05	-
Un-Id-Alpha	-0-	3.020E-01	4.368E-01	1.604E-02	1.791E-03	-0-	-0-	7.566E-01	3.821E-07	-
Un-Id-B & G	2.864E+03	1.782E+04	8.048E+01	2.882E+01	1.056E+01	1.318E+02	8.995E+00	2.094E+04	1.058E-02	1.0
[illegible]-107	5.298E+00	-0-	-0-	-0-	-0-	-0-	-0-	5.298E+00	2.676E-06	-
Zn-65	4.272E+00	-0-	-0-	3.665E+02	4.000E-01	1.701E+00	5.960E-02	3.669E+02	1.853E-04	-
Zr-95	5.130E-02	1.374E+05	1.458E+01	-0-	2.318E+00	3.199E+00	5.295E+01	1.375E+05	6.944E-02	6.9
Zr-Nb-95	3.554E+04	2.736E+00	1.237E+02	1.536E+02	1.142E+02	8.912E+01	1.008E+01	3.603E+04	1.820E-02	1.8
TOTAL CURIES	3.509E+05	2.147E+05	3.399E+05	1.832E+04	1.319E+04	2.108E+05	8.241E+05	1.980E+06		

NUCLIDE DISTRIBUTION - ILTSF (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
MFP	-0-	-0-	-0-	-0-	-0-	1.890E+01	2.843E+01	4.733E+01	9.443E-01	94.4
Pu-238	-0-	-0-	-0-	-0-	-0-	-0-	5.193E-02	5.193E-02	1.036E-03	.1
Pu-239	-0-	-0-	-0-	-0-	-0-	2.526E+00	1.479E-01	2.674E+00	5.335E-02	5.3
Pu-240	-0-	-0-	-0-	-0-	-0-	-0-	6.135E-04	6.135E-04	1.224E-05	-
Pu-241	-0-	-0-	-0-	-0-	-0-	-0-	5.975E-02	5.975E-02	1.192E-03	.1
Pu-242	-0-	-0-	-0-	-0-	-0-	-0-	4.477E-06	4.477E-06	8.933E-08	-
U-233	-0-	-0-	-0-	-0-	-0-	-0-	1.733E-04	1.733E-04	3.458E-06	-
U-235	-0-	-0-	-0-	-0-	-0-	-0-	4.247E-05	4.247E-05	8.474E-07	-
TOTAL	-0-	-0-	-0-	-0-	-0-	2.143E+01	2.869E+01	5.012E+01		

NUCLIDE DISTRIBUTION - ILTSF (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% >.1
Eu-155	-0-	-0-	-0-	2.422E+01	2.154E+01	9.000E-02	2.001E+01	6.586E+01	3.326E-05	-
Fe-59	2.935E+04	6.701E+02	5.918E+02	1.440E+03	5.630E+02	1.865E+04	6.319E+04	1.145E+05	5.703E-02	5.8
H-3	5.000E-01	-0-	2.300E-01	-0-	-0-	-0-	-0-	7.300E-01	3.687E-07	-
Hf-181	2.805E-01	-0-	-0-	-0-	4.882E-02	7.310E-02	5.960E-02	4.620E-01	2.333E-07	-
I-131	1.569E+00	-0-	-0-	-0-	8.167E-03	8.800E-01	5.500E+00	7.957E+00	4.019E-06	-
La-140	3.533E-01	3.775E-01	-0-	-0-	2.053E+00	5.890E+01	-0-	6.168E+01	3.115E-05	-
MAP	2.219E+00	1.083E+01	2.309E+04	9.224E+01	1.367E+01	3.074E+01	1.009E+02	2.334E+04	1.179E-02	1.2
MFP	6.709E+01	3.037E+01	1.292E+02	7.614E+02	2.866E+02	2.133E+02	2.615E+02	1.750E+03	8.838E-04	-
Mn-54	1.241E+00	4.370E+00	2.081E+04	7.201E+01	3.669E+02	2.973E+01	7.391E+04	9.519E+04	4.808E-02	4.8
Mn-56	1.485E+00	2.600E+01	-0-	-0-	5.530E+02	-0-	-0-	5.813E+02	2.936E-04	-
Na-22	-0-	-0-	-0-	-0-	-0-	-0-	1.160E-06	1.160E-06	5.859E-13	-
Na-24	3.537E+00	-0-	-0-	-0-	-0-	2.499E+01	-0-	2.853E+01	1.441E-05	-
Nb-95	3.724E+00	-0-	-0-	3.196E-01	3.096E-01	2.671E+00	5.503E+01	6.205E+01	3.134E-05	-
Ni-59	5.000E+02	1.299E+03	9.931E+02	3.200E+03	-0-	-0-	-0-	5.992E+03	3.026E-03	.3
Np-237	-0-	-0-	6.345E-07	-0-	-0-	4.200E-06	-0-	4.835E-06	2.442E-12	-
Pm-147	-0-	-0-	7.400E-01	-0-	-0-	-0-	-0-	7.400E-01	3.737E-07	-
Po-210	1.100E-01	-0-	-0-	-0-	-0-	-0-	-0-	1.100E-01	5.556E-08	-
Pu-238	-0-	2.101E-04	1.231E-03	1.679E-02	1.183E-03	1.062E-03	2.287E-01	2.492E-01	1.259E-07	-
Pu-239	1.842E-01	8.807E-03	2.467E-01	5.355E-01	1.275E-01	8.660E-03	1.555E-01	1.267E+00	6.494E-07	-

NUCLIDE DISTRIBUTION - DISPOSED WASTE (CURIES)

Nuclide	1971	1972	1973	1974	1975	1976	1977	Total	Fraction	% > .1
Ag-110M	2.330E-02	-0-	-0-	-0-	-0-	2.180E-01	5.960E-02	3.010E-01	1.520E-07	-
Am-241	-0-	1.000E-05	-0-	-0-	1.850E-07	-0-	3.240E-07	1.051E-05	5.308E-12	-
Ba-133	-0-	-0-	-0-	-0-	-0-	4.000E-07	3.400E-08	4.340E-07	2.192E-13	-
Ba-La-140	2.022E+00	8.629E+00	-0-	-0-	1.430E+00	4.368E+01	-0-	5.576E+01	2.816E-05	-
Be-10	4.290E+00	-0-	1.000E+01	-0-	-0-	-0-	-0-	1.429E+01	7.217E-06	-
Bi-210	-0-	-0-	-0-	-0-	-0-	3.930E-08	-0-	3.930E-08	1.985E-14	-
C-14	-0-	-0-	-0-	-0-	-0-	2.870E-07	-0-	2.870E-07	1.449E-13	-
Cd-109	-0-	-0-	-0-	-0-	-0-	-0-	1.180E-06	1.180E-06	5.960E-13	-
Ce-141	2.944E+01	2.789E+04	2.954E+00	1.717E+00	1.895E+00	2.889E+01	1.316E+01	2.797E+04	1.413E-02	1.4
Ce-144	5.465E+01	1.093E+01	4.130E+02	8.047E+02	9.517E+02	3.981E+02	2.092E+03	4.725E+03	2.386E-03	0.2
Cl-36	-0-	-0-	-0-	-0-	-0-	3.970E-08	-0-	3.970E-08	2.005E-14	-
Co-57	-0-	-0-	-0-	-0-	-0-	-0-	1.110E-06	1.110E-06	5.555E-13	-
Co-58	8.477E+00	6.108E+00	3.900E+03	2.079E+00	3.154E-01	3.080E+01	1.061E+05	1.100E+05	5.556E-02	5.5
Co-60	4.610E+04	1.444E+04	2.082E+05	7.662E+03	7.289E+03	4.689E+04	6.217E+04	3.928E+05	1.994E-01	19.8
Cr-51	2.359E+05	5.163E+03	8.003E+04	8.170E+01	2.233E+02	1.512E+05	5.147E+05	9.873E+05	4.986E-01	49.9
Cs-134	2.119E+00	3.288E+00	5.243E+01	6.636E+01	4.619E+01	5.713E+00	1.706E+01	1.932E+02	9.758E-05	-
Cs-137	4.005E+02	2.700E+02	8.947E+02	1.424E+03	5.697E+02	4.726E+02	6.683E+02	4.700E+03	2.374E-03	.2
Eu-152	-0-	-0-	-0-	-0-	1.060E+00	4.308E-01	1.630E+02	1.645E+02	8.308E-05	-
Eu-154	-0-	-0-	-0-	4.199E+01	3.521E+01	5.008E-01	7.656E+01	1.543E+02	7.793E-05	-

Annex 2

INEL CONTAINERS FOR TRU WASTE

STANDARD CONTAINERS

Standardized containers are used at the INEL Radioactive Waste Management Complex (RWMC). These containers are designed to provide safety, integrity, and improved space utilization of the RWMC. The following containers are approved by the Department of Transportation (DOT) and by DOE-10 for use at INEL. DOE-ID will provide the procurement specifications, noted below, upon request.

(1) The DOT 17C 55-gallon drum, per procurement specification S72001, is standard steel drum, constructed of 16-gauge materials, with a removable head (see Figure 1).

(2) The DOT 6M packaging consist of a DOT 17C 55-gallon drum with fiberboard centering media and a DOT spec 2R inner containment vessel (see Figure 2). DOT 6M packaging is acceptable at the INEL for storage only when the drums have no mechanism for venting. This requires the generator to obtain approval for modification to the DOT 6M packaging which may be obtained when the 6M package is shipped inside another DOT approved transport device.

The DOT specification 2R, or equivalent, containment vessel must be made of stainless steel, malleable iron, brass or other material having equivalent physical strength. The vessel shall be less than 25 3/4 inches overall length and have a maximum outside vessel diameter of 5 inches. Ends of the vessel must be fitted with a screw-type closure, flanges of welded or brazed plate. The waste generator must submit the details of the 6M packaging, including 2R containment vessel to DOE-ID and EG&G WMPO for information prior to usage.

(3) The DOT 1/H 30-gallon drum, per procurement specification 572006, is a standard steel drum constructed of 18-gauge material with a removable head (see Figure 3).

(4) Two styles of DOT 7A boxes are acceptable (see Figures 4 and 5). Packaging of transuranic waste per Section V, Table II, requires the box to be coated with 1/8" of fiberglass per procurement specification 572013 as shown on Figure 4.

(a) The DOT 7A wooden box, per procurement specification 572016, is an externally cleated plywood box, normally 4' x 4' x 7' long (see Figure 5). These boxes are being replaced by the box shown in Figure 6.

(b) The DOT 7A wooden box, per procurement specification 572011, is a plywood box with internal stiffeners, normally 4' x 4' x 7' (see Figure 6).

(5) The DOT 7A steel box, per procurement specification 572010, is a rectangular steel box of dimensions 50 3/8" x 58 3/8" x 72 3/8" (see Figure 7). When used as an overpack it will hold eight (8) 17C 55-gallon drums in two (2) layers of four (4) drums each or twelve

(12) 17M 30-gallon drums in two (2) layers of six (6) drums each. This box does not require a security seal when it is used as an overpack, provided each of the DOT approved inner containers is properly sealed.

(6) See Section VIII Exceptions of Special Shipment Requirements for use of containers that do not meet the above criteria.

DOT SPEC. 17C STEEL DRUM (55 gallon)

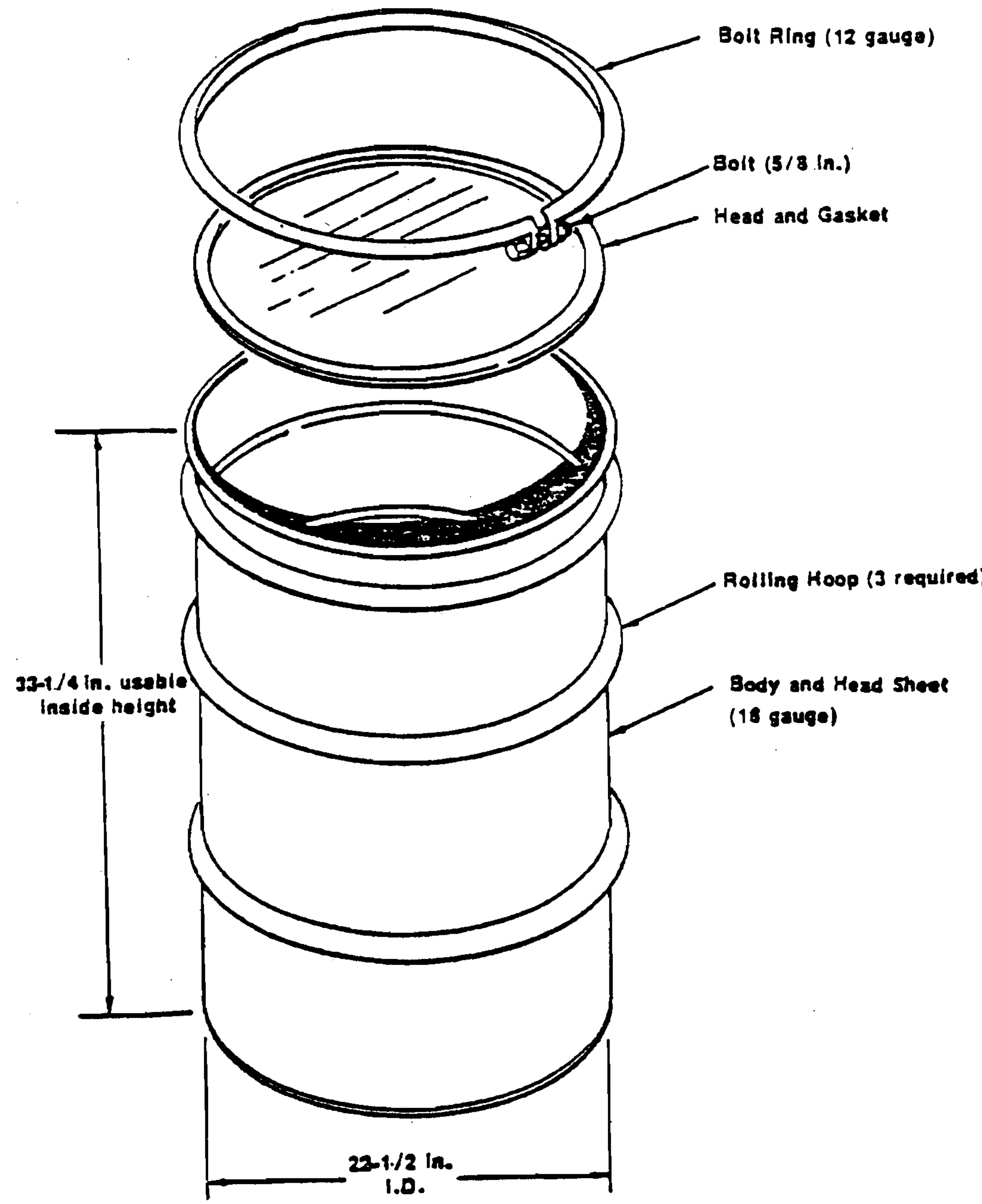


Figure 1

DOT SPEC. 6M Packaging

(CFR 49 § 178.104)

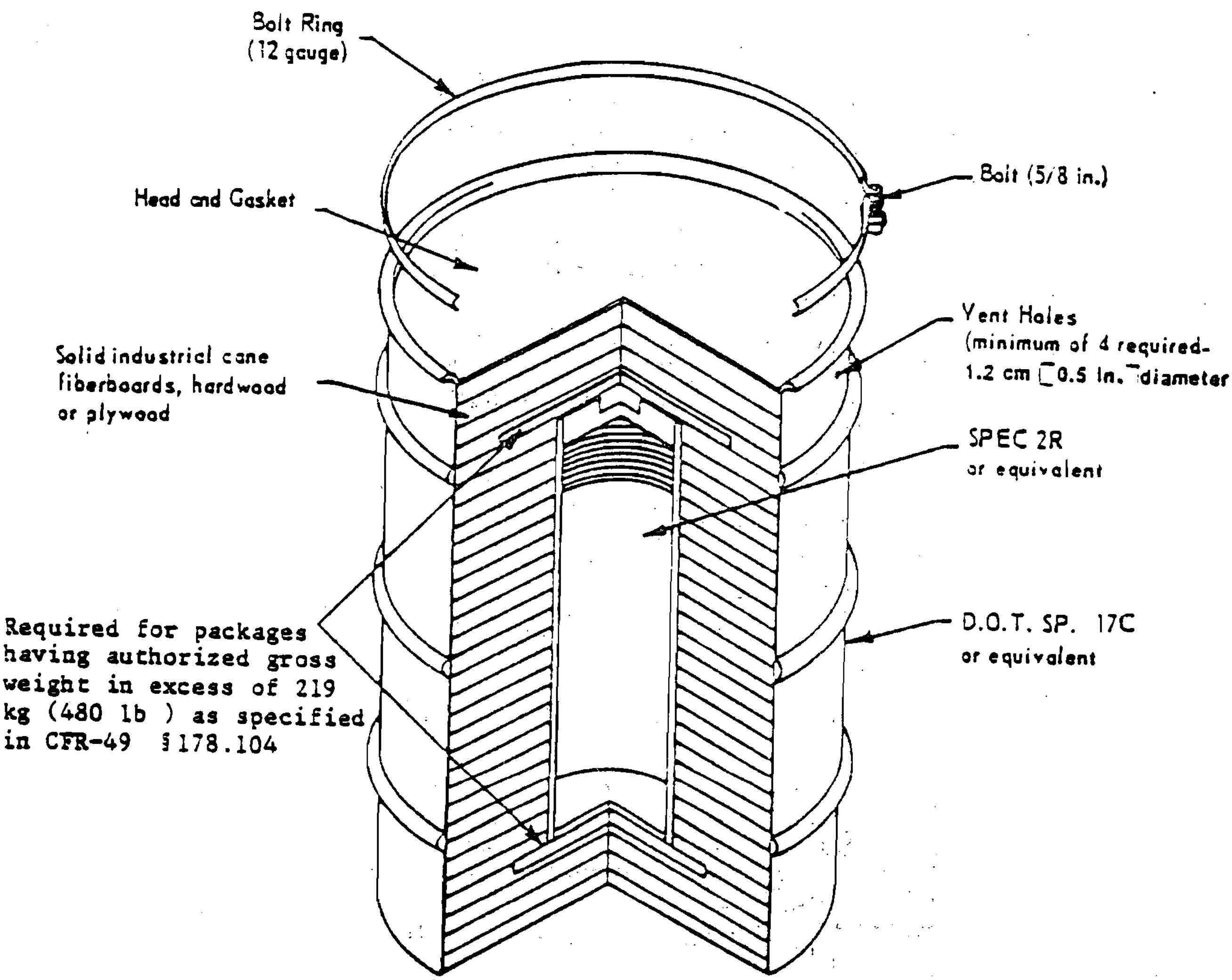


Figure 2

DOT SPEC. 17H STEEL DRUM (30 gallon)

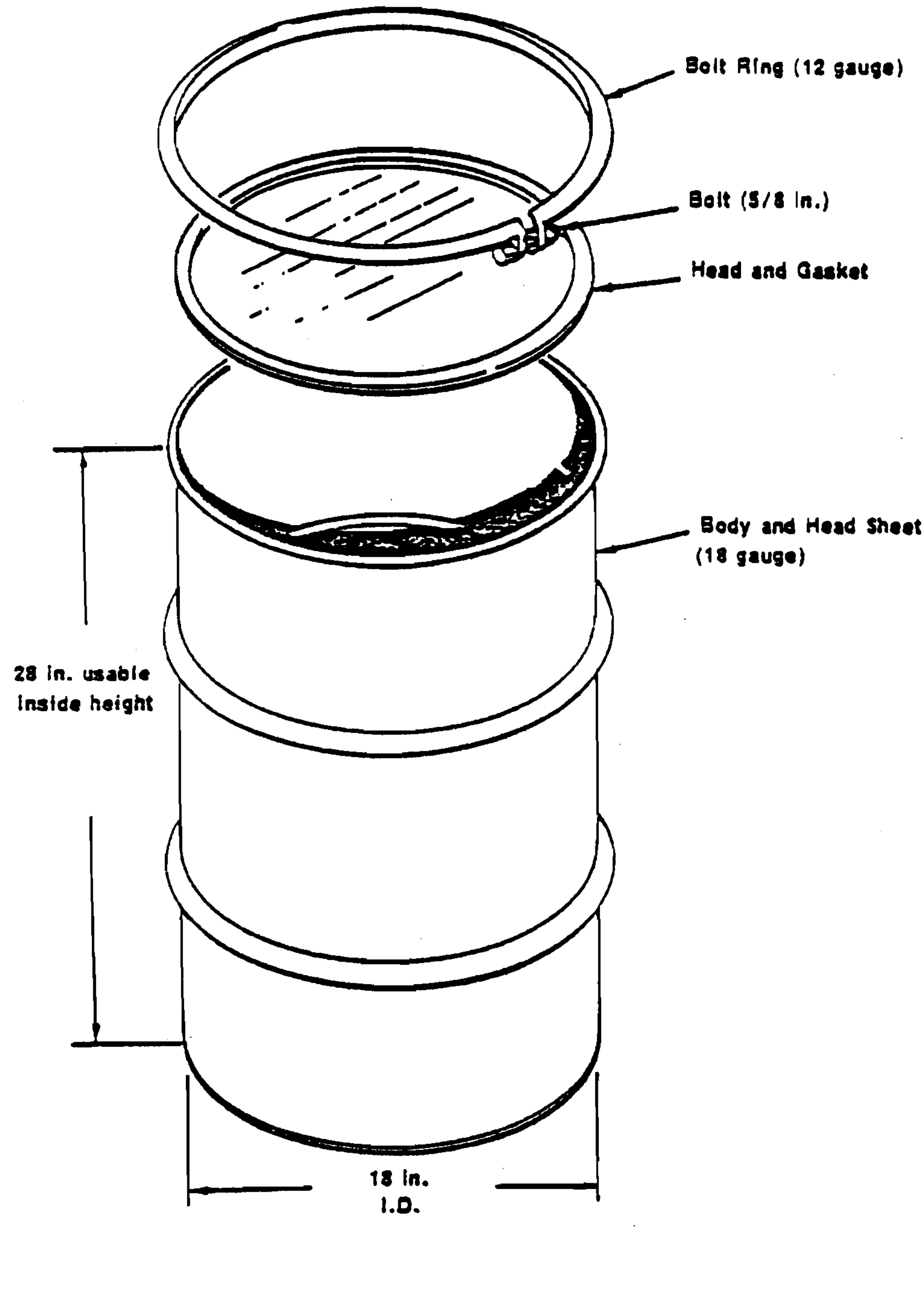
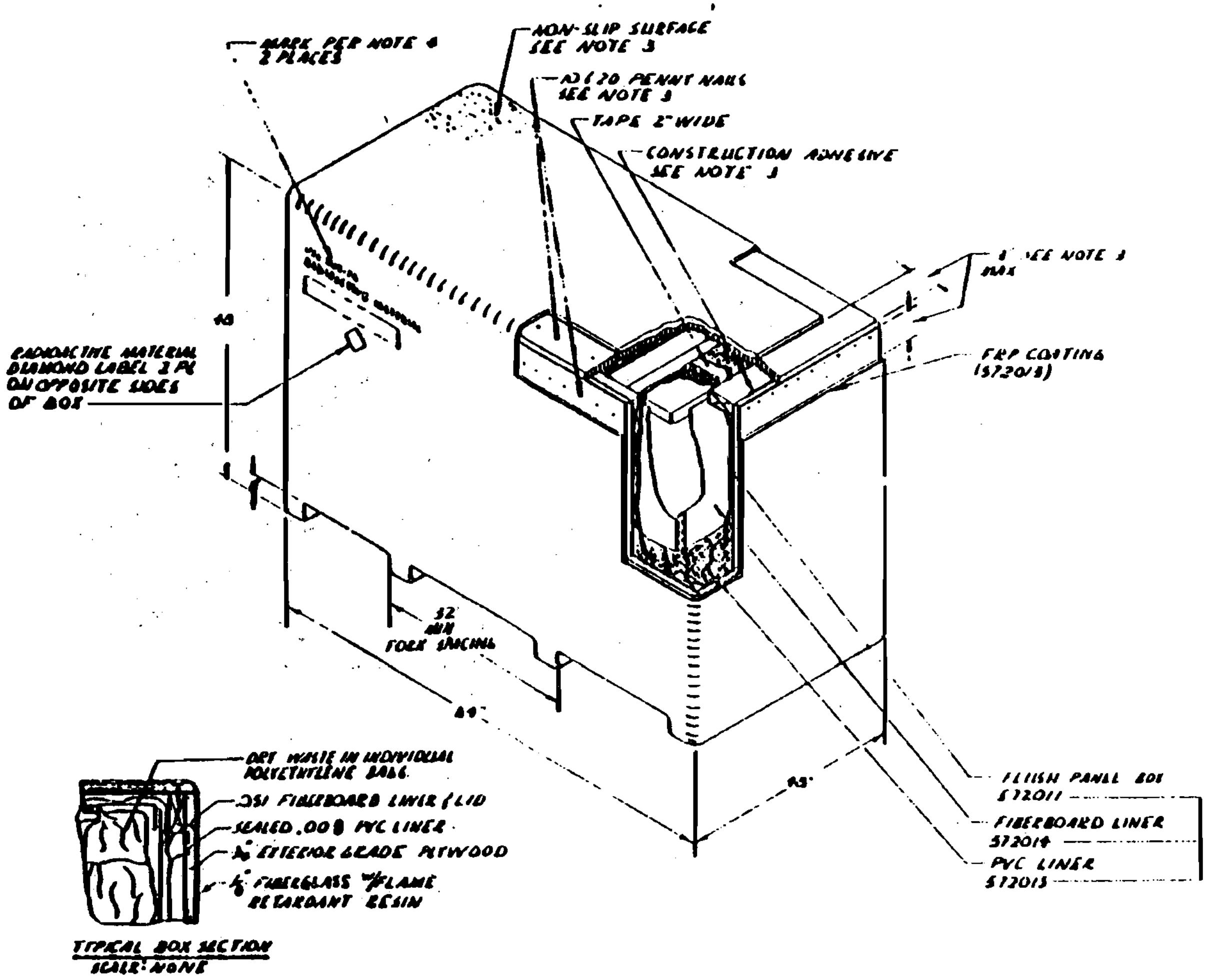


Figure 3

DOT 7A FIBERGLASS REINFORCED FLUSH PANEL OR CLEATED PLYWOOD BOX ASSEMBLY



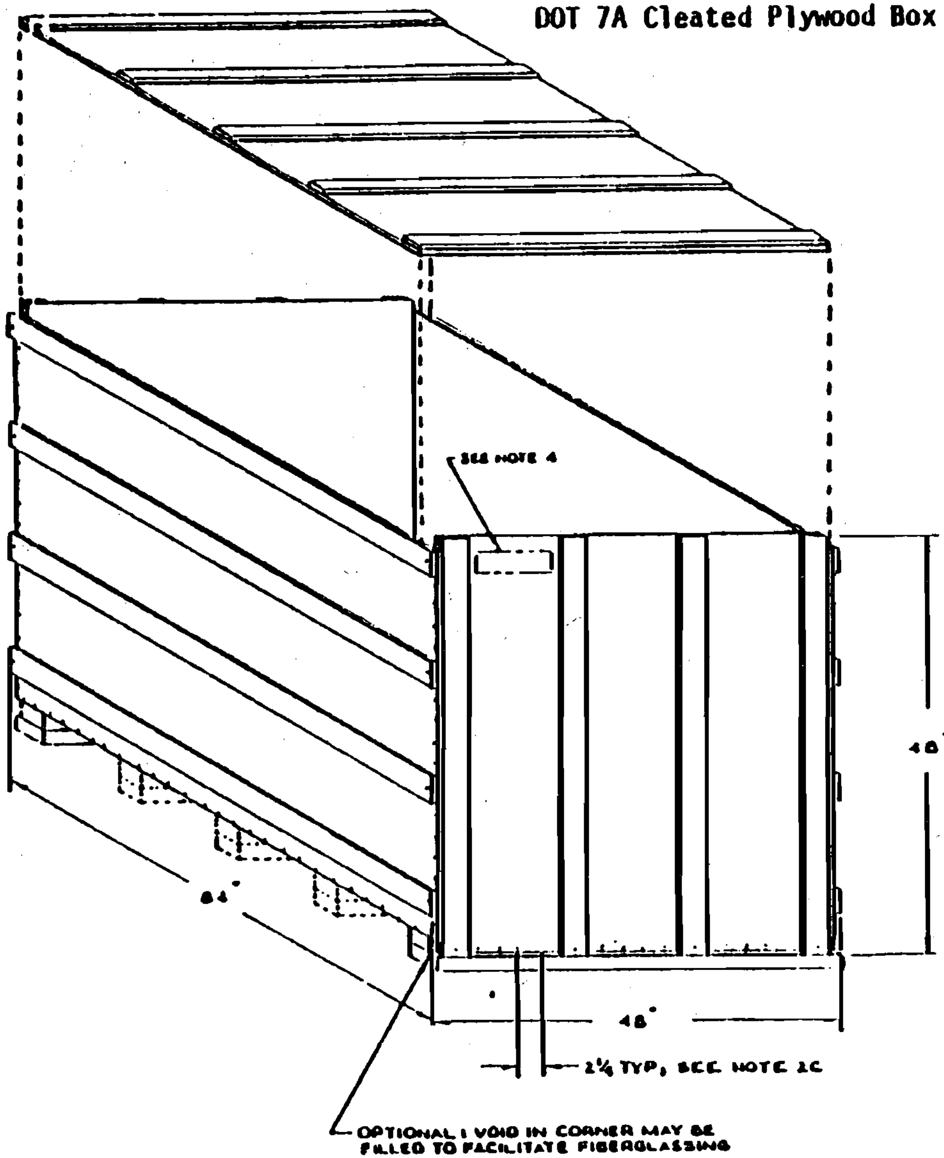
NOTES:

1. SECURELY BLOCK LARGE, HEAVY ITEMS WITHIN THE BOX TO PREVENT MOVEMENT. TIGHTLY PACK OTHER MATERIAL IN INDIVIDUAL PLASTIC BAGS AS APPROPRIATE. ALL MATERIAL SHALL BE FREE OF LIQUID.
2. PLACE LID ON FIBERBOARD LINER, FOLD OVER PVC LINER AND SEAL WITH TAPE.
3. FASTEN LID ON BOX USING CONSTRUCTION ADHESIVE AND CEMENT-COATED NAILS PER THE APPLICABLE BOX ASSEMBLY DRAWING. ADD FRP COATING PER 572013 IN AREA THREE INCHES EITHER SIDE OF JOINT TO SEAL BOX. SPRAY TOP OF BOX WITH A LIGHT COAT OF RESIN AND DISTRIBUTE ABOUT ONE QUART OF FINE GRAVEL INTO WET RESIN TO PROVIDE A NON-SLIP SURFACE.
4. DURABLY AND LEGIBLY MARK "USA DOT-7A", "RADIOACTIVE MATERIAL", NAME AND ADDRESS OF USER, AND GROSS WEIGHT USING CHARACTERS AT LEAST 1.0 INCH HIGH, 2 PLACES, ON OPPOSITE SIDES OF BOX.
5. ALL DIMENSIONS ARE IN INCHES AND ARE GIVEN FOR REFERENCE ONLY. SEE THE APPLICABLE BOX ENGINEERING DRAWING FOR DETAILS. FLUSH PANEL BOX SHOWN. BOXES MAY BE ORDERED IN TWO HEIGHTS. SEE TABLE FOR SIZES.
6. WHEN USING 24x48x84 BOX, CUT FIBERBOARD AND PVC LINERS TO FIT.

NOMINAL BOX SIZE	OVERALL HEIGHT
48x48x84	52
24x48x84	[illegible]

Figure 4

DOT 7A Cleated Plywood Box Assembly



NOTES:

1. BOX DIMENSIONS BEFORE FIBERGLASSING:

   OUTSIDE: 84L x 48W x 49-1/2D = 115 FT^3
   INSIDE: 81L x 45W x 42-1/2D = 90 FT^3

2. ASSEMBLE BOX WITH THREE-WAY CORNERS AS FOLLOWS:

   A. APPLY ELASTOMERIC CONSTRUCTION ADHESIVE (B.F. GOODRICH PL-200 OR APPROVED EQUIVALENT) IN A CONTINUOUS BEAD OF 1/4 INCH MINIMUM DIAMETER ALONG EACH PLYWOOD-TO-PLYWOOD JOINT. REMOVE EXCESS ADHESIVE FROM OUTSIDE OF BOX.

   B. EACH END OF EACH CLEAT SHALL BE FASTENED WITH AT LEAST ONE 16 PENNY CEMENT-COATED BOX NAIL.

   C. APPLY 8 PENNY CEMENT-COATED BOX NAILS OR 2 INCH PLASTIC COATED STAPLES THRU THE PLYWOOD INTO THE APPROPRIATE CLEAT OR STRINGER AS SHOWN. FASTENERS SHALL BE FLUSH TO 1/16 MAXIMUM BELOW SURFACE. STAPLE CROWNS SHALL CROSS GRAIN OF FACE PLY AT NOT LESS THAN A 40° ANGLE. INTERIOR OF BOX SHALL BE FREE OF PROTRUDING FASTENERS.

3. FIBERGLASS BOX AND ASSEMBLE SKIDS PER S72013. COATING MAY BE DONE ON INDIVIDUAL PANELS OR ON ASSEMBLED BOX.

4. DURABLY AND LEGIBLY MARK MANUFACTURER'S NAME OR SYMBOL AND DATE OF MANUFACTURE 2 PLACES ON OPPOSITE ENDS OF BOX, USING CHARACTERS AT LEAST 1/4 INCH HIGH. A PAPER LABEL WITH RESIN COVERCOAT ACCEPTABLE.

5. WHEN THE PURCHASE ORDER SPECIFIES A NON-FIBERGLASSED BOX, OMIT ASSEMBLY STEPS PER NOTE 3. ATTACH SKIDS PER SHEET 2 OF THIS DRAWING SERIES. TEMPORARILY SECURE LID WITH DOUBLE HEADED NAILS OR OTHER SUITABLE FASTENERS TO RESIST BLOWING IN HIGH WINDS DURING STORAGE OR TRANSPORTATION.

6. FINAL LID CLOSURE BY USER SHALL BE MADE USING CONSTRUCTION ADHESIVE AND 8 PENNY CEMENT COATED NAILS OR 2 INCH PLASTIC COATED STAPLES.

Figure 5

DOT 7A Flush Panel Plywood Box Assembly

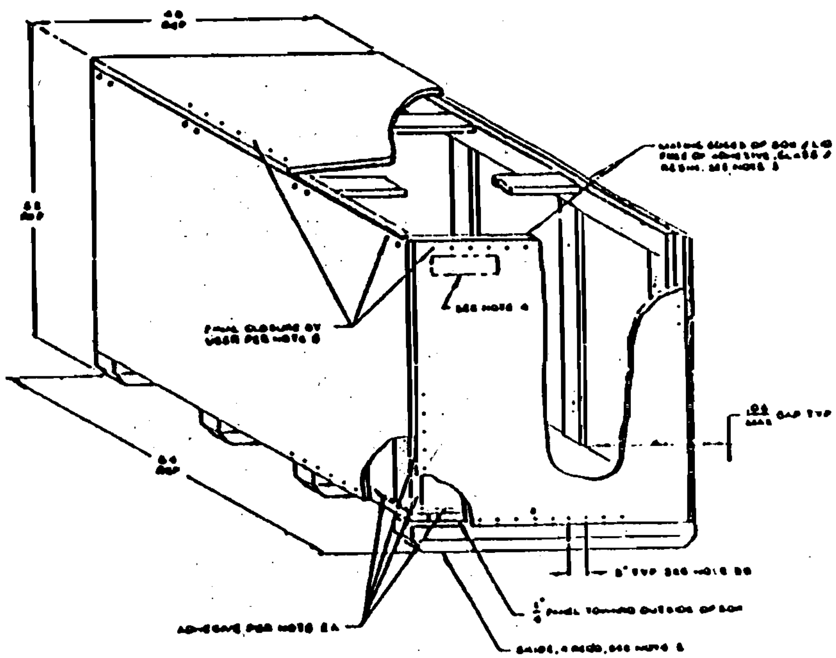


Figure 6

NOTES:

1. NOMINAL BOX SIZE:

   TYPE 1 - 48 x 48 x 84: OVERALL HEIGHT 52
   TYPE 2 - 24 x 48 x 84: OVERALL HEIGHT 28

   ALL DIMENSIONS ARE IN INCHES, EXCEPT AS NOTED

2. ASSEMBLE BOX AS FOLLOWS:

   A. APPLY ELASTOMERIC CONSTRUCTION ADHESIVE (B F. GOODRICH PL-200 OR APPROVED EQUIVALENT) IN A CONTINUOUS BEAD OF 1/4 INCH MINIMUM DIAMETER ALL AROUND 3/4 INCH BOTTOM PANEL AND ON BOTH SIDE EDGES OF END PANELS. APPLY A BEAD OF ADHESIVE BETWEEN VERTICAL END STRUTS AND END PANELS. REMOVE EXCESS ADHESIVE FROM OUTSIDE OF BOX.

   B. FASTEN PANELS USING 10 PENNY CEMENT-COATED BOX NAILS OR 2 INCH PLASTIC-COATED STAPLES WITH 3 INCH MAXIMUM SPACING. FASTENERS SHALL BE DRIVEN FLUSH TO 1/16 MAXIMUM BELOW SURFACE. STAPLE CROWNS SHALL CROSS GRAIN OF FIRST PLY AT NOT LESS THAN A 40° ANGLE. INTERIOR OF BOX SHALL BE FREE OF PROTRUDING FASTENERS AND SPLIT LUMBER.

   C. EDGES OF SIDE AND END PANELS SHALL BE FLUSH TO 1/16 MAXIMUM ABOVE BOTTOM OF BOX.

3. FIBERGLASS BOX AND ASSEMBLE SKIDS PER 572013. COATING MAY BE DONE ON INDIVIDUAL PANELS OR ON ASSEMBLED BOX. MATING EDGES OF BODY AND LID SHALL BE FREE OF GLASS AND MEASURABLE RESIN OVERSPRAY. BOX EDGES MAY BE BROKEN 3/4 MAXIMUM RADIUS OR CHAMFER TO FACILITATE FIBERGLASSING.

4. DURABLY AND LEGIBLY MARK MANUFACTURER'S NAME OR SYMBOL, DATE OF MANUFACTURE, 2 PLACES ON OPPOSITE ENDS OF BOX USING CHARACTERS AT LEAST 1/4 INCH HIGH (MAY BE PAPER LABEL WITH RESIN OVERCOAT.)

5. USER SHALL MAKE FINAL BOX CLOSURE WITH THE MATERIALS SPECIFIED IN NOTE 2. APPLY ADHESIVE ALL AROUND TOP EDGES OF VERTICAL 3/4 INCH PANELS. IN ADDITION TO 10 PENNY NAILS ON 3 INCH CENTERS, DRIVE TWO 20 PENNY CEMENT-COATED NAILS THROUGH SIDE PANEL INTO EACH 2x4 ON TOP PANEL (8 PLACES)

6. WHEN THE PURCHASE ORDER SPECIFIES A NON-FIBERGLASSED BOX, OMIT ASSEMBLY STEPS PER NOTE 3. ATTACH SKIDS PER SHEET 2 OF THIS DRAWING SERIES. TEMPORARILY SECURE LID WITH DOUBLE-HEADED NAILS OR OTHER SUITABLE FASTENERS TO RESIST BLOWING OFF IN HIGH WINDS DURING STORAGE OR TRANSPORTATION.

DOT SPEC. 7A STEEL BOX

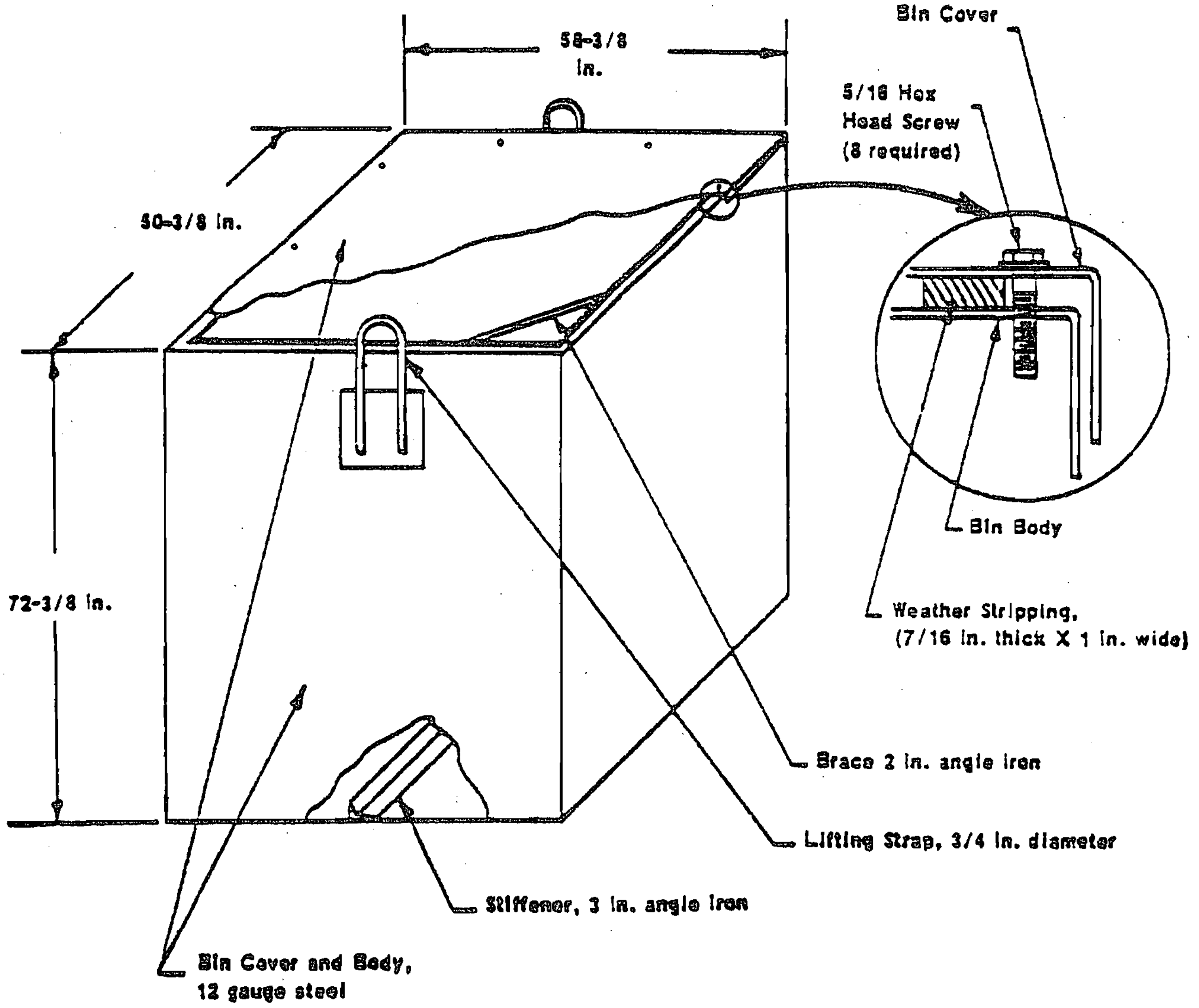


Figure 7

Appendix F

INCINERATION AND IMMOBILIZATION PROCESSES

CONTENTS

Appendix F

INCINERATION AND IMMOBILIZATION PROCESSES

As explained in Section 5.3, several studies of the processing of transuranic waste have been carried out at the Idaho National Engineering Laboratory. One of these analyses, performed by the FMC Corporation (1977), evaluated 17 incineration processes (nine for radioactive waste and eight for municipal or commercial waste) and 11 immobilization processes. This appendix briefly describes these processes.

F.1 INCINERATION PROCESSES

F.1.1 Processes for Radioactive-Waste Incineration

An acid-digestion process is being developed at the Westinghouse Hanford Company, Richland, Washington. This system treats combustibles with sulfuric and nitric acids at about 240°C. The residue from this process consists of inorganic sulfates and oxides in a salt-cake form.

An agitated hearth is an adaptation of a commercial incinerator. This operation is being developed by Rockwell International at Rocky Flats, Colorado. In this process a batch of contaminated combustible material is charged into a primary chamber where rotating rabble arms agitate the combustible material to improve the burning. The output is a dry ash.

A controlled-air incinerator, also a modification of commercially available equipment, is under construction at the Los Alamos National Scientific Laboratory, Los Alamos, New Mexico. This incinerator uses a starved-air primary chamber with an oxygen-rich secondary chamber. The offgas is treated by wet scrubbing. The output of this process is also a dry ash.

A cyclone-drum incinerator is being operated at the Mound Facility, Miamisburg, Ohio. Contaminated laboratory waste is burned in a vortex-type incinerator inside a 55-gallon drum. The contaminated waste may be handled both in and out of the incinerator in the 55-gallon drums. The residue from the combustible portion of this process is almost completely oxidized.

A fluidized-bed incinerator is being developed by Rockwell International at Rocky Flats, Colorado. This process feeds combustible material into a hot fluidized bed of sodium carbonate. The hot air that fluidizes the bed provides immediate ignition for combustibles, which are burned. The ash is separated in a cyclone. A second fluidized bed is used for complete oxidation. The residue is an ash collected in the cyclone separator. The sodium carbonate provides in-situ neutralization of the hydrogen chloride and other acidic gases formed during the oxidation.

The molten-salt incinerator was developed by Atomics International for the Idaho National Engineering Laboratory. This process feeds finely divided combustibles and noncombustibles, including metals, into a molten-salt bath.

The combustibles immediately oxidize within the bath, and the ash is captured there along with the metal oxides and other noncombustibles. When the bath is fully loaded with noncombustible material, it is drained along with the captured incinerator residue. The sodium carbonate in the molten bath provides in-situ neutralization of the acid gases formed during the oxidation process.

A controlled-air pyrolysis incinerator is being developed by E. I. du Pont de Nemours & Company, Inc., at Savannah River, South Carolina. This process moves combustible material into a refractory-lined chamber heated to 1000°C by electric heaters. The oxygen is maintained below stoichiometric levels to obtain flameless incineration. Under these conditions the volatile materials are driven off and oxidized in an oxygen-rich secondary chamber. The principal residue of this process is a char relatively high in carbon.

A commercial rotary-kiln incinerator, adapted for radioactive waste, is under construction for the Rocky Flats Plant in Colorado. The contaminated waste material is fed into the upper end of the rotary kiln and oxidized as the kiln rotates. The dry ash is continuously removed from the bottom of the kiln. The offgases are burned in an afterburner.

A slagging-process incinerator, installed at the CEN-SCK waste facility in Mol, Belgium, is a commercial incinerator adapted for radioactive-waste disposal. The waste material is shredded before being fed into a waste hopper that surrounds the incineration chamber. As the waste material feeds into the incineration chamber, it is oxidized, and the noncombustible materials are melted into a slag at 1600°C. The slag output material drips continuously from the hearth into a water quench tank below the incinerator. The output material is a basaltlike glassy slag.

F.1.2 Processes for the Incineration of Commercial or Municipal Waste

The commercial controlled-air incinerator is similar to the radioactive-waste unit; it uses a "starved-air" primary combustion chamber process to produce a low level of turbulence that minimizes the transfer of particulate matter to the offgas. An oxygen-enriched secondary chamber with vigorous air turbulence is used to completely oxidize the offgas.

Commercial fluidized-bed incinerators (FBIs), although similar in principle to the Rocky Flats FBI, are quite different. All commercial FBIs operate at high temperatures and consequently use refractory linings. Physical sizes and capacities are much larger. Usually the feed material they process can be in much larger chunks that need not be shredded as fine.

The commercial application of molten-salt incinerators is in the development stage. The molten-salt incinerator developmental programs are in the areas of coal gasification, flue-gas purification, etc. Production rates vary from 1 to 3 metric tons per hour.

The commercial moving-grate is a common type of municipal solid-waste incinerator or combustion system for waste-heat boilers, etc. This incinerator requires finely shredded combustible feed material with little foreign noncombustible material. The maximum capacities of these units in tons per hour are large.

The commercial multiple-hearth combustor is used frequently for incinerating municipal and industrial sludges, shredded solid wastes, etc. An advantage of the multiple hearth is a long residence time in the incinerator and varying temperature ranges for the individual hearths so that the top hearths may be drying the waste, the middle hearths pyrolyzing the waste, the lower hearths oxidizing the waste, and the bottom hearth cooling the waste. Because the individual hearths are vertically above each other, the units are efficient in operation, utilizing all the waste heat of combustion. The maximum capacities of multiple-hearth units can be more than 100 tons per hour.

The commercial versions of the pyrolysis incinerators are operated more nearly as a controlled-air process than as a pure pyrolysis process. These units completely oxidize the pyrolysis char residue in the primary chamber to provide a dry inert ash. A secondary combustion chamber oxidizes the tars and other volatile products of pyrolysis.

The rotary kiln is another large-capacity, standard incinerator for commercial or municipal waste. Rotary kilns are also used for hazardous-waste incineration in which 55-gallon drums of material are directly fed into the rotating kiln with little deleterious effect on the kiln lining.

The slagging-pyrolysis process is a relatively new form of municipal-waste incineration. The original objective of this process was to generate gas from a pyrolysis zone that could be used as fuel for industrial or municipal operations. In this process waste material is loaded into a vertical shaft chamber. As the material descends, it passes through a drying zone, a pyrolysis zone, an oxidation zone, and, finally, a slagging zone in the bottom of the chamber. The hot gases driven off each zone rise and form the fuel for the upper zones. In the pyrolysis zone, the volatile gases are collected; they may be used as fuel in a steam boiler or oxidized in an afterburner, with the hot gases running to heat exchangers. The output of this process is a basalt-like glassy slag that entraps the ash along with metals and noncombustibles in the waste material.

F.2 IMMOBILIZATION PROCESSES

Bitumen. Any form of waste residue may be encapsulated in bitumen (asphalt) that can be handled by the bitumen mixer. This process has been used primarily for waste residues that are to be disposed of in the sea.

Cement. Hydraulic cement may be used to stabilize ash, salt, or even small pieces of metal and other noncombustibles, so long as these materials can be handled by the mixer. The cement with embedded waste materials may be cast into any desired form for handling. Steel reinforcements are used to increase the strength of the packages.

Ceramic. In this process, the waste material in the form of a calcine is combined with glass frit to produce glass ceramics. For immobilizing high-level waste, the output ceramic is embedded in a metal matrix for heat dispersion.

Clay. Radioactive waste in the form of sodium-salt solutions combines chemically with clays to immobilize the waste. The clay may be formed into bricks, which are fired at 700 to 900°C; this firing decreases the leach rate.

Glass (solution). Various waste materials may be combined with glass-forming materials and melted at high temperatures. When the forms of the output materials are finely ground ash, salts, oxides, or calcines, they dissolve and are dissolved in the glass matrix.

Glass (encapsulation). Small pieces of metals and other noncombustible materials are encapsulated in molten glass poured over them.

Metal matrix. Metals are used to stabilize the radioactive-waste materials that are in the form of vitrified pellets or beads or in some other calcined form. The principal advantages of the metal matrices are high impact strength and high thermal conductivity.

Pellets. The radioactive material and ash are ground very finely and mixed with high-alumina cement. This powder is then pressed into pellets and sintered. The principal advantage of this process is that the concentration of radioactive waste in the pellets (80%) is higher than that obtained with other techniques. For example, in the glass-solution process the radioactive-waste concentration is 50% at a maximum.

Plastic materials. A variety of resins and plastic materials have been used as matrices to immobilize ash, salts, and oxides. These materials could be used to stabilize small pieces of metal and noncombustibles. The primary disadvantage is that these resins are combustible.

Salt cake. The cast salt cake taken directly from the output of the molten-salt incinerator or the acid-digestion process adequately immobilizes the fine ash material. However, the salt cake has a very high leach rate and thus will not meet stabilization requirements.

Slag. The product of the slagging incinerator is a granular basaltlike glassy slag. Glass formers may be added to the waste-material feed in the incinerator to improve the vitrified output.

REFERENCE

FMC Corporation, 1977. Selection of Waste Treatment Process for Retrieved TRU Waste at Idaho National Engineering Laboratory, R-3689.

Appendix G

METHODS USED TO CALCULATE RADIATION DOSES FROM RADIONUCLIDE RELEASES DURING OPERATION

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Appendix G

METHODS USED TO CALCULATE RADIATION DOSES FROM RADIONUCLIDE RELEASES DURING OPERATION

G.1 INTRODUCTION

The radiation-dose calculations for radionuclide releases during operation were performed with a modified version of the computer code AIRDOS-II. Because excellent documentation describing the code and its input instructions is available (Moore, 1977), this appendix only highlights the major features of the code and outlines modifications made to the code.

Generally, AIRDOS-II is primarily intended to calculate doses from a continuous release of radionuclides, but, with the proper adjustments of input parameters, it can be used for a pulse release--that is, a release over a short time that would resemble a release resulting from an accident. The unmodified code calculates its own atmospheric-dilution factors (χ/Q values); it was used in Chapter 6 to calculate doses from transportation-accident releases. In calculating doses from normal and accidental releases from the WIPP in Chapter 9, site-specific χ/Q values were desired. These values were obtained with the integrated-puff model MESODIF, described in Appendix H, Section H.4. In order to use these χ/Q values, it was necessary to write a subroutine that allows the direct input of χ/Q values into AIRDOS-II.

The general flow of information in the code is indicated in Figure G-1. The MAIN subroutine drives the code as it differentiates between user options and directs the logical calculation process. MAIN first calls either CONCEN or COMPAG. CONCEN estimates ground-level air concentrations and surface-deposition rates. CONCEN calls QX, which accounts for plume depletion over the study area. COMPAG inputs previously calculated χ/Q values and then calculates surface-deposition rates. Once the concentrations and deposition rates are calculated, MAIN calls DOSE to compute the dose delivered to people. DOSE then calls DOSMIC, which simply provides a structured output of DOSE results.

G.2 METEOROLOGICAL ROUTINE

The AIRDOS-II code consists of two major calculation routines: the meteorological routine and the dose routine. The meteorological routine is based on a dispersion model that considers plume rise, plume depletion, and an inversion lid. The equation used to estimate plume dispersion is the Gaussian plume equation of Pasquill, as modified by Gifford (1972):

$$\chi = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

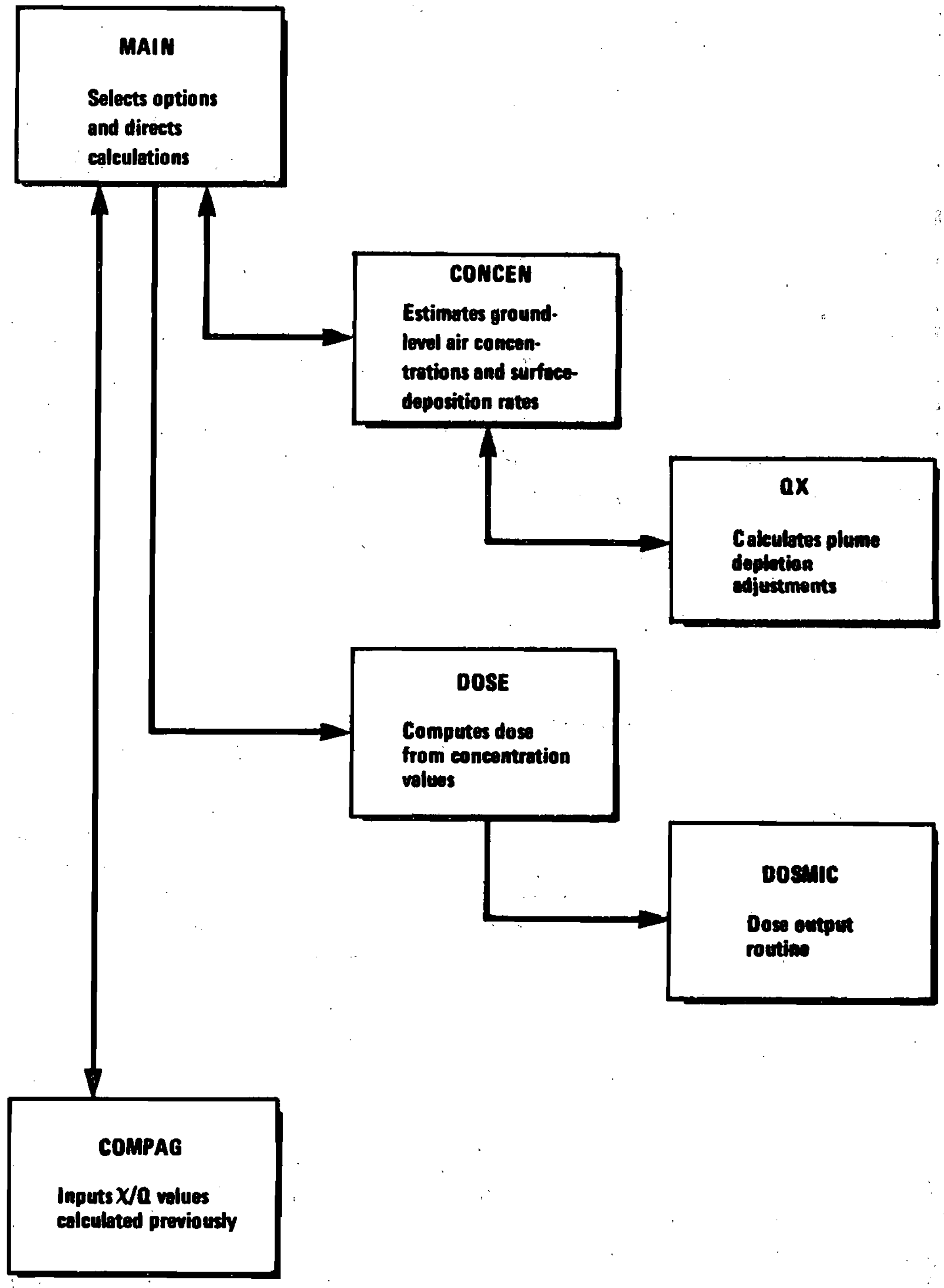


Figure G-1. Flow of information in the AIRDOS-II code.

where

χ = concentration in air at x meters downwind, y meters crosswind, and z meters above the ground (pCi/m^3)
Q = uniform emission rate from the stack (pCi/sec)
u = mean wind speed (m/sec)
σ_y = horizontal dispersion coefficient (m)
σ_z = vertical dispersion coefficient (m)
H = effective stack height (physical stack height h plus the plume rise Δh) (m)
y = crosswind distance (m)
z = vertical distance (m)

For calculating ground-level concentrations, this equation may be reduced to the following:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

The values of the dispersion coefficients are calculated from equations developed by G. A. Briggs of the National Oceanic and Atmospheric Administration. They are described in Table G-1 for each Pasquill category.

Table G-1. Formulas Recommended by Briggs[a] for σ_y and σ_z for Open-Country Conditions[b]

Pasquill category	σ_y (meters)	σ_z (meters)
A	$0.22d(1 + 0.0001d)^{-1/2}$	$0.20d$
B	$0.16d(1 + 0.0001d)^{-1/2}$	$0.12d$
C	$0.11d(1 + 0.0001d)^{-1/2}$	$0.08d(1 + 0.0002d)^{-1/2}$
D	$0.08d(1 + 0.0001d)^{-1/2}$	$0.06d(1 + 0.0015d)^{-1/2}$
E	$0.06d(1 + 0.0001d)^{-1/2}$	$0.03d(1 + 0.0003d)^{-1}$
F	$0.04d(1 + 0.0001d)^{-1/2}$	$0.016d(1 + 0.0003d)^{-1}$

[a]G. A. Briggs, Air Resources Atmospheric Turbulence and Diffusion Laboratory, National Oceanic and Atmospheric Administration, Oak Ridge, Tennessee.
[b]The quantity d is the downwind distance in meters.

In calculations performed for the transportation-impact analysis, a distributed source of finite size was represented by an upwind virtual point source that produced a plume with dimensions matching the assumed height of the distributed source (see Figure G-2). To match these dimensions, the distance to the virtual source was calculated by simultaneously solving two equations:

$$H = 4.3\sigma_z$$

$$\sigma_z = 0.016d(1 + 0.0003d)^{-1}$$

The first equation defines the distributed-source height, and the second defines the standard deviation of the vertical distribution coefficient for type F stability as indicated above. The resultant equation for the distance between the virtual source and the distributed source is

$$d(1 + 0.0003d)^{-1} = 14.5H$$

The value of d is the virtual source distance for a source of height H. Once the distance of the virtual source from the actual distributed source is calculated, the distance used in the diffusion equations is the sum of the distances x and d in Figure G-2.

The Rupp model for momentum-dominated plume rise is used. The Rupp equation for momentum-dominated plumes is

$$\Delta h = 1.5vd/u$$

where

Δh = plume rise (m)
v = effluent stack-gas velocity (m/sec)
d = inside stack diameter (m)
u = wind speed (m/sec)

As the plume extends in size, some of the particles it contains will be deposited on the ground or on water surfaces by dry deposition or by scavenging. Dry deposition is a process by which particles are removed from the plume at the ground surface by impingement, electrostatic attraction, or chemical interaction with the ground cover or ground surface. The rate of dry deposition is determined by the following equation:

$$R_d = V_d \chi$$

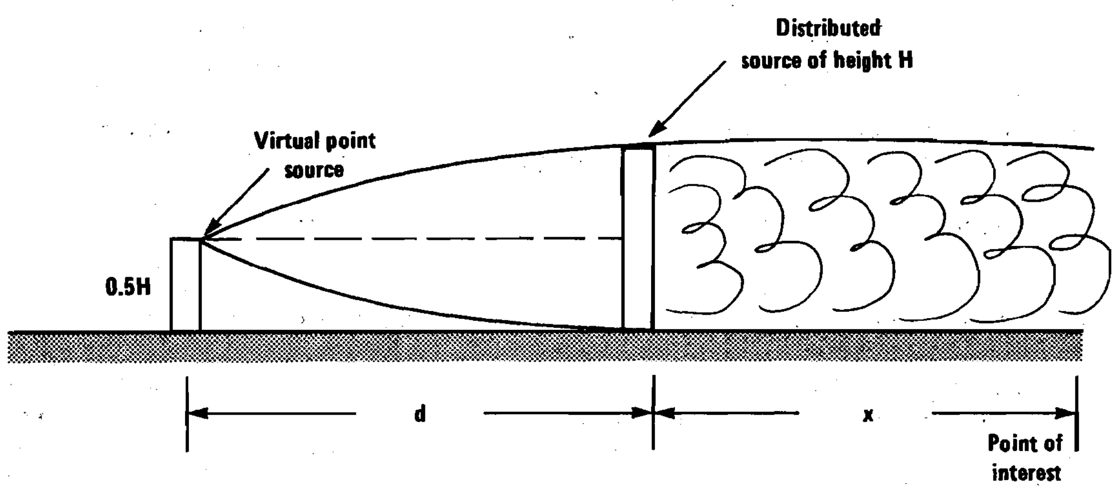


Figure G-2. Virtual point source.

where

R_d = surface-deposition rate (pCi/cm^2-sec)
V_d = deposition velocity (cm/sec)
χ = ground-level concentration in air (pCi/cm^3)

Rain or snow scavenges particles in a plume by depositing them on the ground. The rate of scavenging deposition is defined by

$$R_s = L\phi\chi_{va}$$

where

R_s = surface-deposition rate (pCi/cm^2-sec)
L = lid height (cm)
ϕ = scavenging coefficient (sec^{-1})
χ_{va} = average concentration in vertical column up to lid height (pCi/cm^3)

The AIRDOS-II code accounts for the effect of these depletion processes by calculating a reduced release rate (source term) at each downwind distance and by using this reduced release rate in place of the input source term. It also accounts for depletion by radionuclide decay.

Often throughout a typical year, a stable air mass will reside above an unstable one. This condition, commonly referred to as an atmospheric inversion, produces a ceiling, or lid, above which a plume will not disperse. Consequently, above the lid altitude no vertical dispersion will occur. AIRDOS-II accounts for the increase in ground-level concentration by allowing the user to input an inversion-lid altitude. The average concentration of particulates is adjusted by means of this input parameter as is the surface-deposition rate.

For releases from the WIPP, atmospheric-dilution factors (χ/Q values) were calculated by another code. Consequently, it was not necessary to use the CONCEN subroutine. CONCEN was circumvented by writing COMPAG, which is a subroutine that allows the direct input of concentrations into DOSE.

Calculations were also performed for releases of radioactive material from the WIPP during accidents in order to determine the resultant dose to a maximally exposed individual at the site boundary. As discussed earlier, the input was modified to accommodate an instantaneous release. To maximize the site-boundary dose, it was assumed that the mixing depth was limited by the worst-case lid height and that the individual exposed remains at the site boundary for the duration of the passage of the plume. An elevated release (momentum-dominated) based on the ventilation-system design was used for these calculations. The site-boundary χ/Q value used in the calculations is the elevated equivalent of the 5% ground-level 1-hour-duration χ/Q value at the boundary. In order to calculate the maximum site-boundary dose that could result from accidents, the atmospheric dispersion was limited to a single wind direction under class F conditions with a wind speed of 2 meters per second. These conditions very nearly approximate the 5% χ/Q value at 5 kilometers from the point of release.

G.3 DOSE ROUTINE

The dose routine calculates the radiation dose delivered to people through several major pathways. It considers internal exposure resulting from the inhalation and ingestion of radionuclides and external exposure resulting from immersion in air, immersion in water, and standing on contaminated surfaces. The dose from the inhalation of radionuclides is estimated from the following equation:

$$D_{inh} = (1.0 \times 10^{-6})(8760)\ \chi B_r C_{inh}$$

where

D_{inh} = inhalation dose (rem/yr)
χ = ground-level concentration of the radionuclide in air (pCi/cm^3)
B_r = breathing rate (cm^3/hr)
C_{inh} = dose-conversion factor for inhalation (rem/μCi)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr

The only parameter that is calculated by the code is the ground-level concentration; the other values are user inputs. The analyses of normal and accidental releases were performed with the same dose routine but different user inputs.

The dose from ingestion is calculated by using the terrestrial model of Booth et al. (1971). The code considers radionuclide intake only through the ingestion of vegetables, beef, and milk. It takes into account both radionuclides deposited on the surfaces of vegetables and those absorbed through the root system; it does the same for grass in the beef- and milk-intake pathways. General agricultural and demographic information must be input by the user for ingestion-dose calculations.

External doses from gamma radiation emitted by the radionuclides in the plume are calculated as follows:

$$D_{imm} = (1.0 \times 10^{-6})(8760)\ \chi C_{imm}$$

where

D_{imm} = air-immersion dose (rem/yr)
χ = ground-level concentration of the radionuclide in air (pCi/cm^3)
C_{imm} = dose-conversion factor for immersion in an infinite cloud (rem-cm^3/μCi-hr)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr

Once again, the code used calculated concentrations and user-input dose-conversion factors.

A similar treatment is used for estimating doses that result from immersion in water on which radionuclides have been allowed to deposit. This is seldom a significant exposure pathway, but the dose contribution is calculated from the equation

$$D_{wimm} = (1.0 \times 10^{-6})(8760)\,\frac{R_t}{d}\,\frac{1 - \exp(-\lambda_T t)}{T}\,(3600)(24)C_{wimm}$$

where

D_{wimm} = water-immersion dose (rem/yr)
R_t = surface-deposition rate (pCi/cm^2-sec)
d = depth of water (cm)
λ_T = radioactive-decay constant + environmental-decay constant for water (day^{-1})
t = time allotted for buildup in water (days)
C_{wimm} = dose-conversion factor for immersion in a body of water of infinite dimensions (rem-cm^3/μCi-hr)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr
3600 = sec/hr
24 = hr/day

As can be seen in the equation, a shallow body of water makes a more significant contribution to the resultant dose than does a deep body of water. The deposition rate is calculated by the code; the other parameters are input.

The final pathway--exposure resulting from standing on a contaminated surface--is evaluated by using the following equation:

$$D_{surf} = (1.0 \times 10^{-6})(8760)R_t\,\frac{1 - \exp(-\lambda_T t)}{T}\,(3600)(24)C_{surf}$$

where

D_{surf} = dose from surface exposure (rem/yr)
R_t = surface-deposition rate (pCi/cm^2-sec)
λ_T = radioactive-decay constant + environmental-decay constant (day^{-1})
t = time allotted for surface buildup (days)
C_{surf} = dose-conversion factor for surface exposure to an infinite plane at a point 1 m above the ground (rem-cm^2/μCi-hr)
1.0×10^{-6} = μCi/pCi
8760 = hr/yr
3600 = sec/hr
24 = hr/day

The expression

$$R_t\,\frac{1 - \exp(-\lambda_T t)}{T}\,(3600)(24)$$

represents the surface concentration after time t in days. The value of t used in analyses for the WIPP was a conservative 15 years. The deposition rate is calculated by the code, and the other parameters are input by the user.

G.4 INPUT DATA

Input data for the WIPP analyses performed with AIRDOS-II were obtained from published documents and interviews with county agents. These sources are listed by category in Table G-2.

Table G-2. Sources of Input Data for the Analyses

Category	Source
Meteorological data	Appendix H, Section H.4
Scavenging coefficients	Moore, 1977 NCRP, 1975
Physical and dimensional data	Chapter 8 and the WIPP conceptual design (as of December 1978)
Radiological data	
Decay constants	Lederer, 1967
Biological decay constants	Ng et al., 1968 NRC, 1977a
Dose-conversion factors	Killough et al., 1976
External exposure	Moore, 1977
Internal exposure	NRC, 1977a
Biological data	NRC, 1977b Wolfe et al., 1977 Killough et al., 1976 Ng et al., 1968 Discussions with Lea County Agent, R. Henard, January 25, 1978, and January 18, 1979 Eddy County Agent, D. Liesner, January 26, 1978, and January 19, 1979
Living patterns	NRC, 1977b Discussions with Lea County Agent, R. Henard, January 25, 1978, and January 18, 1979 Eddy County Agent, D. Liesner, January 26, 1978, and January 19, 1979

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Appendix H

DESCRIPTION OF THE LOS MEDANOS SITE

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Appendix H

DESCRIPTION OF THE LOS MEDANOS SITE

H.1 SCENIC, HISTORIC, AND CULTURAL RESOURCES

H.1.1 General Appearance

The Los Medanos site* in Eddy County, New Mexico, is covered with vegetation characteristic of semiarid climates. The land is used for ranching, and cattle are often to be seen. Ranch buildings are miles apart; in between there are a few windmills, several stock-watering tanks, and an occasional drilling rig. There are many roads in the area, the better ones surfaced with caliche, the poorer ones often little more than tracks in the sand. The most noticeable man-made features are the potash mines and processing plants, the latter with large buildings and stacks. Their emissions often create a haze heavy enough locally to block the view of the mountains 40 to 60 miles to the west.

The overall scenic quality of the study area was evaluated in April 1975 by the Bureau of Land Management (BLM) for an environmental analysis related to potash leasing (BLM, 1975). The Bureau has a standard quality-evaluation scoring system that takes into account landform, color, water, vegetation, uniqueness, and intrusions. On a scale of 1 to 24, with 24 high, the scores from 16 observation points about the study area averaged 8.3 ± 2.9. (The same BLM scoring system applied to the center of the WIPP site resulted in a score of 8.) Only one of the 16 observation points received a rating as high as 15; it was a view from New Mexico highway 31 of a salt lake in the lower end of Nash Draw. This observation point is 13 miles west-southwest of the site.

H.1.2 History

The State of New Mexico has an extensive history of Spanish exploration and settlement, dating from the reconnaissance of Marcos de Niza in 1539, which was sparked by reports brought to Mexico by Cabeza de Vaca, telling of enormous wealth in the land to the north. De Vaca himself probably passed through New Mexico near present-day Carlsbad in 1534 or 1535. However, most Spanish exploration and settlement took place in the Rio Grande valley to the west. The next entry of Spaniards into southeastern New Mexico was in 1583, when an expedition led by Antonio de Espejo traveled down the Pecos River on the way back from the north. In 1590, an expedition led by Gaspar Castano de Sosa traveled north up the Pecos to the village of Pecos and then turned west to the Rio Grande.

For almost three centuries after de Sosa passed through the area, there were only two significant recorded entries by white men. The first was in 1775, when Commandant-General Hugh O'Conor conducted military campaigns

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*In this appendix the terms "Los Medanos site" and "WIPP site" are synonymous.

against the Apaches in the Pecos Valley. The second occurred in 1854, when Brevet Captain John Pope conducted a survey of a possible route for a railroad to the Pacific through southern New Mexico.

H.1.3 Registered Historic Sites

The WIPP site contains no sites listed by the National or the State Register of Historic Sites. There are, however, historic sites in the vicinity of the site. Nine miles south-southwest is the Project Gnome site, which is presently undergoing the nomination procedure. It was the site of the first underground nuclear detonation (December 1961) of the Plowshare program, the AEC's program of search for nonmilitary uses of nuclear explosions. North of the site two areas believed to be of National Register quality are also undergoing the nomination procedure: Laguna Plata, 15 miles north, and Maroon Cliffs, 11.5 miles northwest of the center of the site. Another site being nominated is Pope's Wells, near the State line 20 to 26 miles to the south.

Nearby sites now on the State Register include Rattlesnake Draw, Monument Springs, the Lusk Ranch, and Boot Hill (listed as the Red Tank Archaeological Site), all on private land. Rattlesnake Draw is said to contain the best stratigraphic sequences found to date in southeastern New Mexico. Monument Springs consists of pit-house ruins and a large midden. The Lusk Ranch is the site of a mammoth-bison kill dating from 9000 B.C. Boot Hill dates from A.D. 900-1300 and contains a series of Jornada Mogollon pit houses.

Table H-1 lists the sites on the State Register of Cultural Properties that are within 30 miles of the WIPP site; these sites are recorded in the office of the State Historic Preservation Officer. Table H-2 lists similar sites identified in a survey of historic engineering sites. Most of the latter have not been evaluated for registration purposes.

H.1.4 Settlement

Aboriginally, the study area was inhabited by wandering bands of American Indians, predominantly Lipan Apaches. Occasional parties of Mescalero Apaches, Comanches, and Kiowas probably crossed the area on hunting or raiding forays. With the coming of the cattlemen, there were occasional encounters between white men and Indians, but these were infrequent, and by the 1880s Indians were no longer a significant presence in the Pecos area. Today the nearest group of Indians is the Mescalero Apaches 100 miles to the northwest.

Ownership of New Mexico changed from Spain to the Republic of Mexico in 1821 and from Mexico to the United States in 1848. Southeastern New Mexico played no part in these changes other than being a small portion of large tracts of land changing hands.

It was the coming of the cattlemen, led by Charles Goodnight and Oliver Loving in 1866, that started the modern development of southeastern New Mexico. When the Army and the Indian Bureau called for bids to furnish beef

Table H-1. Sites on the State Register of Cultural Properties Within 30 Miles of the WIPP Site

Listing	Name	Distance (miles)	Direction
007	Carlsbad Reclamation Project, Carlsbad[a,b]	25	W
280	Eddy & Bissell Livestock Company headquarters, Carlsbad	25	W
208	Eddy National Bank, Carlsbad[a]	25	W
472	Hagerman House, Carlsbad	25	W
557	Lake Avalon, 4 miles north of Carlsbad	28	WNW
159	Lusk Ranch site, 20 miles east and 12 miles north of Carlsbad	15	N
474	Phenix Adobe, Carlsbad	25	W
240	Pope's Wells Site, 8 miles east of the confluence of the Delaware and Pecos Rivers	24	S
567	Original potash bullwheel, 10 miles southeast of Carlsbad	19	WSW
168	Red Tank Archaeological Site (Boot Hill), 5 miles north and 7 miles west of Maljamar	39[c]	N
167	Rattlesnake Draw Site, 12 miles west and 3 miles south of Buckeye	28	N
162	Monument Springs Site, 4 miles west of Monument	32[c]	NE

[a]Listed on the National Register of Historic Places.
[b]National Historic Landmark.
[c]Included in table because mentioned in text.

for the Navajos and Mescalero Apaches who had been forced onto a reservation at Fort Sumner, New Mexico, local ranchers and farmers could not meet the demand. Goodnight and Loving drove a mixed herd of Texas cattle across the southern part of the Llano Estacado and up the Pecos River to Fort Sumner. In the next year John Simpson Chisum followed the Goodnight-Loving trail with another herd. When the contractors would not accept cows with calves, Chisum placed these unacceptable cattle on the range south of Fort Sumner. Eventually, with the addition of unacceptable cattle from subsequent drives, Chisum had cattle grazing along the Pecos River all the way to the Texas border. Trading posts catering to the needs of the cowboys were established, and settlement of southeastern New Mexico was begun. One such trading post was located near the present-day town of Malaga, south of Carlsbad.

In 1888, another cattleman, Charles Bishop Eddy, founded the Pecos Valley Land and Ditch Company to build irrigation ditches and canals. Carlsbad was founded in 1889 as the town of Eddy.

The twentieth century in southeastern New Mexico has seen the development of other industries. The Hammond well, and later the Brown well, produced oil near Artesia in 1909; oil and gas development started in earnest in Lea County and adjacent Texas in 1934. Oil drilling led to the discovery of potash in 1925, and the commercial exploitation of these resources began in 1931. Mining is now the principal industry of Eddy County.

Table H-2. Sites Identified by the State Historic Engineering Sites Survey Within 30 Miles of the WIPP Site

Listing	Name	Date	Distance from WIPP site (miles)	Direction
35010	Lake Avalon (CRP)[a-c]	1891	28	WNW
35039	Carlsbad Water Works	1920	25	W
35151	Carlsbad Irrigation District Flume[a,d]	1903	25	W
35155	Carlsbad Municipal Building	1955	25	W
35287	United Salt Supply	1937		
35365	Pecos River Railroad Bridge	ca. 1900	36	NW
35421	Salt Draw Bridge	1932	19	SW
35447	Six Mile Dam	1920	19	W
35462	Tansill Dam	1888	25	W
35515	Judkins Mill	1900		
35539	Harroun Dam	1930	16	WSW
35441	Pecos River Railroad Bridge, Carlsbad	1940	25	W
35617	Southern Main Canal[c]	1906	25	W
35618	East Canal[c]	1906	25	W
35677	Black River Canal[c]	ca. 1890	17	SW

[a]Listed on the State Register.
[b]National Historic Landmark.
[c]Part of the Carlsbad Reclamation Project.
[d]Listed on the National Register of Historic Places.

H.1.5 Archaeology

Little archaeological research has been done in southeastern New Mexico. Interest has instead tended to focus on areas to the north and west, partly because of the more spectacular ruins there--such as Chaco Canyon and Mesa Verde--and partly because of the possibility of relating these ruins to the present Pueblo Indians. These northern areas were felt to be the major cultural centers, whereas southeastern New Mexico has been regarded as a less fruitful area for investigation than areas to the north and west. More recently, however, the marginal nature of the southeastern environment has been recognized as offering opportunities for studies on the relationship between environment and culture.

Studies by Mera (1943), Lehmer (1948), and Jelinek (1967) are the three basic sources of information on the archaeology of southeastern New Mexico. Lehmer synthesized the knowledge of the archaeology of the area and incorporated Mera's data to define what he called the Jornada branch of Mogollon culture. This did not include the more easterly portions of southern New Mexico or the area of the WIPP site. Jelinek conducted a survey of the Pecos Valley north of Roswell. The earliest phase he identified, his "Early 18 Mile" (A.D. 800 to 900), was generally similar to late Archaic. The area appears to have been abandoned for some time after the mid-14th century. The studies of Lehmer and Jelinek and later field observations in Lea and Eddy Counties have led to the extension of the boundaries of Lehmer's Jornada Mogollon to include the rest of southeastern New Mexico.

Sites in southeastern New Mexico are generally classified as Paleo-Indian (before 500 B.C.), Archaic (500 B.C. to A.D. 950), Jornada Mogollon (A.D. 950 to 1400), or Historic (since A.D. 1400). The Jornada Mogollon, being particularly rich in sites and in pottery types, has been subdivided by several authors (Figure H-1). Lehmer's classification, as the names he used imply, was based on work considerably to the west of the site area; Jelinek's, on work on the middle Pecos River valley to the north of the site. Corley's classification (1965) is based on work nearer the site. Corley, in fact, saw the Jornada Mogollon as having three regional variants: Lehmer's north and south, and his own eastern variant.

Various groups of expert amateurs, especially the Lea County Archaeological Society, have been active in the excavation, survey, and publication of the archaeological values of southeastern New Mexico. Contract archaeological firms have also been active in the Carlsbad Potash District immediately west and north of the WIPP study area.

A Bureau of Land Management study (BLM, 1975, p. II-254) has estimated the density of archaeological sites in the potash areas, using data gathered by the Eastern New Mexico University (ENMU) on a survey to the north and projections made by Schaafsma (1975) from similar areas elsewhere in New Mexico. It concluded that the "site densities within the potash basin may be expected to range between 12 and 15 sites per square mile. The majority of sites will be located in dunes, on cliffs, in close proximity to playas, or a combination of these. The majority of sites will be of the Archaic and Jornada Mogollon time periods, with pithouses and surface structures not uncommon." Earlier, the Bureau, drawing on Schaafsma (1975), indicated that, at a density of 12 sites per square mile, one site would be Paleo-Indian, ten would be Archaic, and one would be Jornada Mogollon. The Bureau's own partial survey indicated more Jornada Mogollon than Archaic sites, with the reason for the discrepancy unknown, though possibly "a result of reporting biases."

Prehistoric dwellings are rare in southeastern New Mexico. Until recently, the known dwellings nearest to the WIPP site were those at Maroon Cliffs, 11.5 miles northwest. The presence of pit houses has not been confirmed there, but year-round occupation is suggested by a deep midden recently excavated by the ENMU. The Lea County Archaeological Society reported pit houses at Laguna Plata, 15 miles north, though J. L. Haskell (ENMU, personal communication, 1977) questions its conclusions. The nearest confirmed pit houses are at the Marchant site (southwest of Hobbs and about 18 miles east of the site), excavated by the Lea County Archaeological Society in the 1960s (Leslie, 1965).

In the summer of 1976, the ENMU surveyed the central 4 square miles of the WIPP site, including all of control zones I and II (sites ENM 10201 through ENM 10246 in Figure H-2). They found 64 isolated artifact sites and 33 archaeological sites (three outside the 4 square miles). The latter were taken to be localities that had been used and occupied by prehistoric man. One such site, with a metate, is shown in Figure H-3.

The number of archaeological sites corresponds to an average density of 7.5 per square mile, significantly fewer than the Bureau of Land Management

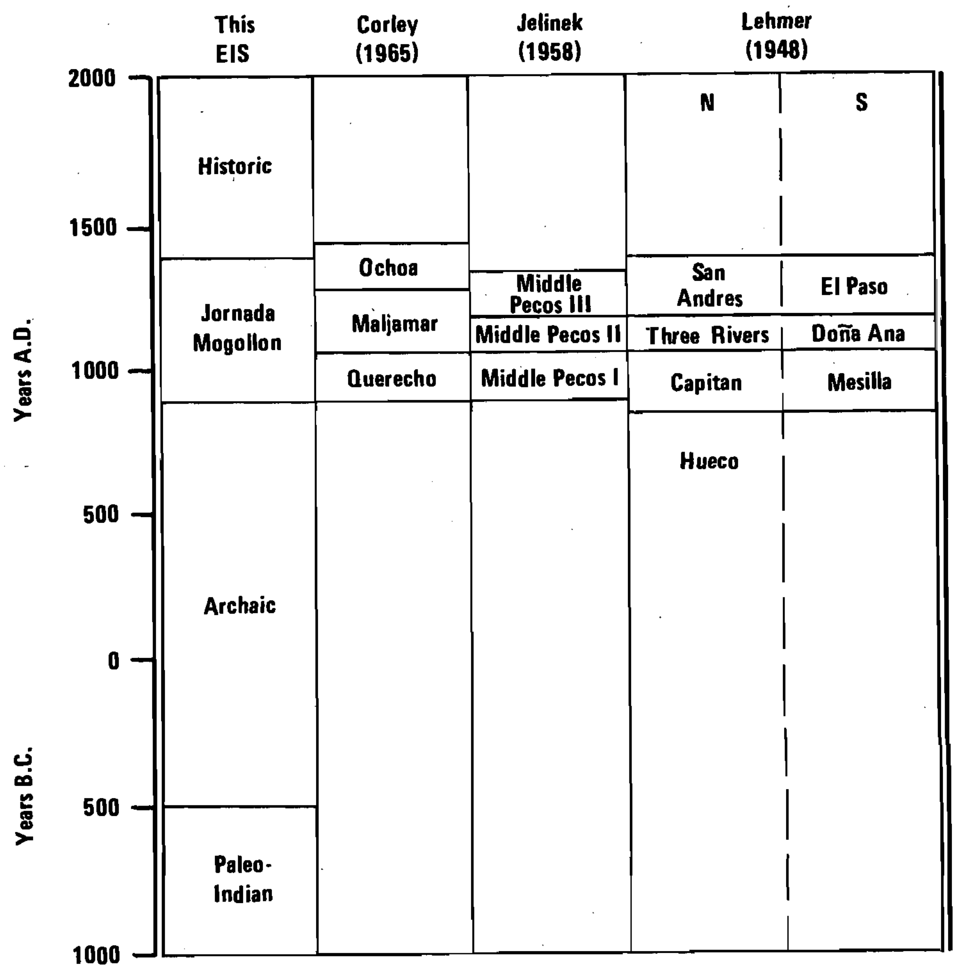


Figure H-1. Classification of archaeological sites according to various authorities.

had inferred from earlier surveys. The ENMU classified the 33 sites according to a scale defined by the School of American Research: Task Locus, Special Activity Zone, Limited Base, Home Base, Central Base, and Occupation Zone. By this scale, twenty-seven of the sites (including the one shown in Figure H-3) are Task Locuses and the remaining six are Special Activity Zones. No pit houses, permanent structures, or other indications of heavy use were found at that time. (As indicated below, some have been found since.)

The main conclusions of the ENMU at that time were as follows (Nielsen, 1976, p. 23):

> Cultural resources are remarkably uniform across the area. Groundstone consists of wedge-shaped manos, and oval-shaped metates. Although few in number, potsherds belong to the El Paso Brown, Jornada Brown, and Chupadero Black-on-White types, which date between A.D. 900-1300. These resources are tied to the

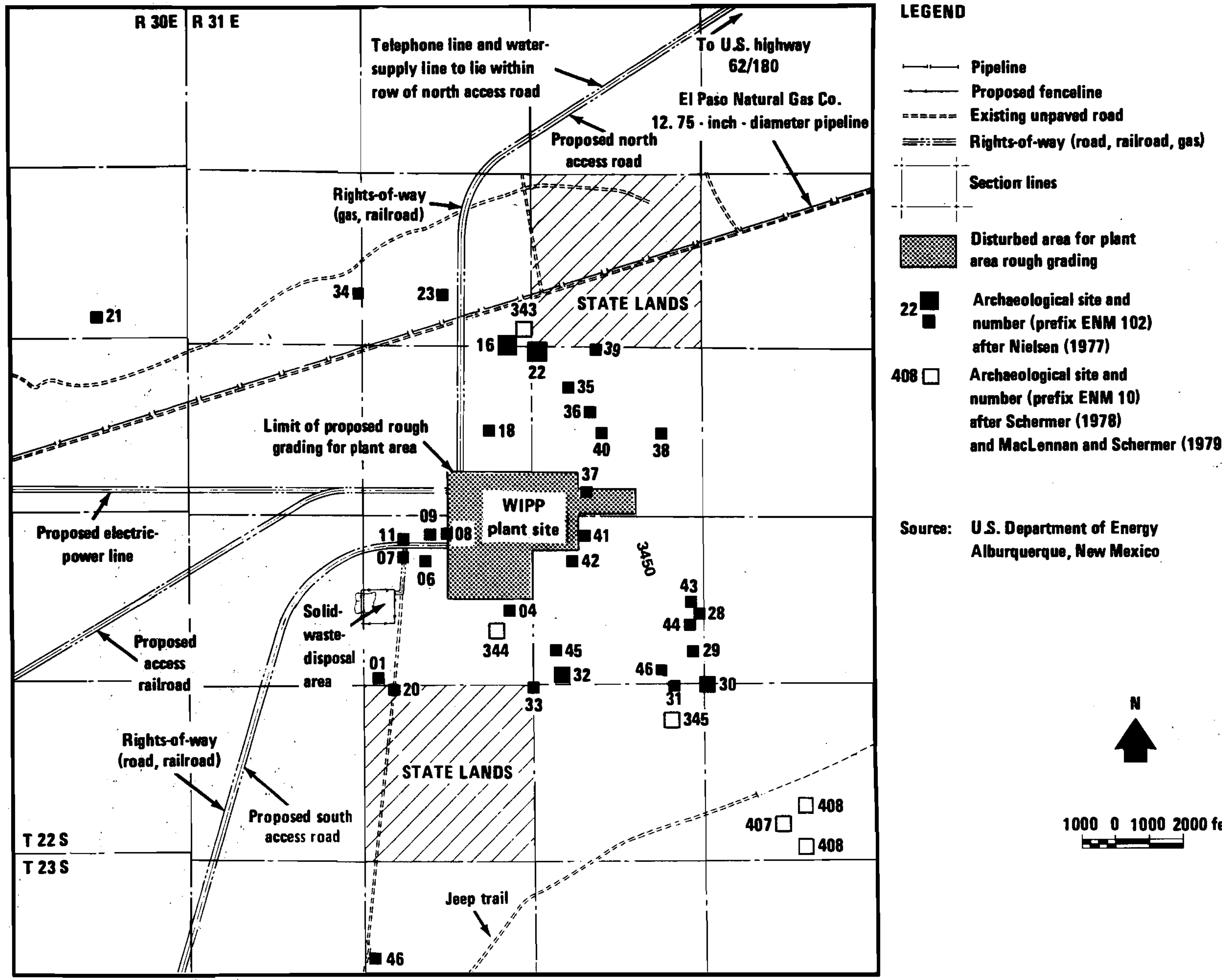
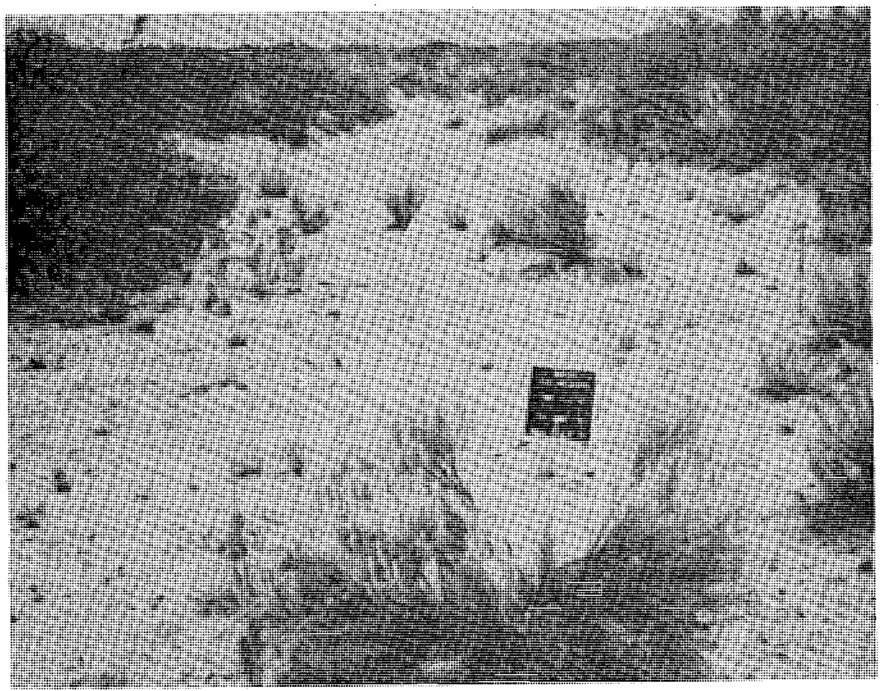


Figure H-2. Archaeological sites in the area of the WIPP site.



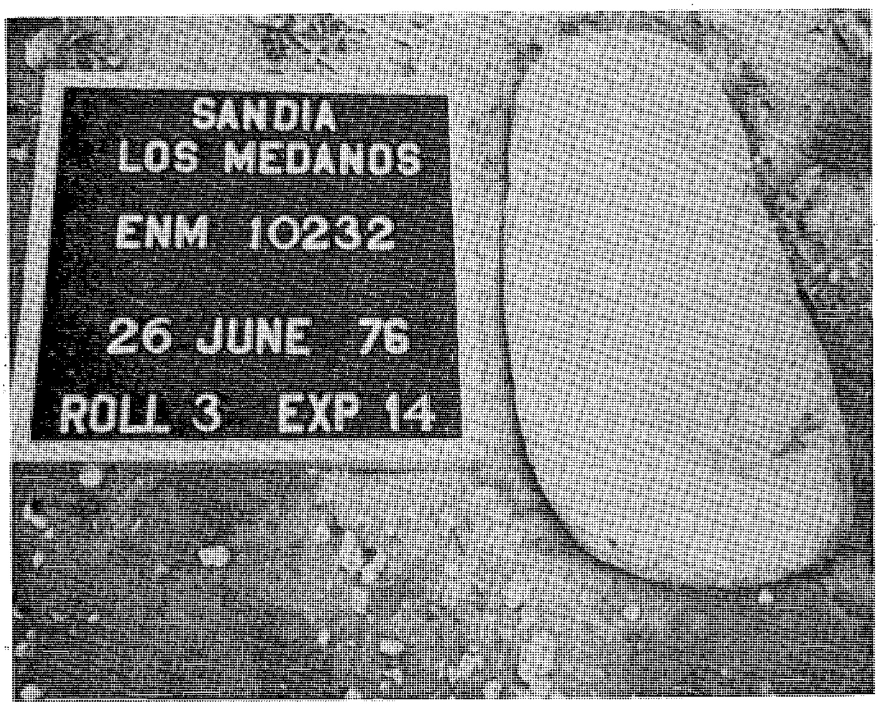


Figure H-3. Overview of an archaeological site looking toward the east (top) and oval basin metate (bottom).

Jornada Branch of the Mogollon. Of the seven projectile points found, one was from the Archaic period (4000 B.C. to A.D. 500). The others were probably of Jornada Mogollon authorship. . . . Hearths were often noted, with their presence being indicated either by a dark stain in the soil, or by a scatter of burned caliche or sandstone.

It is believed that the area was occupied seasonally by hunting/gathering bands. The prime resources are acorns, mesquite beans, rabbit, and deer. Owing to the relatively large number of groundstone fragments, it seems likely that these acorns and mesquite beans were probably primary resources of these people.

As a result of these surveys, and at the instance of Thomas S. Merlan, State Historic Preservation Officer, the WIPP site has been declared eligible for nomination as an archaeological district (Appendix I) because the 33 sites located in the first archaeological survey, when taken together, are considered likely to yield significant information on prehistoric occupation. Subsequent surveys have turned up two prehistoric structures, thus adding to interest in the area. These structures are described below.

Continued site investigation has so far (June 1980) required building about 30 miles of new road, drilling 56 holes or hole complexes, installing a meteorological tower, running 156 miles of off-road seismic lines, and making about 9000 off-road resistivity measurements. Much of this work was outside the original 4 square miles surveyed in 1976 and required archaeological clearance. In addition, surveys were made of the rights-of-way for the two access roads and for the railroad. In the process, 15 new sites were discovered, eight of them Special Activity Areas. Also found were two structures and one possible structure.

On the other hand, in the areas where the new surveys overlapped the original one, eight of the previous sites could no longer be found. In mid-1978, a survey was made for a seismic line along the northern edge of the original 4 square miles. Schermer (1978, pp. 17-18) reports that "three previously described sites lie along this corridor. . . . Of these sites, ENM 10222 and ENM 10239 were not encountered during this survey although the areas in which they are supposedly located were surveyed. These areas have been previously impacted, and the sites may have been destroyed." On the right-of-way for the south access road, six sites (ENM 10206, ENM 10207, ENM 10208, ENM 10209, ENM 10211, and ENM 10212) could no longer be found. Of them, MacLennan and Schermer (1979, pp. 6-7) say that "during both the August, 1978, seismic survey (Schermer, 1978) and this reconnaissance, these sites could not be relocated. Due to the extremely low artifact density within these sites and to the extensive activity in this area, ACA the Agency for Conservation Archaeology of ENMU feels that these sites either do not exist or are not identifiable."

The first of the three structures was found on an extension of a site identified earlier outside the original 4 square miles (Schermer, 1978, pp. 13-14). His description of the site is as follows:

ENM 10230 is a massive site which follows the southwest face of a ridge for more than 1/4 mile. The site is shaped roughly

> like a boot . . . . The ridge top and area immediately surrounding the site are occupied by moderately large dunes (up to 3 m high). The majority of the site area is covered by a dense lithic and ceramic scatter with evidence of numerous hearths. Lithic materials include primary and secondary decortication flakes, bifaces, utilized flakes, and numerous ground stone fragments. Ceramics include Jornado Brown, Carlsbad Brown, Chupadero Black-on-White, and an unidentified red-on-brown ware.
>
> The most important addition to the description of this site is the location of at least one room block. The room block is an L-shaped sandstone foundation which measures 8.5 x 7.6 meters. The structure consists of at least four rooms . . . . The foundation is located five to eight ft below the crest of the ridge and on the southwest face. In addition to this structure, two more possible structures were located further north. These areas contain rectangular concentrations of small fragments of caliche, approximately 3 to 5 m square. Concentrations of caliche as described above also occur at ENM 10229 and ENM 10407.

The second of these structures (ENM 10408) is in a newly discovered site well outside the original 4 square miles. Of it, Schermer (1978, p. 16) says only that "the site consists of a rectilinear concentration of caliche which appears to be the remains of a three to four room jacal structure. The structure appears to have measured 3 x 5 meters. Several metate fragments occur in the surrounding area."

Finally, another possible structure was reported in the southeast corner of Section 17, just outside the original 4 square miles (Schermer 1978, p. 18). However, it has since been established that this site is a modern campsite established by field workers for the WIPP biology program.

Areas not yet surveyed archaeologically include most of control zones III and IV as well as the rights-of-way for the electric-power line from the northwest and for the water line to the north of U.S. Highway 62/180.

In summary, the area of the WIPP site seems to have been lightly but pervasively used by pre-Western man. It is not unique but is much like its surroundings. Indeed, the number of sites so far found is considerably smaller than would be inferred from the Bureau of Land Management estimates. It is principally of interest archaeologically for the light it might shed on how man can live in a marginal environment.

H.2 POPULATION

H.2.1 Population Trends and Distribution

In 1912, when New Mexico became a state, Eddy County contained approximately 9600 people. Between 1920 and 1930 the population grew to 15,842. After the start of potash mining in 1931, the population increased again (24,311 persons in 1940) and continued to grow from 1940 to 1960, principally because of the mining operations. By 1960 the population had reached 50,783 (BBER, 1962). After 1960 the potash industry in the area became severely depressed, and the population dropped to 41,119 by 1970. Since 1970 the economy of the area has improved, and the population has again increased. The 1979 population estimate compiled for this report shows that Eddy County had 48,200 inhabitants, an increase of approximately 7100 people over the 1970 Census figure. Since 1931 the population has fluctuated basically with activity in the potash-mining industry. The county contains four municipalities: Artesia, Carlsbad, Loving, and Hope. Carlsbad, the largest, had an estimated 28,600 inhabitants in mid-1979, up from the 25,541 in 1960 and 21,297 in 1970 (Table H-3).

Lea County was organized in 1917 from parts of Chaves and Eddy Counties and had 3545 residents in 1920. Oil exploration, begun in southeastern New Mexico in 1924, brought substantial growth: by 1930 the population had increased to 6144 and by 1940 had more than tripled to 21,154. Continued growth raised the population to 53,429 in 1960 (BBER, 1962). Between 1960 and 1970 Lea County sustained a population decrease of approximately 7.3%, owing mainly to decreased oil and gas exploration or production (USDC, 1970a). After 1970 the population increased from 49,554 to 57,500 in mid-1979 (Adcock, 1979). Most of the growth was related to increased activity in the oil and gas industry after 1973. Lea County has five municipalities: Hobbs, Lovington, Eunice,

Table H-3. Population in Eddy and Lea Counties: 1960-1979

Location	Distance from site[a] (miles)		Population		
	Air	Road	1960[b]	1970[b]	1979[c]
Eddy County	NA	NA	50,783	41,119	47,300
Artesia	47	64	12,000	10,315	10,950
Carlsbad	26	33	25,541	21,297	28,600
Loving	18	23	1,646	1,192	1,600
Hope	61	80	108	90	190
Lea County	NA	NA	53,429	49,554	57,500
Eunice	35	49	3,531	2,641	2,550
Hobbs	41	51	26,275	26,025	32,600
Jal	37	47	4,133	3,241	2,700
Lovington	45	55	9,660	8,915	9,500
Tatum	64	77	1,168	982	900

[a]Distance rounded to the nearest mile; NA = not applicable.
[b]Data from USDC (1970b).
[c]Data from Adcock (1979).

Jal, and Tatum (Table H-3). Hobbs, the largest incorporated place in the county, had an estimated 1979 population of 32,600.

Both counties are fairly homogeneous racially and ethnically (Table H-4), with a relatively small Spanish-origin ethnic group (statewide average 30.3%). The American Indian population is also relatively low: 0.3%, or 258 individuals in 1970 (statewide average 7.2%) (USDC, 1970c).

The age distribution of the population in the two-county area differs slightly between the counties, as well as between New Mexico as a whole and the United States. In both Eddy and Lea Counties the median age (27.2 and 25.9, respectively) is below that of the United States as a whole but significantly above New Mexico's median age of only 23.9 years in 1970. The population of Carlsbad has a relatively low percentage in the less-than-20 age group and a relatively high percentage in the over-50 age group (39.4% and 26.7%, respectively). The number of residents who are 65 or older is significantly higher in Carlsbad than the statewide average and the average for either Eddy or Lea County. An active program to attract retirees is supported by the Carlsbad area. The median age in Hobbs (25.5 years) is lower than that in Carlsbad (29.4 years) (Table H-5).

Table H-4. Characteristics of the Population in Eddy and Lea Counties[a]

Characteristic	Percentage of population[b]	
	Eddy County	Lea County
Race		
White	97.1	93.7
Black	2.2	5.3
Other	0.7	1.1
Spanish origin or descent	25.4	10.9
Residence		
Urban	76.9	81.1
Rural, nonfarm	18.1	15.1
Rural, farm	5.0	3.8

[a]Data from USDC (1970c).
[b]Percentages may not add to 100.00% because of rounding errors.

Net-population-migration figures indicate significant changes during the last few years. In the 1960-70 period the two-county area was somewhat depressed because of reduced hydrocarbon exploration and potash mining. As a result, Eddy County experienced a net loss of more than 11,000 individuals during a 5-year period and Lea County a loss of approximately 5200 (USDC, 1977). Since the 1970 Census, however, there has been a significant change in the net migration trend, with both counties showing a reversal: Eddy County received a net migration gain of 3700 during 1970-79 and Lea County a net gain of 2100 (Adcock, 1979).

Table H-5. Percentage Age Distribution of Population (1970 Census)[a]

Age	Percentage age distribution					
	United States	New Mexico	Eddy County	Lea County	Carlsbad	Hobbs
Under 5	8.5	9.5	8.2	9.0	8.2	9.4
5-14	20.1	23.8	22.3	22.8	20.8	22.8
15-19	9.4	10.4	10.9	10.7	10.4	10.5
20-29	14.5	14.6	11.3	12.5	11.2	13.0
30-39	11.1	11.6	10.5	12.7	9.9	12.9
40-49	11.8	11.0	12.0	13.4	12.6	12.9
50-59	10.4	8.9	11.3	9.9	12.1	9.6
60-64	4.3	3.4	4.5	3.6	4.9	3.6
65+	9.9	6.9	8.8	5.4	9.7	5.3
Median age	28.1	23.9	27.2	25.9	29.4	25.5

[a]Data from USDC (1970a).

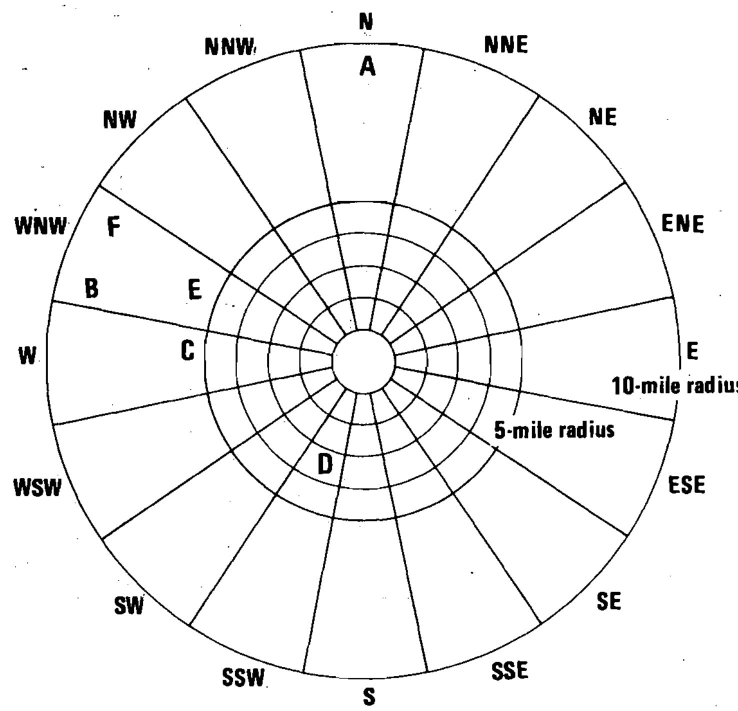
Although net migration during the last 9 years has been positive, major growth in the two counties has been caused by natural increase (births minus deaths): about 3400 persons in Eddy County and 5800 persons in Lea County, or about 1.5 times the growth caused by in-migration (Adcock, 1979).

Population densities in the two counties are relatively low but slightly higher than the 1979 statewide average of about 10.1 persons per square mile. The population density in Eddy County was 9.9 in 1970 and is now approximately 11.6 persons per square mile. The population density in Lea County was 11.3 in 1970 and is now estimated at 13.1 persons per square mile. It should be noted that the density figures are somewhat misleading because most of the population in Eddy County live in Carlsbad and Artesia. In Lea County slightly fewer than 85% of the total population live in four urban places. Thus, except for the six urban places, the two-county area is very sparsely populated (USDC, 1970b; Adcock, 1979).

Within 10 miles of the site, there are currently 16 permanent residents and three commercial mining operations (Figure H-4) with a total daytime employment of about 650 persons and considerably smaller swing shifts and night shifts (Adcock, 1979).

Within 50 miles of the site (Figure H-5) there were more than 102,000 inhabitants in 1979 (Table H-6). The major population centers are listed in Table H-3.

Population projections to the year 2010 are presented in Appendix M. From 1980 to 2010 Eddy County is projected to grow at a compound annual rate of 1.7% and Carlsbad at an annual rate of just more than 1.8%. Lea County growth for the 30-year period is approximately 1.3% per year, and the projected annual growth rate for Hobbs is about 1.4% (Adcock, 1979).



A Kerr-McGee plant and mine: 151 employees (maximum), day shift
B International Minerals and Chemical Corporation: 450 employees (maximum), day shift
C Duval Corporation (Nash Draw Mine): 46 employees (maximum), day shift
D James Ranch: six permanent residents (six seasonal part-time employees)
E Smith (Crawford) Ranch: seven permanent residents (18 seasonal part-time)
F Pue's Store: three permanent residents

Figure H-4. Population within a 10-mile radius of the site.

Demographic changes

Few demographic changes are expected within 10 miles of the site in the foreseeable future. Interviews with ranch owners and managers indicate that one ranch house is expected to be built in the next 5 years, at the Mobley ranch just south of NM 128, approximately 8 miles west-southwest of the center of the site (Figure H-4).

One other demographic change may occur north-northeast of the site, just outside the 10-mile radius. A small trailer park (approximately 20 units) is being built in and around the commercial establishment now known as the Half-way Bar. Future plans for further trailer-park development are reported to be partially contingent on the construction of the WIPP (Adcock, 1979).

The population of workers at various mining operations in the 10-mile radius may vary from one period to another. During 1960-1970, the employment level dropped significantly because of a decreased demand for potash produced in the Carlsbad area. Potash production now appears to have stabilized, at least for the near future. This work force is not expected to change significantly in the next few years.

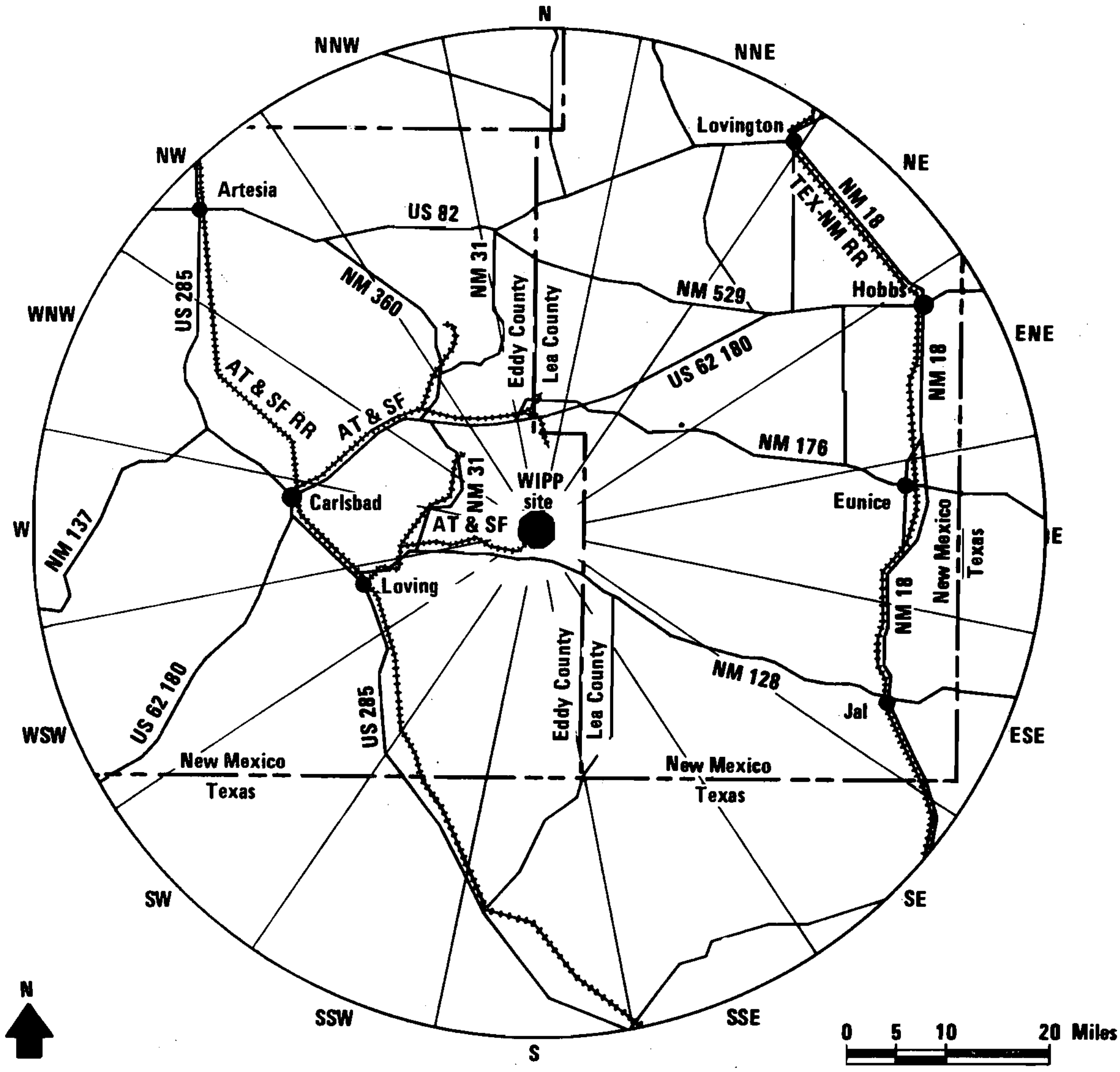


Figure H-5. Area covered by a 50-mile radius of the site.

Maintenance workers for oil and gas wells are transients in the area. The number of active oil and gas wells in Eddy County has been increasing during the past few years, and there are many active wells within 10 miles of the site. Although the average number of workers in the area is not known, it is not expected to increase significantly during the next few years.

H.2.2 Social Characteristics

Employment structure and unions

In 1970 nearly 90% of the employed in Eddy County were wage and salary workers (74% in the private sector, 16% in the government sector), approxi-

Table H-6. 1979 Resident Population Within 50 Miles of the Site[a,b]

Sector	Distance from site (miles)						
	0-5	5-10	10-20	20-30	30-40	40-50	Total
North	0	0	35	25	175	25	260
North-northeast	0	0	25	5	55	5,610	5,695
Northeast	0	0	0	25	75	8,660	8,760
East-northeast	0	0	15	70	205	33,200	33,490
East	0	0	5	15	3,240	155	3,415
East-southeast	0	0	5	10	3,035	295	3,345
Southeast	0	0	5	15	25	30	75
South-southeast	0	0	0	25	10	40	75
South	0	0	5	15	55	15	95
South-southwest	6	0	5	30	90	15	145
Southwest	0	0	55	30	10	45	140
West-southwest	0	0	1750	200	50	65	2,065
West	0	0	70	31,780	40	35	31,925
West-northwest	0	10	5	190	55	50	310
Northwest	0	0	30	20	65	12,055	12,170
North-northwest	0	0	15	5	220	10	280
Radius total	6	10	2025	32,460	7,440	60,305	102,245
Cumulative total	6	16	2040	34,500	41,940	102,245	--

[a]Population estimated by Adcock and Associates (1977-1979).

[b]Figures for all areas beyond the 10-mile radius have been rounded to the nearest 5.

mately 9% were self-employed, and 1% were unpaid family workers. In Lea County a slightly larger proportion of wage and salary workers were in the private sector and a correspondingly smaller proportion (12%) were in the government sector (USDC, 1970b, 1975-1979).

A large proportion of employed workers are blue collar (craftsmen and foremen, operatives, nonfarm laborers, and farm laborers), with 45% of Eddy County workers and 49% of Lea County workers belonging in this category in 1970 (USDC, 1970b). Data on earnings, poverty, and employment are given in Tables H-7, H-8, and H-9.

Five unions are represented in Eddy and Lea Counties (Table H-10); the largest is the United Steelworkers Union. Four unions have local headquarters in Eddy County.

Sociocultural conditions

During September and October 1979, unstructured discussions were held with approximately 200 persons in the Carlsbad area. A number of general topics were covered in an attempt to determine the sociocultural attitudes of residents in the general area of the WIPP. The persons interviewed were asked to describe their feelings about their local communities and various issues related to the quality of life in the area. The topics of discussion included attachment to the community, political processes, and land use.

Table H-7. Median Earnings by Occupation, Ethnic Group, and Sex, Eddy and Lea Counties, 1969[a]

Occupation	Median earnings					
	Eddy County			Lea County		
	All groups	Spanish	Black	All groups	Spanish	Black
Males 16 and older with earnings	$7068	$4286	$4820	$7695	$4883	$4225
Professional, managers	9158	4808	--	9909	8000	--
Crafts, foremen	8050	6667	4375	8127	6085	5211
Operatives	7244	5019	7078	7629	4477	4853
Nonfarm labor	4297	3306	5469	3793	3800	3500
Farmers and managers	6729	5533	--	4944	--	--
Farm laborers and foremen	2960	2871	--	3608	3350	--
Females 16 and older with earnings	$2810	$1596	$ 994	$2707	$1435	$1066
Clerical	3551	2575	--	3551	1875	--
Operatives	1241	830	--	2079	848	875

[a]Data from USDC (1970c).

Table H-8. Income and Poverty Status of Families by Ethnic Group and Sex of Household Head, Eddy and Lea Counties, 1969[a]

Families with income below poverty level	Percentage of all families	
	Eddy County	Lea County
All families	17.8	12.5
Spanish	41.5	31.5
Black	24.4	50.7
Families with female head	50.0	47.0

[a]Data from USDC (1970c).

A clear majority of the interviewees rated the Carlsbad area as an above-average area in which to live. Their reasons included climate, the friendliness of residents, access to recreational facilities, and the rural nature of the area. Those rating it average or below average cited excessive heat, high living costs, a lack of adequate commerce, and a dearth of cultural amenities as reasons.

A significant majority of those interviewed expressed a sense of belonging to the community, but a small percentage felt that they were excluded from the political process. Some people voiced concern about racial or ethnic relationships, though most interviewees suggested that the problem was less serious now

Table H-9. Employment Distribution by Industry, Sex, and Ethnic Group, Eddy and Lea Counties, 1969[a]

Industry	Distribution (%) in Eddy County					Distribution (%) in Lea County				
	Total	Male	Female	Spanish	Black	Total	Male	Female	Spanish	Black
Total number employed, 16 and older	14,145	9374	4771	3046	364	18,255	12,745	5510	1571	729
Agriculture	7	9	1	17	4	5	6	1	10	3
Mining	21	38	3	11	12	27	45	6	19	7
Construction	6			6	2	6			14	12
Manufacturing	5	6	3	6	7	5	6	3	4	1
Transportation, communications, and public utilities	7	8	4	6	6	7	8	5	4	5
Wholesale trade	3	4	1	2	—	3	4	1	2	2
Food, bakery dairy stores	2	2	4	3	—	3	2	4	3	2
Eating and drinking establishments	3	1	6	3	2	4	1	11	7	5
Other retail	11	10	13	12	9	12	10	16	14	6
Finance, insurance and real estate	3	3	5	1	4	3	2	5	2	2
Business and repairs	2	3	2	2	—	4	4	3	3	3
Personal and other services	7	3	16	10	32	5	2	14	8	32
Entertainment and recreation	1	1	1	1	3	1	1	1	1	6
Health services and hospitals	6	2	13	4	2	3	1	8	2	3
Education	9	5	18	10	5	7	3	14	3	6
Other professions	4	3	6	3	5	3	2	5	2	4
Public administration	4	4	4	3	7	3	3	3	1	1

[a]Data from the 1970 Census of Population.

Table H-10. Unions Represented in Eddy and Lea Counties, 1978[a,b]

Name of union	Number of members	Area and activities covered
Carpenters' Local 1245	266	Carlsbad, Hobbs, Roswell Portales, Clovis, Tucumcari; construction contractors
International Brotherhood of Electrical Workers Local 693	259	Eddy and Lea Counties; electrical workers at potash mines (Duval, Potash Company of America, and Mississippi Chemical); four out of five local construction contractors
Iron Workers Local 775	40	Eddy and Lea Counties; local construction contractors, potash mines
Retail Clerks Local 462[c]	325	Eddy and Lea Counties; retail stores, grocery and department stores
United Steel Workers Locals 177, 178A, 181, 183, 187, 188A, 8507	1560	Eddy and Lea Counties; potash mines, Carlsbad city employees, school custodial and maintenance workers

[a]Data from Adcock (1979).
[b]Local offices in Carlsbad unless otherwise indicated.
[c]Local offices in Las Cruces.

than it had been in the past. A large number stressed that there were no problems. It is important to note that very few persons perceived any conflict between old and new residents. Overall, the interviewed persons characterized local residents as friendly, helpful, honest, and good.

In contrast to the positive attitudes about the community, approximately half the interviewees felt they had no meaningful chance of affecting political events. They felt that their involvement in the political process did not count. Furthermore, many of the responding persons saw no reason for becoming involved and were not interested in doing so. Only a small minority perceived an ability to influence decisionmaking.

Attitudes toward elected officials and their representation of the local constituency were generally consistent with the feelings about ability to affect local government decisions. Approximately half the interviewees felt well represented, while the other half did not. Those who did perceive a lack of good representation believed that only the wealthy and special interests are taken into account.

Local residents show a general preference for the current environment in the Carlsbad area. The local consensus on land-use patterns leaned toward no changes or only very minor ones. The changes most desired are increased agricultural development, mineral development, and urbanization-industrialization.

Churches and community organizations

Carlsbad has 60 churches and 1 synagogue; Hobbs has 70 churches and 1 synagogue; Loving has 3 churches. Of these churches, two in Carlsbad and one each in Hobbs and Loving are Catholic. Many of the remaining churches are Protestant (BBER, 1977a,b; Adcock, 1979).

There are 22 major civic and community organizations in Hobbs, 13 in Carlsbad, and 2 in Loving. Most of these are fraternal organizations, with membership in many restricted to men, although many have auxiliaries for wives (Adcock, 1979).

Social services

The social services available in both the Carlsbad-Loving area and in the municipality of Hobbs are rather extensive and cover a wide range of activities. The organizations providing these services are listed in Tables H-11 and H-12 for Carlsbad-Loving and Hobbs, respectively.

Community planning capabilities

Carlsbad and Hobbs are experiencing considerable growth in population and housing; this growth is expected to continue throughout the mid-1980s and probably into the year 2000. Both communities have planning agencies and various other city agencies that analyze and assist in the management of growth. The village of Loving, which has also experienced growth since 1970, currently has no municipal planning department (Adcock, 1979).

Table H-11. Social Services in Carlsbad-Loving, New Mexico[a]

Type of service or facility	Total staff[b]	Total participants[c]	Program or activity
			MENTAL HEALTH AND HEALTH SERVICES
Carlsbad Area Resource and Counseling Center	19	373	Rape Crisis Center Hotline Crisis Center First offenders program Mental-health services Treasure House Activity Center Youth service counseling Family counseling Parents Anonymous Testing and evaluation Drug-abuse clinic
Alcoholism Council of South Eddy County	6	60	Outpatient counseling Group counseling Seminars and lectures Initial screening for Cavern Lodge Halfway house

Table H-11. Social Services in Carlsbad-Loving, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total partic-ipants[c]	Program or activity
			MENTAL HEALTH AND HEALTH SERVICES (continued)
El Centro Rural de Salud	6	500	Primary medical care Prenatal care Family planning Social worker Counseling
Eddy County Health Center	16	3000-5000	Family planning Prenatal care Child-care clinic Maternity education Immunization program Crippled-children's services Social worker, South Eddy County Women's, Infants', Children's Nutrition Program Vital statistics
			SENIOR CITIZENS SERVICES
Eddy County Senior Citizens Program	NA	200 daily	Senior Citizens Nutritional Mealsite Recreation
Senior Recreation Center	4	550 daily	Recreation Club meetings Classes
Loving Mealsite Nutritional Program	NA	50 daily	Senior Citizens Nutritional Mealsite Recreation
			DAY CARE AND PRESCHOOL SERVICES
Cottage Preschool	4	34	Informal education, day care
Hillcrest Day Care Center	6	35	Informal education, day care
Harding Webster Preschool	NA	NA	Informal education, day care
First United Methodist Preschool	4	39	Informal education, day care
			YOUTH SERVICES
Campfire Girls	NA	NA	Informal education and vocational guidance Recreation

Table H-11. Social Services in Carlsbad-Loving, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total participants[c]	Program or activity
			YOUTH SERVICES (continued)
Boys Club of Carlsbad	3	600	Organized sports Recreation Library
			OTHER SERVICES
American Red Cross	2	200	Water safety training Blood-donor program Cardiopulmonary resuscitation training First-aid training Disaster relief Blood-pressure screening Services to military families
			EDUCATIONAL, VOCATIONAL, AND REHABILITATION SERVICES
Carlsbad Child Development Center	2	6-20	Preschool--handicapped children Family counseling
Carlsbad Association of Retarded Citizens Farm	NA	20-25	Counseling Vocational rehabilitation Recreation
			STATE AND FEDERAL SERVICES
Community Action Programs	125	550-600	Family planning Head Start Program Rural Health Clinic, Loving Weatherization program Rural housing program Senior Citizens Nutritional Program Summer youth recreation Emergency energy assistance Crisis intervention program Youth tutoring Home education livelihood program
New Mexico Social Services Division	14	463	Referrals Protective service for children and adults Disease investigation Adult services Adoption Foster care

Table H-11. Social Services in Carlsbad-Loving, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total partic- ipants[c]	Program or activity
			STATE AND FEDERAL SERVICES (continued)
			Nursing-home discharge planning
			Homemakers service permanency planning for children
			Day care
			Family planning
			Health support
			Critical in-home care
			Drug abuse
			Youth services
			Legal services
			Emergency shelter
			Family counseling
Employment Services Division	20	463	Employment information and referral
			Aid to Families with Dependent Children

[a]Data from Adcock (1979).
[b]Data for 1979; NA = not available.
[c]Monthly estimates unless otherwise indicated.

Table H-12. Social Services in Hobbs, New Mexico[a]

Type of service or facility	Total staff[b]	Total partic- ipants[c]	Program or activity
			MENTAL HEALTH AND HEALTH SERVICES
Crisis Center of Lea County	25	500	Day activities for senior citizens
			Group therapy
			Alcohol abuse
			Child services
			Parent education services
			Drug abuse
			Medication program
			Methadone program
			Educational programs for public schools
			Rape crisis program
			Volunteer Shelter Bed

Table H-12. Social Services in Hobbs, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total participants[c]	Program or activity
			MENTAL HEALTH AND HEALTH SERVICES (continued)
Parents Anonymous (prevention and treatment of child abuse)	4	200	Telephone hotline and referral Group meetings
Mental Health Activity Center	1	119	Recreation, socials Special education, gifts and parties Special Olympics Annual scholarships
			SENIOR CITIZENS SERVICES
Senior Citizens Center	6	1070	Classes Dances Workshops Luncheons Meals on Wheels Information and referral Occasional transportation services
Good Samaritan Village	68	124	Residence, recreation, entertainment
La Siesta Retirement Center	37	55	Nursing, residence, recreation
			EDUCATIONAL, VOCATIONAL, AND REHABILITATION SERVICES
Child Development Center of Lea County	4	79	Level D special education Speech therapy Physical therapy
Vocational Rehabilitation (oil-field injuries)	2	35	Medical treatment Counseling Reeducation Arranging financial assistance
Lea Work Activity Center (for the handicapped)	7	36	Recreation Community services Transportation
			STATE SERVICES
Social Services Division	24	600	Counseling services Limited critical in-home care Family planning

Table H-12. Social Services in Hobbs, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total participants[c]	Program or activity
			STATE SERVICES (continued)
			Health support Homemaker services Information and referral Adoption services Day care Protective services for children Foster care
Employment Services Division	9	337	Information and referral Aid to Families with Dependent Children
			DAY CARE AND PRESCHOOL SERVICES
Kinder Care Learning Centers, Inc.	9	88	Informal education, day care
Washington Nursery	10	90	Day care
Little Peoples Kountry Kindergarten	3	21	Informal education, day care
			YOUTH SERVICES
Boys Club of Hobbs	5	1300	Indoor recreation Library Television Organized sports
Girl Scout House	1	1000	World of Arts World of People World of the Out-of-Doors World of Well-Being
Junior Achievement of Hobbs	NA	NA	Recreation Community service
			OTHER SERVICES
American Red Cross	1	270	Services to military families Disaster relief Blood-pressure screening Water safety training Blood-donor program

Table H-12. Social Services in Hobbs, New Mexico[a] (continued)

Type of service or facility	Total staff[b]	Total partic- ipants[c]	Program or activity
			OTHER SERVICES (continued)
			Cardiopulmonary resuscitation training
			First-aid training

[a]Data from Adcock (1979).
[b]Data for 1979; NA = not available.
[c]Monthly estimates unless otherwise indicated.

H.3 ECONOMIC SETTING

H.3.1 General Economic Characteristics

As defined by standard economic-base theory, there are three basic economic sectors in Eddy and Lea Counties: mining, manufacturing, and agriculture. Although government is a basic industry* in many parts of New Mexico because of heavy Federal activity, most governmental activity in Eddy and Lea Counties is only a supportive function (USDC, 1975-1979). The nonbasic sectors in the two counties include contract construction; transportation, communications, and utilities; trade; finance, insurance, and real estate; and services. Certain activities in the retail-and-services sector are larger than might be expected because of heavy tourist traffic (Carlsbad Caverns). Transportation facilities and the transportation sector in the area are well developed because of the heavy industry.

Basic industries

Mining, which includes oil and gas extraction, is the major industry in both counties. In 1978 mining employed approximately 3600 and 6000 persons in Eddy and Lea Counties, respectively. In both counties employment in mining was substantially higher than in any other industrial sector (NMESD, 1975-1979). In Eddy County potash mining employs more than nine out of ten persons working in this sector. Figures for 1977 showed that New Mexico (Eddy and Lea Counties) supplied 93% of the total potash mined in the United States (USBM, 1978). In Lea County mining is centered on oil and gas (5800 employees in 1978); mining in potash, sand and gravel, rock salt, and caliche employed fewer than 200 people in 1977 (NMESD, 1975-1979).

In Eddy County personal income from mining accounted for more than 24.6% of total personal income in 1977. In Lea County this figure was just more than 31.2%. Moreover, the impact of mining is increasing: personal income from mining rose approximately 170% from 1970 through 1977, while personal income from other services rose 118% over the same period (USDC, 1975-1979).

At the beginning of 1978, there were 43 manufacturing companies with approximately 920 employees in Eddy County and 51 manufacturing companies with approximately 1085 employees in Lea County. In 1976 manufacturing was second in income generated by a basic industry. However, the total personal income from manufacturing was only 5.2% of all personal income generated in the two-county area (NMESD, 1975-1979).

In 1975 the principal subsector of agriculture in the two-county area was meat animals and livestock. In the immediate area of the WIPP site (10-mile radius), agriculture is restricted to cattle grazing. Personal income from agriculture in 1975 was less than 4% of the total personal income derived in the two-county area.

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*Basic industries are those whose level of activity is not closely tied to the level of economic activity in the local community (Tiebout, 1962, p. 74).

Trade and services

The 1972 Census of Business shows 454 retail outlets in Eddy County and 614 in Lea County, for a total of 1068. In Eddy County the majority, 281, are located in Carlsbad. The total sales volume in 1972 was about $185.9 million, or just over 8% of the statewide total of more than $2.3 billion. Although little sales-volume information is available after 1972, retail sales in the area have increased substantially. During the period 1972-1978, employment in wholesale and retail trade increased from an average of 2500 to approximately 3500 in Eddy County and from approximately 3600 to 5200 in Lea County (NMESD, 1975-1979).

The Rand-McNally 1978 Commercial Atlas and Marketing Guide shows both Eddy and Lea Counties as basic trade areas (i.e., areas in which normal retail-trade purchases are made). Rand-McNally defines 50 major trade areas with a major central city from which substantial retailing and wholesaling operations are conducted. The Carlsbad basic trade area, Eddy County, is in the major trade area of El Paso; the Hobbs trade area, Lea County, is in the major trade area of Dallas. It is important to note that the basic trade areas for both Carlsbad and Hobbs do not extend beyond their respective county limits to any significant degree. Therefore, Rand-McNally notes few leakages in normal retail purchases from the two-county area. However, for major retail purchases and wholesaling there is substantial leakage out of the State into El Paso and Dallas.

There were 835 service establishments (e.g., hotels, motels, barber shops, advertisers, business services, repair shops) at the time of the 1972 Census of Business. Activity in this sector increased substantially during the period 1972-1978, with service-sector employment in Eddy County rising from approximately 1900 to 2700 and in Lea County from approximately 1800 to 2300 (NMESD, 1975-1979).

Tourism

Tourism contributes substantially to economic activity in the two-county area, particularly in Eddy County. The main tourist attraction in the area is Carlsbad Caverns National Park, which is approximately 22 miles southwest of Carlsbad and 41 miles west-southwest of the site. In 1978 it received 867,276 visitors, or nearly 44% of the visitors to all 11 national parks and monuments throughout the State (USDI, 1970-1978). Nearby parks (Guadalupe Mountains National Park, Living Desert State Park, the Presidents' Park in Carlsbad, and others) also attract local residents and tourists.

The effects of tourism in the area can be readily seen in employment statistics, with retail trade and selected services being most affected. For example, employment in eating and drinking establishments more than triples in the three summer months, and summer employment in lodging increases 60% to 70% over winter employment (NMESD, 1975-1979). Other secondary and tertiary services affected by tourism (e.g., curio sales, barber shops, cleaners) also show substantial increases.

Tourism is highly seasonal, with visits to Carlsbad Caverns fluctuating from a high of 187,970 in July 1977 to a low of 25,350 in January (USDI, 1970-1978). To support the tourist industry, the City of Carlsbad, which receives most of the impact from the national park, has a total of 20 motels and hotels with approximately 1100 rooms (data from the Carlsbad Department of Development, 1979).

Financial resources

In Eddy and Lea Counties there are a total of nine chartered banks--four holding state charters and five holding national charters. Five of these eight banks (three state and two national) are in Eddy County. Assets, liabilities, and deposits as of December 31, 1978, are reported in Table H-13.

There are four savings and loan institutions in the two-county area. The three with main offices in Eddy County are mutual savings and loan institutions that have combined assets of more than $148.3 million and total savings accounts of more than $118.9 million. The savings and loan institution with a main office in Lea County at Hobbs is a capital-stock institution; it has total assets of more than $27.4 million and about $21.3 million in total savings accounts.

There are three credit unions in the two-county area. The two credit unions in Eddy County (one in Carlsbad and one in Artesia) are for school employees; both are insured by the National Credit Union Administration. They have combined assets of more than $2.7 million and combined shares and deposits of just over $2.2 million. The credit union in Lea County at Lovington, insured by the New Mexico Credit Union Insurance Corporation, has total assets of over $1.4 million and total shares and deposits of $1.2 million.

Nineteen small-loan licensees are doing business in the two-county area. Ten are in Eddy County: six in Carlsbad, three in Artesia, and one in Loving. Nine are in Lea County: six in Hobbs, one in Jal, and two in Lovington (NMDB, 1979).

In Carlsbad long-term (25-30 years) financing for residential mortgage loans is provided primarily by the savings and loan associations. The banks do provide some short-term and interim financing.

The availability of mortgage loans has fluctuated in accordance with the credit (interest-rate) conditions throughout the nation. The State of New Mexico Usury Law requires any mortgage loan with an interest rate higher than 10% to be sold in the "secondary" mortgage-loan market. Secondary-market funds have also fluctuated in accordance with the credit conditions and interest rates.

The Carlsbad municipal area is regulated by the existence of a 100-year floodway, as defined by the Federal Insurance Administration's Flood Insurance Study. Because the local government has rejected the criteria that establish qualification for Federal flood insurance, local mortgage loans are available only for developments outside the boundaries of the 100-year floodway (Figure H-6).

Periodically, the State of New Mexico Finance Authority (NMFA) provides funds for residential mortgage loans. The financial institutions in Carlsbad do participate in the distribution of these funds when they are available.

Table H-13. Banking Activity in Eddy and Lea Counties[a]

Location	State banks	Branches	National banks	Branches	Total assets[b]	Total liability[b]	Equity capital[b]	Total deposits[b]
New Mexico	46	113	40	111	4904.7	4547.1	323.8	4296.3
Eddy County	3	4	2	1	231.9	213.3	16.9	211.2
Carlsbad	2	4	2	1	143.2	133.0	9.4	131.0
Artesia	1	0	1	0	88.7	81.2	7.5	80.1
Lea County	1	7	3	8	342.0	317.9	19.4	302.4
Hobbs	1	7	2	5	297.7	276.3	17.4	261.2
Lovington	0	0	1	3	44.3	41.6	2.0	41.3

[a]Data from Sixty-fourth Annual Report, New Mexico Department of Banking, issued 1979 (December 31, 1978, data).

[b]Millions of dollars.

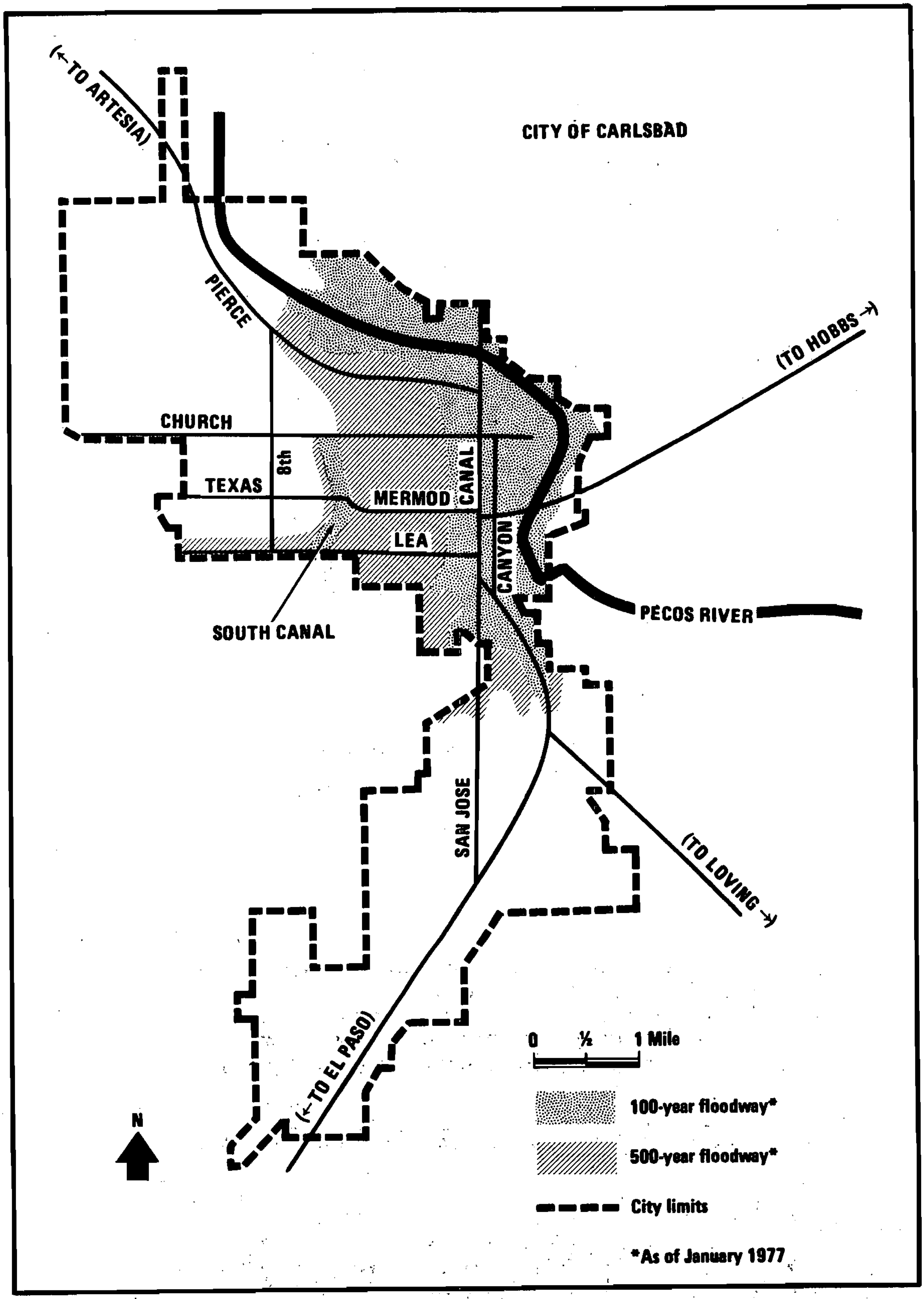

Figure H-6. Map of Carlsbad floodway.

During 1979, NMFA funds bearing a 7.75% interest rate were available throughout Eddy and Lea Counties; demand for the NMFA loans liquidated the available funds soon after they became available.

Currently, neither the savings and loan associations nor the banks extend mortgage loans for commercial establishments in Carlsbad.

In Hobbs the savings and loan associations and the banks provide financing for long- and short-term mortgage loans. Generally, the availability of residential and commercial loans has fluctuated, the conditions being similar to those described for Carlsbad. A municipal bond issue has recently provided funds for residential mortgage loans.

Because of Loving's proximity to Carlsbad (12 miles), its residential and commercial mortgage-loan market reflects the conditions existing in Carlsbad.

H.3.2 Labor Force

Labor force is defined by the U.S. Department of Labor as persons who are employed and those who are unemployed and are actively seeking employment. In the first 6 months of 1979 the combined total labor force in Eddy (19,905) and Lea (25,815) Counties was approximately 45,700. Total employment in the two-county area was 43,855 (NMESD, 1975-1979).

Between 1974 and 1978 the economy of both counties expanded, the total labor force increasing by approximately 7800 individuals (20.6% for the period, 4.8% annually). The overall growth of employment for the 4-year period was 22.4%, or about 5.2% annually. Therefore, the number and the percentage of unemployed persons have decreased during the last 4 years. Although the combined unemployment rate for the two counties in the first 6 months of 1979 was approximately 4.1%, the rate varies significantly between Eddy (4.3%) and Lea (3.9%) Counties (NMESD, 1975-1979).

Employment

Mining is by far the largest employer in the two-county area. Accurate figures on agricultural employment are difficult to obtain and are normally out of date; the latest available credible information shows just under 2000 employees in the two counties in 1977 (USDC, 1975-1979). In 1978 manufacturing employed approximately 2000 persons: 921 in Eddy County and 1087 in Lea County (NMESD, 1975-1979).

The distribution of employment among industrial sectors is presented in Table H-14.

Unemployment

Unemployment in the two-county area is lower than the State average; the 1978 average rates were 4.5% in Eddy County and 4.0% in Lea County. Seasonal unemployment rates vary significantly, with higher rates during June and lower rates in late spring and late fall. The variations occur primarily because of fluctuations in the summer-month employment patterns of agricultural, student, and certain noncontract school personnel (NMESD, 1975-1979).

Table H-14. Employment Sectors

Industry	Percentage distribution[a]
Agriculture	5
Mining	26
Manufacturing	5
Construction	6
Transportation, communications, and utilities	9
Wholesale and retail trade	24
Finance, insurance, and real estate	4
Services	13
Government	12

[a]Data from the New Mexico Employment Security Department NMESD (1975-1979). Percentages do not add to 100% because of rounding.

Applications for work through the New Mexico Employment Security Department (formerly the Employment Security Commission) reveal that a large number of people with technical skills, many directly connected with construction and mining, and a large number of clerical and secretarial workers are available in the area.

Underemployment and disguised unemployment

The unemployment rate computed by the State and Federal governments is based on persons actively seeking employment. An area may sometimes have a concurrent low level of defined unemployment and significant underemployment (i.e., occupations or jobs that do not take full advantage of an employee's potential). Although labor statistics and wage rates indicate that there may be some underemployment because of seasonal employment patterns in the two-county area, underemployment does not appear to be significant in the labor market.

Disguised unemployment may exist when many persons who are not actively seeking employment would take a job if one were available in the area. Disguised unemployment is measured by labor-force participation rates. In the two-county area the labor-force participation rate for males is higher than the State average, while the rate for females is lower than the State average (USDC, 1970b). These data imply that not all females who are willing to work are actively seeking employment and that the labor-force availability for females may be greater than current statistics indicate.

Major employers

Nine of the 20 major employers in the two-county area are mining or service-to-mining companies (Table H-15). Only two of the 20 major employers, Levi Strauss and the Holly and Navajo Corporation, are listed by the Employment Security Department as manufacturing companies.

Table H-15. Major Employers in Eddy and Lea Counties[a]

Number of employees	Company	Services
	EDDY COUNTY	
151-250	Mississippi Chemical	Mining
	Lakeview Christian Home	Retirement home
	Holly and Navajo Corporation	Refining
251-500	Kerr-McGee Corporation	Mining
	Duval Corporation	Mining
	Amax Chemical	Mining
	Guadalupe Medical Center	Medical
501-750	Potash Company of America (Ideal Basic Industries)	Mining
	International Minerals	Mining
Not known	Evangelical Lutheran Center	Nursing home
	LEA COUNTY	
100-150	Halliburton Company	Oil field
	Moran Company	Oil-well drilling
	First National Bank	Banking
151-250	B&M (well service)	Oil field
	Levi Strauss	Manufacturing
	General Telephone	Utility
251-750	Lea County Regional Hospital	Medical
	El Paso Natural Gas	Refining natural gas
	National Potash	Mining
Not known	M.G.F. Drilling Company	Oil-well drilling

[a]Data from the Carlsbad Department of Development (1977-1979) and the Industrial Development Corporation of Lea County (1979).

Personal income

The total annual personal income in 1977 was listed by the Bureau of Economic Analysis as $276.8 million in Eddy County and $360.5 million in Lea County. The two-county area accounts for about 9% of the total annual personal income of all State residents. The total annual personal income in Lea County has been showing steady increases in recent years. Because of declines in the potash industry during the middle and late 1960s, Eddy County sustained a decrease in the total personal income in 1968 and in 1969 barely reached the level established in 1967; since 1968, however, it has shown increases. While information after 1977 is not available, trends in the area and in the State indicate that the total personal income in the two-county area has been increasing at more than 12% per year since 1976 (USDC, 1975-1979).

The per-capita income in the two counties is higher than that in the State: in 1977 it was $6811 in Lea County, or approximately 16.5% above the $5846 registered statewide level, and $6089 in Eddy County, about 4.2% above the statewide level. In Lea County the per-capita income increased 118.5% between 1970 and 1977, while in Eddy County the increase was only slightly less at 101.7%. The statewide level increased 99.8% during the same period; thus the per-capita income for the two-county area is increasing faster than the statewide average. It is important to note that the per-capita income in both counties is above the national average for non-SMSA (Standard Metropolitan Statistical Area) counties. In Lea County the per-capita income is 118.2% of the non-SMSA county national average, while the Eddy County level is 106.0% (USDC, 1975-1979).

H.3.3 Housing and Land Use

Carlsbad

According to officials of the City of Carlsbad, between June 1977 and August 1979 Carlsbad annexed 8544 acres of land, thereby increasing the land area within its city limits to 13,335 acres. With the addition of the annexed land, most of which is vacant, the total vacant land area in Carlsbad amounts to approximately 7500 acres, which is 57% of the total municipal acreage.

Land-use patterns inside the city limits are currently changing. Much of the city is being rezoned, with the outcome of the rezoning in doubt. Until rezoning is settled, it is not possible to accurately predict either the location or the total amount of land to be available for future residential, commercial, and industrial development.

Information from the City of Carlsbad shows that, during the period 1970-1977, new housing units were added to the city's housing stock at a rate of approximately 160 per year. Actual construction averaged approximately 180 units per year for that period, with approximately 25 of the new construction units replacing structures that were classified as "demolitions." Concurrently, the vacancy rate decreased from approximately 3% in 1970 to 1% by 1977. In 1978 construction activity increased, with 257 new housing units being constructed. However, demolitions and population growth maintained the vacancy rate at an average of approximately 1%. If the vacancy rate were to have been reestablished at a level of 3%, generally accepted as the desirable vacancy rate that permits orderly population and community growth, it would have been necessary to construct an additional 153 housing units in 1978.

By mid-1979, the Carlsbad housing stock was estimated to be approximately 10,198 units (Table H-16). The most recent information from the City of Carlsbad (1979) indicates that the vacancy rate has remained at a level of approximately 1%.

Temporary housing is available on a seasonal basis in Carlsbad's 20 motels, which have a total of about 1100 rooms. Between Memorial Day and Labor Day occupancy rates are about 100%. Nonsummer occupancy rates on weekends are as low as 50% in some motels but 95% to 100% on weekdays (data from the Carlsbad Department of Development, 1979).

The Federal Housing Authority's Section 8 program provides rent and utility assistance (75%) to qualified renters. Generally, to qualify, a person must be more than 62 years old, disabled, or handicapped and have an income of less than $8500 (single-person limit). In November 1979 there were 91 program participants and approximately 25 to 30 applicants for the program (personal communication from J. Haut, U.S. Department of Housing and Urban Development, Roswell, New Mexico, 1979).

Table H-16. Housing Stock in Carlsbad, 1978

Type	Total	Occupied	Unoccupied
All units	10,198[a]	10,045[b]	153
Single-family units	8,166[a]	8,044[c]	122
Multifamily units	1,101[a]	1,084[c]	17
Mobile homes	931[d]	917[c]	14

[a]Based on data from the U.S. Department of Commerce, 1970 Census of Housing (USDC, 1970c), and subsequent building-permit and demolition data.
[b]Based on population and household-size estimates prepared for this report.
[c]Occupancy rates assumed identical for all housing types.
[d]Datum from Adcock (1979).

Hobbs

According to current information from the City of Hobbs (1979), the total land area inside the Hobbs city limits, including the Hobbs Industrial Air Park, is about 14,830 acres. Not including the Air Park, approximately 1070 acres are vacant and available for residential, commercial, or industrial development. Virtually the total area of the Air Park is vacant at present, providing an additional 3500 acres for industrial development. Since Hobbs has no zoning ordinance, there are no figures on the total amount of land available for specific types of use.

From 1970 to 1977, new housing units were added to the Hobbs housing stock at a rate of about 215 per year. Actual construction averaged 254 units per year for the period, with about 40 units per year replacing condemned or removed structures. This relatively low rate of addition to the housing stock caused the vacancy rate to decline from nearly 9% in 1970 to just over 1% in 1975. In 1976 and 1977 construction activity increased, with 414 new housing units added in 1976 and 611 units in 1977, and vacancy rates increasing to about 2% because of the recent construction activity. At the end of 1977, the housing stock in Hobbs was estimated at 10,879 units. The year 1978 saw a continuation of increased housing construction, with 466 new units added. However, demolitions and population growth maintained the vacancy rate at an average of approximately 2%. If a vacancy rate of 3% were to have been re-established, it would have been necessary to construct 114 additional housing units in 1978.

At the end of 1978, the Hobbs housing stock was estimated to be approximately 11,345 units (Table H-17). The most recent information from the City of Hobbs (1979) indicates that the vacancy rate has remained at a level of approximately 2%.

Temporary housing in Hobbs is available in 11 motels with 482 rooms. Seasonal occupancy patterns are very similar to those for Carlsbad. On a year-round basis, occupancy averages 84%, with the Memorial Day to Labor Day rate at 95% or higher. Nonsummer occupancy is lower than summer occupancy on the average, but midweek occupancy is very high even in nonsummer months.

The Federal Housing Authority's Section 8 Program currently provides rent and utility assistance to 39 qualified renters in Hobbs, and there are approximately five applicants on the waiting list (personal communication from J. Haut, U.S. Department of Housing and Urban Development, Roswell, New Mexico, 1979).

Table H-17. Housing Stock in Hobbs, 1978[a]

Type	Total	Occupied	Unoccupied
All units	11,345	11,119	226
Single-family units	8,677	8,503	174
Multifamily units	1,295	1,269	26
Mobile homes	1,373	1,345	28

[a]Data from the City of Hobbs, 1979. Occupancy based on a vacancy-rate estimate in this housing count, with vacancy rates assumed to be identical for all housing types.

Loving

During the period 1970 through October 1979, the housing stock in Loving increased by 19.9% from 403 (USDC, 1970c) to 483 housing units (Table H-18) (Adcock, 1979). The vacancy rate decreased from 27% (109 units) in 1970 (USDC, 1970c) to 4.3% (21 units) in October 1979 (Adcock, 1979).

Official information regarding the current (November 1979) quality of housing is not available; the most recent information is for 1974. According to the results of a 1974 housing survey conducted by the Southeastern New Mexico Economic Development District (SENM EDD), 58% of the housing units were of sound condition, 26% were deteriorating, and 16% were dilapidated.

The 1974 SENM EDD survey used the number of mobile homes in the community as a measure of the quality of housing stock; mobile homes are considered to be inferior to other types of structurally sound housing units. Recently, the number of mobile homes in Loving has been increasing. During the period 1974-1979, mobile homes increased from the 14 units counted in the above-mentioned survey to 49 units (Adcock, 1979), an increase of 250%.

The results of the 1979 Loving structure inventory compiled by Larry Adcock and Associates show that neither the overall numbers nor the percentages of sound versus deteriorating and dilapidated housing units have changed significantly since 1974.

The Federal Housing Authority's Section 8 Program had no recipients in Loving as of October 1979 (personal communication from J. Haut, U.S. Department of Housing and Urban Development, Roswell, New Mexico, 1979).

Table H-18. Housing Stock in Loving, 1979[a]

Type	Total	Occupied	Unoccupied
All units	483	462	21
Single-family units	410	389	21
Multifamily units	24	24	NA[b]
Mobile homes	49	49	NA[b]

[a]Data from Larry Adcock and Associates (1979), Residential, Commercial, and Service Structure Inventory.
[b]NA = not applicable.

H.3.4 Community Facilities

Education

There are three public school districts in Eddy County and five in Lea County, with a combined 1978-1979 enrollment of 21,927. Three public school districts appear likely to experience substantial impacts from the WIPP. Special education, adult education, and technical-vocational programs are offered through the municipal school systems in Carlsbad and Hobbs.

Three institutions of higher education are in the vicinity of the WIPP site: a branch of the New Mexico State University in Carlsbad and the New Mexico Junior College and the College of the Southwest (a small 4-year institution) in Hobbs. The Eastern New Mexico University maintains a branch in Roswell, about 75 miles north of Carlsbad, and has its main campus in Portales, approximately 110 miles north of Hobbs. The New Mexico Military Institute is also located in Roswell. Somewhat farther from the site are the New Mexico State University, with a main campus in Las Cruces and a branch in Alamogordo, and the University of Texas at El Paso.

Carlsbad. Information obtained in 1979 from the Carlsbad School District shows that the Carlsbad school system consists of ten elementary schools, two junior high schools, one mid-high school, and one senior high school, with a combined enrollment of about 6620 students. This enrollment is well below the capacity of 10,000 students. As shown in Table H-19, the excess capacity exists at all grade levels.

Table H-19. Carlsbad School District Enrollment[a]

Year	K-6[b]	Grade 7-8	9-10	11-12	Total
		ENROLLMENT CAPACITY[c]			
	4600	1860	1770	1870	10,000
		ACTUAL ENROLLMENT[d]			
1977-1978	3178	1390	1132	1037	6737
1978-1979	3501	982	1178	960	6621

[a]Data from the Carlsbad School District (1979).
[b]Includes special education "C" and "D" kindergarten students counted as full time.
[c]Assumes a capacity of 24 students per classroom.
[d]Carlsbad 40-day average daily membership reports.

The Carlsbad school system has a complete special education program that conforms to standards set by the State of New Mexico. With approximately 455 students at present, the special education program serves mentally retarded persons between the ages of 5 and 21 and also assists children with speech and learning disabilities.

Adult-education programs are provided through the public school system. These programs offer training in basic skills as well as classes leading up to General Education Development Tests.

Technical-vocational training programs are provided by both the high schools and the branch of the New Mexico State University. There are also work/study and other vocational training programs for the mentally retarded.

Hobbs. The Hobbs school system currently consists of ten elementary schools (kindergarten through grade 6), three junior high schools (grades 7 through 9), and one high school (grades 10 through 12). According to information from the Hobbs School District, the total enrollment for the 1978-1979 school year was about 7630 students (Table H-20). This enrollment is somewhat below the estimated capacity of 8350 students.

Special education programs are offered for persons between the ages of 6 and 21. There are also programs for children in grades 1 through 6 with learning disabilities.

Table H-20. Hobbs School District Enrollment in the 1978-1979 School Year[a]

Grade			
K-6[b]	7-9	10-12	Total
	ENROLLMENT CAPACITY[c]		
4630	1990	1730	8350
	ACTUAL ENROLLMENT[d]		
4237	1715	1677	7629

[a]Data from the Hobbs School District (1979).
[b]Includes special education "C" and "D" kindergarten students counted as full time.
[c]Assumes a capacity of 24 students per classroom.
[d]Hobbs 40-day average daily membership reports.

Table H-21. Loving School District Enrollment in the 1978-1979 School Year[a]

Grade			
K[b]	1-6	7-9	Total
	ENROLLMENT CAPACITY[c]		
48	240	140	428
	ACTUAL ENROLLMENT[d]		
35	188	199	342

[a]Data from the Loving School District (1979).
[b]Includes special education "C" and "D" kindergarten students counted as full time.
[c]Assumes a capacity of 24 students per classroom.
[d]Loving 40-day average daily membership reports.

Adult education classes that upgrade basic skills to the eighth-grade level are offered. Classes preparing for the General Education Development Tests are also provided.

Technical-vocational programs are provided by the high school and the New Mexico Junior College. There is also a special vocational rehabilitation program for the mentally retarded.

Loving. The Loving school system currently consists of two schools: one elementary and one junior high school. According to information obtained in 1979 from the Loving School District, some 120 high-school-age students from the Loving district currently attend classes in Carlsbad schools. The district's combined enrollment totals 342 full-time students (Table H-21). The enrollment is well below the school-district capacity of approximately 430 pupils. This excess capacity exists at all levels except the fourth and sixth grades.

Municipal water systems

Carlsbad. According to information provided by city officials in 1979, Carlsbad obtains its water from a well field in the Capitan Reef (Figure H-7) and through a pipeline from the Double Eagle System to the northeast of the city. There are eight wells presently pumping water from the Capitan field and 22 wells in the Double Eagle field. In addition, there are three wells within the city limits that are not used because the water under Carlsbad is of lower quality than water outside the city limits.

The city has rights to 9200 acre-feet per year in the Capitan Reef and 7648 acre-feet per year in the Double Eagle field. In addition, Carlsbad has rights to 10,640 acre-feet per year from a well field north of the city in the Ogallala Formation, giving the city total rights to over 27,000 acre-feet per year.

Current (1979) consumption averages about 5.8 million gallons per day (mgd) in Carlsbad. Peak consumption is about 16 mgd, well within the current 26.4-mgd capacity of the delivery system.

Hobbs. Information obtained in 1979 from city officials shows that Hobbs currently has rights to 18,888 acre-feet of water per year from ground-water sources (primarily inside city limits) in the Ogallala Formation. In addition, it has an allocation of 15,340 acre-feet per year from the proposed Eastern New Mexico Water Supply System, which would deliver water from the Ute Reservoir to 10 communities in eastern New Mexico. The status of this project is currently very uncertain, and it is not known when, if ever, the delivery of water to Hobbs will begin.

Municipal water is supplied from 28 wells located in and around the city (Figure H-8). The current potential yield of the wells is about 14 mgd.

Average consumption is currently about 12 mgd. Peak daily consumption, normally about double the average daily rate in this area, is limited by the capacity of the delivery-and-storage system to just over 14 mgd. Thus, although the total water rights in the Ogallala Formation are adequate for current demands (about 7050 acre-feet per year), there is a need for additional wells and storage-and-delivery facilities. The recent completion of four additional wells will partially alleviate the existing water system's limitations.

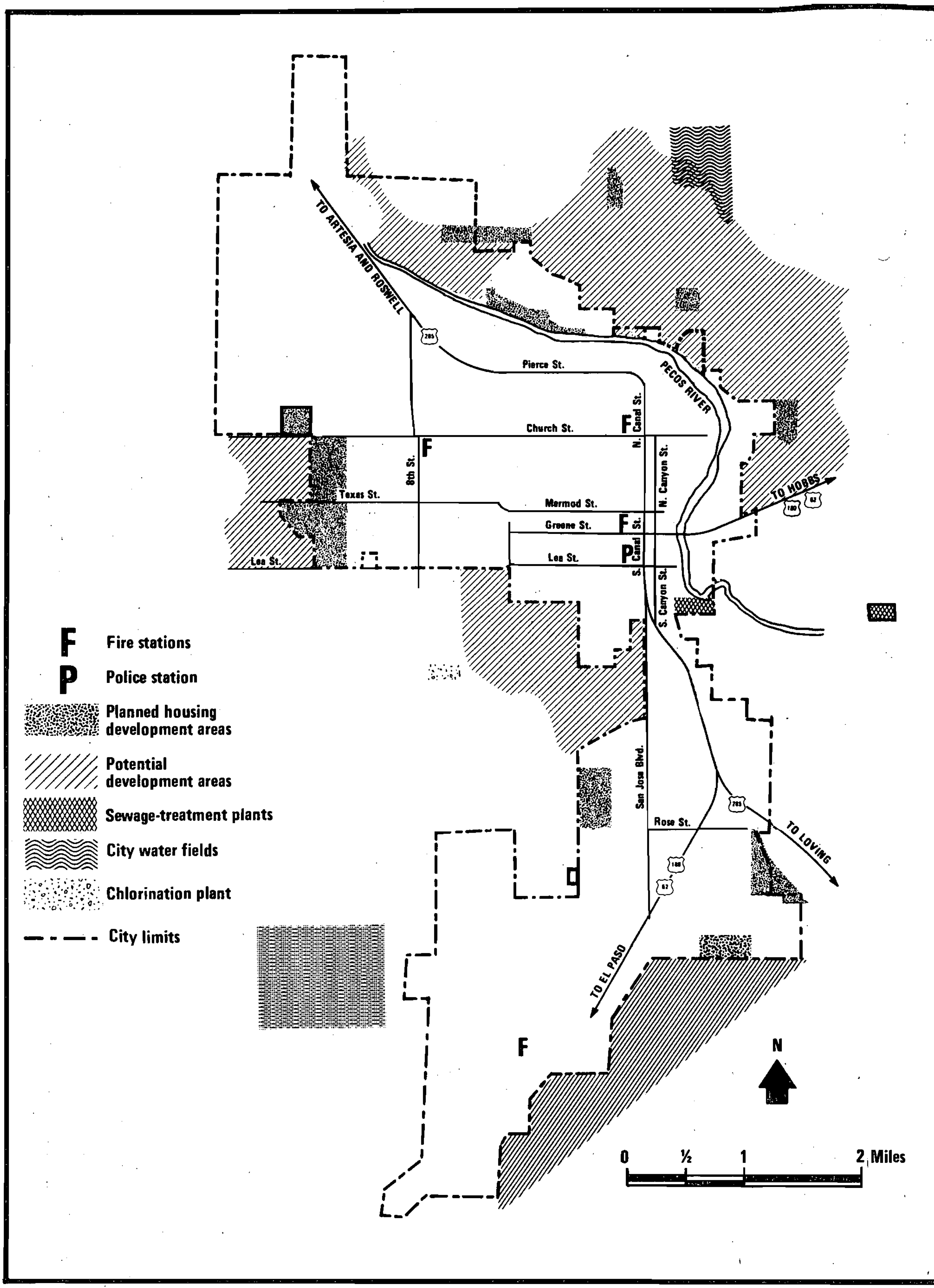

Figure H-7. Municipal facilities, water system and sewage-treatment plants, Carlsbad.

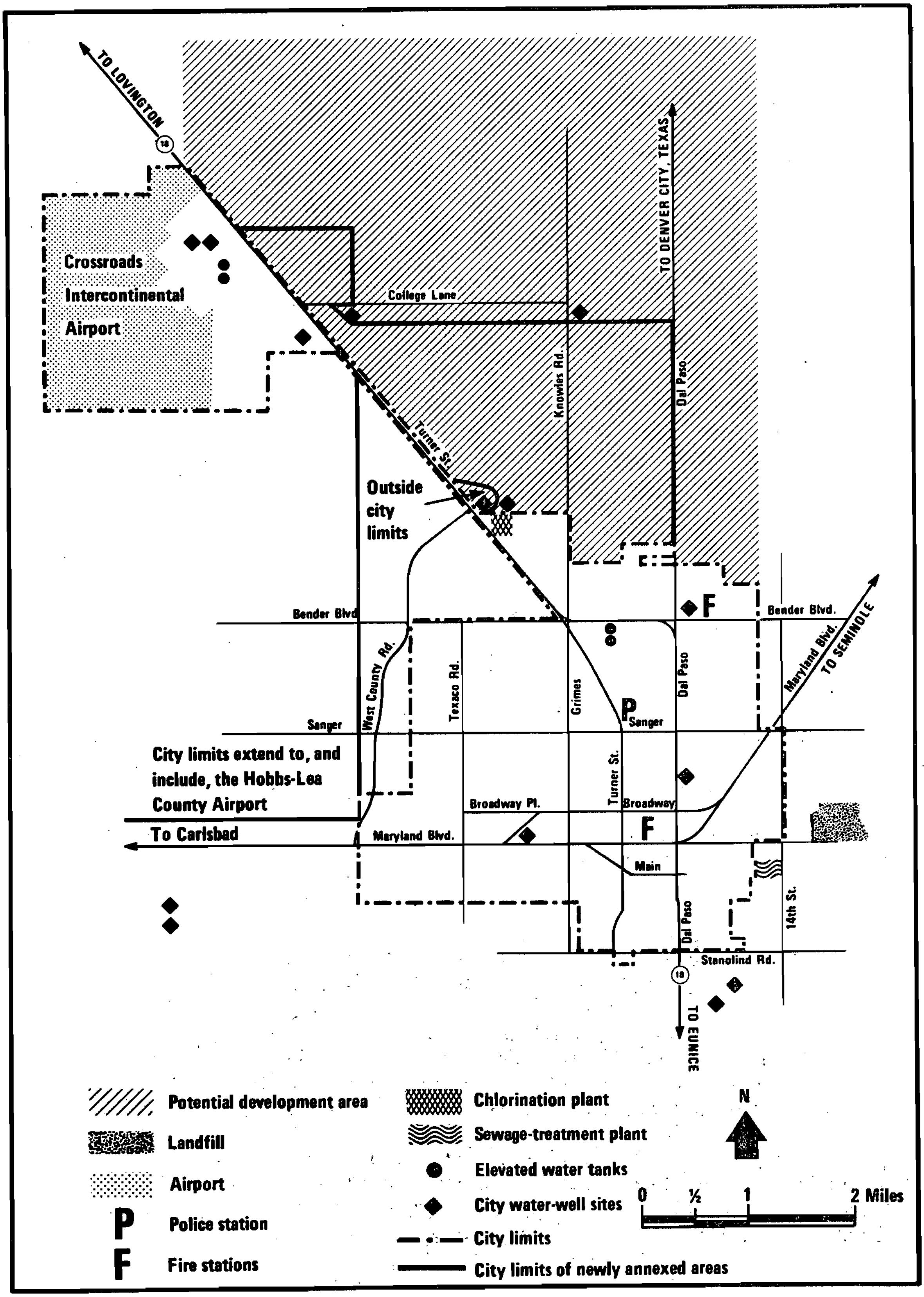

Figure H-8. Municipal facilities, water system, and sewage-treatment plant, Hobbs.

Loving. Loving currently obtains its water supply from four wells located about 7 miles from the community (Figure H-9). The village purchased the system in 1960 from a private firm. The system contains one 125,000-gallon and one 150,000-gallon storage tank. Water is also supplied to the community of Malaga, which is south of Loving (communication from Molzen-Corbin and Associates, Albuquerque, New Mexico, 1979).

The available water rights of 800 acre-feet per year are sufficient to meet the current and future needs of the community, considering its relatively slow growth.

The current average consumption is approximately 91 million gallons per year, or 258,000 gallons per day. The peak consumption of approximately 500,000 gallons per day exceeds the present system's delivery and storage capacity of 250,000 gallons per day (data from Molzen-Corbin and Associates, Albuquerque, New Mexico, 1979).

To meet the current water demand, the existing 6- and 8-inch pipeline is scheduled to be replaced by a 10-inch pipeline. In addition, a new 500,000-gallon storage facility is to be constructed at the well site. Bids for the water-system improvements were opened in October 1979.

Municipal wastewater systems*

Carlsbad. The Carlsbad municipal sewage-treatment plant, inadequate for current needs, is being expanded and upgraded, with construction expected to be completed by September 1981. On completion, the plant will have a design capacity adequate to serve 50,000 people. Effluent waste will be used to irrigate a 700-acre farm owned by the city.

Sewage-collection facilities provide service to the entire city (Figure H-7). Residential areas outside city limits use septic systems. About 25% to 30% of the developing areas in the vicinity of the city are currently not suited to the use of conventional percolation septic systems and must use the somewhat more expensive evapotranspiration septic systems.

Hobbs. The construction of a new municipal sewage-treatment plant is under way, with completion expected in early 1980. The new plant will have an initial capacity of 5 mgd and a capability to expand to 6 mgd.

There are also plans to expand and upgrade the main sewer lines in the city. Two of the three existing main trunk lines will be affected, with one being rebuilt and one being paralleled by a new bypass line. The completion of the project is expected early in 1980.

Since April 1, 1978, developing areas north of Hobbs (Figure H-8) have been restricted by the New Mexico Environmental Improvement Division to the use of evapotranspiration septic systems because of past problems with sewage from percolation systems seeping into local water supplies. The use of the

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*Data obtained from the City of Carlsbad (1979), the City of Hobbs (1979), and the New Mexico Environmental Improvement Division (1978), unless otherwise stated.

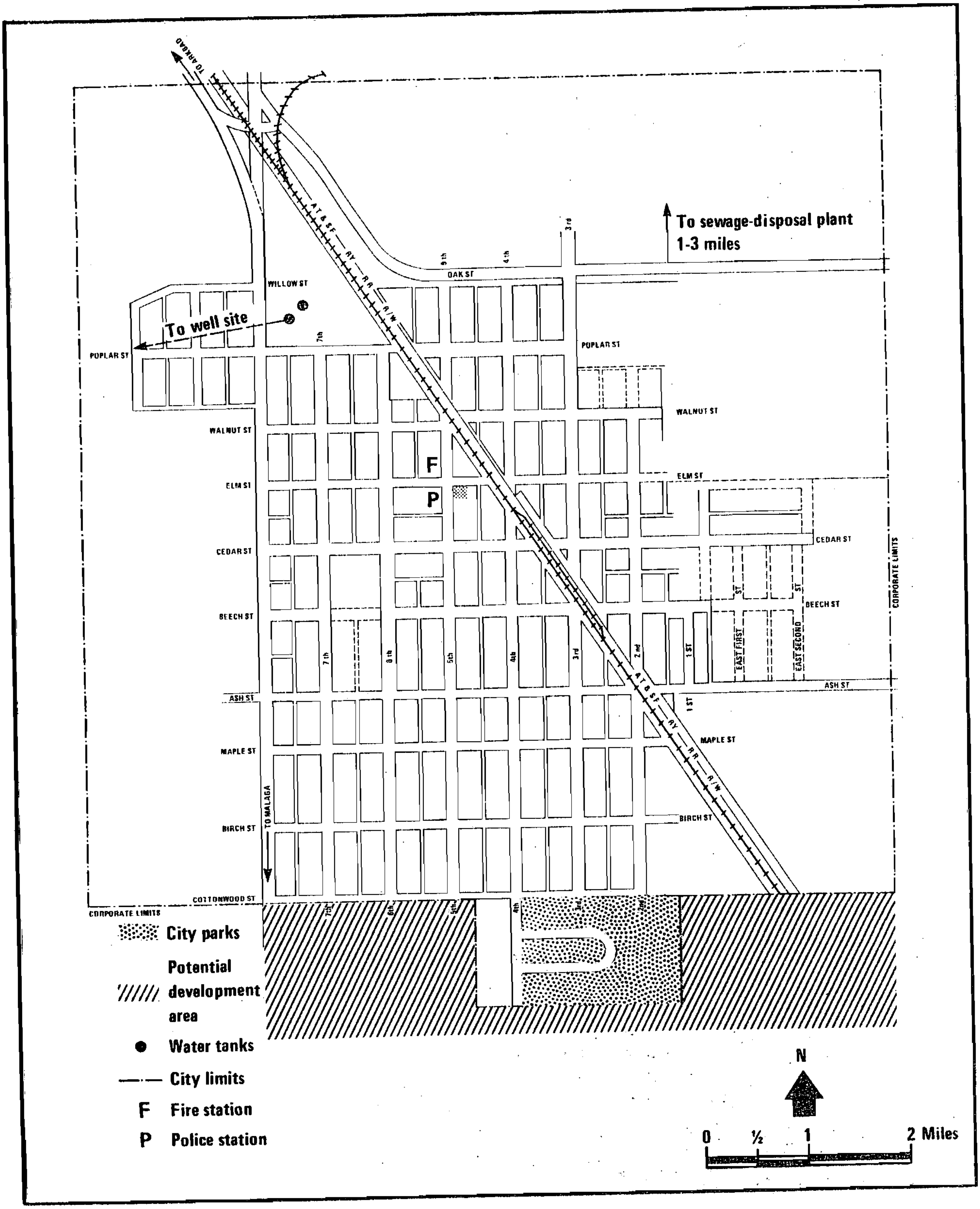

Figure H-9. Municipal facilities, water system, and sewage-treatment plants, Loving.

evapotranspiration systems is expected to prevent further problems with residential sewage in areas not connected to the Hobbs municipal sewage system.

Loving. The municipal sewage-treatment plant built in 1950 does not meet current effluent standards set by the New Mexico Water Quality Commission. Consequently, the village has received a Federal grant to construct a new treatment facility. At present, the appropriated funds ($300,000) equal approximately 50% of the design and construction costs for an adequate plant. Loving is still seeking additional funding to start the project (information from Molzen-Corbin and Associates, Albuquerque, New Mexico, 1979).

The treatment plant now in use is a primary system and has a rated capacity of 0.15 mgd. According to the Southeastern New Mexico Economic Development District, it is experiencing a demand of 55% to 60%. The sewage facility serves approximately 1600 people (Adcock, 1979).

Sewage-collection facilities provide service to the majority of Loving's residents. The only exception is the extreme eastern section of Cedar Street (Figure H-9). Because this area's elevation is lower than that of the current system, a lift station would be required to provide collection services. The residents of the area now use individual septic tanks.

Electric service*

Carlsbad and Loving. Eddy County obtains electricity from the Southwestern Public Service Company. In April 1979, the area including Carlsbad, Loving, and the surrounding rural area contained 12,536 customers. Of this total, 11,247 were residential and 1289 were commercial or industrial customers. Although the residential customers were numerically the largest class of electricity users, they accounted for only 22% of electricity demand; the commercial, industrial, and miscellaneous customers accounted for the remaining 78%. Approximately 75% of the power is currently generated by natural-gas plants and 25% by coal-fired plants. Another coal-fired plant will become operational in June 1980, changing the ratio of power-generation sources to 65% for natural gas and 35% for coal. In addition, it is expected that one coal-fired plant will be completed in each of the years 1982 and 1984; the effect of the two additional coal-fired plants on the ratio of natural-gas to coal-fired generation cannot now be ascertained.

Hobbs. The New Mexico Electric Service Company supplies electricity to Hobbs. In September 1979, New Mexico Electric served 13,607 customers in the area within the Hobbs School District boundaries. Of this total, 11,548 were residential, 1747 were commercial, and 312 were industrial customers. Although the residential customers were numerically the largest class of electricity users, they accounted for only 16% of electricity demand; the commercial and industrial customers accounted for 15% and 69%, respectively, of electricity demand. The electricity is generated by a single natural-gas plant. The company is studying the feasibility of using coal, but no decision on a conversion has been made.

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*Data obtained in 1979 from the Southwestern Public Service Company (Carlsbad and Loving) and the New Mexico Electric Service Company (Hobbs).

Natural-gas service*

Carlsbad. In January 1979, the Gas Company of New Mexico was supplying natural gas to 9816 customer accounts in the Carlsbad area (8845 residential, 856 commercial, 17 industrial, and 98 miscellaneous). The residential, commercial, industrial, and miscellaneous users accounted for 16%, 6%, 76%, and 2%, respectively, of the natural-gas demand in Carlsbad.

Hobbs. In January 1979, the Hobbs Gas Company was supplying natural gas to 10,712 customer accounts in the Hobbs area (9415 residential, 1245 commercial, 6 industrial, and 46 miscellaneous). The residential, commercial, industrial, and miscellaneous users accounted for 64%, 27%, 2%, and 7%, respectively, of the natural-gas demand in Hobbs.

Loving. In January 1979, the Gas Company of New Mexico was supplying natural gas to 453 customers in the Loving area (395 residential, 34 commercial, 1 industrial, and 23 miscellaneous). The residential, commercial, industrial, and miscellaneous users accounted for 56%, 7%, 28%, and 9%, respectively, of the natural-gas demand in Loving.

Fire protection**

Carlsbad and Eddy County. The Carlsbad Fire Department has 30 full-time employees, or about 1.04 per 1000 people, operating out of the main fire station and four substations (Figure H-7). Major equipment includes two 1500-gpm pumpers, one 1000-gpm pumper, three 750-gpm pumpers, and a dry-chemical truck at the airport. The primary service area for the department is the city, but occasional trips are made outside the city limits to assist the all-volunteer Eddy County Fire Department. These trips are made on the basis of a verbal mutual-aid agreement between the city and the county.

Hobbs and Lea County. The Hobbs Fire Department currently has 44 full-time employees, including two dispatchers, or about 1.35 per 1000 people. There are two fire stations (Figure H-8) and seven fire trucks. Approximately one-third of the department's calls are outside the city limits to assist the all-volunteer Lea County Fire Department.

Loving. The Loving Fire Department currently is an all-volunteer organization composed of 25 members. The department operates out of one station (Figure H-9) and is equipped with three pumpers and one emergency vehicle. The general service area for the department is the Village of Loving, but service to areas adjacent to the village limits is also provided.

Police protection**

Carlsbad and Eddy County. The Carlsbad Police Department has 48 full-time employees, or about 1.7 per 1000 people. The primary area served by the

*Data obtained in 1979 from the Gas Company of New Mexico (Carlsbad and Loving) and the Hobbs Gas Company.

**Data obtained in 1979 from the cities of Carlsbad, Hobbs, and Loving unless otherwise stated.

department is the city, but officers go outside the city limits to assist New Mexico State police or Eddy County Sheriff's officers on request. City police also have Eddy County Sheriff's commissions to facilitate their activities outside city limits.

The Eddy County Sheriff's office has about 23 full-time employees. In addition, as discussed above, the office can call on Carlsbad police officers for assistance if needed (data from the Eddy County Sheriff's Office, 1979).

Eddy County had a total of 89 officers (State Police, Sheriff's Office, and Police Department) in 1978, or 1.9 per 1000 people (Adcock, 1979).

Hobbs and Lea County. The Hobbs Police Department has 81 full-time employees, or about 2.5 per 1000 people. Moreover, Hobbs has developed a program (Operation Saturation) in which off-duty police officers use marked patrol cars. The effect of the program is to increase the apparent size of the department by making police officers visible, whether on or off duty. The police department serves the city primarily, with only occasional calls outside city limits.

The Lea County Sherriff's department has approximately 33 full-time employees. In addition, the department can call on Hobbs police officers for assistance if needed.

Lea County had 124 officers (State Police, Sheriff's Office, and Police Department) in 1978, or approximately 2 per 1000 people.

Loving. The Loving Police Department has two full-time employees and three vehicles. The department services the city, with only occasional calls outside the village limits.

Health care*

Carlsbad and Eddy County. The Guadalupe Medical Center in Carlsbad is the principal short-term hospital in Eddy County. It opened in late 1977 and has 134 beds. There is also the 34-bed Artesia General Hospital. On the basis of mid-1978 Eddy County population estimates, the 168-bed county total amounts to 3.5 per 1000 population. This is below the national average of 4.0 beds per 1000, but it is representative of the State of New Mexico's average of 3.5 per 1000. Nonetheless, the mid-1979 Guadalupe Medical Center occupancy rate of 65% is below the Federal standard of 80% proposed for all nonfederal, general, short-term hospitals (Bennett, 1977). Additional medical facilities available in the area are indicated in Table H-22.

There are 35 physicians in Eddy County, 30 of whom use the facilities of the Guadalupe Medical Center. Twenty-one of the county's physicians provide primary care, or about 0.5 per 1200 population. Although there are no generally accepted standards for primary care physician-to-population ratios, the Eddy County ratio of 0.5 is only half the suggested level of 1.0 per 1200 (Bennett, 1977). Eddy County was classified as a medically underserved area

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*Data obtained in 1979 from the Guadalupe Medical Center (Carlsbad and Eddy County), the Lea Regional Medical Center (Hobbs and Lea County), the City of Carlsbad, and the Village of Loving, unless otherwise stated.

Table H-22. Area Medical Facilities[a]

Facility	Carlsbad	Eddy County[b]	Hobbs	Lea County[c]
Short-term hospitals	1	2	1	2
Hospital beds (plus basinettes)	134 (18)	168 (NA)	180 (20)	203 (20)
Nursing homes	2	2	2	3
Intermediate-care facilities and home health agencies	NA[d]	3	NA	3
Clinics (including mental health)	NA	6	NA	4
Primary-care clinics	0	1	1	1
Pharmacies	14	17	8	18

[a]Data from the New Mexico Health Resources Registry, Guadalupe Medical Center, Lea Regional Medical Center, and Adcock (1979).
[b]Includes Carlsbad.
[c]Includes Hobbs.
[d]Not available.

in 1976 by the Secretary of Health, Education, and Welfare for purposes of determining eligibility for Health Maintenance Organization funding (Bennett, 1977). In addition, there are 17 dentists in Eddy County (NMHRR, 1979).

Emergency medical services are provided by a Dallas, Texas, company that has a contract with the Guadalupe Medical Center. The emergency services operate a 24-hour emergency room staffed by three physicians, of whom one is always in attendance and specializes in emergency treatment.

Ambulance service is provided by the Carlsbad Fire Department. There are currently four vehicles in use, and a fifth has been ordered. Ambulance service normally covers an area within about 30 miles of the city. Each ambulance is staffed by two emergency medical technicians (EMTs). The Fire Department has three full-time EMTs on the staff, and 25 additional paid volunteer (part-time) EMTs are available.

Hobbs and Lea County. Lea County has two short-term hospitals: the Lea Regional Medical Center in Hobbs, with 180 beds, and the Community General Hospital in Jal, with 23 beds. Population estimates for mid-1978 show that Lea County has 3.6 hospital beds per 1000 population, which is less than the national average of 4.0 beds per 1000 and more than the New Mexico average of 3.5 per 1000. Nevertheless, the mid-1979 Lea Regional Medical Center occupancy rate of 65% is below the Federal standard of 80% proposed for all non-federal, general, short-term hospitals.

Additional medical facilities in Lea County (Table H-22) include five clinics, one of which, located in Hobbs, provides primary care. In addition, there are three nursing homes and three intermediate-care and home health agencies (NMHRR, 1978).

There are 33 physicians in Lea County, 25 of whom are located in Hobbs. Thirty of the physicians provide primary care, or 0.6 per 1200 people. This ratio is considerably lower than the ratio suggested by Bennett (1977) of 1.0 per 1200. Partly as a result of this low ratio of primary-care physicians to the population, Lea County was classified as a medically underserved area in 1976 by the Secretary of Health, Education, and Welfare for purposes of determining eligibility for Health Maintenance Organization funding (Bennett, 1977). In addition, there are 12 dentists in Lea County (NMHRR, 1979).

Emergency medical services are provided by a Dallas, Texas, company that has a contract with the Lea Regional Medical Center. The emergency room is open 24 hours per day, with one physician who specializes in emergency treatment always in attendance.

Ambulance service is provided by the Hobbs Fire Department, which currently operates three ambulances. The ambulance service area extends to Lovington on the north, the county line on the west, into Texas on the east, and about 15 miles to the south of Hobbs. Each ambulance carries two EMTs on all calls. The Hobbs Fire Department employs 40 EMTs full time, which is to say that most fire-department personnel are qualified as EMTs. The department also employs one EMT instructor.

Loving. The community of Loving has only one medical facility, El Centro Rural de Salud. It opened in 1977 and has a staff of six. Federally funded, the health center specializes in primary medical care. Services at the clinic include prenatal care, family planning, counseling, and medical advice and referral.

Short-term hospitalization is available in Carlsbad at the Guadalupe Medical Center. Ambulance service is available from either the Loving or the Carlsbad Fire Department.

Traffic and transportation: regional

Pipeline transportation. According to information obtained in 1979 from the El Paso Natural Gas Company, a 12.75-inch natural-gas pipeline passes through the WIPP site about a mile north of its center, running in an east-west direction. This pipeline was built in the 1940s. Approximately 8 to 9 miles south of the site is a 26-inch El Paso Natural Gas line that also runs east-west.

Air transportation. The commercial airport nearest to the WIPP site is the Cavern City Air Terminal, about 30 miles to the west. To the east-northeast lies the Hobbs-Lea County Airport, about 35 miles away. There are no landing strips within 10 miles of the site. The site, however, is traversed by commercial air traffic between Carlsbad and Hobbs.

Highway transportation. Figure H-10 shows the average daily traffic flow in the environs of the site (the annual average daily traffic flow at selected control locations is shown in Figures H-11, H-12, and H-13). Data for the overall flow of vehicles indicate sufficient capacity for the highway: capacity ratings vary from 20 to 29 on a scale of 30 on the section of road between Carlsbad and Hobbs.

Portions of NM 31 and NM 128 lie within 10 miles of the site, and U.S. Highway 62-180 runs east to west about 10 miles north of the site. U.S. Highway 62-180, part of the Federal Aid Primary System, is a four-lane divided

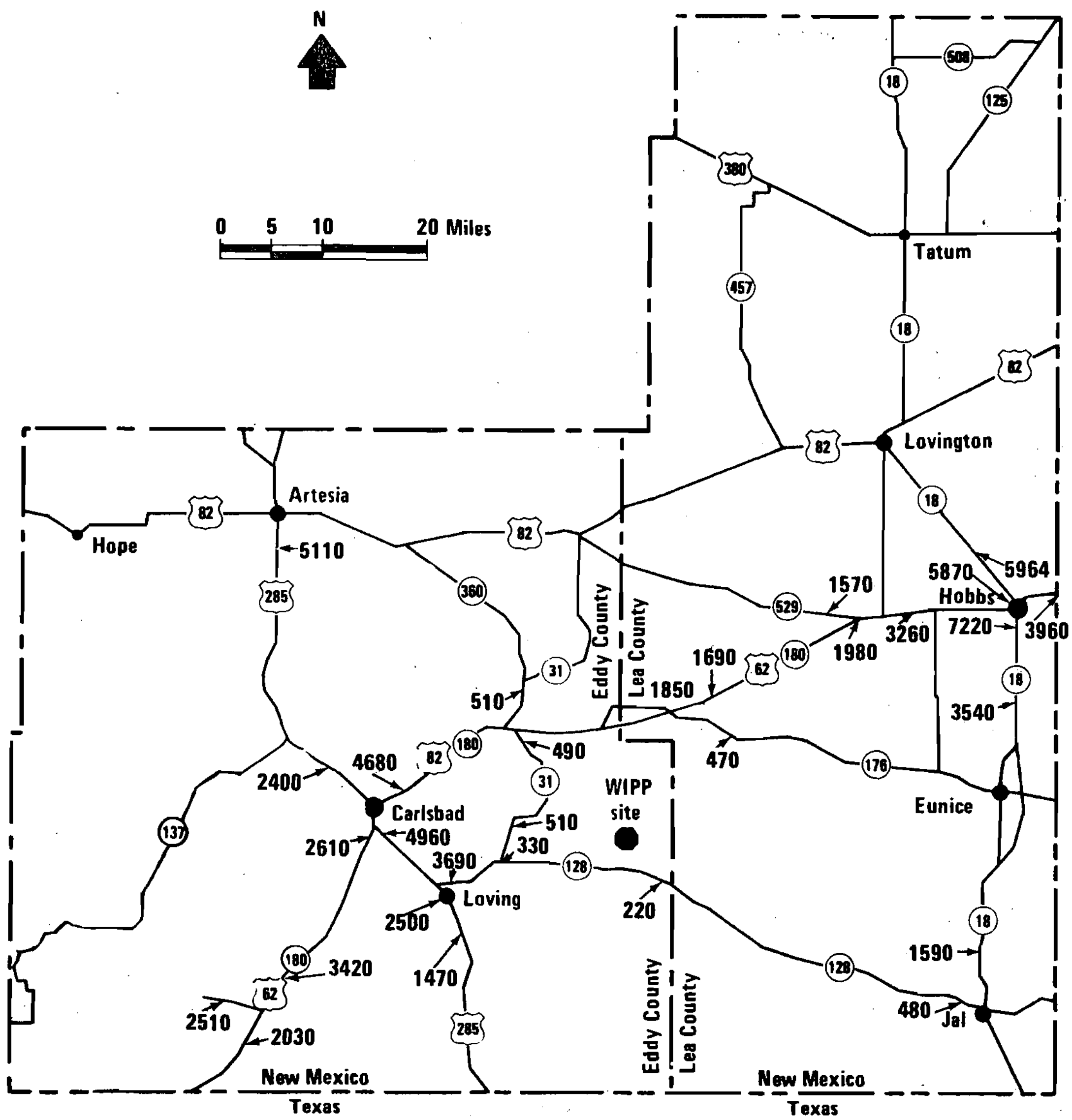


Figure H-10. Average daily traffic flow in the area of the WIPP site, 1978.

highway from Carlsbad to the Lea County line. For 17 miles east of the Lea County line, the highway has two lanes; for the rest of the distance into Hobbs, it is again a divided four-lane highway.

New Mexico 31, a two-lane road with a bituminous surface, runs north to south about 10 miles west of the site. There is little or no shoulder on certain portions of the highway. According to the New Mexico State Highway Department (1979), one section within 10 miles of the site has an overall pavement width of 18 feet and a total roadway width of 20 feet.

New Mexico 128, running east to west, traverses the southern portion of the 10-mile radius. This State-maintained two-lane bituminous-surface highway is part of the Rural Federal Aid Secondary System, as is NM 31. Pavement widths vary between 20 and 22 feet for sections within 10 miles of the site, and the roadbed is at least 22 feet wide. From the intersection of NM 31 and NM 128 to the present access road to the site, the highway traverses several small salt lakes or ponds; here there is virtually no shoulder, and in some areas there is an abrupt drop of 2 to 3 feet from the paved surface level to the pond or lakebed level. Several inspection trips revealed a significant amount of maintenance along these areas on NM 128 and along similar areas on NM 31. Surface and safety ratings and Figures H-11 and H-12 show significant deficiencies along certain portions of NM 128 and 31. It is suspected that these low ratings are caused partially by the presence of certain low areas that collect salt water and turn into salt lakes or ponds (Adcock, 1979).

Railroad transportation. In the two-county area, two companies operate rail systems: the Atchison, Topeka and Santa Fe, and the Texas-New Mexico Railroad. The Atchison, Topeka and Santa Fe enters New Mexico from the south, running parallel to U.S. 285. It connects the communities of Loving, Carlsbad, and Artesia in Eddy County and proceeds north to connect with the Atchison, Topeka and Santa Fe main line at Clovis. Spur lines to the potash-mining area have also been constructed.

The spur line to the Duval Nash Draw mine offers the closest access to the WIPP site. The proposed extension of this spur will connect the site with the Atchison, Topeka and Santa Fe line. The Texas-New Mexico line enters at the southeast corner of Lea County and parallels NM 18, connecting the communities of Jal, Eunice, Hobbs, and Lovington. The line ends just north of Lovington.

Carlsbad transportation system

Current traffic-flow levels are well within the existing capacity of the street system. Inspection of the street system shows few unpaved streets within the city limits. The condition of the street system appears to be good and shows adequate maintenance.

Commercial air service is provided by three airlines: Air Midwest, Crown Aviation, and Permian Airways. Each airline company has two daily scheduled arrivals and departures. Commercial air service is provided for transportation between Carlsbad and Hobbs and Albuquerque, New Mexico, and Midland, Odessa, and El Paso, Texas.

The Santa Fe Railway provides the area with freight service. Piggyback service is available, and daily switching service is sustained.

Three interstate motor-freight carriers (Apex Freight Lines, Sun Freightways, and Sundance Transportation) serve Carlsbad. Each freight-carrier company has terminal facilities in Carlsbad.

Intrastate and interstate bus transportation is available through the New Mexico Transportation Company, Inc., an affiliate of Greyhound Bus Lines. A private carrier provides mass transportation to the commercial mining operations. Currently there are 28 round trips per day to the mining sites in the Carlsbad area. There are no public-transit facilities in Carlsbad other than a taxicab company that operates four vehicles (Adcock, 1979).

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	DR[10]	SAF[11]	CAP[12]	OVAL[13] RATG
1	N	7.7	Bit	20	22	663	10	11	09	02	27	56
2	N	8.7	Bit	20	20	250	10	11	07	01	29	63
3	N	3.4	Bit	18	20	272	10	10	05	02	29	60
4	N	2.9	Bit	24	28	487	10	09	10	02	29	60

Source: Ratings for Highway Improvements, Rural Federal-Aid Secondary System, 1976, New Mexico State Highway Department, Planning and Programming Division, in cooperation with U.S. Department of Transportation, Federal Highway Administration.

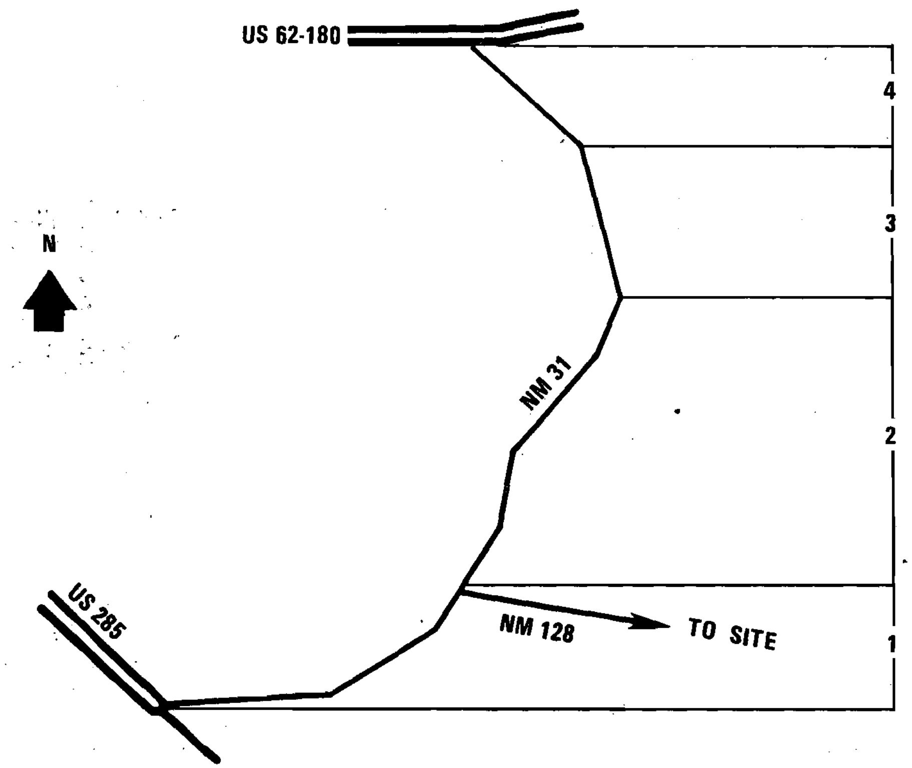


Figure H-11. Average daily traffic flow on NM 31, 1977. (See page H-56 for explanation.)

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	DR[10]	SAF[11]	CAP[12]	OVAL[13] RATG
1	E	9.1	Bit	20	22	237	10	10	06	01	29	62
2	E	9.8	Bit	22	22	168	10	12	07	02	29	68
3	E	9.5	Bit	22	22	271	10	11	06	02	29	62

Source: Ratings for Highway Improvements, Rural Federal-Aid Secondary System, 1976, New Mexico State Highway Department, Planning and Programming Division, in cooperation with U.S. Department of Transportation, Federal Highway Administration.

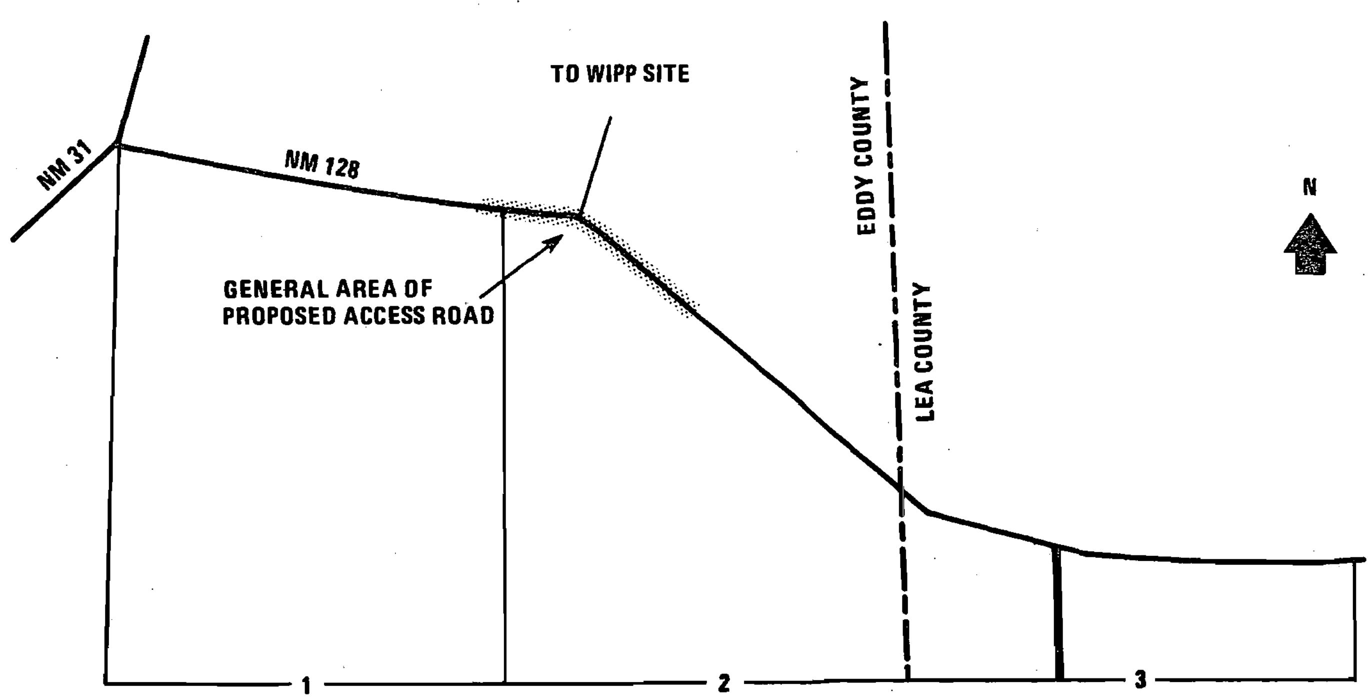


Figure H-12. Road conditions and traffic flow on NM 128, selected sections. (See page H-56 for explanation.)

RD SECT[1] LOC #	FLOW[2] DIR	SECT[3] LENG	SURF[4] TYPE	WIDTH IN FEET PAVT[5]	RDWY[6]	ADT[7]	FDNT[8]	CONDITION RATING SUR[9]	DR[10]	SAF[11]	CAP[12]	OVAL[13] RATG
9	E	2.3	Bit	24	36	2,409	10	15	10	03	28	63
9	W	2.3	Bit	22	28	2,409	10	12	10	03	28	59
10	E	4.1	Bit	24	40	2,123	10	24	10	04	28	75
10	W	4.1	Bit	20	26	2,123	10	16	10	02	28	64
11	E	5.3	Bit	24	40	2,031	10	27	10	20	28	95
11	W	5.3	Bit	20	30	2,031	10	16	10	04	28	67
12	E	1.4	Bit	24	40	1,854	10	27	10	20	28	95
12	W	1.4	Bit	20	26	1,854	10	16	09	03	29	66
13	D	8.4	Bit	22	30	1,881	10	12	09	03	20	53

Source: Ratings for Highway Improvements, Rural Federal-Aid Primary System, Interstate System Included, 1977, New Mexico State Highway Department in cooperation with U.S. Department of Transportation, Federal Highway Administration.

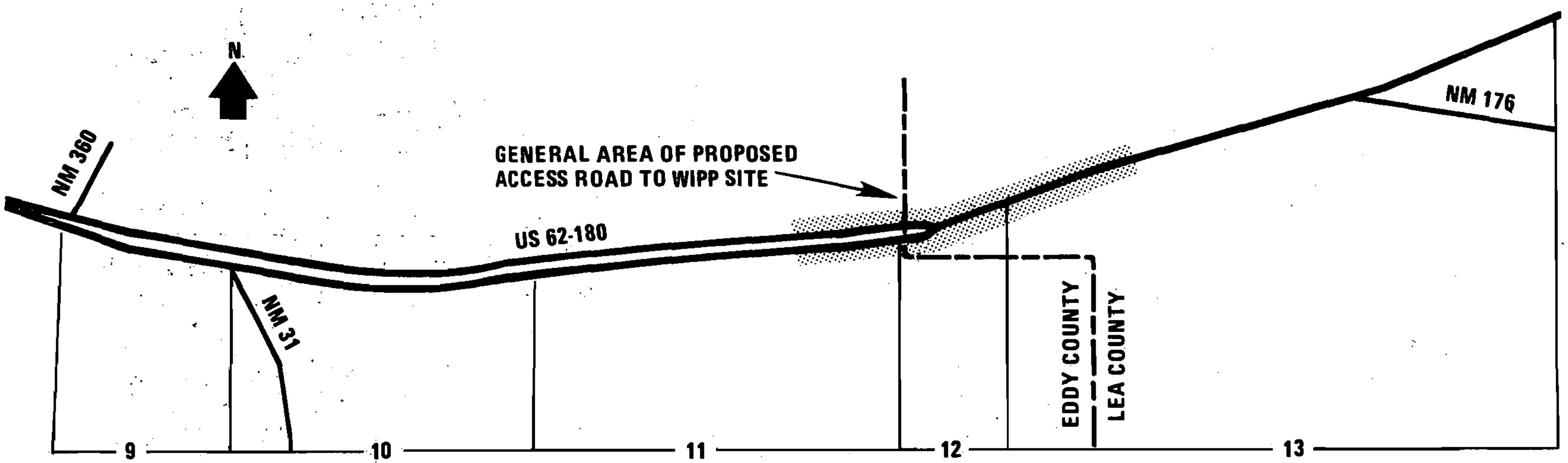


Figure H-13. Road conditions and traffic flow on US 62-180, selected sections. (See page H-56 for explanation.)

EXPLANATION OF TERMS FOR
Figures H-11, H-12, and H-13

1. **RD SECT, LOC #:** Number on route map identifying the subject location.
2. **FLOW DIR:** Traffic flow or direction. O - undivided highway; N - northbound; E - eastbound; W - westbound.
3. **SECT LENG:** Length of the rating section in miles and tenths.
4. **SURF TYPE:** Bit - bituminous.
5. **WIDTH IN FEET/PAVT:** Width of bituminous surface recorded in an even number of feet.
6. **WIDTH IN FEET/RDWY:** The distance between outside shoulder lines.
7. **ADT:** Average daily traffic, the average number of vehicles passing a given point on the highway in a typical 24-hour period of up to 72 hours; count in both directions on the divided highways.
8. **FDNT:** Foundation rating - 10 points. Foundation can be rated only 10 for adequacy or 0 for inadequacy. A rating of 0 is given to sections if any of the following conditions exist: 1 - traveled way less than 18 feet wide; 2 - lack of adequate and uniform cross section, including side ditches; 3 - paved surface indicating failure that could not be corrected by the addition of a few inches of surface material.
9. **SUR:** Surface. The surface receives a rating on the scale of 0 to 30. If surface is in relatively good condition but showing first signs of deterioration, it receives a rating of 15. More advanced decay, while still in fair, usable condition, is rated between 10 and 15. Pavement in a condition justifying replacement is assigned a rating of 10. Increasingly poor conditions to the point of complete deterioration are rated 10 to 0.
10. **DR:** Drainage - 10 points. Lack or inadequacy of drainage facilities reduces the total of 10 points allotted for completely adequate drainage. The amount of reduction is proportional to the relative lengths of the deficient segment to the total rating section and the degree of the deficiency.
11. **SAF:** Safety - 20 points. The other conditions that are rated also involve features of safety; however, this rating is concerned with certain conditions as follows: 1 - stopping sight distance less than permitted by the design speed; 2 - horizontal curves sharper than permitted by the design speed; 3 - bridges narrower than the traveled way width; and 4 - dips.
12. **CAP:** Capacity. A rating between 0 and 30 is assigned to represent the capacity characteristic of the rating section. From a rating of 30, indicating full capability to carry the actual existing traffic load (ADT), to a rating of 0 to 10 indicating a deficient section, the decreasing numerical value indicates the increasing presence of significant factors contributing to the decline of the traffic-carrying capability of the roadway.
13. **OVAL RATG:** Overall rating. This overall condition rating is an adjusted indicator representing a weighted average of the previous five categories. The formula used to arrive at this adjusted rating from the total rating takes into account the average traffic volume for the system of which it is a part.

Hobbs transportation system

Current traffic-flow levels are well within the existing capacity of the street system. Inspection of the street system shows few unpaved streets within the city limits. The condition of the street system appears to be good and shows adequate maintenance.

The Hobbs area is served by the Hobbs-Lea County Airport, 3.2 miles west of Hobbs on a paved four-lane highway. The Federal Aviation Administration maintains a control tower and provides air and ground communications. The longest runway at this airport is 7400 feet. At present, three commercial carriers provide air service to Hobbs: Air Midwest, Crown Aviation, and Permian Airways. Air Midwest has six, Crown has three, and Permian has two daily arrivals and departures. These carriers give Hobbs connecting service with Albuquerque and Carlsbad, New Mexico and Lubbock, Midland, and El Paso, Texas.

Hobbs is served by the Texas-New Mexico Railroad, a subsidiary of the Texas and Pacific Railway. This railroad provides daily freight service to the Hobbs area and operates piggyback service from Lubbock, Texas.

Six interstate and intrastate motor-freight carriers serve the Hobbs area: APEX Freight Lines, C-B Motor Freight, Illinois-California Express, OEA Express, Texas and Pacific Motor Freight, and Yellow Freight Systems, Inc. In addition, several trucking firms provide specialized or custom hauling of heavy equipment. United Parcel Service serves the Hobbs area for the shipment of small packages and envelopes. Bus service is provided by Texas-New Mexico and Oklahoma Coaches, Inc., with nine arrivals and departures daily. There are no public-transit facilities in Hobbs other than two taxicab companies operating a total of five vehicles.

Loving transportation system

Traffic-flow levels within Loving are well within the existing capacity of the street system. According to information obtained in 1979 from the Village of Loving, no unpaved streets inside the corporate limits were left after the paving construction completed by the New Mexico State Highway Department in 1978. Traffic-flow statistics published by the New Mexico State Highway Department are only for urban areas with a population of 5000 or more. Therefore, no statistics for Loving are available to the public.

Air transportation for the city is available at the Cavern City Municipal Airport in Carlsbad.

The Santa Fe Railroad, which passes directly through Loving, offers piggyback services in Carlsbad for area residents. The New Mexico Transportation Company (Greyhound Bus Lines) provides six scheduled departures daily. Three of these proceed north to Carlsbad, while three continue south to Pecos, Texas. Motor-freight service is available in Carlsbad. Local bus or taxi service is not available.

Loving has no public-transit facilities. However, the Eddy County Community Action Corporation operates a low-income transportation service. The Carlsbad Association for Retarded Citizens Farm also provides transportation for its Loving clients.

Communications services and facilities

Information on communications services and facilities was obtained in 1979 from the General Telephone Company of the Southwest, which serves Carlsbad, Loving, and Hobbs.

Carlsbad. In September 1979, the General Telephone Company of the Southwest had 12,302 main stations in the Carlsbad area. Of this total, 10,069 were residential customers and 1811 were business customers. The remaining 422 main stations include mobile services, pay stations, rural services, and four-party business services.

Hobbs. In September 1979, 10,688 main stations were in service. Of this total, 7403 were residential customers, 3200 were business customers, and 85 were mobile business customers.

Loving. In September 1979, 539 main stations were in service, with 476 residential and 52 business customers. The remaining 11 main stations included four-party business, mobile services, and rural services.

Recreation

The State Comprehensive Outdoor Recreation Plan produced in 1976 lists a variety of popular activities in the two-county area. The 10 most popular activities, in decreasing order of popularity, are park visits, picnicking, attending sports events, bicycling, walking for pleasure, sightseeing, swimming in pools, fishing, tennis, and camping.

The many recreation facilities shown in Figure H-14 meet the demand for these activities. Primary among these facilities are the Lincoln National Forest in the Guadalupe Mountains, the Presidents' Park along the Pecos River in the City of Carlsbad, the Carlsbad Caverns National Park, the Living Desert State Park, and several small fishing lakes. New Mexico Highway 137, which enters the Lincoln National Forest, has been proposed as a scenic route.

Both Eddy and Lea Counties offer a variety of opportunities for hunting birds and game.

Recreation within 10 miles of the site consists mainly of scattered bird hunting on Bureau of Land Management property, recreational-vehicle driving, or trail-biking. The area within the 10-mile radius offers very few unique sightseeing attractions. Interviews with ranchers indicate that birdhunters frequent the area mainly for quail. Some target practice and rabbit hunting have been noted. However, none of these activities occur on a large scale or appear to be coordinated among the local inhabitants.

Regarding the future, there are plans for developing new recreational facilities and for expanding and improving existing facilities throughout Eddy and Lea Counties.

The communities of Carlsbad, Hobbs, and Loving have plans for developing, expanding, and improving their recreational facilities (parks, tennis courts, shooting ranges, etc.) under the auspices of the Heritage Conservation and Recreation Service Grants Program of the U.S. Department of the Interior.

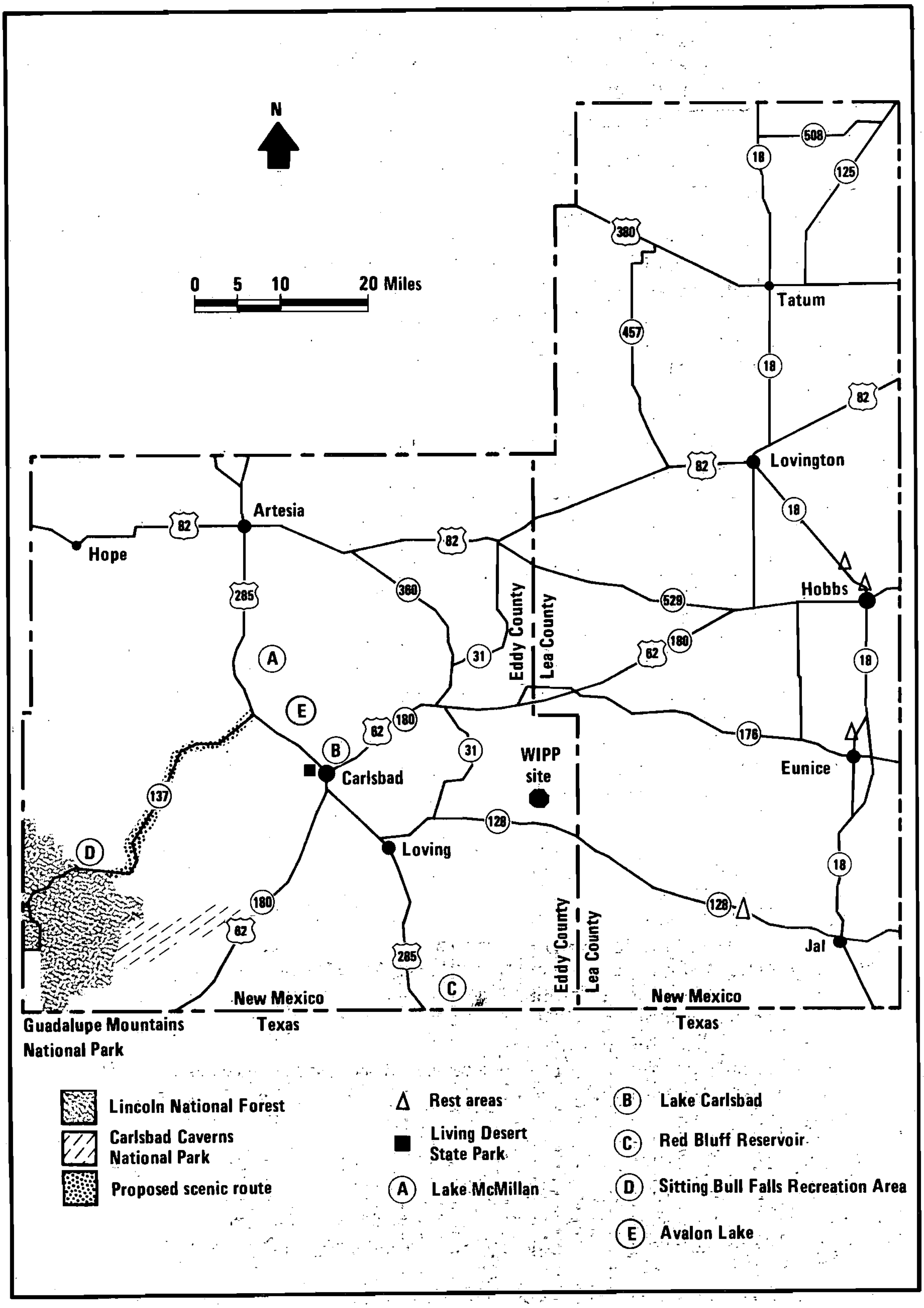


Figure H-14. Major recreational facilities in Lea and Eddy Counties.

Outside the communities, primary examples of projects with future development plans are the Living Desert State Park (State of New Mexico Parks and Recreation Department), Cottonwood Cave (U.S. Forest Service) and the McKittrick Hill Caves (Bureau of Land Management).

Carlsbad. The City of Carlsbad has numerous recreational facilities: more than 100 playing fields; 12 tennis courts; 2 golf courses; 1 dirt auto-race track; 1 bowling alley; 1 indoor and 1 outdoor movie theater; and 1 rollerskating rink. There are 17 municipal parks and 3 others just outside the city. Other main attractions within the city limits include the Carlsbad Municipal Museum and the complex of Lake Carlsbad and Presidents' Park. At Lake Carlsbad there is an overnight campground as well as many picnic tables. In addition, there is a senior citizens' recreation center. One KOA campground is within the city limits and one is 20 miles south, at the entrance to the Carlsbad Caverns National Park at White City (Adcock, 1979).

Hobbs. The recreational facilities include 28 tennis courts, 2 golf courses, 4 swimming pools, and 2 bowling alleys. There are 12 municipal parks, 16.5 acres of public picnic grounds, and a variety of playground equipment at the city parks. There are various ball parks throughout the city and an active Little League. In addition, the State of New Mexico is constructing a 120-acre state park at the Industrial Air Park just north of the city's center. Completion is expected in late 1983 or early 1984.

Just north of Hobbs, at Humble City, there is a dirt track for auto racing. To the south there is a motor cross track on the Kornegay Ranch. Each year in the Hobbs area there is a national soaring meet for sailplanes.

Other local recreational amenities include three fully enclosed handball courts and many outdoor courts. There are a gun club and target range with trap shooting nearby and several rodeo arenas (Adcock, 1979).

Loving. The recreational facilities available in the community of Loving are primarily located in the village's two parks. A small children's park containing a basketball court is located near the city hall. The larger Guevara Park and recreational complex is in the southern part of town. The park contains two baseball fields, a tennis court, a children's playground, and a community center and picnic area. Other local recreational facilities include the junior-high-school gymnasium and adjacent playing fields (Adcock, 1979).

Residents of Loving have access in Carlsbad to entertainment facilities like swimming pools, movie theaters, bowling alleys, golf courses, etc. (Adcock, 1979).

Solid-waste management

Data on solid-waste management were obtained in 1979 from the cities of Carlsbad, Hobbs, and Loving. A summary is presented in Table H-23.

Carlsbad. Solid-waste collection and disposal service for Carlsbad is provided by the city. The landfill site, northeast of the city (Figure H-7), is operated in conjunction with Eddy County, which excavates the disposal trenches. The landfill site is new and has an estimated life of 30 years.

Table H-23. Solid-Waste-Disposal Systems[a]

Item	Carlsbad	Hobbs	Loving
	COLLECTION		
Responsible agency	Municipal	Private	Municipal
Residential			
Frequency	Twice per week	Twice per week	Once per week
Monthly fee	$3.00	$3.00	$2.00
Number of routes	7	4	1
Commercial			
Frequency	1-6 per week	1-6 per week	None
Monthly fee	Based on time to collect	Based on container size and frequency	
Number of routes	1	2	
Number of vehicles by age			
Two years or less	7	3	0
Three to five years	4	2	0
More than five years	3	3	1
	SANITARY LANDFILL		
Responsible agency	Municipal and county	Private and county	Municipal and county
Type of landfill	Trench and area	Trench	Trench and area
Size of landfill	~50 acres	480 acres	50
Estimated remaining life	30 years	30 years	30 years
Pieces of equipment	1[b]	2[b]	1[b]
Disposal fee	None	None	None
	PERSONNEL		
Number of employees	45[b]	25[b]	2[b]

[a]Data from the Carlsbad Sanitation Department (October 1979), Waste Control of New Mexico (Hobbs, October 1978), and the Village of Loving (October 1979).
[b]Figures given do not include equipment or personnel provided by the county for excavation.

The city uses 14 garbage trucks, three of which are at least 5 years old, to cover one commercial and seven residential routes. The service area is defined by the city limits.

Hobbs. Solid-waste collection and disposal in Hobbs is provided by a private firm using eight vehicles to cover the four residential and two commercial routes in the city. The landfill site for Hobbs, located east of the city (Figure H-8), is operated in conjunction with Lea County. The 480-acre site has an estimated life of 30 years.

Loving. Solid-waste collection and disposal service for Loving is provided by the village. The landfill site, located northeast of Carlsbad, is operated in conjunction with Eddy County, which excavates the disposal trenches at the landfill site. The site is new and has an estimated life of 30 years.

Loving has one vehicle to provide this service to the area defined by the village limits shown in Figure H-9. The vehicle is more than 5 years old.

H.3.5 Local Government

Carlsbad. A mayor-council form of city government serves the City of Carlsbad. The mayor is elected for a 2-year term; the council members are elected for 4-year terms.

Revenues for Carlsbad were about $10.4 million in fiscal year 1978-1979 (Table H-24).

About 64% of Carlsbad revenues came from intergovernmental transfers in 1978-1979, with State gross-receipts-tax distributions accounting for most of the State transfers. In fact, gross-receipts-tax revenues constitute the largest single source of revenues for the city, accounting for more than 22% of the 1978-1979 total. More than 52% of Carlsbad's own-source revenues came from utilities in 1978-1979. On the other hand, as in most New Mexico communities, property taxes contributed very little to total revenues, about 1% of general-fund revenues in 1978-1979 and an additional 1% to general-obligation-bond revenues for the year.

In 1978-1979, Carlsbad municipal expenditures were $10.2 million (Table H-25). One-third of all spending in the most recent fiscal year was for personal services, 20% went to operating expenses, and 40% of the total spending was for capital improvements. Debt service accounted for 7% of the total expenditures.

The Constitution of the State of New Mexico limits the amount of general-obligation bonded debt that a municipality may incur without voter approval to 20 mills, or $20 per $1000 of assessed property value. On the basis of an assessed valuation at the start of the 1978-1979 fiscal year of $47.2 million (NMDFA, 1979a), the general-obligation bonded-debt limit without voter approval for Carlsbad is $944,000. As of June 30, 1979, Carlsbad had an outstanding general-obligation bonded debt in the amount of $825,000 (NMDFA, 1979b).

There are no limits on the amount of bonded debt for bonds other than general-obligation bonds, although many debt issues require voter approval. The total debt outstanding for Carlsbad as of June 30, 1979, was $6.7 million (NMDFA, 1979b).

Hobbs. Hobbs has a commission-manager form of government, with a five-member commission. Commission members are elected at large to 4-year overlapping terms. A mayor is elected from the commission for a term of 2 years. A professional city manager is hired by the commission.

Table H-24. Carlsbad Municipal Revenues for 1978-1979 (Thousands of Dollars)[a]

Source of revenue	Actual revenues[a]	Revenues in constant 1979 dollars[b]
OWN-SOURCE REVENUES		
Taxes	620	648
Property	213	223
Franchise	213	223
Occupation	113	118
Lodgers	80	84
Charges and miscellaneous	3,102	3,242
Licenses, permits, and fees	72	75
Charges for services		
Utilities	1,941	2,028
Solid-waste disposal	377	394
Other	222	232
Fines and forfeits	118	124
Interest on investments	27	29
Sale of bonds	150	157
Miscellaneous	194	203
INTERGOVERNMENTAL TRANSFERS		
State	2,679	2,800
Gasoline tax	188	196
Cigarette tax	117	122
Gross-receipts tax	2,302	2,406
Fire-district allocation	30	32
Auto-license distribution	2	2
Grants	40	41
Federal	942	985
Revenue sharing	224	234
Grants	718	751
Transfers, n.e.c.[c]	3,109	3,248
Total	10,453	10,922

[a]Based on the Carlsbad Budget Report, June 30, 1979, the Carlsbad Municipal Quarterly Cash Report, June 30, 1979, and the Carlsbad Municipal Quarterly Report, June 30, 1978. Because of the level of detail in the sources, it was necessary to estimate the values for some revenue categories. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

[c]Not elsewhere classified. Source of these transfers not clear.

Table H-25. Carlsbad Municipal Expenditures for 1978-1979 (Thousands of Dollars)[a]

Service function	Actual expenditures[a]	Expenditures in constant 1979 dollars[b]
General government	1,946	2,033
Personal services	338	354
Operating expense	375	392
Capital outlay	1,233	1,288
Public safety	1,388	1,450
Personal services	1,124	1,174
Operating expense	187	195
Capital outlay	77	80
Public works	5,435	5,679
Personal services	1,627	1,700
Operating expense	1,141	1,192
Capital outlay	2,667	2,786
Health and welfare	31	32
Personal services	29	31
Operating expense	1	1
Capital outlay	0	0
Recreation and culture	689	720
Personal services	326	341
Operating expense	287	300
Capital outlay	76	79
Debt service	732	765
General-obligation bonds	85	89
Revenue bonds	647	676
Total	10,221	10,680

[a]Based on the Carlsbad Budget Report, June 30, 1979, the Carlsbad Municipal Quarterly Cash Report, June 30, 1979, and the Carlsbad Municipal Quarterly Report, June 30, 1978. Because of the level of detail in the sources, it was necessary to estimate the values of some expenditure items. Detail may not equal total because of rounding.

[b]Actual expenditures adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

Hobbs municipal revenues were about $13.5 million in 1978-1979 (Table H-26). Intergovernmental transfers accounted for about 52% of 1978-1979 revenues, mostly in the form of gross-receipts-tax distributions from State and Federal grants. Utility operations provided a second major source of revenues--19% of own-source revenues and 9% of total revenues. Property taxes, including those allocated to debt service, accounted for about 2% of revenues in 1978-1979.

Expenditures for Hobbs were $13.5 million in 1978-1979 (details are given in Table H-27). Spending for personal services amounted to approximately 30% of the total spending for 1978-1979. During the same period operating expenses were about 19% of the total, and capital outlays were about 47%. Debt service required an additional 4%.

With an assessed valuation of $58 million (NMDFA, 1979a), Hobbs has a debt limit of $1.06 million on general-obligation bonds that may be issued without voter approval. The bonded debt may exceed the limit with voter approval.

The current (June 30, 1979) general-obligation bonded debt for the city is $4.8 million. The total outstanding bonded debt as of June 30, 1979, was $7.97 million (NMDFA, 1979b).

Loving. Loving has a mayor-council form of government. The mayor and the five council members are elected for 4-year terms.

Loving municipal revenues were $278,500 in 1978-1979 (Table H-28). Utility fees were the largest single revenue source, contributing 35% of total revenues in 1978-1979. Local sources accounted for about 58% of total revenues, and intergovernmental transfers provided about 42%.

Expenditures for Loving were $285,500 in 1978-1979, or about $7000 more than revenues (Table H-29). Personal services and operating expenses each required about 30% of 1978-1979 expenditures, while capital outlays accounted for 32%. Debt service was 7% of spending for the year.

An assessed valuation of nearly $1.1 million as of June 30, 1978, gave Loving a general-obligation debt limit of $21,560. Loving has no outstanding general-obligation bonds. As of June 30, 1978, the city had $102,000 in revenue bonds outstanding (NMDFA, 1979c).

Eddy County. Eddy County revenues for fiscal year 1978-1979 were $5.2 million (Table H-30). In 1978-1979, 74% of the revenues were from county sources, with taxes on oil-and-gas production and equipment contributing 24% of total revenues. Property taxes accounted for about 17% of the total for the year.

Eddy County expenditures for 1978-1979 totaled $4.1 million (Table H-31). General governmental functions and public works accounted for most of the spending in 1978-1979, with the former requiring more than 30% and the latter 41% of total county expenditures.

The assessed valuation of property in the county as of August 1, 1978, was $455 million (NMDFA, 1979a). With the New Mexico limit on county general-obligation bonded debt of 4% of assessed valuation, Eddy County had a bonding limit of $18.2 million. As of mid-1979, the county had no general-obligation bonds outstanding.

Table H-26. Hobbs Municipal Revenues for 1978-1979
(Thousands of Dollars)

Source of revenue	Actual revenues[a]	Revenues in constant 1979 dollars[b]
OWN-SOURCE REVENUES		
Taxes	997	1,042
Property	379	396
Franchise	257	269
Occupation	16	17
Gross receipts	321	336
Oil and gas	23	24
Charges and miscellaneous	7,375	7,706
Licenses, permits, and fees	41	43
Charges for services		
Utilities	1,629	1,702
Solid-waste disposal	619	647
Other	307	320
Fines and forfeits	190	198
Interest on investments	729	761
Sale of bonds	3,716	3,883
Miscellaneous	145	151
INTERGOVERNMENTAL TRANSFERS		
State	4,704	4,916
Gasoline tax	268	280
Cigarette tax	173	181
Gross-receipts tax	3,831	4,003
Fire-district allocation	24	25
Auto-license distribution	81	84
Grants	328	342
Federal	4,561	4,765
Revenue sharing	144	151
Grants	4,416	4,615
Transfers, n.e.c.[c]	4	4
Total	17,640	18,433

[a]Data from the Hobbs Municipal Report, June 30, 1979. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

[c]Not elsewhere classified. Source of these transfers not clear.

Table H-27. Hobbs Municipal Expenditures for 1978-1979 (Thousands of Dollars)[a]

Service function	Actual expenditures[a]	Expenditures in constant 1979 dollars[b]
General government	1,644	1,718
Personal services	602	629
Operating expense	670	700
Capital outlay	373	390
Public safety	2,106	2,201
Personal services	1,912	1,998
Operating expense	123	129
Capital outlay	71	74
Public works	7,935	8,292
Personal services	846	884
Operating expense	1,339	1,399
Capital outlay	5,751	6,009
Health and welfare	540	564
Personal services	164	171
Operating expense	334	349
Capital outlay	42	44
Recreation and culture	765	799
Personal services	486	508
Operating expense	132	138
Capital outlay	147	154
Debt service	522	545
General-obligation bonds	173	181
Revenue bonds	348	364
Total	13,512	14,120

[a]Data from the Hobbs Municipal Report, June 30, 1979. Detail may not equal total because of rounding.

[b]Actual expenditures adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

Table H-28. Loving Municipal Revenues for 1978-1979 (Thousands of Dollars)[a]

Source of revenue	Actual revenues[a]	Revenues in constant 1979 dollars[b]
OWN-SOURCE REVENUES		
Taxes	16.7	17.4
Property	2.6	2.7
Franchise	8.2	8.6
Occupation	1.8	1.8
Gross receipts (1/4%)	4.2	4.3
Charges and miscellaneous	145.8	152.4
Licenses, permits, and fees	1.3	1.4
Charges for services		
Utilities	98.3	102.7
Solid-waste disposal	14.6	15.2
Other	18.7	19.6
Fines and forfeits	9.5	9.9
Miscellaneous	3.4	3.5
INTERGOVERNMENTAL TRANSFERS		
State	41.8	43.7
Gasoline tax	5.0	5.2
Cigarette tax	2.8	3.0
Gross-receipts tax	16.6	17.3
Fire-district allocation	15.9	16.6
Grants	1.4	1.5
Federal	16.3	17.0
Revenue sharing	16.1	16.8
Grants	0.2	0.2
Local	57.9	60.5
Total	278.5	291.0

[a]Data from the Loving Municipal Report, June 30, 1979. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

Table H-29. Loving Municipal Expenditures for 1978-1979
(Thousands of Dollars)

Service function	Actual expenditures[a]	Expenditures in constant 1979 dollars[b]
General government	32.1	33.5
Personal services	11.6	12.2
Operating expense	20.2	21.1
Capital outlay	0.2	0.2
Public safety	70.0	73.2
Personal services	30.4	31.8
Operating expense	16.2	16.9
Capital outlay	22.6	23.6
Lease purchase payment	0.8	0.8
Public works	148.7	155.4
Personal services	40.5	42.3
Operating expense	45.4	47.4
Capital outlay	62.8	65.6
Health and welfare	5.3	5.6
Personal services	4.4	4.6
Operating expense	0	0
Capital outlay	0.9	1.0
Recreation and culture	9.8	10.2
Personal services	0.2	0.2
Operating expense	3.6	3.8
Capital outlay	6.0	6.2
Debt service	19.7	20.6
General-obligation bonds	0	0
Revenue bonds	19.7	20.6
Total	285.5	298.4

[a]Data from the Loving Municipal Quarterly Report, June 30, 1979. Detail may not equal total because of rounding.

[b]Actual expenditures adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

Table H-30. Eddy County Revenues for 1978-1979
(Thousands of Dollars)

Source of revenue	Actual revenues[a]	Revenues in constant 1979 dollars[b]
OWN-SOURCE REVENUES		
Taxes	2231	2331
Property	910	951
Oil and gas	1259	1316
Lodgers	16	17
Special	45	47
Charges and miscellaneous	1632	1706
Licenses, permits, and fees	116	121
Charges for services	1	1
Fines and forfeits	1	1
Interest on investments	380	397
Payment in lieu of taxes	916	957
Miscellaneous	218	228
INTERGOVERNMENTAL TRANSFERS		
State	557	582
Gasoline tax	28	29
Cigarette tax	3	3
Motor-vehicle tax	429	448
Fire-district allotments	93	97
Miscellaneous	5	5
Federal	802	838
Revenue sharing	752	786
Taylor Grazing Act	44	46
Miscellaneous	6	6
Total	5222	5457

[a]Data from the Eddy County Treasurer's Financial Report for June 1979. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for the third and fourth quarters estimated.

Table H-31. Eddy County Expenditures for 1978-1979
(Thousands of Dollars)

Service function	Actual expenditures[a]	Expenditures in constant 1979 dollars[b]
General government	1270	1327
Personal services	518	541
Operating expense	670	700
Capital outlay	83	86
Public safety	713	745
Personal services	360	377
Operating expense	252	263
Capital outlay	100	105
Public works	1671	1746
Personal services	717	750
Operating expense	687	718
Capital outlay	267	279
Health and welfare	349	365
Personal services	16	16
Operating expense	316	330
Capital outlay	18	19
Recreation and culture	96	100
Personal services	0	0
Operating expense	51	54
Capital outlay	44	46
Total	4099	4284

[a]Eddy County Budget Report for month ending June 30, 1979. Detail may not equal total because of rounding.

[b]Annual expenditures adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

Lea County. Lea County revenues in fiscal year 1978-1979 were $5.5 million (Table H-32). At $1.9 million, oil-and-gas production and equipment taxes provided 35% of county revenues in 1978-1979. Property taxes contributed an additional 16%. Overall, county sources accounted for 73% of total revenues.

Expenditures for 1978-1979 were $4.2 million (Table H-33). Spending on public works accounted for 45% of county expenditures in 1978-1979, and general government functions required 30%.

The total assessed valuation of property in Lea County as of August 1, 1978, was $596 million. The general-obligation-bonded debt limit (4% of assessed valuation) was $23.8 million in mid-1978. Lea County has no outstanding general-obligation bonds.

Table H-32. Lea County Revenues for 1978-1979 (Thousands of Dollars)

Source of revenue	Actual revenues[a]	Revenues in constant 1979 dollars[b]
OWN-SOURCE REVENUES		
Taxes	2810	2937
Property	889	929
Oil and gas	1921	2007
Charges and miscellaneous	1233	1289
Licenses, permits, and fees	110	115
Charges for services	100	104
Fines and forfeits	25	26
Interest on investments	639	667
Payment in lieu of taxes	307	321
Miscellaneous	53	56
INTERGOVERNMENTAL TRANSFERS		
State	518	542
Gasoline tax	10	11
Motor-vehicle tax	484	506
Cigarette tax	2	2
Fire-district allotments	22	24
Federal	980	1024
Revenue sharing	625	653
Taylor Grazing Act	21	22
Grants	334	350
Total	5542	5791

[a]Data from the Lea County Budget Officers Report (Detail of Receipts), June 29, 1979. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for the third and fourth quarters estimated.

Table H-33. Lea County Expenditures for 1978-1979
(Thousands of Dollars)

Service function	Actual expenditures[a]	Expenditures in constant 1979 dollars[b]
General government	1,293	1,351
Personal services	487	509
Operating expense	398	416
Capital outlay	407	425
Public safety	674	704
Personal services	405	423
Operating expense	161	168
Capital outlay	108	112
Public works	1,895	1,980
Personal services	724	756
Operating expense	648	677
Capital outlay	523	547
Health and welfare	372	388
Personal services	46	48
Operating expense	201	210
Capital outlay	125	130
Recreation and culture	10	10
Personal services	0	0
Operating expense	10	10
Capital outlay	0	0
Total	4,243	4,433

[a]Data from the Lea County Budget Officers Report, June 30, 1979. Detail may not equal total because of rounding.

[b]Actual expenditures adjusted by the Gross National Product Price Index. Index values for third and fourth quarters estimated.

School-district finances

Carlsbad. Carlsbad School District C, which encompasses most of southern Eddy County, had total revenues of $23.1 million in 1978-1979 (Table H-34). Some 42% of total resources were allocated to the operational fund. State sources provided 77% of operational fund income; local sources provided 22%. The largest single source of income for the year was a bond sale, which yielded $9.23 million, or nearly 40% of receipts for 1978-1979.

District expenditures totaled $15.2 million in 1978-1979, about $8 million less than income (Tables H-34 and H-35). Operational expenditures accounted for 68% of total spending, with direct-instruction costs contributing the largest single share (34%).

The total assessed valuation of property in the district in 1977 was $214 million, up 17% from the previous year. A total school-district tax rate of $10.925 per $1000 of assessed valuation was in effect during both 1976-1977 and 1977-1978. In 1978-1979 the tax rate was $17.509 (NMPSFD, 1978).

Hobbs. Hobbs School District 16, which includes much of central Lea County, had a 1978-1979 income of $12.6 million (Table H-34). About 85% of the total district income went to the operational fund. State sources provided more than 82% of operational-fund revenues, while local sources provided 17%.

A total of $12.7 million was spent by the district in 1978-1979 (Table H-35). Of this total, $10.6 million, or 84%, were operational expenditures, chiefly for direct instruction.

The property in the district had a total assessed value of $164 million in 1977, an increase of 9.5% over the previous year. The district tax rate for 1978-1979 was $11.580 per $1000 of assessed valuation, down from $11.780 for the previous year (NMPSFD, 1978).

Loving. Loving School District 10, which runs in a narrow band from Loving to the Eddy and Lea County line, had total revenues of $752,000 in 1978-1979 (Table H-34). Operational-fund revenues accounted for 74% of the total. State sources, primarily from property-tax equalization, provided 69% of operational fund revenues, while local sources provided 30%.

District expenditures amounted to $785,000 in 1978-1979 (Table H-35). Operational-fund expenditures accounted for nearly 80% of total spending, while special projects accounted for the remaining expenditures.

The total assessed valuation of property in the Loving district in mid-1977 was $6.6 million, up 3.4% from the previous year. The district tax levy in effect for the 1978-1979 school year was $10.925 per $1000 of assessed valuation, the same tax rate as that for the previous 2 years (NMPSFD, 1978).

Table H-34. School District Revenues for 1978-1979
(Thousands of Dollars)

Source of revenue	Actual revenues[a]			Revenues in constant 1979 dollars[b]		
	Carlsbad	Hobbs	Loving	Carlsbad	Hobbs	Loving
Operational fund	9,706	10,621	553	10,142	11,098	578
Local sources						
District school-tax levy	1,988	1,623	146	2,077	1,695	153
Other	105	203	20	110	212	21
State sources						
State equalization	6,951	8,392	350	7,263	8,769	366
Transportation	372	275	25	389	287	26
Other	158	84	5	165	87	5
Federal sources						
Public Law 874	146	0	3	153	0	3
Other	34	43	4	36	44	4
Abatements	(42)	(3)	0	(44)	(3)	0
Debt service funds	1,220	457	(c)	1,275	478	(c)
Interest fund	453	56	(c)	474	58	(c)
Principal fund	767	401	(c)	801	419	(c)
Building funds	9,726	21	0	10,163	22	0
Sale of bonds	9,230	0		9,645	0	
Earnings from investments	494	20		516	21	
Other	2	(c)		2	(c)	
Federal-projects fund	754	326	103	788	341	108
Capital-improvement fund	467	76	42	488	79	44
Activity and cafeteria funds	1,026	1,052	54	1,072	1,099	56
Other funds	243	0	0	254	0	0
Total	23,142	12,553	752	24,182	13,117	786

[a]Data from the "Monthly Cash Report" and the "Monthly Activity Report," 1978-1979, for the Carlsbad, Hobbs, and Loving School Districts. Detail may not equal total because of rounding.

[b]Actual revenues adjusted by the Gross National Product Price Index. Index values for the third and fourth quarters estimated.

[c]Less than $500.

Table H-35. School District Expenditures for 1978-1979
(Thousands of Dollars)

Expenditures	Actual expenditures[a]			Expenditures in constant 1979 dollars[b]		
	Carlsbad	Hobbs	Loving	Carlsbad	Hobbs	Loving
Administration	327	309	37	342	323	38
Direct instruction	5,163	5,873	307	5,395	6,137	321
Instructional support	1,349	1,140	82	1,409	1,192	85
Health services	76	47	4	79	50	4
Pupil transportation	402	273	25	420	285	26
Operation of plant	815	930	50	851	972	52
Maintenance of plant	357	316	8	373	330	9
Fixed charges	1,319	1,237	78	1,378	1,292	82
Food services	8	0	0	8	0	0
Noninstructional support	172	71	4	180	74	5
Community services	34	57	17	35	60	18
Capital outlay	179	339	15	187	352	16
Special projects	47	23	0	49	24	0
Subtotal	10,247	10,613	627	10,707	11,090	655
Building fund	2,223	62	0	2,323	65	0
Debt service	252	572	0	263	598	0
Special projects	2,445	1,447	158	2,555	1,512	165
Total	15,168	12,695	785	15,849	13,266	820

[a]Data from the "Monthly Budget Report," 1978-1979, for the Carlsbad, Hobbs, and Loving School Districts. Detail may not equal total because of rounding.

[b]Actual expenditures adjusted by the Gross National Product Price Index. Values for the third and fourth quarters estimated.

H.4 METEOROLOGY

H.4.1 Regional Climate

The information used to evaluate the climate of the region surrounding the WIPP site consisted of Climatological Data summaries for recording stations in New Mexico, Local Climatological Data summaries for Roswell, New Mexico, and wind summaries for Lubbock, Midland-Odessa, and El Paso, Texas. The climatological data were obtained from the National Climatic Center of the National Oceanic and Atmospheric Administration. Precipitation and temperature summaries from stations at Carlsbad, the Duval potash mine, Jal, Pearl, and Ochoa were also included because of their proximity to the WIPP site. The Local Climatological Data summaries provided extreme and normal values of the meteorological parameters (for the period of record at the Roswell Municipal Airport and more recent data from the Roswell Industrial Air Center) that were used to characterize the regional climate.

General climate

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are most commonly from the southeast and moderate. During the winter, the weather is dominated by a high-pressure system often situated in the central portion of the Western United States and a low-pressure system commonly located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona. The regional climate is significantly affected by these large-scale pressure systems and their seasonal variations (EDS, 1968; Baldwin, 1973; NOAA, 1974).

The region, meteorologically referred to in New Mexico as the Southeastern Plains, is an area of over 30,000 square miles that marks the western extremity of the Great Plains, which end at the Sacramento and Guadalupe Mountains 40 to 60 miles west of the site. It is bounded on the east and south by an erosional escarpment in central Texas. Elevations range from less than 3000 feet in the south and east to more than 4000 feet in the north, with the downslope to the east and south averaging 600 feet per 100 miles. The terrain is characterized by gently rolling hills of moderate relief, dissected by many small stream valleys.

Moderate temperatures are typical throughout the year, although seasonal changes are distinct. Mean annual temperatures in southeastern New Mexico are near 60°F (Eagleman, 1976). Temperatures in December through February show a large diurnal variation, averaging 36°F at Roswell (the nearest National Weather Service station with appropriate data and an adequate period of record). Although on approximately 75% of winter days morning temperatures are below freezing, afternoon maximum temperatures average well up in the fifties, and afternoon winter temperatures of 70°F or more are not uncommon. Nighttime lows average near 23°F, occasionally dipping as low as 14°F. There are perhaps only 2 or 3 winter days when the temperature fails to rise above freezing. The lowest recorded temperature at Roswell was -29°F, in February 1905. During June through August, the temperature is above 90°F approximately 75% of the days, with readings of 100°F or higher occurring on a number of afternoons. However, even the hottest month, July, with average daily temperatures in the upper seventies, will have morning lows below 68°F. The highest recorded temperature at Roswell was 110°F, in July 1958 (NOAA, 1974).

Precipitation in the region is light and unevenly distributed through the year, averaging 11 to 13 inches (Table H-36) (NOAA, 1972-1976). Winter is the season of least precipitation, averaging less than 0.6 inch of rainfall per month. Snow averages about 5 inches per year (Baldwin, 1973) and seldom remains on the ground for more than a day at a time because of the typically above-freezing temperatures in the afternoon. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region. The minimum annual precipitation measured during the last 40 years at Roswell was 4.35 inches, in 1956; the maximum recorded was 32.92 inches, in 1941. The maximum monthly precipitation was 9.56 inches, in August 1916; the maximum 24-hour rainfall was 5.65 inches, in November 1901 (NOAA, 1974).

Prevailing winds are from the south. The normal mean wind speed at Roswell is 9.6 mph (see Table H-37) (NOAA, 1974).

Heavy precipitation

The maximum cumulative rainfall (Jennings, 1963) at Roswell is shown in Table H-38; the maximum 24-hour rainfall was 5.65 inches, in October 1901. The maximum 24-hour snowfall in Roswell was 15.3 inches, in December 1960. The greatest snow accumulation over a 1-month period was 23.3 inches, in February 1905 (NOAA, 1974).

Thunderstorms and hail

The region experiences about 33 thunderstorm days annually, with about 80% occurring from May to September (NOAA, 1978). A thunderstorm day is recorded if thunder is heard; the record is not related to observations of rain or lightning and does not indicate the severity of the storms experienced in the region.

Hail is most likely in April through June and is not likely to develop more than three times a year. During a 39-year period at Roswell, hail was observed 97 times (about 2.5 times per year), occurring nearly two-thirds of the time between April and June (U.S. Army, 1958). For the 1-degree square surrounding the WIPP site (32° to 33° N by 103° to 104° W) hailstones 0.75 inch or larger were reported eight times from 1955 to 1967 (slightly less than once per year) and windstorms with speeds of 50 knots or higher occurred 10 times--approximately one per year (Pautz, 1969).

Tornadoes

For the period 1916-1958, 75 tornadoes were reported in New Mexico on 58 tornado days (Wolford, 1960). Data for 1956 through 1974 indicate a statewide total of 191 tornadoes on 141 tornado days (NOAA, 1975), or an average of 10 tornadoes per year on 7 tornado days. The greatest number of tornadoes in 1 year was 18; the least was 2. Most tornadoes occur in May and June (Pautz, 1969). From 1955 through 1967, 15 tornadoes were reported in the 1-degree square containing the site (Markee et al., 1974).

Table H-36. Precipitation Rates for Southeastern New Mexico[a]

Station and distance from WIPP (mi)	Elevation above MSL (ft)	Precipitation (inches)																	
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.	1972	1973	1974	1975	1976
Carlsbad, 25	3,120	0.37 (0.45)	0.78 (0.30)	0.24 (0.51)	0.07 (0.48	1.07 (1.51)	1.31 (1.44)	2.46 (1.62)	1.54 (1.76)	4.51 (1.61)	1.94 (1.47)	0.38 (0.35)	0.28 (0.41)	14.96 (11.91)	18.74	11.47	23.11	10.22	11.26
Duval potash mine[b] 12	3,520	0.53	0.67	0.37	0.33	1.24	0.50	3.11	1.79	4.29	1.92	0.46	0.24	15.46	17.31	11.91	19.49	13.92	14.69
Jal, 31	3,149	0.43 (0.51)	0.53 (0.30)	0.36 (0.48)	0.51 (0.65)	1.23 (1.52)	1.15 (1.31)	2.40 (1.63)	1.72 (1.60)	2.88 (1.48)	1.33 (1.39)	0.28 (0.74)	0.14 (0.42)	12.96 (11.67)	8.16	9.83	20.57	13.68	12.56
Pearl, 25	3,799	0.35 (0.40)	0.69 (0.34)	0.32 (0.52)	0.32 (0.64)	2.01 (1.79)	2.19 (1.68)	3.74 (2.11)	2.08 (1.95)	3.81 (1.80)	1.50 (1.31)	0.39 (0.33)	0.20 (0.43)	17.54 (13.32)	17.92	11.62	22.10	24.68	11.87
Ochoa, 22	3,458	0.53 (0.49)	0.55 (0.30)	0.31 (0.51)	0.24 (0.63)	1.15 (1.38)	0.89 (1.35)	2.25 (1.48)	2.18 (1.19)	3.16 (1.53)	0.96 (1.24)	0.25 (0.40)	0.13 (0.32)	12.74 (11.17)	8.86	9.43	19.14	11.65	14.64

[a]Monthly and annual average precipitation for the years 1971-1976, and normal precipitation (shown in parentheses; based on period 1941-1970) for stations in southeastern New Mexico.

[b]Normal values not available.

Table H-37. Normal Mean Wind Speeds for Roswell, New Mexico, 1941-1970

Month	Mean wind speed (mph)	Month	Mean wind speed (mph)
January	8.4	July	9.4
February	9.8	August	8.4
March	11.5	September	8.3
April	11.8	October	8.2
May	11.4	November	8.5
June	10.8	December	8.4

Table H-38. Maximum Cumulative Rainfall at Roswell, New Mexico, for Various Time Periods[a]

	Maximum cumulative rainfall (inches)				
	5 min	10 min	15 min	30 min	60 min
Roswell	0.55	1.01	1.34	1.71	2.22
Date	6/6/30	6/6/30	5/12/50	5/12/50	9/14/23
	2 hr	3 hr	6 hr	12 hr	24 hr
Roswell	2.88	3.38	4.82	5.19	5.65
Date	9/16/23	8/8/16	8/7/16	8/7/16	10/31/01

[a]Period of record 1905-1961, except for the 24-hour rainfall, for which the period of record is 1895-1961.

Thom (1963) has developed a procedure for estimating the probability of a tornado's striking a given point. The method uses a mean tornado path length and width and a site-specific frequency. Applying Thom's method to the WIPP site yields a point probability of 0.00081 on an annual basis, or a recurrence interval of 1235 years. An analysis by Fujita (1978) yields a point tornado-recurrence interval of 2832 years in the Pecos River valley.

According to Fujita (1978), the design-basis tornado with a million-year return period has a maximum wind speed of 183 mph, a rotational speed of 146 mph, a maximum translational speed of 37 mph, a minimum translational speed of 5 mph, a maximum-rotational-speed radius of 150 feet, a pressure drop of 0.69 psi, and a pressure-drop rate of 0.08 psi/sec.

Freezing precipitation

The region can expect about 1 day of freezing rain or drizzle per year (U.S. Army, 1958). An ice accumulation of more than 0.25 inch has not been observed. Any ice accumulation that does occur is thin because of the scarcity of precipitation during the winter months and because daytime temperatures rise well above freezing.

Strong winds

The fastest-mile winds* recorded at the Roswell Industrial Air Center during a 6-year period of record are shown in Table H-39 (NOAA, 1978). The fastest observed 1-minute wind ever recorded at Roswell was 75 mph from the west in April 1953 (NOAA, 1978). The 100-year-recurrence 30-foot-level wind speed in southeastern New Mexico is 82 mph. The mean recurrence interval for high wind speeds at 30 feet above the ground in southeastern New Mexico is shown in Table H-40 (ANSI, 1972; Thom, 1968).

Table H-39. Fastest-Mile Wind Speeds at Roswell, New Mexico

Month	Speed (mph)	Direction	Month	Speed (mph)	Direction
January	47	NW	July	42	NE
February	56	NW	August	44	NW
March	52	NW	September	40	NE
April	48	SW	October	44	(a)
May	60	NW	November	65	NE
June	73	NW	December	58	SW

[a]This speed was measured on a 1-minute anemometer as 44 mph from 220 degrees (approximately southwest).

Table H-40. Recurrence Intervals for High Winds[a] in Southeastern New Mexico[b]

Recurrence (years)	Speed (mph)[c]
2	58
10	68
25	72
50	80
100	82

[a]Fastest mile.
[b]Data from Thom (1968).
[c]At 30 feet above the ground.

*The fastest-mile wind speed listed for each month is the fastest speed determined during that month by measuring the time taken for a 1-mile-long column of air to pass a measuring instrument. These are averages, for example, over a period of 1.25 minutes at 48 mph.

Table H-41. Seasonal Frequencies of Inversions[a]

Season	Inversion frequency (% of total hours)	Frequency (%) of 24-hr periods with at least 1 hr of inversion based below 500 ft
Spring	32	65
Summer	25	68
Fall	36	72
Winter	47	80

[a]Data from Hosler (1961).

Inversions and high air-pollution potential

Hosler (1961) and Holzworth (1972) have analyzed records from several National Weather Service stations with the objective of characterizing the atmospheric-dispersion potential. Seasonal frequencies of inversions based below 500 feet for the region are shown in Table H-41. A large number of these inversions are diurnal (induced by solar radiation) as a consequence of the elevation and the continental climate.

Holzworth (1972) gives estimates of the average depth of vertical mixing, which indicates the thickness of the atmospheric layer available for the mixing and dispersion of effluents. The seasonal afternoon mixing depths for the region (Table H-42) range from 1320 meters in the winter to 3050 meters in the summer.

Table H-42. Daily Mixing Depths: Seasonal Values

Season	Daily afternoon mixing depth (meters)
Spring	2800
Summer	3050
Fall	2000
Winter	1320
Annual	2400

H.4.2 Site Climate

On-site meteorological data were used to characterize the local meteorology of the site. The meteorology station was located in Section 11, R 31 E, T 22 S, from January to June 1976 and in Section 15 from June 1976 to May 1977; it has been in Section 21 since May 1977. These locations are representative of local terrain conditions. Until May 1977, a 10-meter tower was used primarily to collect wind, temperature, and precipitation (surface) data. Subsequently, the station was upgraded to a 30-meter tower designed to comply with most of the criteria of Regulatory Guide 1.23 of the Nuclear Regulatory Commission (NRC). The primary measurements obtained include wind, temperature, and the temperature difference (ΔT) between 3 and 10 meters, and between 10 and 30 meters above the ground. Additional climatological data (e.g., dew point, precipitation, solar and terrestrial radiation, etc.) are also collected. In September 1978 the 30-meter-level instruments were raised to 40 meters to improve the accuracy of ΔT measurements in compliance with Regulatory Guide 1.23. All data are recorded by a data logger and backup stripchart recorders. A detailed description of the data-collection program is given in Appendix J.

Available summary on-site meteorological data presented in this document include temperature and precipitation data for the period May 1976 through May 1979 as well as wind and atmospheric-stability data for June 1977 through May 1979. The representativeness of the on-site data-collection period has been established by comparison of concurrent data from the Roswell Industrial Air Center with long-term data.

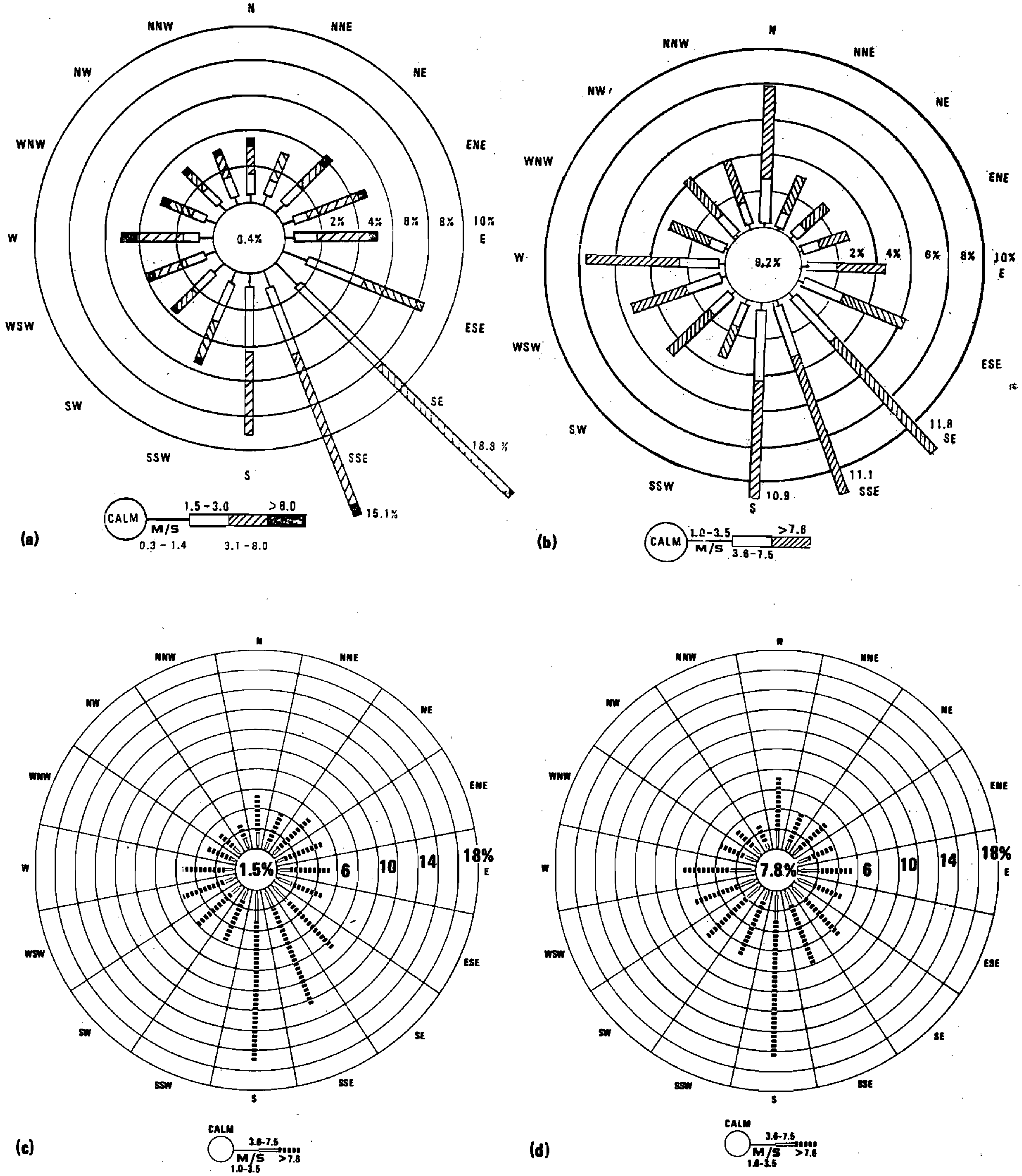
Normal and extreme values of meteorological parameters

Wind summaries. Wind-direction and wind-speed measurements were obtained from the 2-year site data collected at the 30-foot level. Wind roses for the site and for Roswell, New Mexico, for the period June 1, 1977, to May 31, 1979, are shown in Figure H-15. Long-term (1973-1976) annual wind roses for Roswell and Midland-Odessa, Texas (the next nearest National Weather Station with suitable data) are also shown in this figure. Differences between station summaries are attributed to regional terrain effects and variations in the periods of record used.

The 2-year site wind record (Table H-43) shows the southeast, south-southeast, and east-southeast winds occurring most frequently (18.9%, 15.2%, and 9.1% of the time, respectively). All other directions are about equally represented at 2.9% to 8.4% of the time. Monthly wind-rose data are presented in Tables 1 through 24 in Annex 1.

Temperatures. Monthly average, average daily maximum, and average daily minimum temperatures for June 1, 1976, through May 31, 1979, are presented in Table H-44, which also shows corresponding data and normal values for Roswell (NOAA, 1977, 1978, 1979).

Average temperatures at the site show large seasonal differences, ranging from 37.2°F in the winter to 82.6°F in the summer. The highest and lowest temperatures recorded at the Roswell Industrial Air Center between January 1, 1973, and December 31, 1978, were 107°F (June 1977) and 3°F (January 1977) (NOAA, 1978), respectively; the highest and lowest temperatures recorded at the site between June 1, 1976, and May 31, 1979, were 103.1 and 0.7°F, respectively. At the site, the average winter minimum temperatures are consistently higher than those in Roswell, and the summer maximum temperatures are lower. These differences can be mainly attributed to the locations of the temperature sensors (30 feet above the surface at the site and 5 feet at Roswell).



Note: wind direction is defined as the direction from which the wind is flowing.

Figure H-15. Annual wind roses for (a) the WIPP site, June 1, 1977, to May 31, 1979; (b) Roswell, June 1, 1977, to May 31, 1979; (c) annual average (1973-1976) for Midland-Odessa, Texas; and (d) annual average for Roswell (1973-1976).

Table H-43. Distribution of Wind Directions at the Site, June 1977-May 1979

Month	Direction																
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	Calm
January	4.3	3.1	4.5	6.4	9.2	16.3	17.3	11.0	5.0	2.0	2.5	5.2	3.9	2.1	3.3	3.5	0.6
February	3.9	7.4	5.8	5.1	6.6	13.6	14.0	8.3	4.0	4.1	4.5	5.0	5.0	4.7	3.5	3.7	0.5
March	2.8	2.9	3.4	8.9	6.6	15.2	12.0	7.8	4.0	3.9	6.7	8.9	4.5	3.4	3.2	4.0	0.2
April	2.9	3.8	5.1	5.0	8.8	15.7	9.3	7.5	4.7	5.6	8.3	7.5	4.5	3.4	3.5	3.5	0.2
May	3.9	3.0	3.5	4.0	8.2	17.0	13.2	9.6	7.0	5.6	4.9	7.2	3.4	2.5	3.3	4.7	0.2
June	2.8	3.7	4.6	5.4	8.2	27.8	22.9	9.2	4.0	2.3	0.9	1.0	0.9	1.8	2.7	1.9	0.2
July	1.1	2.4	3.1	3.8	11.0	37.0	24.8	7.9	3.3	1.8	0.7	0.6	0.2	0.3	0.8	1.0	0.2
August	1.5	3.4	5.9	4.2	8.8	21.9	20.2	12.8	5.8	2.2	2.2	2.3	1.9	1.9	2.4	2.3	0.3
September	3.7	6.4	5.9	4.5	6.5	17.8	13.9	6.9	6.2	4.2	4.2	5.9	2.4	3.3	4.4	3.3	0.3
October	2.8	4.5	4.1	4.1	12.4	18.9	13.0	11.4	6.9	2.8	3.5	3.7	2.3	2.9	2.5	3.3	0.8
November	5.6	6.1	6.3	5.6	9.7	15.3	11.6	8.2	4.7	3.8	3.4	4.3	3.9	3.2	3.2	4.9	0.2
December	5.0	5.4	5.3	4.8	5.0	10.7	10.5	8.4	6.2	6.7	6.4	6.9	4.9	5.0	3.9	4.2	0.6

Table H-44a. Temperatures at Roswell and the WIPP Site, 1976-1977

	Temperature (°F)								
	Monthly average			Average daily maximum			Average daily minimum		
	Roswell		Site,	Roswell		Site,	Roswell		Site,
Month	Normal	6/76-5/77	6/76-5/77	Normal	6/76-5/77	6/76-5/77	Normal	6/76-5/77	6/76-5/77
January	38.1	38.6	38.7	55.4	52.5	51.6	20.8	24.7	27.1
February	42.9	48.2	48.6	60.9	63.0	61.9	24.8	33.4	36.9
March	49.3	52.1	54.3	57.7	68.2	67.6	30.9	35.9	40.6
April	59.7	62.3	63.5	78.2	76.7	77.2	41.2	47.9	48.6
May	68.5	73.3	73.8	86.4	87.5	86.9	50.5	59.1	61.9
June	77.0	79.3	78.4	94.2	93.4	91.2	59.8	65.2	65.1
July	79.2	78.6	75.4	94.7	90.1	87.8	63.7	67.1	65.1
August	77.9	80.3	78.6	93.4	93.1	91.2	62.3	67.4	66.7
September	70.4	71.2	70.3	86.5	82.9	82.0	54.3	59.4	60.8
October	59.6	56.2	56.1	77.0	70.3	69.6	42.2	42.1	44.2
November	46.9	42.7	46.4	64.8	56.5	58.1	29.0	28.9	34.5
December	39.3	39.3	42.1	56.8	56.1	57.0	21.8	22.5	28.9
Annual	59.1	60.2	60.5	76.3	74.2	73.5	41.8	46.1	48.4

Table H-44b. Temperatures at Roswell and the WIPP Site, 1977-1978

Month	Temperature (°F)								
	Monthly average			Average daily maximum			Average daily minimum		
	Roswell		Site,	Roswell		Site,	Roswell		Site,
	Normal	6/77-5/78	6/77-5/78	Normal	6/77-5/78	6/77-5/78	Normal	6/77-5/78	6/77-5/78
January	38.1	36.04	37.2	55.4	47.6	48.7	20.8	24.3	28.6
February	42.9	43.6	39.6	60.9	55.7	51.3	24.8	31.5	32.2
March	49.3	55.6	55.6	57.7	71.1	67.8	30.9	40.1	43.2
April	59.7	66.2	66.9	78.2	82.3	79.2	41.2	50.1	53.8
May	68.5	71.5	72.0	86.4	86.1	83.7	50.5	56.8	59.5
June	77.0	81.6	78.6	94.2	96.1	91.4	59.8	67.0	61.3
July	79.2	84.2	81.1	94.7	97.4	93.7	63.7	70.9	68.5
August	77.9	83.0	81.7	93.4	95.0	94.3	62.3	71.0	70.2
September	70.4	78.4	57.7	86.5	92.2	90.9	54.3	64.6	66.2
October	59.6	64.1	63.3	77.0	77.5	76.1	42.2	50.6	54.0
November	46.9	53.1	53.6	64.8	68.9	65.8	29.0	37.3	42.4
December	39.3	47.0	49.5	56.8	62.9	60.8	21.8	31.1	37.8
Annual	59.1	63.7	61.4	76.3	77.7	75.3	41.8	49.6	51.5

Table H-44c. Temperatures at Roswell and the WIPP Site, 1978-1979

Month	Temperature (°F)								
	Monthly average			Average daily maximum			Average daily minimum		
	Roswell		Site,	Roswell		Site,	Roswell		Site,
	Normal	6/78-5/79	6/78-5/79	Normal	6/78-5/79	6/78-5/79	Normal	6/78-5/79	6/78-5/79
January	38.1	34.9	37.0	55.4	45.5	46.8	20.8	24.2	28.6
February	42.9	43.6	45.7	60.9	59.2	57.9	24.8	28.0	35.1
March	49.3	50.5	52.9	67.7	65.6	63.5	30.9	35.3	43.2
April	59.7	60.6	62.8	78.2	75.8	73.8	41.2	45.3	44.6
May	68.5	67.5	68.0	86.4	81.2	79.5	50.5	53.7	57.2
June	77.0	79.37	78.4	94.2	92.7	90.9	59.8	65.8	66.6
July	79.2	83.4	82.6	94.7	96.2	93.0	63.7	70.5	72.1
August	77.9	78.0	79.0	93.4	89.9	89.6	62.3	66.0	68.7
September	70.4	69.2	70.2	86.5	79.8	78.6	54.3	58.6	62.6
October	59.6	60.3	61.7	77.0	74.1	72.9	42.2	46.5	52.2
November	46.9	49.0	52.0	64.8	58.7	60.3	29.0	39.3	44.4
December	39.3	37.2	42.3	56.8	50.7	52.7	21.8	23.7	32.2
Annual	59.1	59.5	61.1	76.3	72.5	71.6	41.8	46.4	50.6

Precipitation and atmospheric moisture. Precipitation data for the site are available for June 1, 1976, through May 31, 1979. Table H-45 shows the monthly totals for Roswell and the WIPP site, as well as the average monthly normals for Roswell (NOAA, 1977, 1978, 1979).

Monthly cumulative precipitation at the site ranged from a trace in December 1977 to 5.19 inches in September 1978. At Roswell it ranged from 0.00 inch in December 1976 to 4.45 inches in August 1977 (normal ranges for Roswell are 0.29 and 1.48 inches).

The differences between the Roswell 2-year data and the site are typical of precipitation spatial variations in the area.

The dew-point temperature is the temperature to which the air must be cooled to become saturated with water vapor (pressure and water-vapor content remaining constant). Thus the difference between the ambient and the dew-point temperatures (the dew-point spread) is a measure of the atmospheric moisture content.

The annual average and dew-point temperatures at Roswell and at the WIPP site are shown in Table H-46. The data periods are June 1, 1977, through May 31, 1979. At Roswell, 78.8% of the time the dew-point spread was greater than 8.1°F. At the site, this value was exceeded 88.9% of the time.

Atmospheric stability

Estimates of the average dispersion of effluents by atmospheric fluctuations over extended periods are generally based on the joint probability of

Table H-45. Roswell and WIPP Precipitation[a]

Month	Roswell				WIPP site		
	Normal	76-77	77-78	78-79	76-77	77-78	78-79
June	1.24	1.55	0.25	4.31	0.67	1.09	3.74
July	1.71	2.44	0.46	0.52	0.65	0.69	0.63
August	1.48	1.98	4.45	3.49	0.57	0.57	2.01
September	1.47	2.29	0.29	3.58	3.29	2.09	5.19
October	1.22	0.69	0.62	1.47	0.67	2.02	1.33
November	0.29	0.41	0.48	1.25	0.11	0.19	3.51
December	0.47	0.00	0.02	0.43	0.08	(b)	0.65
January	0.40	0.07	0.50	0.41	0.24	0.07	0.13
February	0.37	0.36	0.48	0.44	0.07	0.43	0.59
March	0.47	0.27	0.39	0.13	0.38	0.07	0.04
April	0.49	1.25	0.02	0.32	0.55	0.20	0.15
May	1.00	2.43	1.81	1.25	1.31	1.63	2.22
Annual	10.61	13.74	9.77	17.60	8.59	9.05	20.19

[a]Measured in inches. Data for Roswell collected at the Industrial Air Center.
[b]Trace amount.

Table H-46. Dew Point and Temperature at Roswell and the WIPP Site, June 1977 Through May 1979

	Roswell		WIPP site	
	Temperature (°F)	Dew point (°F)	Temperature (°F)	Dew point (°F)
Average	61.3	38.8	62.2	34.0
Average max.	73.9	44.7	73.6	40.3
Average min.	49.3	32.9	51.4	27.3

wind-speed, wind-direction, and atmospheric-stability frequencies. These frequencies have been estimated (Table H-47) from data collected at the site by the temperature-difference method outlined in NRC Regulatory Guide 1.23.

The joint frequencies of these stability categories with winds (Annex 1, Tables 25 through 32) show two dominant trends. The first is the very unstable category (category A), where southeast to south winds in the 3.1- to 5.0-m/sec range are most frequent. The second is in the slightly stable (E) and extremely stable (G) categories (and, to a lesser degree, categories D and F), where the southeast wind in the 1.5- to 5.0-m/sec range predominates.

A comparison of available stability data for Roswell is presented in Table H-48. Different methods were used in categorizing the Roswell and the WIPP-site data since the hourly data for Roswell obtained from the National Climatic Center did not contain the data needed for the temperature-difference method (temperature difference ΔT and standard deviation of the horizontal wind direction). The method used for the Roswell data (Turner, 1964) is based primarily on surface wind speed and net solar radiation. This method tends to be biased toward the neutral category D, as evident in Table H-48, while the ΔT method tends to be biased toward the extremely stable and unstable categories.

Table H-47. Monthly Frequency of Stability Categories at the WIPP Site, June 1977 Through May 1979

Category	J	F	M	A	M	J	J	A	S	O	N	D
A	28.7	31.1	34.2	41.5	44.7	46.3	48.1	44.3	36.9	32.7	26.5	27.7
B	2.4	1.7	1.5	0.7	0.2	1.0	0.7	1.2	0.7	1.3	1.5	0.8
C	1.2	0.9	0.8	0.3	0.5	0.7	0.2	0.3	0.3	0.6	0.6	0.7
D	10.7	6.7	2.7	3.2	2.6	4.5	3.6	4.8	2.0	4.0	3.4	4.1
E	13.1	14.0	6.8	5.8	8.9	10.5	9.6	9.6	8.3	10.0	9.9	4.9
F	8.6	7.7	10.0	11.0	14.1	23.9	15.6	18.0	13.3	10.3	11.2	7.8
G	35.8	38.1	44.1	37.5	29.1	13.4	22.8	20.4	38.5	41.1	46.9	54.0

Table H-48. Frequency of Stability Conditions at Roswell and at the WIPP Site

Stability condition	Frequency (%)		
	Roswell,[a] 1973-1976	Roswell,[a] June 1977-May 1979	WIPP site,[b] June 1977-May 1979
A, extremely unstable	1.3	2.1	36.7
B, unstable	7.6	8.6	1.1
C, slightly unstable	16.2	14.1	0.6
D, neutral	37.0	38.1	4.2
E, slightly stable	15.9	14.7	9.2
F, stable	17.0	17.0	12.4
G, extremely stable	5.1	5.3	35.7

[a]Based on the Turner method.
[b]Based on the temperature-difference method.

H.4.3 Short-Term (Accident) Diffusion Estimates

Conservative (5% probability level), realistic (50% probability level), as well as worst-case estimates of the local atmospheric-diffusion factors (χ/Q) for the site have been prepared for the site boundary (control zone IV radius of 3 miles) and distances of 0.5, 1.5, 2.5, 3.5, 4.5, 7.5, 15, 25, 35, and 45 miles. Calculations were made for a 1-hour effluent-release period from hourly data collected at the site for the period June 1977 through May 1979.

The ground-level atmospheric-diffusion factors for the site were calculated from Gaussian plume-diffusion models for a continuously emitting ground-level source (a conservative assumption). Hourly centerline χ/Q values were computed from the concurrent hourly mean wind speed, wind, and stability category. The wind speed at the 10-meter-level sensor was used since a ground-level release was assumed for conservatism. The stability class was determined by the temperature-difference method. Calms were assigned a wind-speed value equal to the starting speed of the wind vane (0.6 mph) and the wind direction in the last noncalm hour. Cumulative frequency distributions were prepared to determine the χ/Q values that were exceeded only 5% and 50% of the time as well as worst-case values.

Gaussian plume-diffusion models for a ground-level concentration were used to describe the downwind spread of effluents from the WIPP. A continuous ground-level release of effluents at a constant emission rate and total reflection of the plume at ground level were assumed in the diffusion estimates. Since it allows for no depletion by deposition or reaction at the surface, this assumption is conservative. For each hour in the 2 years of record χ/Q values were calculated as follows:

$$\frac{\chi}{Q} = \frac{1}{\pi \Sigma_y \sigma_z u_{10}} \qquad (1)$$

$$\frac{\chi}{Q} = \frac{1}{\pi \sigma_y \sigma_z u_{10}} \qquad (2)$$

where

χ/Q = the relative centerline concentration (sec/m^3) at ground level.

u_{10} = wind speed (m/sec) at 10 meters above the ground.

Σ_y = lateral plume spread (meters), a function of atmospheric stability, wind speed, and downwind distance from the point of release. for Distances of up to 800 meters, $\Sigma_y = M_{\sigma y}$, M being a function of atmospheric stability and wind speed. For more than 800 meters, $\Sigma_y = (M - 1)\ \sigma_y(800\ m) + \sigma_y(x)$.

σ_y, σ_z = lateral and vertical plume spread (meters), respectively, as a function of atmospheric stability and distance.

For neutral to stable conditions (categories D to G) with wind speeds at the 10-meter level of less than 6 m/sec, equation 1 was used. For all other stability or wind-speed conditions, χ/Q was calculated from equation 2. This technique of calculating concentration from vents or other building penetrations is described in NRC Regulatory Guide 1.145 (Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants; issued for comment, August 1979).

From the 2 years of 1-hour χ/Q values, cumulative frequency distributions were prepared for each of 16 wind sectors and for several distances from the release point. The values of χ/Q exceeded only 5% and 50% of the time are presented in Table 33 of Annex 1.

H.4.4 Long-Term (Routine) Diffusion Estimates

Annual average diffusion factors were computed for routine releases from WIPP operations. The MESODIF model was run (Start and Wendell, 1974) with meteorological data recorded at the site from June 1977 through May 1979.

MESODIF uses an integrated puff model that differs from other Gaussian puff models in that it allows released materials to be transported back over the source should the wind shift. The effluent is treated as a string of puffs released every hour through the year of record into the wind field recorded by the on-site meteorological station. Individual puffs are tracked until they are too dilute to be of significance or until they leave the area being considered. Concentrations are integrated for the year and then averaged to yield the mean expectation for single puffs. A ground-level release was assumed for conservatism. The results are listed in Table H-49 for the 2 years of record. The strong lobe of concentration in the northwest sector in Table H-49 is consistent with the prevailing winds, which are from the southeast.

Table H-49. WIPP Site Long-Term Average χ/Q Calculations (Period of Record June 1977 through May 1979)

Downwind sector	χ/Q (sec/m^3) at downwind distance (miles)											
	0.5	1.5	2.5	3.5	4.5	5.0	7.5	10.0	15.0	25.0	35.0	45.0
N	2.8-5[a]	2.4-6	1.0-6	6.2-7	4.4-7	3.6-7	1.8-7	1.0-7	3.9-8	1.7-8	7.2-9	8.4-9
NNE	1.1-5	1.4-6	5.7-7	3.7-7	21.-7	1.7-7	9.0-8	4.6-8	2.0-8	9.0-9	3.3-9	2.6-9
NE	9.3-6	2.8-6	6.8-7	4.0-7	2.3-7	2.0-5	1.1-7	6.5-8	3.0-8	1.2-8	4.4-9	3.1-8
ENE	1.1-5	1.1-6	5.4-7	2.9-7	1.8-7	1.5-7	5.7-8	2.8-8	1.5-8	5.4-9	1.1-9	8.6-10
E	7.7-6	4.4-7	4.8-7	2.3-7	1.6-7	1.2-7	4.8-8	1.5-7	1.2-8	4.2-9	1.3-9	1.1-9
ESE	2.3-5	4.0-7	4.5-7	2.0-7	1.4-7	1.1-7	4.2-8	2.7-8	1.1-8	4.7-9	1.0-9	7.3-10
SE	1.0-5	1.4-6	4.3-7	2.0-7	1.4-5	1.1-7	5.3-8	3.0-8	1.6-8	6.2-9	1.7-9	1.5-9
SSE	1.1-5	1.4-6	5.2-7	3.0-7	2.0-7	1.6-7	7.7-8	4.8-8	2.3-8	3.6-7	4.0-9	2.7-9
S	1.1-5	1.6-6	6.4-7	3.7-7	2.5-7	2.1-7	1.1-7	6.7-8	3.0-8	1.0-8	6.0-9	3.21-9
SSW	1.1-5	1.8-6	8.5-7	4.4-7	3.1-7	2.8-7	1.4-7	8.0-8	3.9-8	1.8-8	6.8-9	5.2-9
SW	1.5-5	2.2-6	9.6-7	6.7-7	4.0-7	3.3-7	1.6-7	9.5-8	5.0-8	1.8-8	8.8-9	4.8-9
WSW	1.2-5	1.9-6	8.5-7	5.1-7	3.6-7	2.9-7	1.4-7	7.5-8	3.5-8	1.2-8	5.6-9	3.1-9
W	1.9-5	2.8-6	1.2-6	7.5-7	5.3-7	4.0-7	1.9-7	1.8-7	5.0-8	1.7-8	7.8-9	4.5-9
WNW	5.0-5	6.1-6	2.5-6	1.2-6	9.5-7	7.9-7	3.8-7	2.5-7	1.0-7	3.9-8	1.9-8	9.5-9
WNW	5.0-5	6.1-6	2.5-6	1.2-6	9.5-7	7.9-7	3.8-7	2.5-7	1.0-7	3.9-8	1.9-8	9.5-9
NW	4.9-5	9.3-6	3.2-6	2.0-6	1.6-6	1.4-6	7.6-7	5.0-7	2.5-7	1.1-7	5.5-8	3.2-8
NNW	3.0-5	5.9-6	3.0-6	1.5-6	1.2-6	1.1-6	5.8-7	3.5-7	2.5-7	7.8-8	4.6-8	2.6-8

[a] 2.8-5 = 2.8×10^{-5}.

H.4.5 Air Quality

The United States has been divided by the Environmental Protection Agency (EPA) (40 CFR 81) into Air Quality Control Regions (AQCRs). The EPA has divided its programs in the country into administrative regions. The WIPP site is located in AQCR 155 and is administered by EPA Region VI. The New Mexico Environmental Improvement Division (NMEID) has designated a seven-county area, including Eddy and Lea Counties, as State Air Quality Control Region 5 (Chapter 277, Laws of 1967 as amended).

Existing air pollution in the vicinity of the site consists mostly of high concentrations of total suspended particulates. The entire State experiences occasional high concentrations of total suspended particulates from natural wind-blown dust; near the site, the concentrations are even higher because of potash operations. According to the most recent EPA State Attainment Status Report (Federal Register, September 11, 1978), air quality in the region meets primary and secondary national ambient air-quality standards, except locally near industries.

To better define the ambient air quality at the site, the levels of selected air pollutants have been monitored since January 1976 and will be used to analyze the effects of WIPP construction and operation on air quality locally and regionally. The parameters being measured are total suspended particulates, chemical species in particulates, nitrogen dioxide, sulfur dioxide, hydrogen sulfide, carbon monoxide, and ozone (Metcalf and Brewer, 1977).

Table H-50 presents State and Federal air-quality standards. State standards are not to be exceeded at any time, while Federal standards are not to be exceeded more than once a year. The Federal standards are divided into

Table H-50. Ambient Air-Quality Standards[a]

Pollutant	New Mexico standard	Federal standards	
		Primary	Secondary
Sulfur dioxide (SO_2)			
24-hour average	0.10 ppm (260 $\mu g/m^3$)	0.14 ppm (365 $\mu g/m^3$)	
Annual arithmetic mean	0.02 ppm (52 $\mu g/m^3$)	0.03 ppm (80 $\mu g/m^3$)	
3-hour average			0.50 ppm (1300 $\mu g/m^3$)
Total suspended particulates			
24-hour average	150 $\mu g/m^3$	260 $\mu g/m^3$	150 $\mu g/m^3$
7-day average	110 $\mu g/m^3$		
30-day average	90 $\mu g/m^3$		
Annual geometric mean	60 $\mu g/m^3$	75 $\mu g/m^3$	60 $\mu g/m^3$
Carbon monoxide (C))			
8-hour average	8.7 ppm	9 ppm	9 ppm
1-hour average	13.1 ppm	35 ppm	35 ppm
Photochemical oxidants (ozone), 1-hour average	0.06 ppm	0.12 ppm	0.12 ppm
Hydrocarbons (nonmethane), 3-hour average	0.19 ppm	0.24 ppm	0.24 ppm
Nitrogen dioxide (NO_2)			
24-hour average	0.1 ppm (200 $\mu g/m^3$)		
Annual arithmetic average	0.05 ppm (100 $\mu g/m^3$)	0.05 ppm (100 $\mu g/m^3$)	0.05 ppm (100 $\mu g/m^3$)

[a]State standards--State of New Mexico ambient air-quality data summaries (1973-1976). Federal standards--40 CFR 50.

primary and secondary standards, which are defined in 40 CFR 50.2: "National primary ambient air-quality standards define levels of air quality which the Administrator [Administrator of the EPA] judges are necessary, with an adequate margin of safety to protect the public health. National secondary ambient air-quality standards define levels of air quality which the Administrator judges necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant."

The concentrations of pollutants measured at the WIPP site are presented in Table H-51. The only concentrations that exceeded New Mexico standards during 1976 are the 1-hour carbon monoxide concentration and the 1-hour ozone concentration. The carbon monoxide value does not exceed Federal standards, however. The high ozone concentrations may be at least partially explained by the fact that the concentrations were measured by ultraviolet techniques instead of chemiluminescence; the ultraviolet techniques generally produce higher values. Chemiluminescence is now used for measurements, but no new values are available.

Table H-51. Pollutants Measured at the WIPP Site During 1976

Pollutant	Measured concentration	New Mexico standard
Nitrogen dioxide, annual arithmetic mean	32.19 $\mu g/m^3$	100 $\mu g/m^3$
Sulfur dioxide[a]		
Annual arithmetic mean	4.29 $\mu g/m^3$	52 $\mu g/m^3$
24-hour average	38 $\mu g/m^3$	260 $\mu g/m^3$
Total suspended particulates		
Annual arithmetic mean	18.47 $\mu g/m^3$	[b]60 $\mu g/m^3$
24-hour average	77.7 $\mu g/m^3$	150 $\mu g/m^3$
Carbon monoxide		
1-hour average	17 ppm	13.1 ppm
Daily mean	3.17 ppm	
Ozone		
1-hour average	0.167 ppm	0.06 ppm
Daily mean	0.02 ppm	
Hydrogen sulfide, daily mean	0.11 $\mu g/m^3$	(c)

[a]Below the detection capability of the method used.

[b]Geometric mean.

[c]The standards are 0.003 ppm (1-hour average) for all parts of New Mexico except the Pecos-Permian Basin Intrastate Air Quality Control Region and 0.1 ppm (30-minute average) for that region.

H.4.6 Paleoclimatology

The climatic record of the past indicates long-term variabilities of the climate in a region and provides a basis for postulating the bounds in future climatic changes that may affect the long-term impact of a repository. In evaluating the long-term performance of a repository, the most significant historic period is the last 10,000 to 100,000 years. Detailed climatological information is not available for this historic period. However, qualitative estimates of temperature and precipitation regimes have been made, and the extent of glaciation and flooding can be fairly accurately estimated from geologic evidence. Much of the available paleoclimatological information refers to large geographical areas (continents, hemispheres, etc.), and climatic conditions for the region of a particular site frequently must be inferred from these generic descriptions. However, limited geologic investigations have provided some specific information directly applicable to the region of the WIPP site.

Periodically, at intervals of about 250 million years, there have been major advances of glaciers from the polar regions, advances that lasted on the order of millions of years (Sellers, 1965). The Pleistocene Epoch, which began about 1 to 2 million years ago, is the latest glacial period (Sellers, 1965; NAS-NRC, 1975, 1977; John, 1977). Within the Pleistocene there have been several glacier advances (glacials) and retreats (interglacials), as illustrated by worldwide temperature variations in Figure H-16 (Norwine, 1977). This epoch ended some 10,000 years ago with the beginning of the Holocene Epoch, although continuous ice sheets are still present in the polar regions.

Continental ice sheets of the Pleistocene Epoch did not advance south of Montana and Idaho, and glacial action does not appear to be a threat to the integrity of the WIPP site. However, during these glaciations, individual mountain glaciers were widespread throughout the Rocky Mountains from Canada to central New Mexico, and local ice caps were present in a number of ranges (Richmond, 1965). Mountain glaciers developed as far south as latitude 33° 22' N (Sierra Blanca, peak elevation 13,000 feet, west of Roswell) during the glaciations of late-Pleistocene time. The average end moraines of late-Pleistocene glaciers are at elevations of between 10,200 and 11,400 feet at this latitude (Richmond, 1965). Summer temperatures were about 7 to 16°F colder than at present, but winter temperatures were much the same as at present (Richmond, 1965; Gates, 1976).

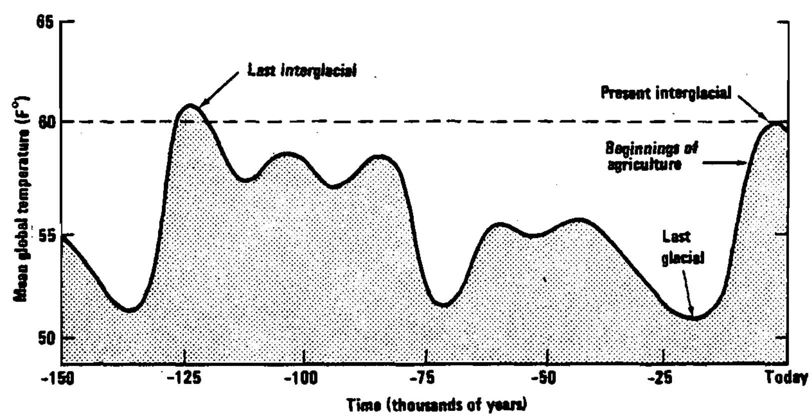


Figure H-16. Worldwide temperature variations.

The advance of glaciers was initially associated with a cold, damp climate, followed by a cold, dry climate that developed over the contiguous ice sheet itself (Schwarzbach, 1963). Precipitation over this area was probably less than that over the same region at present. During these periods, the weather was much more variable than at present. Winters were longer; spring, fall, and summer were shorter; and diurnal and day-to-day variations were greater (Kukla, 1976).

During glaciation periods in North America, the westerly wind belt was displaced toward the equator (Brooks, 1970; Schwarzbach, 1963). This change resulted in some areas south of the continental glacier receiving increased (pluvial) precipitation (Schwarzbach, 1963). In the United States, pluvial effects occurred in the central and western regions. Several lakes were formed or expanded during the pluvial, especially in the Western United States, in areas that are now deserts (Flint, 1967; Schwarzbach, 1963). The climate of New Mexico during this period was characterized by more precipitation (about 64% more than at present), less evaporation (only about 73% of present), and a mean June-September temperature about 18°F lower than at present (Antevs, 1954).

In summary, it can be inferred that the climate of the region during the glacial/pluvial periods of the Pleistocene was probably cooler, wetter, and stormier than at present. Therefore, flooding was also probably more frequent. The geologic history of the region that indicates such effects has been addressed in Section 7.3.

Major glacial epochs have been alternating with interglacials on a 100,000-year cycle (Norwine, 1977). These interglacials have previously lasted 11,000 to 15,000 years. The present global climate is considered interglacial and has lasted approximately 10,000 to 12,000 years (Richmond, 1972; Sellers, 1965), although this has varied by region, and glacial advances have at times occurred. The interglacials of the Pleistocene were typically free of ice and were drier than the present (Sellers, 1965). Moreover, temperatures were similar or at times slightly warmer than those at present: average world temperatures were approximately 3°F above those at present (Sellers, 1965). In the Rocky Mountains, the present interglacial has been less arid and colder than previous interglacials (Richmond, 1972).

A brief summary of the climate of the current epoch is presented in Table H-52. The most significant events are the Cochrane Glacial Readvance (6800 to 5600 B.C.), the Climate Optimum (5600 to 2500 B.C.), and the Little Ice Age (A.D. 1500 to 1900). However, the oscillations of the interglacial climate in the United States during the Holocene have been less severe than those experienced during the Pleistocene, when conditions varied between glacial and interglacial (Lamb, 1966). There are indications that a long-term global cooling trend is still under way, although there has been a relatively recent short-term period (approximately 40 to 100 years ending in about 1950) of global warming (Kukla and Matthews, 1972; Lamb, 1966; Alexander, 1974).

Table H-52. A Brief Chronology of the Climate of the Southwestern United States in the Last 10,000 Years[a]

Dates	Climate
9000-6000 B.C.	Warm and arid in southern Arizona.
6800-5600 B.C.	Cool and dry, with possible extinction of mammals, particularly in Arizona and New Mexico.
5600-2500 B.C.	Warm and moist, becoming warm and dry by 3000 B.C. (Climate Optimum). Intermittent drought in the Western United States after 5500 B.C.
2500-500 B.C.	Generally warm and dry with periods of heavy rain (after 660 B.C.) and intense droughts (near 510 B.C.) in the Western United States.
A.D. 330	Drought.
800	Start of moist period in Mexico.
1180-1215	Wet in the West.
1220-1290	Drought in the West.
1276-1299	"Great Drought" in the Southwest.
1300-1330	Wet in the West.
1500-1900	Generally cool and dry (Little Ice Age). Periodic glacial advances in North America (1700-1750). Drought in the southwestern United States from 1573 to 1593.
1880-1940	Increase of winter temperatures by 1.5°C. Drop of 5.2 meters in the level of the Great Salt Lake. Alpine glaciation reduced by 25% and arctic ice by 40%.
1920-1958	25% decrease in mean annual precipitation in the Southwest.
1942-present	Worldwide temperature decrease and halt of glacial recession.

[a]Data from Sellers (1965).

H.5 ECOLOGY

H.5.1 Introduction

This section discusses the terrestrial and aquatic ecology of the Los Medanos site and its environs, describes the ecological resources at the site, and characterizes preexisting environmental stresses.

The terrestrial ecology study area is the area within a 5-mile radius of the center of the site (Figure H-17). Eighty-nine study plots have been established in the study area and nearby. Seven are fenced for studies of grazing effects, etc.; the remainder are enclosed. In addition, there are 11 soil microclimate stations, also fenced (Figure H-18). Aquatic habitats within the study area are limited to stock-watering ponds and tanks. Sampling stations have been established at a nearby playa, at Laguna Grande de la Sal, and along the Pecos River (see Section H.5.3.1).

This section is based on data collected since 1975. Early studies were carried out by the New Mexico Environmental Institute. The results are published in two progress reports (Wolfe et al., 1977a,b). In 1977, the biology team was reorganized, and ecological studies continued. Methods and data are discussed in a report published in 1979 (Best and Neuhauser, 1979); more recent data will be published later.

The studies provide baseline data for the assessment of environmental impacts. The emphasis is on characterizing terrestrial and aquatic habitats and important plant and animal species. Important species are defined (NRC, 1976) as follows:

a. The species is commercially or recreationally valuable.

b. The species is threatened or endangered.

c. The species is critical to the well-being of some important species within criterion a or b.

d. The species is critical to the structure and function of the ecological system or is a biological indicator of radionuclides in the environment.

These baseline data are of further use in the development of an ecological monitoring program at the site. The emphasis is on (a) documenting the range of natural variation and its cause(s) for important plant and animal communities; (b) characterizing critical pathways and processes in the local ecosystem, including pathways of radionuclide transfer; and (c) predicting, where possible, the kind and the degree of change that may result from WIPP-related activities (e.g., changes in vegetation within control zone II due to the exclusion of cattle).

In order to expand the ecology data base and thereby make it more useful, field studies are continuing.

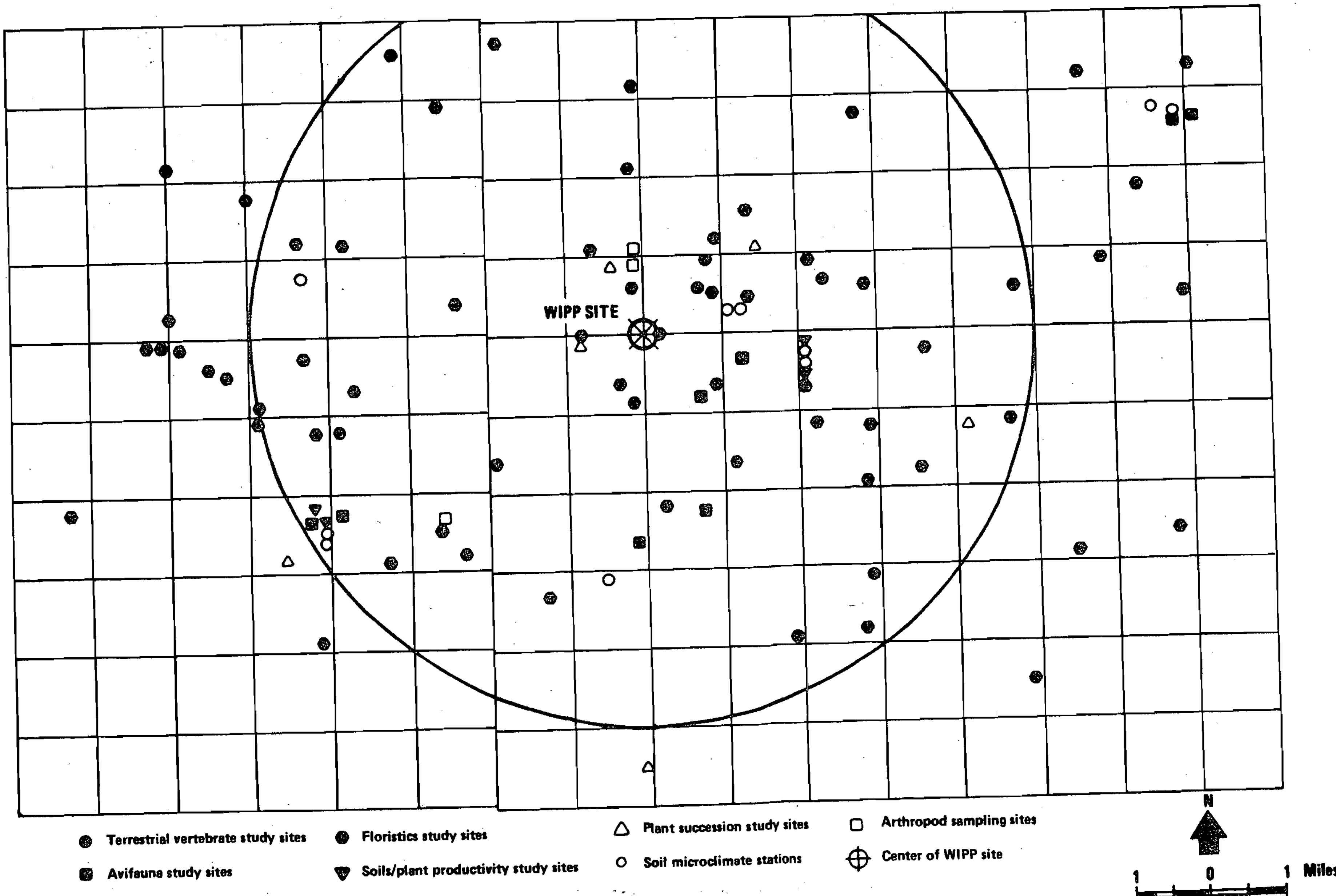


Figure H-17. Map of the site showing bioplot locations.

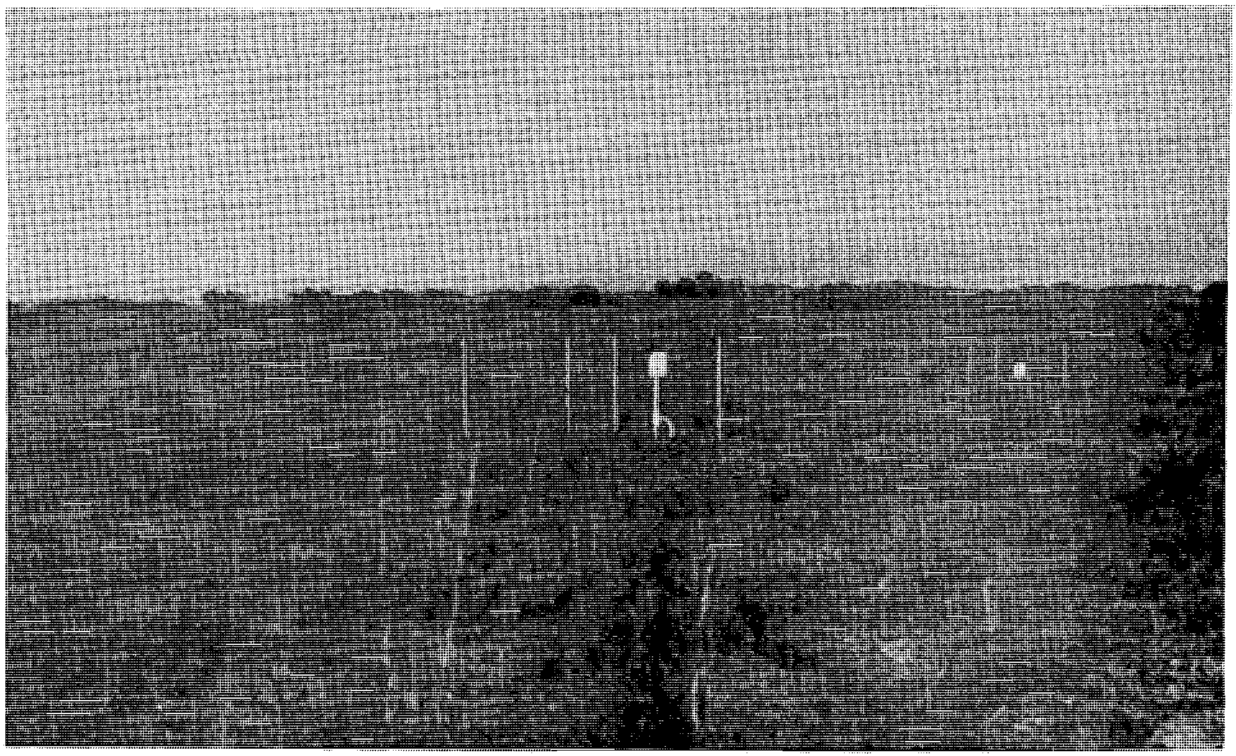


Figure H-18. Soil microclimate station.

To give a regional perspective, the ecology of the two-county region (Eddy and Lea Counties), excluding the Guadalupe Mountains, is discussed below.

H.5.2 Terrestrial Ecology

H.5.2.1 Soil and agricultural resources

The two-county region lies in the Southern Desert Basins, Plains, and Mountains Land Resource Area of the Western Range and Irrigated Land Resource Region (Austin, 1972). Climate and soil limit agriculture to ranching and some irrigated and dry-land farming, with the major cultivated areas being along the Pecos and Black Rivers in Eddy County and in eastern Lea County. Irrigated lands produce sorghum, cotton, alfalfa, and small-grain crops. Over 90% of the region is grazing land, and beef-cattle ranching is the major agricultural enterprise. Grazing areas are used the year round.

The major soils in the region are Aridisols, which occur in arid locales and contain low amounts of organic matter, and Mollisols, found in more moist areas with dark, organic-matter-rich surface horizons. The major suborders of the Aridisols, which are used primarily for rangeland and some irrigated crops, are the Orthids, which have accumulations of calcium carbonate, gypsum, or other salts more soluble than gypsum but no horizontal clay accumulation; and the Argids, which have clay accumulations with or without alkali (sodium). Ustols, the major suborder of Mollisols in the site region, are intermittently dry during the warm season and have subsurface horizons in which salts or carbonates have accumulated. They are used for wheat or small grains and some irrigated crops.

Other soil orders are present, including Entisols, recent soils with no horizon development, and Alfisols, which have a gray to brown surface horizon and a subsurface horizon of clay accumulations. Entisols are used primarily as rangeland. The Alfisols are being used as rangeland, for dry-land farming of small grain, and for irrigated crops.

Terrestrial ecology

The three soil associations that occur in the study area are described in Section 7.3.8. All are Aridisols (Argids and Orthids) or Entisols. The two soil mapping units that occur on the site proper are in the Kermit-Berino Soil Association (Table H-53). Approximately half the site is mapped as Berino complex and the other half as Kermit-Berino fine sands. Both mapping units are Class VII soils--unsuitable for cultivation and suitable only for pasture and wildlife habitat. These sandy soils are subject to severe wind erosion. They are generally stabilized by shinnery oak, mesquite, and other vegetation.

The soils at the site include sandy surface soils with wind-blown particles, a thin (1-mm-thick) soil crust, and a layer of moist subsoil. The wind-blown soil and subsoil contain sparsely distributed bacteria attached to the surfaces of the sand grains but few fungi or algae. The surface material, however, contains partially degraded plant detritus and relatively dense fungal hyphae. This thin crust resists wind erosion and covers much of the site (Caldwell, 1978).

A hard caliche layer, up to 10 feet thick, underlies these soils. Depth to caliche varies from a few centimeters to several meters. The caliche is fully exposed along parts of Livingston Ridge.

H.5.2.2 Native vegetation

Vegetation in the two-county region

The site lies in a region that is an area of transition between the Great Plains Short-Grass Prairie and the Chihuahuan Desert. Since early in the twentieth century, salt cedar trees, naturalized from Eurasia, have invaded major drainageways. Another introduced species--the Russian thistle, or tumbleweed--is a common invader in highly disturbed areas; it is found in the study area. Shrubs and grasses are the most prominent components of the local flora. Vegetative cover is largely controlled by water availability and livestock grazing. The development of specific plant communities is dependent on such factors as the infiltration rate of the surface soil, depth to a restrictive layer (i.e., caliche), and the extent to which the surface soil has been reworked by wind or water erosion.

According to Bailey's (1976) ecoregion classification, the two-county area is in the Grama-Tobosa Section and the Tarbush-Creosote Bush Section of the Chihuahuan Desert and the Grama-Buffalo Grass Section of the Great Plains Shortgrass Prairie. The Grama-Tobosa Section is a climax desert grassland

Table H-53. Ecological Characteristics of Soils at the WIPP Site[a]

Soil mapping unit	Soil series	Soil order/ suborder	Soil capability unit	Soil-management considerations	
				Agricultural potential[b]	Management considerations
Berino complex 0-3% slopes, eroded	Berino	Aridisol Arigid	VIIe-1	Unsuitable for dryland farming. Soils are too sandy and rainfall too low and undependable. Suitable only for native pasture and wildlife habitat.	Soils subject to severe wind erosion if vegetation cover not maintained. Natural revegetation of eroded areas is difficult and slow. Soils must be constantly protected from overgrazing.
Kermit-Berino fine sands, 0-3% slopes:	Kermit	Entisol Psamment			
Kermit fine sand			VIIe-3	Unsuitable for dryland farming. Rainfall is low and undependable and soil texture is too coarse. Suitable for wildlife habitat and native pasture.	Soils subject to severe wind erosion if vegetative cover not maintained. Natural fertility and organic-matter content are low. Grasses should not be overgrazed.
Berino fine sand			VIIe-3	Unsuitable for dryland farming. Rainfall is low and undependable and soil texture is too coarse. Suitable for wildlife habit and native pasture.	Soils subject to severe wind erosion if vegetative cover not maintained. Natural fertility and organic-matter content are low. Grasses should not be overgrazed.

[a]Based on data from the Soil Conservation Service (1971).

[b]None of the soils at the site or in the vicinity are suitable for irrigated farmland. Because of the physical and chemical characteristics of the soils, there is a lack of an adequate supply of good-quality water in the site region.

community. At lower elevations in this section, dense stands of shrubs are common. The Tarbush-Creosote Bush Section has been described as a disclimax shrub type that was originally desert grassland (Castetter, 1956). Overgrazing has caused an increase in shrub species that once occupied only isolated areas (Gardner, 1951). The Grama-Buffalo Grass Section is a short-grass prairie found in arid areas where the growing season is short and precipitation is not retained in the soil (Weaver and Albertson, 1956).

Kuechler (1975) has described the potential natural vegetation of the region largely as Trans-Pecos Scrub Savanna in the southern and central portions, Grama-Buffalo Grass in the north and east, and Grama-Tobosa Shrubsteppe and Creosote Bush-Tarbush in the north and west.

More recently, Donart et al. (1978) have described Eddy County as belonging largely to the Chihuahuan Region of the Grassland Formation and the Chihuahuan Region of the Desert Shrub Formation; the potential natural vegetation of Lea County is classified as the Chihuahuan Region, the Plains Region, and the Prairie Region of the Grassland Formation. The following Chihuahuan Region associations occur:

- Creosote/Bush Muhly--at one time predominantly grasslands with scattered creosote bush; principal grasses were black grama, bush muhly, and scattered tobosa.

- Catclaw--primarily an Arizona shrub, it dominates an association of limited distribution around Carlsbad and in southwestern New Mexico.

The Chihuahuan Region of the Grassland Formation contains four associations in the two-county region (Donart et al., 1978):

- Burrograss--dominated by burrograss in association with tobosa and inclusions of gyp grama, gyp dropseed, coldenia, and fluffgrass.

- Mixed Grama/Three-Awn--dominated by black grama and three-awns in association with moderate amounts of blue, hairy, and sideoats gramas and occasional plants of mesa and sand dropseed.

- Black Grama/Mixed Dropseed--dominated by black grama in association with mesa dropseed, sand dropseed, spike dropseed, giant dropseed, and scattered yucca.

- Mixed Dropseed/Black Grama--dominated by dropseed species in association with black grama, yucca, and, in some areas, sand sagebrush.

Several authors have characterized the successional patterns in the region. Shantz (1917) described the area as a grazing disclimax. Explanations for the shift of vegetation from tall and mid-grasses to shrubs (notably sagebrush, shinnery oak, mesquite, and creosote bush) include the exclusion of fire (Sauer, 1950; Humphrey, 1953; Wingfield, 1955), overgrazing by cattle (Campbell, 1929; Whitfield and Anderson, 1938; Whitfield and Beuther, 1938), and changing climate. York and Dick-Peddie (1969) have attributed the recent occupation by mesquite in southern New Mexico to the effects of cattle and note that the appearance of grazing is the only event that coincides with the time of this spectacular change in vegetation.

Several plant species in the region are important to wildlife. For example, mesquite provides abundant forage for herbivorous and granivorous species, such as scaled quail (BLM, 1977). Mesquite, shinnery oak, and other shrubs provide forage and cover for a variety of game and nongame species, such as mule deer and mourning dove.

Vegetation in the study area

The vegetation of the study area consists of shrub-dominated seral communities that are at least partly a result of severe overgrazing in the late 1800s. No crops are cultivated.

The area is floristically heterogeneous (Figure H-19 and Table H-54). This heterogeneity has a number of causes, which include site-specific terrain features, changes in soil type and depth, etc.

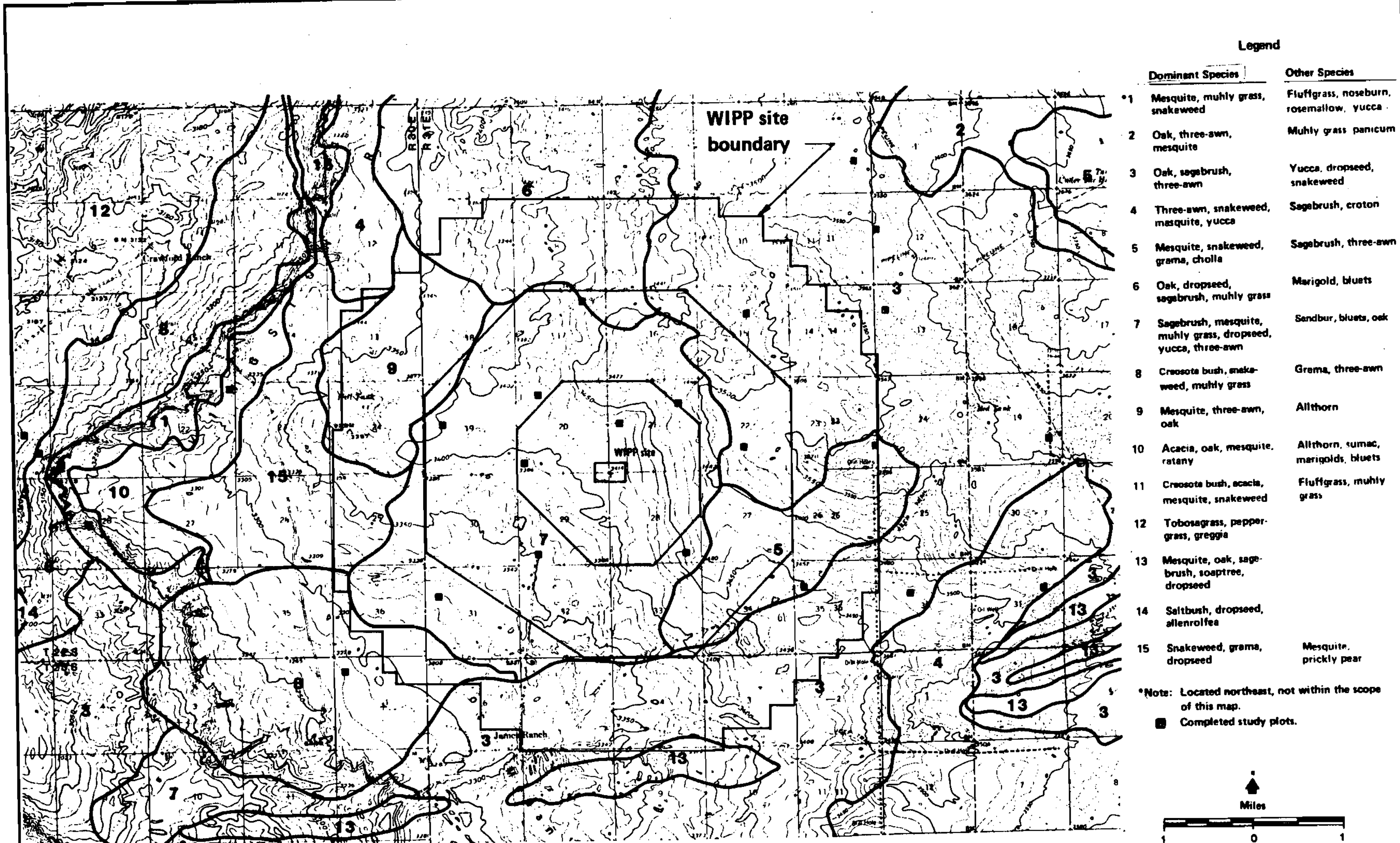
Five terrain-related or topographic-edaphic zones of vegetation can be distinguished within the study area. These are discussed separately below.

Mesquite grassland ("mesa") zone. A low mesa, the Divide, lies on the eastern edge of the study area (see Powers et al., 1978, Section 4.2.2, pp. 4-7 to 4-9, for a discussion of the surficial geology). It supports fairly typical desert grassland vegetation. Honey mesquite (Prosopis glandulosa) and snakeweed (Gutierrezia sarothrae) are the dominant shrub and subshrub, respectively; grasses are also abundant. Important species include burrograss (Scleropogon brevifolius), black grama (Bouteloua eriopoda), bush muhly (Muhlenbergia porteri), and fluffgrass (Tridens pulchellus).

Cacti, especially varieties of prickly pear (Opuntia phaeacantha), are present but not common. Yucca torreyi, also uncommon, is completely absent from the dune plains, where another species, Y. campestris, is common. This area is heavily grazed. Further deterioration in its range condition in future could lead to increased shrub density.

Central dune zone. This zone actually is made up of three dune-related subzones: stabilized dunes, oak-mesquite hummocks, and active dunes.

Stabilized dunes make up the greatest part of the central dune zone. This is reflected in the traditional name for the area, Los Medanos ("the dunes"). Shinnery oak (Quercus havardii), honey mesquite (Prosopis glandulosa), sand sagebrush (Artemisia filifolia), snakeweed (Gutierrezia sarothrae), and dune yucca (Yucca campestris) are the dominant shrubs. In certain sites, all of these species are present; in other sites, one or more is either missing entirely or very low in density. Localized variations in soil type and depth appear to be the major causes of this heterogeneity. The stabilized-dune subzone, therefore, consists of a "patchwork" of closely related but distinct floristic associations. Grasses are common throughout the subzone. Purple three-awn (Aristida purpurea) is found at the majority of the study sites and is the most common perennial grass in the zone. Other frequent species are red three-awn (A. longiseta), sand dropseed (Sporobolus cryptandrus), giant dropseed (S. giganteus), black grama (Bouteloua eriopoda), hairy grama (B. hirsuta), and fall witchgrass (Leptoloma cognata).



Source: USGS 15 minute topographic quadrangles of Nash Draw, New Mexico, dated 1939, photorevised 1965, and Hat Mesa, New Mexico, dated 1963, photorevised 1972; scale 1:62,500.

W. C. Martin, Floristics of the WIPP Site, 1978 and 1979. (Map compiled by Paul Knight, 1979.)

Figure H-19. Vegetation map.

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a]

Taxon	Common name	Growth form[b]
Agavaceae		
*Yucca campestris	Dune yucca	S
Y. elata	Palmilla, soaptree yucca	S
Y. torreyi	Torrey yucca, Spanish dagger	S
Aizoaceae		
Mollugo verticillata	Indian chickweed	A
Amaranthaceae		
*Amaranthus albus	Tumbleweed amaranth	A
A. blitoides	Prostrate pigweed	A
A. hybridus	Green amaranth	A
A. palmeri	Giant amaranth	A
A. prostrata		
*Froelichia floridana var. campestris	Snakecotton	A
Guilleminea densa var. aggregata	Cottonflower	P
Tidestromia lanuginosa	Woolly tidestromia	A
Amaryllidaceae		
Zephyranthes longifolia	Zephyr-lily	P
Anacardiaceae		
Rhus microphylla	Littleleaf sumac	S
Asclepiadaceae		
*Asclepias arenaria	Dune milkweed	P
A. nyctaginifolia	Four-o-clock milkweed	P
A. oenotherioides	Primrose milkweed	P
A. viridiflora	Green-flowered milkweed	P
Bignoniaceae		
Chilopsis linearis	Desert willow	S
Boraginaceae		
Amsinckia intermedia	Fiddleneck	A
Coldenia canescens	Spreading coldenia	SS
C. hispidissima	Hispid coldenia	SS
Cryptantha angustifolia	Narrowleaved hiddenflower	A
*C. jamesii var. laxa	James hiddenflower	B, P
C. jamesii var. setosa	Setose hiddenflower	B, P
*Heliotropium convolvulaceum	Bindweed heliotrope	A
H. curassavicum	Salt heliotrope	P
H. curassavicum var. obovatum	Bluntleaf heliotrope	P
H. greggii	Desert heliotrope	P
Lithospermum multiflorum	Stoneseed	P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Cactaceae		
Coryphantha macromeris	Pincushion cactus	P, SS
Echinocactus texensis	Texas devilshead	SS
Echinocereus caespitosus	Caespitose hedgehog	SS
*E. fendleri	Fendler hedgehog	SS
Opuntia davisii	Davis cholla	SS
O. kleiniae	Klein cholla	SS
O. leptocaulis	Christmas cactus	SS
*O. phaeacantha	Prickly pear	SS
Caryophyllaceae		
Paronychia jamesii	Nailwort	SS
Chenopodiaceae		
Allenrolfea occidentalis	Pickleweed	S
Atriplex canescens	Four-wing saltbush	S
Chenopodium desiccatum	Thickleaf goosefoot	A
C. hians	Fetid goosefoot	A
C. incanum	Gray goosefoot	A
*Cycloloma atriplicifolia	Winged pigweed	A
*Salsola kali var. tenuifolia	Russian thistle, tumbleweed	A
Commelinaceae		
Commelina dianthifolia	Birdbill dayflower	P
*C. erecta var. angustifolia	Erect dayflower	P
Tradescantia occidentalis	Western spiderwort	P
Compositae		
Ambrosia artemisifolia	Short ragweed	A
Aphanostephus ramosissimus	Lazy daisy	A
Artemisia filifolia	Sand sagebrush	SS
A. ludoviciana	Wormwort	P
Baccharis wrightii	Wright baccharis	SS
Bahia pedata	Bahia	A
Baileya multiradiata	Desert marigold	A, P
Berlandiera lyrata	Lyrate greeneyes	P
Chrysothamnus pulchellus	Southwest rabbitbrush	S
C. spathulatus	Bluntleaf rabbitbrush	S
Cirsium spp.	Thistle (rosette)	P
Conyza coulteri	Coulter conyza	A
Dyssodia acerosa	Acerose dogweed	SS

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Compositae (continued)		
Dyssodia pentachaeta var. hartwegii	Hartweg dogweed	P
Erigeron bellidiastrum	Western fleabane	A
E. bigelovii Gray	Bigelow fleabane	P
Flourensia cernua	Tarbush	S
Franseria confertiflora	Bursage	A
Gaillardia pinnatifida	Pinwheel	P
G. pulchella	Firewheel	A
Gutierrezia microcephala	Smallhead snakeweed	SS
*G. sarothrae	Snakeweed, broom snakeweed	SS
Haplopappus spinulosus var. australis	Spiny yellow aster	P
H. spinulosus var. glaberrimus		P
H. spinulosus var. scabrellus		P
*Helianthus petiolaris	Prairie sunflower	A
H. petiolaris subsp. fallax	Prairie sunflower	A
*Heterotheca psammophila	Camphorweed	A
Hymenopappus flavescens var. cano-tomentosus	White ragweed	A, B
Hymenoxys scaposa var. glabra	Smooth hymenoxys	P
H. scaposa var. scaposa	Scapose hymenoxys	P
Leucelene ericoides	Baby white aster	P
Machaeranthera tanacetifolia	Cutleaf aster	A
Melampodium cinereum	Blackfoot	P
*M. leucanthum	Blackfoot	P
*Palafoxia sphacelata		A
Parthenium confertum	Desert feverfew	P, B
*Pectis angustifolia	Fetid marigold	A
Perezia nana	Dwarf holly	P
P. wrightii	Wright desert holly	P
Psilostrophe tagetina	Paper daisy	P
P. villosa	Desert paperflower	B
Ratibida tagetes	Marigold coneflower	P
Sartwellia flaveriae	Gypsumweed	A
*Senecio multicapitatus	Groundsel	P
S. douglasii var. longilobus	Longlobed groundsel	SS
Stephanomeria pauciflora	Wire lettuce	P
Thelesperma megapotamicum	Greenthread	P
*Verbesina encelioides	Golden crownbeard	A
Xanthocephalum texanum	Snakeweed	SS
*Zinnia grandiflora	Wild zinnia	P
Convolvulaceae		
Cuscuta leptantha	Dodder	A
Evolvulus nuttallianus		P
E. pilosus		P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Cruciferae		
Descurainia pinnata var. halictorum	Tansy mustard	A
D. pinnata var. ochroleuca	Tansy mustard	A
Dithyrea wislizenii	Spectacle pod	A
Draba brachycarpa	Twistpod	A, WA
Erysimum asperum	Western wallflower	P, A
Greggia camporum var. linearifolium		P
Lepidium montanum	Mountain peppergrass	B, P
*L. virginicum var. medium	Peppergrass	B, A
Lesquerella fendleri	Fendler bladderpod	P
L. gracilis	Smooth bladderpod	A
Streptanthus carinatus	Wright twistflower	A
Cucurbitaceae		
*Cucurbita foetidissima	Buffalogourd	P
*C. texana	Texas gourd	A
Citrullus vulgaris var. citroides	Citron melon	A
Ibervillea tenuisecta	Cutleaf globeberry	P
I. tripartita	Three-lobed globeberry	P
Cyperaceae		
*Cyperus schweinitzii	Flatsedge	P
Euphorbiaceae		
Argythamnia humilus var. laevis	Wild mercury	P
*Croton dioicus	Doveweed	P
C. glandulosa var. lindheimeri	Croton	A
C. pottsii	Leatherweed	P
*C. texensis	Texas croton	A
Ditaxis neomexicana	New Mexico mercury	P
Euphorbia fendleri	Fendler spurge	P
E. glyptosperma	Ridge-seed spurge	A
E. heterophylla	Catalina	A
E. lata	Spurge	P
E. micromera	Spurge	A
*E. missurica	Spreading spurge	A
E. missurica var. intermedia	Spreading spurge	A
E. prostrata	Flat spurge	A
*E. serpens	Serpent spurge	A
E. serpyllifolia	Thymeleaf spurge	A
E. serrula	Serrulate spurge	A
Phyllanthus abnormis	Leaf-flower	A
Reverchonia arenaria	Dune reverchonia, duneweed	A
Tragia stylaris	Noseburn	P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Ephedraceae		
Ephedra torreyana	Joint-fir, Mormon tea	S
Fagaceae		
**Quercus havardii*	Havard oak, shinnery oak	S
Q. havardii X *Q. muhlenbergii* (hybrid)		S
Gentianaceae		
Centaurium calycosum var. *breviflorum*	Small-flowered rosita	P
C. calycosum var. *calycosum*	Rosita	P
Gramineae		
Andropogon barbinodis	Cane bluestem	P
A. scoparius	Little bluestem	P
**Aristida barbata*	Havard three-awn	P
**A. longiseta*	Red three-awn	P
A. pansa	Wooton three-awn	P
A. parishii	Parish three-awn	P
**A. purpurea*	Purple three-awn	P
A. wrightii	Wright three-awn	P
Avena sativa	Common oat	A
Bouteloua barbata	Sixweeks grama	A
B. curtipendula	Side-oats grama	P
B. eriopoda	Black grama	P
**B. hirsuta*	Hairy grama	P
**Brachiaria ciliatissima*	False buffalograss	P
**Bromus catharticus* (*B. unioloides*)	Rescue grass	A
**Cenchrus insertus*	Sandbur	P
Chloris cucullata	Hooded fingergrass	P
Enneapogon desvauxii	Spike pappusgrass	P
Eragrostis arida	Desert lovegrass	A
**E. secundiflora*	Mexican lovegrass	P
E. silveana		P
Hilaria mutica	Tobosa	P
**Leptoloma cognata*	Fall witchgrass	P
Muhlenbergia arenacea	Ear muhly	P
**M. porteri*	Bush muhly	P
M. torreyi	Ring muhly	P
**Munroa squarrosa*	False buffalograss	A
**Panicum capillare*	Common witchgrass	A
P. obtusum	Vine-mesquite	P
**Paspalum setaceum*	Knotgrass	P
P. stramineum	Stramineous knotgrass	P
**Scleropogon brevifolius*	Burrograss	P
Setaria leucopila	Bristlegrass	P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Gramineae (continued)		
*S. macrostachya	Plains bristlegrass	P
Sporobolus contractus	Spike dropseed	P
*S. cryptandrus	Sand dropseed	P
S. flexuosus	Mesa dropseed	P
*S. giganteus	Giant dropseed	P
Stipa neomexicana	New Mexico needlegrass	P
Trichachne californica	Arizona cottontop	P
Tridens muticus	Slim tridens	P
T. pulchellus	Fluffgrass	P
*Triplasis purpurea	Purple sandgrass	A
Hydrophyllaceae		
Nama carnosum	Perennial nama	P, SS
N. hispidum	Hispid nama	A
Phacelia corrugata	Corrugate scorpionweed	A
P. integrifolia	Small-lobed scorpionweed	A, B
P. intermedia	Wooton scorpionweed	A, B?
Koeberliniaceae		
Koeberlinia spinosa	Allthorn	S
Labiatae		
*Monarda punctata var. lasiodonta	Spotted horsemint	A
Scutellaria drummondii	Drummond skullcap	A
Teucrium canadense	Germander	P
Leguminosae		
Acacia constricta	Mescat acacia	S
A. neovernicosa		S
Cassia bauhinioides	Senna	P
Dalea formosa	Featherbush	S
D. lanata	Woolly dalea	P
Hoffmanseggia brachycarpa		SS
H. densiflora	Hog potato	P
H. drepanocarpa	Sicklepod rushpea	P
H. glauca	Smooth rushpea	P
H. jamesii	Hog potato	P
Krameria lanceolata	Lanceleaf ratany	P
K. glandulosa	Sticky ratany	S
Mimosa biuncifera var. glabrescens	Catclaw mimosa	S
*Prosopis glandulosa	Honey mesquite	S
Linaceae		
*Linum aristatum	Plains flax	P
*L. aristatum var. australe	Southern Plains flax	P
L. puberulum	Plains flax	P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Loasaceae		
Cevallia sinuata	Stinging stickleaf	P
Mentzelia humilis	Stickleaf	P
M. pumila	Golden blazingstar	P, B
M. pumila var. multiflora	Golden blazingstar	P, B
M. reverchonii	Reverchon stickleaf	P
M. strictissima	Prairie stickleaf	P
Malvaceae		
Sida physocalyx	Sida	P
Sphaeralcea coccinea	Rosemallow	P
S. digitata	Digitate rosemallow	P
S. subhastata	Coulter rosemallow	P
Martyniaceae		
Proboscidea sabulosa	Dune unicornplant	A
Nyctaginaceae		
*Abronia fragrans	Snowball sandverbena	A
Acleisanthes longiflora	Angel trumpets	P
Ammocodon chenopodioides	Goosefoot moonpod	P
Boerhaavia intermedia	Spiderling	A
Oxybaphus albidus	White four-o-clock	P
O. glaber	Smooth four-o-clock	P
*O. linearis var. decipiens	Narrow-leaved four-o-clock	P
Selinocarpus diffusus	Spreading moonpod	P
Oleaceae		
Menodora scabra var. ramosissima	Rough menodora	SS
Onagraceae		
Calylophus drummondianus	Drummond primrose	P, A
C. hartwegii subsp. pubescens	Hartweg primrose	P, SS
*C. serrulatus		P
Gaura coccinea	Scarlet gaura	P
G. suffulta subsp. nealleyi	Nealley gaura	A
*G. villosa	Hairy gaura	SS
*Oenothera albicaulis	Whitestem evening primrose	A
O. biennis subsp. centralis	Dune primrose	P
O. engelmanii		A
O. neomexicana	New Mexico evening primrose	A
Orobanchaceae		
Orobanche multiflora	Broomrape	A

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Papaveraceae		
Argemone aenea	Prickly poppy	A, B, P
Polemoniaceae		
Ipomopsis longiflora	Blue gilia	A
I. pumila		A
Polygonaceae		
Eriogonum abertianum	Abert buckwheat	A, B
E. annum	Winged buckwheat	A
E. leptocladon		P
E. polycladon	Woolly buckwheat	A
*E. rotundifolium	Roundleaf buckwheat	A
Rumex hymenosepalus	Wild rhubarb	P
Polypodiaceae		
Notholaena sinuata var. chochisensis	Cloakfern	P
Portulacaceae		
*Portulaca parvula	Small purslane	A
P. retusa	Retuse purslane	A
Talinum angustissimum	Fameflower	P
Ranunculaceae		
Delphinium ajacis	Rocket larkspur	A
D. vierescens subsp. wootonii	Plains larkspur	P
Rhamnaceae		
Microrhamnus ericoides	Javelinabush	S
Ziziphus obtusifolia	Lotebush	S
Rubiaceae		
*Hedyotis humifusa	Bluets	A
Rutaceae		
Thamnosma texana	Dutchman's breeches	P
Sapindaceae		
*Sapindus drummondii	Drummond soapberry	T
Scrophulariaceae		
Castilleja sessiliflora	Desert paintbrush	P
Linaria texana	Texas toadflax	A
*Maurandya wislizenii	Vining snapdragon	HV, P
*Penstemon ambiguus	Plains beardtongue	SS
P. buckleyi	Buckley beardtongue	P
P. fendleri	Fendler beardtongue	P

Table H-54. Plants Reported in the Terrestrial Ecology Study Area and at Nearby Sites During 1978 and 1979[a] (continued)

Taxon	Common name	Growth form[b]
Solanaceae		
Chamaesaracha conioides	False nightshade	P
C. villosa	Villous false nightshade	P
Lycium berlandiera	Wolfberry	S
Nicotiana trigonophylla	Wild tobacco	B, P
Physalis lobata	Lobed ground-cherry	A
P. hederaefolia var. cordifolia	Clammy ground-cherry	P
P. hederaefolia var. puberula		P
*Solanum elaeagnifolium	Horsenettle	P
S. rostratum	Spiny nightshade	A
Tamaricaceae		
Tamarix pentandra	Salt cedar	T, S
Ulmaceae		
Celtis reticulata	Netleaf hackberry	T
Umbelliferae		
Eurytaenia texana	Texas spreadwing	A
Verbenaceae		
Aloysia wrightii	Wright lemon verbena	S
Tetraclea coulteri	Coulter tetraclea	P
Verbena bracteata	Prostrate vervain	A
V. ciliata	Ciliate vervain	A
V. plicata	Fanleaf vervain	A
V. wrightii	Desert vervain	A
Violaceae		
Hybanthus verticillatus	Green violet	P
Zygophyllaceae		
Kallstroemia grandiflora	Desert poppy	A
Larrea tridentata	Creosote bush	S
Peganum mexicanum	Garbancillo	P
*Tribulus terrestris	Goathead	A

[a]Taxa arranged alphabetically by family, genus, and specific epithet. Those marked with an asterisk have been found within 2 km of ERDA-9.

[b]Growth form: A = annual; WA = winter annual; B = biennial; P = perennial; SS = suffrutescent; S = shrubby; T = arborescent; HV = herbaceous vine; WV = woody vine.

Sandbur (Cenchrus incertus) is locally abundant in sandy spots. Muhly (Muhlenbergia spp.) occur sporadically on compact soils. Scattered bluestem (Andropogon spp.) occur at many sites. False buffalograss (Munroa squarrosa) is the most common annual grass, being very dense in spring and early summer in some years.

In certain areas the sand is only partially stabilized by vegetation. Stabilized "islands" of shinnery oak and mesquite-anchored soil are separated by stretches of bare sand. The bare sand is highly susceptible to erosion. Thus wind erosion forms depressions, or blowouts, in the bare-sand areas, leaving the stabilized portions as slightly elevated hummocks. The vegetation is not greatly different from that found in shinnery oak-mesquite associations in the fully stabilized dune area. Its configuration in isolated hummocks is what is most distinctive about this subzone. The potential for wind erosion is, of course, greater in years of low rainfall, when ground cover is lowest, than in years of good rainfall.

A relatively small zone of active dunes running east-west is located just southeast of the James Ranch headquarters. Vegetation is sparse, but includes stands of a small tree, western soapberry (Sapindus drummondii), and the annual dune reverchonia (Reverchonia arenaria). Perennials are snowball sandverbena (Abronia fragrans) and species of unicornplant (Proboscidea spp.). All but Reverchonia occur sporadically elsewhere in the central dune area.

Creosote flats. West and southwest of the central dune area, the soils become relatively dense and shallow (often only a few centimeters deep). The caliche may even be exposed in places. The floristic composition changes drastically. Creosote bush (Larrea tridentata) becomes dominant. Snakeweed (G. sarothrae) is the dominant subshrub. Shinnery oak and sand sagebrush are absent. Species of the perennial muhlys (Muhlenbergia spp.) are quite dense here, as are purple three-awn and black grama. Mesquite is present, sporadically occurring in clumps in depressions, but does not have significant cover value.

Livingston Ridge. In this area the soil remains compact and shallow, with occasional outcrops of rock or caliche. Creosote bush gives way to an Acacia-dominated association at the top of the ridge. In addition to mescat acacia (A. constricta), also known as white thorn acacia, Q. havardii, G. sarothrae, and Y. campestris are the shrubby dominants here. A croton (Croton dioicus) and a ratany (Krameria lanceolata) are common perennial herbs. Muhlenbergia porteri is the most abundant perennial grass.

Tobosa flats. The western face of Livingston Ridge drops abruptly about 200 feet to a broad valley floor ("flats") densely populated with tobosa grass (Hilaria mutica). This species is uncommon elsewhere in the study area. Purple three-awn (Aristida purpurea) is the only other grass of significance. Creosote bush and ratany reappear; acacia is absent. Snakeweed is unimportant here. Sparse stands of Yucca torreyi are found.

Studies have concentrated on the central dunes area because it includes all of control zones I and II. In the four sections around ERDA-9, the vegetation has been examined in detail. It is a relatively homogeneous stabilized-dune area supporting a shinnery oak, sand sagebrush, and dune yucca association.

Mesquite is not a prominent shrub, although it is frequently a dominant elsewhere in the dune area. Very dense stands of shinnery oak are common. They exist as low shrubs usually less than 1 meter tall. Thickets form by vegetative reproduction (root sprouts); thus many of the oak stands are genetically single entities (i.e., clones). Acorn formation depends on rainfall. The failure of the spring rains in 1978 inhibited pistillate flower formation and resulted in very few acorns that year. In 1979, a relatively "wet" year, the crop was larger than in 1978. Snakeweed (Gutierrezia sarothrae) is sparse in the ERDA-9 area.

Annuals are especially abundant; bindweed heliotrope (Heliotropium convolvulaceum), desert bluets (Hedyotis humifusa), and fetid marigold (Pectis angustifolia) are most common.

False buffalograss (Munroa squarrosa) in some years is the most abundant grass (up to 310,000 plants per hectare). Other common grasses are black grama (Bouteloua eriopoda) and species of three-awn (Aristida). Species of Sporobolus (dropseed) and Muhlenbergia (muhly), and purple sandgrass (Triplasis purpurea) occur late in the growing season.

All taxa collected and identified in the area around ERDA-9 are listed in Table H-54. Typical views of the site are shown in Figures H-20 through H-23.

H.5.2.3 Wildlife

Typical grassland and shrubland species dominate the fauna of Eddy and Lea Counties; their distribution and abundance are strongly affected by water availability. The limited areas of cropland are of special importance to many species of wildlife because they provide both food and water. Stock ponds on rangelands are water sources for wildlife as well as cattle.

Mammals

About 46 species representing nine mammalian orders are reported to occur within the two-county region. Among these are 15 species of bats, few of which have ever been observed east of the Pecos River. Some species form very large colonies (e.g., the Brazilian free-tailed bat in the Carlsbad Caverns area). The one ground-dwelling insectivore, the desert shrew, is widely distributed but scarce throughout its range.

Lagomorphs (rabbits and hares) include the desert cottontail and black-tailed jack rabbit. Both are common in desert-shrub communities, but they also occur in grassland and farmland.

Desert-dwelling rodent species include kangaroo rats, grasshopper mice, and pocket mice. Two introduced species, the house mouse and the Norway rat, are typically found near human habitations.

Several carnivore species are widespread and relatively common (e.g., coyote, gray fox, badger, striped skunk, bobcat).

Four game and ten furbearer species (Table H-55) are found in the region. Furbearers that are closely associated with water (e.g., beaver and muskrat)

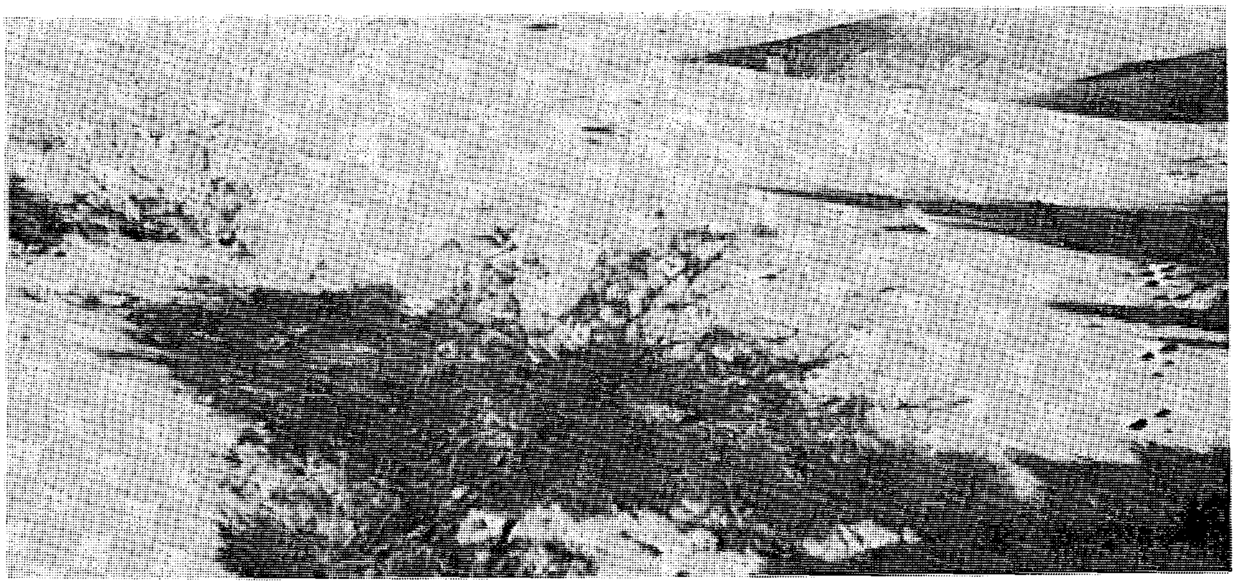


Figure H-20. Sand dunes at the WIPP site.

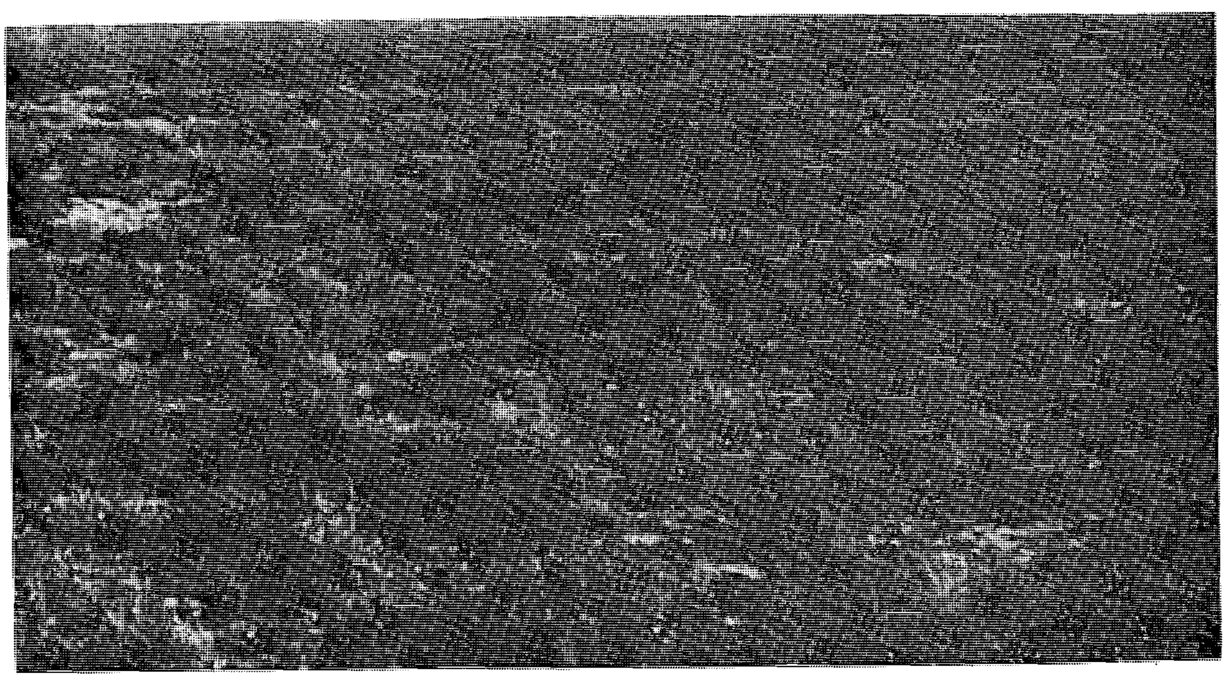


Figure H-21. Typical view of the WIPP site.

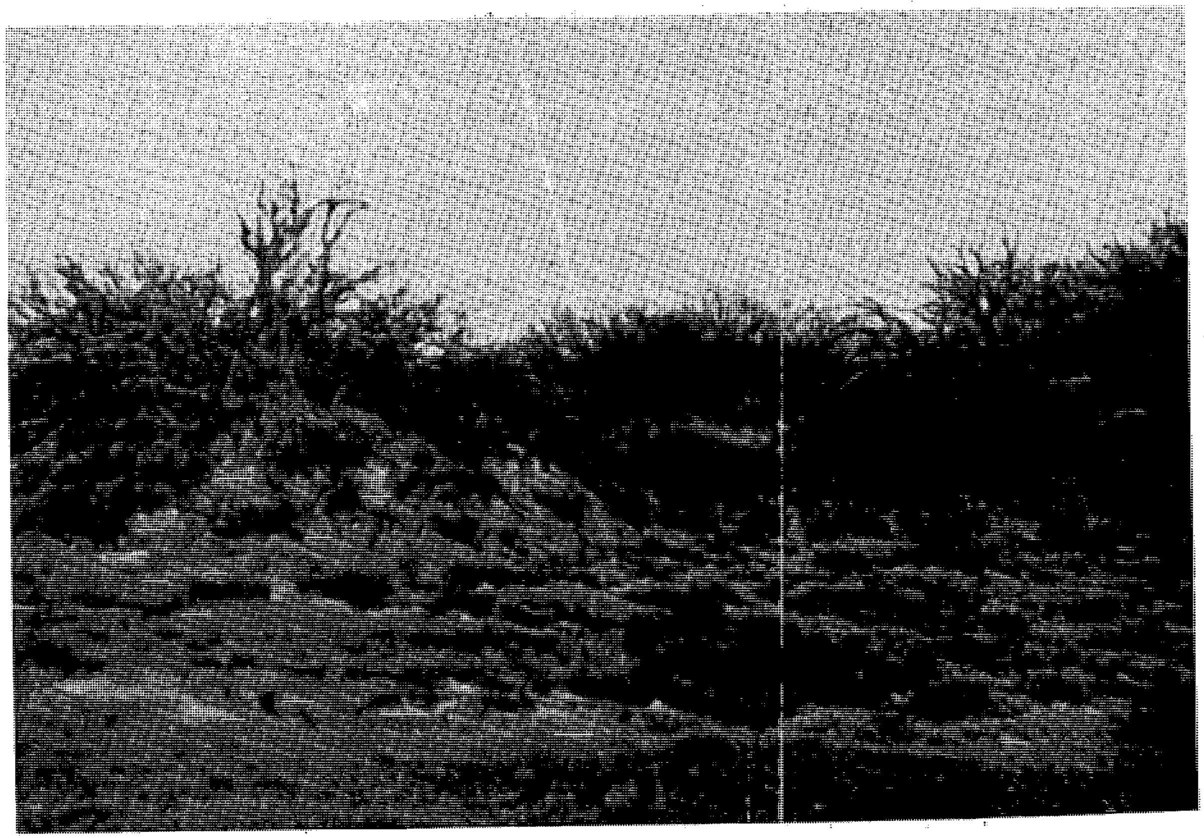


Figure H-22. Blowout area.

Figure H-23. Typical stabilized dunes.

Table H-55. Game Mammals and Furbearers of the Two-County Region

Common name[a]	Scientific name[a]	Status[b]
Beaver	*Castor canadensis*	F
Muskrat	*Ondatra zibethicus*	F
Swift fox	*Vulpes velox*	F
Gray fox	*Urocyon cinereoargenteus*	F
Ringtail	*Bassariscus astutus*	F
Raccoon	*Procyon lotor*	F
Long-tailed weasel	*Mustela frenata*	F
Badger	*Taxidea taxus*	F
Western spotted skunk	*Spilogale gracilis*	F
Striped skunk	*Mephitis mephitis*	F
Mountain lion	*Felis concolor*	G
Mule deer	*Odocoileus hemionus*	G
White-tailed deer	*Odocoileus virginianus*	G
Pronghorn	*Antilocapra americana*	G

[a]Common and scientific names follow Jones et al. (1975).
[b]Game status from 1977 hunting and trapping regulations: F = furbearer; G = game species.

are not common and occur only along the Pecos River, more than 10 miles from the site. Coyote are trapped intensively throughout the region. Mule deer are an important game animal in the region. The pronghorn is basically a plains animal, but it is also found in desert-shrub and desert-grassland habitats in the arid southwest (Wallmo, 1975).

Mammals of the study area

Thirty-nine species of mammals are known to occur within the study area.

Three species of bats have been collected during two summer seasons of bat study. None of these were previously reported east of the Pecos in southeastern New Mexico. The most commonly collected bat at the site, the cave myotis (*Myotis velifer*), almost certainly roosts nearby because heavily pregnant females with limited flight ranges were collected in 1978 and 1979. It is likely that roost sites occur along Livingston Ridge, but none have been located. The Brazilian free-tailed bat (*Tadarida braziliensis*), which inhabits Carlsbad Caverns, was first collected at the site in 1979. All specimens of bats were collected at stock tanks at the site.

Several small mammals are abundant. The desert cottontail and the blacktailed jackrabbit occur in all habitats.

Among the rodents, there are obvious habitat preferences. Ord's kangaraoo rat (*Dipodomys ordii*), for example, is found in all habitats of the central dunes zone and on the mesa, but not on the creosote bush flats, which are inhabited by Merriam's and bannertail kangaroo rats (*D. merriami* and *D. spectabilis*). The Southern Plains woodrat (*Neotoma micropus*) is found in all habitats. The spotted ground squirrel (*Spermophilus spilosoma*), on the other hand, is only found in the oak-mesquite associations of the stabilized-dune area.

The mammals observed at the site and their habitat preferences are listed in Table H-56; those potentially inhabiting the site are listed in Table H-57.

Certain species recorded for Eddy County, such as the rock mouse (Peromyscus difficilis) and the brush mouse (P. boylii), that are only found west of the Pecos are not included in Table H-57 because it is highly unlikely that they inhabit the study area even though suitable habitat may be present.

The desert shrew probably does occur in the study area, but has not been collected. It is very difficult to trap and is always scarce.

The southern grasshopper mouse (Onychomys torridus) cannot be definitely distinguished anatomically from the northern grasshopper mouse (O. leucogaster) without examining the skulls of specimens (Traut, 1963). Their habitat preferences are distinct, however; O. torridus prefers dense soil while O. leucogaster prefers sandy soils (Gennaro, 1968). Thus, it is possible that some specimens identified as O. leucogaster, especially those collected in creosote bush areas, are in fact O. torridus (see Table H-56).

Mule deer and pronghorn have been observed in the study area. Mule deer are common; they frequent the oak-mesquite associations of the stabilized-dune area and the various stock-watering tanks and ponds, but are also sighted in the creosote bush association.

The most common predator is the coyote (Canis latrans), which is frequently observed in all habitats of the study area. The swift fox (Vulpes velox) and the elusive gray fox (Urocyon cinereoargentus) are uncommon.

The house mouse (Mus musculus), an introduced species, has been collected in the central dune area.

Domestic animals are included in the mammal list because they are frequently encountered in the study area. Cattle and horses are pastured, usually separately, throughout the study area and are the most abundant large herbivores.

Birds

A large variety of bird species are recorded for Eddy and Lea Counties.

Among the typical birds of the region is the white-necked raven, a year-round resident in much of the region. Other fairly common breeding species are the mockingbird, the pyrrhuloxia, and the loggerhead shrike. The lark bunting is a common migrant throughout the area, as are several warblers and sparrows. Black-necked stilts breed on the salt flats. Common raptors in the region include the marsh hawk, the American kestrel, Swainson's hawk, and the Harris hawk.

Mourning dove and scaled quail are widespread and heavily hunted; the lesser prairie chicken and the bobwhite are also hunted. Bobwhite are generally restricted to wooded or brushy river valleys. The mourning dove is common in agricultural land and is outnumbered only by scaled quail in total numbers harvested. The game birds of the region are listed in Table H-58.

Table H-56. Mammals Observed in the Terrestrial Ecology Study Area

Common name	Scientific name	Food type[a]	Abundance[b]	Habitat[c]
Bats				
Cave myotis	Myotis velifer	IV	C	A
Pallid bat	Antrozous pallidus	IV	U	A
Brazilian free-tailed bat	Tadarida braziliensis	IV	U	A
Lagomorphs				
Desert cottontail	Sylvilagus audubonii	P	VC	OM, M, CB, D, HM
Black-tailed jackrabbit	Lepus californicus	P	VC	OM, M, CB, D, HM
Rodents				
Mexican ground squirrel	Spermophilus mexicanus	P, S, IV, SV	C	CB, OM
Spotted ground squirrel	S. spilosoma	P, S, IV, SV	VC	OM
Plains pocket gopher	Geomys bursarius	R	VC	OM
Yellow-faced pocket gopher	Pappogeomys castanops	S, P, IV	VC	CB
Silky pocket mouse	Perognathus flavus	S, P, IV	C	OM, CB
Plains pocket mouse	P. flavescens	S, P, IV	C	OM, M
Hispid pocket mouse	P. hispidus	S, P, IV	U	OM, M
Desert pocket mouse	P. penicillatus	S, P, IV	C	D, HM, CB
Ord's kangaroo rat	Dipodomys ordii	P, S	VC	OM, (M), D, HM
Banner-tailed kangaroo rat	D. spectabilis	P, S	VC	M, CB
Merriam's kangaroo rat	D. merriami	P, S	VC	D, HM, M
Western harvest mouse	Reithrodontomys megalotis	P, IV	U	OM, CB
Deer mouse	Peromyscus maniculatus	S, P, IV	U	OM
White-footed mouse	P. leucopus	S, P, IV	C	OM, M, CB, D, HM
Northern grasshopper mouse	Onychomys leucogaster	S, IV, SV	VC	OM, (CB), (M), HM, D
Hispid cotton rat	Sigmodon hispidus	P	U	OM, M, (CB)
Southern Plains woodrat	Neotoma micropus	S, F, P	VC	OM, D, HM, M, (CB)
White-throated woodrat	N. albigula	S, P	C	CB, M
House mouse	Mus musculus	S, P, IV	U	OM
Porcupine	Erethizon dorsatum	P	U	OM, M, CB, HM, D
Carnivores				
Coyote	Canis latrans	V, IV, P	VC	OM, CB, D, HM, M, A
Swift fox	Vulpes velox		U	CB
Gray fox[d]	Urocyon cinereoargenteus		U	?
Badger	Taxidea taxus	SM	U	OM, M
Striped skunk	Mephitis mephitis	C, P	U	OM
Bobcat	Lynx rufus	V	U	OM
Ungulates				
Mule deer	Odocoileus hemionus	P	C	OM, CB, A
Pronghorn	Antilocapra americana	P	U	M
Domestic species[e]				
Dog	Canis familiaris			
Cat	Felis catus			
Goat	Capra sp.			
Cattle	Bos taurus (and B. indicus)			
Horse	Equus caballus			

[a]Food type: P = plant tissue; F = fruit; S = seeds; K = roots and tubers; IV = invertebrates; SV = small vertebrates; V = vertebrates; SM = small mammals; C = carrion.

[b]Abundance: VC = very common; C = common; U = uncommon.

[c]Habitat descriptions are based on vegetation. Edaphic factors are frequently of equal importance in distribution. Key: OM = oak-mesquite associations; CB = creosote bush associations; M = mesa (mesquite grassland); HM = hummock mesquite associations; A = aquatic (stock pond or tank); D = active dunes.

[d]Based on tracks and collection of a single gray-fox skull in 1979.

[e]Goats are penned; all other domestic species may occur in all six habitats.

Table H-57. Mammalian Species Potentially Inhabiting but Not Observed in the Terrestrial Ecology Study Area[a]

Common name	Scientific name
Desert shrew	Notiosorex crawfordi
Townsend's big-eared bat	Plecotus townsendii
Western pipistrelle	Pipistrellus hesperus
Long-eared myotis	Myotis evotis
Fringed myotis[b]	M. thysanodes
California myotis[b]	M. californicus
Yuma myotis[b]	M. yumanensis
Long-legged myotis[b]	M. volans
Small-footed myotis	M. leibii
Silver-haired bat[b]	Lasionycteris noctivagans
Big brown bat[b]	Eptesicus fuscus
Red bat[b]	Lasiurus borealis
Big free-tailed bat[b]	Tadarida macrotis
Pocketed free-tailed bat	T. femorosacca
Plains harvest mouse	Reithrodontomys montanus
Southern grasshopper mouse[c]	Onychomys torridus
Kit fox	Vulpes macrotis
White-tailed deer	Odocoileus virginianus

[a]Common and scientific names follow Jones et al. (1975).
[b]Never reported east of the Pecos River.
[c]See discussion in Section H.5.2.3 under "Mammals of the Study Area."

Migratory birds that might be hunted in the region include several species of waterfowl. The region is not an important breeding area for waterfowl.

The region is in the Central Flyway (a Federal administrative management unit for waterfowl). Mallards, pintails, blue-winged teal, and green-winged teal are the most common dabbling ducks in the region; the first two species constitute one-half to two-thirds of the annual harvest of waterfowl in the Central Flyway (Buller, 1964). The redhead, the canvasback, and the lesser scaup are common diving ducks in the Flyway.

Birds of the study area. One hundred and twenty-two species of birds have been observed in the study area and nearby areas: Laguna Grande de la Sal and the intersection of New Mexico Highway 31 and the Pecos River (Table H-59). Six of these (mallard, blue-winged teal, green-winged teal, bobwhite, scaled quail, and mourning dove) are classified as game species. Only the scaled quail and the mourning dove, however, are present in huntable numbers (J. Herring, New Mexico Game and Fish Department, personal communication, August 2, 1978). The three duck species were rare visitors observed on stock ponds near the site (Wolfe et al., 1977a).

In addition to the scaled quail and the mourning dove, the mockingbird, the loggerhead shrike, the pyrrhuloxia, the black-throated sparrow, the western meadowlark, the lark bunting, the vesper sparrow, Cassin's sparrow, and the white-crowned sparrow are the avian species present in greatest densities

Table H-58. Game Birds in the Two-County Region[a]

Common name	Scientific name[b]	Status[c]
Canada goose	*Branta canadensis*	1
White-fronted goose	*Anser albifrons*	1
Snow goose	*Chen caerulescens*	1
Mallard	*Anas platyrhynchos*	1
Gadwall	*A. strepera*	1
Pintail	*A. acuta*	1
Green-winged teal	*A. crecca*	1
Blue-winged teal	*A. discors*	1
Cinnamon teal	*A. cyanoptera*	1
American wigeon	*A. americana*	1
Northern shoveler	*A. clypeata*	1
Redhead	*Aythya americana*	1
Ring-necked duck	*A. collaris*	1
Canvasback	*A. valisineria*	1
Lesser scaup	*A. affinis*	1
Common goldeneye	*Bucephala clangula*	1
Bufflehead	*B. albeola*	1
Ruddy duck	*Oxyura jamaicensis*	1
Common merganser	*Mergus merganser*	1
Lesser prairie chicken	*Tympanuchus pallidicinctus*	2
Bobwhite	*Colinus virginianus*	2
Scaled quail	*Callipepla squamata*	2
Ring-necked pheasant	*Phasianus colchicus*	2
Sandhill crane	*Grus canadensis*	1
Virginia rail	*Rallus limicola*	1
Sora	*Porzana carolina*	1
American coot	*Fulica americana*	1
Common snipe	*Capella gallinago*	1
Mourning dove	*Zenaida macroura*	1

[a]Ranges from Bellrose (1976) and Johnsgard (1973, 1975).
[b]Nomenclature follows the American Ornithologists' Union (1957, 1973, 1976).
[c]Key: 1 = migratory species, hunting regulations controlled by the Federal Government; 2 = permanent resident.

in the study area (Table H-60). The Harris hawk, the white-necked raven, Swainson's hawk, the marsh hawk, and the American kestrel are never more numerous than one per 100 hectares, but are sighted consistently. Many other species are present in low densities and in only one or a few months. Many of these are migrants, such as the blue-winged teal, the yellow-rumped warbler, Wilson's warbler, and the clay-colored sparrow.

Rocky escarpments along Livingston Ridge (4 to 5 miles northwest of the site) provide suitable nesting habitat for several raptor species. The marsh hawk, a ground-nesting species, may nest in undisturbed areas near the site.

Table H-59. Birds Observed in the Terrestrial Ecology Study Area and at Nearby Aquatic Sites[a]

Common name[b]	Scientific name	Food type[c]	Abundance[d]	Season[e]
Grebes	Podicipedidae			
*Pied-billed grebe	Podilymbus podiceps	C_2, C_3	I	M
Herons and egrets	Ardeidae			
Great blue heron	Ardea herodias	C_3, C_2	UC	S
*Green heron	Butorides virescens	C_3, C_2	UC	S
Little blue heron	Florida caerulea	C_3, C_2	UC	S
Cattle egret	Bubulcus ibis	C_3, C_2	UC	S
Snowy egret	Egretta thula	C_3, C_2	UC	S
Black-crowned night heron	Nycticorax nycticorax	C_3, C_2	UC	S
Ducks	Anatidae			
Mallard	Anas platyrhynchos	C_1, C_2, C_3	UC	M
*Northern shoveler	A. clypeata	C_1, C_2, C_3	UC	M
Green-winged teal	A. crecca	C_1, C_2, C_3	UC	M
Blue-winged teal	A. discors	C_1, C_2, C_3	UC	M
Vultures	Cathartidae			
Turkey vulture	Cathartes aura	C_3, C_2	C	S
Hawks and eagles	Accipitridae			
*Sharp-shinned hawk	Accipiter striatus	C_2, C_3	UC	M
Red-tailed hawk	Buteo jamaicensis	C_2, C_3	C	Y
Swainson's hawk	B. swainsoni	C_2, C_3	UC	S
Ferruginous hawk	B. regalis	C_2, C_3	UC	W
Harris' hawk	Parabuteo unicinctus	C_2, C_3	UC	Y
Golden eagle	Aquila chrysaetos	C_2, C_3	UC	Y
Marsh hawk	Circus cyaneus	C_2, C_3	C	W
Falcons	Falconidae			
Peregrine falcon	Falco peregrinus	C_3, C_2	I	M
Prairie falcon	F. mexicanus	C_3, C_2	UC	W
American kestrel	F. sparverius	C_2, C_3	C	M
Grouse	Tetraonidae			
Lesser prairie chicken	Tympanuchus pallidicinctus	C_1	UC	Y
Quail	Phasianidae			
Bobwhite	Colinus virginianus	C_1	UC	Y
Scaled quail	Callipepla squamata	C_1	VC	Y
Cranes	Gruidae			
Sandhill crane	Grus canadensis	C_1, C_2	UC	M
Rails, coots, gallinules	Rallidae			
*American coot	Fulica americana		I	M
Plovers	Charadriidae			
Snowy plover	Charadrius alexandrinus	C_2, C_3	C	S
Killdeer	C. vociferus	C_2, C_3	C	M
*Mountain plover	Eupoda montana	C_2, C_3	UC	M
Sandpipers	Scolopacidae			
Common snipe	Capella gallinago	C_2, C_3	UC	M
*Long-billed curlew	Numenius americanus	C_2, C_3	UC	M
Spotted sandpiper	Actitis macularia	C_2, C_3	UC	M
Solitary sandpiper	Tringa solitaria	C_2, C_3	UC	M
*Greater yellowlegs	T. melanoleucus	C_2, C_3	UC	M
*Least sandpiper	Calidris minutilla	C_2, C_3	UC	M
*Stilt sandpiper[f]	Micropalama himantopus	C_2, C_3	I	M
*Western sandpiper	Calidris mauri	C_2, C_3	UC	M

Table H-59. Birds Observed in the Terrestrial Ecology Study Area and at Nearby Aquatic Sites[a] (continued)

Common name[b]	Scientific name	Food type[c]	Abundance[d]	Season[e]
Avocets, stilts	Recurvirostridae			
American avocet	Recurvirostra americana	C_2, C_3	C	S
Black-necked stilt	Himantopus mexicanus	C_2, C_3	C	S
Phalaropes	Phalaropodidae			
Wilson's phalarope	Steganopus tricolor	C_2, C_3	C	M
*Northern phalarope	Lobipes lobatus	C_2, C_3	UC	M
Gulls and terns	Laridae			
Least tern	Sterna albifrons	C_1, C_2, C_3	I	M
Pigeons and doves	Columbidae			
Mourning dove	Zenaida macroura	C_1	VC	Y
Cuckoos	Cuculidae			
Yellow-billed cuckoo	Coccyzus americanus	C_2, C_3	UC	M
Roadrunner	Geococcyx californianus	C_2, C_3	C	Y
Barn owl	Tytonidae			
Barn owl	Tyto alba	C_3, C_2	UC	Y
Owls	Strigiformes			
Great-horned owl	Bubo virginianus	C_3, C_2	C	Y
Burrowing owl	Athene cunicularia	C_3, C_2	C	Y
*Short-eared owl	Asio flammeus	C_3, C_2	I	M
Nightjars	Caprimulgidae			
Poor-will	Phalaenoptilus nuttallii	C_2, C_3	UC	S
Common nighthawk	Chordeiles minor	C_2, C_3	VC	S
Kingfishers	Alcedinidae			
Belted kingfisher	Megaceryle alcyon	C_2, C_3	UC	M
Woodpeckers	Picidae			
Common flicker	Colaptes auratus	C_2, C_3	C	M
Ladder-backed woodpecker	Picoides scalaris	C_2, C_3	C	
Flycatchers	Tyrannidae			
Western kingbird	Tyrannus verticalis	C_2, C_3	C	S
*Cassin's kingbird	T. vociferans	C_2, C_3	I	M
Scissor-tailed flycatcher	Muscivora forficata	C_2, C_3	C	S
Ash-throated flycatcher	Myiarchus cinerascens	C_2, C_3	C	S
Say's phoebe	Sayornis saya	C_2, C_3	C	M, W
*Traill flycatcher	Empidonax traillii	C_2, C_3	UC	M
*Least flycatcher	E. minimus	C_2, C_3	UC	M
	E. sp.[g]	C_2, C_3	UC	M
Western wood pewee	Contopus sordidulus	C_2, C_3	C	S, M
*Olive-sided flycatcher	Nuttallornis borealis	C_2, C_3	UC	M
Larks	Alaudidae			
Horned lark	Eremophila alpestris	C_1, C_2, C_3	UC	M, W
Swallows, martins	Hirundinidae			
*Violet-green swallow	Tachycineta thalassina	C_2, C_3	UC	M
Barn swallow	Hirundo rustica	C_2, C_3	UC	S
Cliff swallow	Petrochelidon pyrrhonota	C_2, C_3	UC	S
Crows, ravens, and jays	Corvidae			
White-necked raven	Corvus cryptoleucus	C_1, C_2, C_3	VC	S
Chickadees, titmice	Paridae			
*Mountain chickadee	Parus gambeli	C_2, C_3	I	M

Table H-59. Birds Observed in the Terrestrial Ecology Study Area and at Nearby Aquatic Sites[a] (continued)

Common name[b]	Scientific name	Food type[c]	Abundance[d]	Season[e]
Wrens	Troglodytidae			
House wren	Troglodytes aedon	C_2, C_3	UC	M
Bewick's wren	Thryomanes bewickii	C_2, C_3	UC	M
Carolina wren[f]	T. ludovicianus	C_2, C_3	I	M
Cactus wren	Campylorhynchus brunneicapillus	C_2, C_3	VC	S
Rock wren	Salpinctes obsoletus	C_2, C_3		
Mockingbirds, thrashers	Mimidae			
Mockingbird	Mimus polyglottos	C_2, C_3	C	S
Brown thrasher	Toxostoma rufum	C_2, C_3	I	M
*Bendire's thrasher[f]	T. bendirei	C_2, C_3	I	M
Curve-billed thrasher	T. curvirostre	C_2, C_3	C	Y
Crissal thrasher	T. dorsale	C_2, C_3	C	Y
Sage thrasher	Oreoscoptes montanus	C_2, C_3	C	W
Thrushes, bluebirds	Turdidae			
*Mountain bluebird	Sialia currocoides	C_1, C_2, C_3	UC	M
Shrikes	Laniidae			
Loggerhead shrike	Lanius ludovicianus	C_2, C_3	VC	Y
Starlings	Sturnidae			
Starling	Sturnus vulgaris	C_2, C_3	UC	Y
Warblers	Parulidae			
*Orange-crowned warbler	Vermivora celata	C_2, C_3	UC	M
Yellow-rumped warbler	Dendroica coronata	C_2, C_3	UC	M
*MacGilliuray's warbler	Oporornis tolmiei	C_2, C_3	UC	M
Yellow-breasted chat	Icteria virens	C_2, C_3	UC	M
Wilson's warbler	Wilsonia pusilla	C_2, C_3	UC	M
Weaver finches	Ploceidae			
House sparrow	Passer domesticus	C_2, C_3	C	Y
Blackbirds, orioles	Icteridae			
Eastern meadowlark	Sturnella magna	C_2, C_3	C	S, (Y?)
Western meadowlark	S. neglecta	C_2, C_3	VC	Y
Yellow-headed blackbird	Xanthocephalus xanthocephalus	C_2, C_3	C	M
Red-winged blackbird	Agelaius phoeniceus	C_2, C_3	C	M
*Scott's oriole	Icterus parisorum	C_2, C_3	C	S
Northern oriole	I. galbula	C_2, C_3	C	S
Brewer's blackbird	Euphagus cyanocephalus	C_2, C_3	C	M
Brown-headed cowbird	Molothrus ater	C_2, C_3	C	S
Tanagers	Thraupidae			
*Western tanager	Piranga ludoviciana	C_2, C_3	I	M
Grosbeaks, finches, sparrows, buntings	Fringillidae			
Pyrrhuloxia	Cardinalis sinuata	C_1, C_2	VC	Y
Blue grosbeak	Guiraca caerulea	C_1, C_2	C	S
*Lazuli bunting	Passerina amoena	C_1, C_2	I	M
House finch	Carpodacus mexicanus	C_1, C_2	C	Y
Pine siskin	Carduelis pinus	C_1, C_2	UC	M
American goldfinch	C. tristis	C_2, C_2	UC	M
*Lesser goldfinch	C. psaltria	C_1, C_2	I	M
Green-tailed towhee	Pipilo chlorurus	C_1, C_2	UC	M
Rufous-sided towhee	P. erythrophthalmus	C_1, C_2	UC	M
*Brown towhee	P. fuscus	C_1, C_2	I	M

Table H-59. Birds Observed in the Terrestrial Ecology Study Area and at Nearby Aquatic Sites[a] (continued)

Common name[b]	Scientific name	Food type[c]	Abundance[d]	Season[e]
Grosbeaks, finches, sparrows, buntings (continued)	Fringillidae (continued)			
Lark bunting	Calamospiza melanocorys	C_1, C_2	VC	M
Savannah sparrow	Passerculus sandwichensis	C_1, C_2	I	M
Vesper sparrow	Pooecetes gramineus	C_1, C_2	C	W
Baird's sparrow[f]	Ammodramus bairdii	C_1, C_2	I	M
Lark sparrow	Chondestes grammacus	C_1, C_2	C	M
Cassin's sparrow	Aimophila cassinii	C_1, C_2	VC	S
Black-throated sparrow	Amphispiza bilineata	C_1, C_2	VC	Y
Sage sparrow	A. belli	C_1, C_2	C	W
Dark-eyed junco	Junco hyemalis	C_1, C_2	C	W
*Chipping sparrow	Spizella passerina	C_1, C_2	UC	M
Clay-colored sparrow	S. pallida	C_1, C_2	I	M
Brewer's sparrow	S. breweri	C_1, C_2	C	M, W
White-crowned sparrow	Zonotrichia leucophrys	C_1, C_2	VC	W
*Song sparrow	Melospiza melodia	C_1, C_2	UC	M

[a]Includes stock tanks in area, nearby salt lakes, and Pecos River.

[b]An asterisk indicates species added to the list during October 1978 through September 1979.

[c]Trophic levels (C_1 = primary consumer; C_2 = secondary consumer; C_3 = tertiary consumer) listed in order of relative importance.

[d]Abundance: VC = very common; C = common; UC = uncommon; I = incidental (seen only once or twice).

[e]Season: S = summer only; W = winter only; M = migrant; Y = year-round resident.

[f]Record questionable, reported without details.

[g]Empidonax difficilis removed from checklist because substantiating evidence is lacking and because field identification is extremely difficult. All observations were recorded as Empidonax sp. until a specimen was collected.

Reptiles and amphibians

Amphibians are not an important part of the fauna at the WIPP site because suitable habitat is limited. However, several amphibian species are adapted to arid-land habitats. Others occur along the Pecos River and in irrigated cropland. Characteristic reptiles in the region include the western box turtle, the side-blotched lizard, the western whiptail, the bullsnake, and the western rattlesnake.

Twenty-nine species (6 amphibians and 23 reptiles) are observed in the site vicinity (Table H-61). Suitable habitat for amphibians and aquatic reptiles is limited to stock tanks. Sand dunes, rocky outcrops, and the various shrub associations provide a variety of habitats. Species potentially inhabiting the site vicinity are listed in Table H-62.

The amphibian species (e.g., tiger salamander, green toad, and plain's spadefoot) are adapted for survival in relatively arid situations. All require water for breeding and for the aquatic stages of development, but adults can survive periods of drought.

One aquatic and one terrestrial species of turtle are observed. The yellow mud turtle is commonly found in stock tanks and ponds. The western box turtle inhabits much of the study area but avoids habitats dominated by creosote bush.

Table H-60. Estimated Densities of Bird Species at, or in the Vicinity of, the WIPP Site

Species	Density (number per 100 hectares)															
	1975				1976						1977					
	S	O	N	D	J	F	M	J	J	A	M	A	M	J	J	A
Ducks																
Mallard	<1															
Green-winged teal		<1														
Blue-winged teal		<1														
Hawks and allies																
Turkey vulture	<1	<1						<1	<1	<1			<1	<1		
Red-tailed hawk					<1	<1		<1								
Swainson's hawk	<1	<1						<1	<1	<1	<1	<1	<1	<1		<1
Ferruginous hawk					<1	<1								<1		
Harris' hawk		<1							<1	<1	<1	<1	<1	<1	<1	<1
Marsh hawk	<1	<1	<1	<1	<1	<1	<1				<1	<1	<1			
American kestrel	<1	<1	<1	<1	<1	<1	<1		<1							<1
Quails																
Bobwhite									<1	<1						
Scaled quail	4	3	7	4	3	3	6	3	1	7	3	2	2	2	3	7
Cranes																
Sandhill crane		<1														
Doves																
Mourning dove	19	7	5	4	1			<1	1	2	<1	<1	<1	<1	2	2
Cuckoos																
Yellow-billed cuckoo	<1															
Roadrunner	<1	<1			<1	<1		<1	<1	<1		<1	<1	<1	<1	<1
Owls																
Great horned owl										<1						<1
Burrowing owl								<1	<1	<1						
Nighthawks																
Common nighthawk								4	2	2			1	2		<1
Woodpeckers																
Ladder-backed woodpecker						<1	<1		<1	<1				<1	<1	
Red-shafted flicker											<1					
Perching birds																
Western kingbird	<1							1		<1		<1	<1		1	
Scissor-tailed flycatcher	<1								<1				<1			
Ash-throated flycatcher								<1				<1		<1	<1	
Say's phoebe	<1	<1										<1				<1
Western empidonax fly-catcher	<1	1														
Western wood pewee	<1												<1			
Cliff swallow	<1															

Table H-60. Estimated Densities of Bird Species at, or in the Vicinity of, the WIPP Site (continued)

Species	Density (number per 100 hectares)															
	1975				1976						1977					
	S	O	N	D	J	F	M	J	J	A	M	A	M	J	J	A
Blue jay		<1														
White-necked raven	1	<1				<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
House wren		<1				<1										
Carolina wren		<1			1											
Cactus wren				1		1	1	1	2	2	<1			<1	<1	<1
Rock wren										<1						
Mockingbird	1	<1						4	1	<1	<1	<1	4	2	<1	<1
Brown thrasher		<1										<1	<1			
Curve-billed thrasher		<1												<1		
Crissal thrasher		<1						<1	<1	<1			<1	<1	<1	<1
Sage thrasher		<1														
Loggerhead shrike	4	3	3	2	4	3	4	3	3	4	5	4	4	5	6	3
Yellow-rumped warbler	<1	<1														
Wilson's warbler	2															
Western meadowlark[a]	<1	2	13	6	12	12	6	<1		<1	5		<1			
Bullock's oriole	<1								<1				<1			
Brewer's blackbird								<1								
Brown-headed cowbird	<1								2				<1	<1		<1
Pyrrhuloxia	1	4	7	10	4	4	6	10	9	5	4	8	4	10	10	6
House-finch				1												
Lark bunting	10	9	7	21	9	12	25	1	1	10			<1			<1
Pine siskin				1	31	2	19									
American goldfinch				3		2										
Green-tailed towhee		1	2													
Rufous-sided towhee		1	1													
Baird's sparrow		<1														
Vesper sparrow	1	8	9	6	3	1	10									
Lark sparrow	1											<1	<1	<1		
Cassin's sparrow	11							<1								
Black-throated sparrow	1	1	1		4	1	3	2	3	1	4	2	3	2	<1	<1
Sage sparrow					<1	4										
Chipping sparrow																<1
Dark-eyed (Oregon) junco				1		1										
Clay-colored sparrow	<1	<1														
Brewer's sparrow		<1														
White-crowned sparrow		9	9	18	16	12	8					<1				

[a]May include eastern meadowlarks; species are difficult to distinguish.

Table H-61. Amphibians and Reptiles Observed in the Terrestrial Ecology Study Area

Common name	Scientific name	Food type[a]	Abundance[b]	Habitat[c]
Amphibians				
Tiger salamander	Ambystoma tigrinum	I	C	A, M
Couch's spadefoot	Scaphiophus couchi	I	UC	A, CB
Plain's spadefoot	S. bombifrons	I	C	A, OM
Texas toad	Bufo speciosus	I	UC	A
Great Plains toad	B. cognatus	I	UC	A, OM
Green toad	B. debilis	I	C	A
Reptiles				
Yellow mud turtle	Kinosternon flavescens	P, I, SV	VC	A, M, OM
Western box turtle	Terrapene ornata	P, F, I	VC	OM, M, D, HM
Collared lizard	Crotaphytus collaris	I	UC	M
Leopard lizard	C. wislizenii	I, SV	UC	D, HM, OM
Lesser earless lizard	Holbrookia maculata	I	UC	OM
Greater earless lizard	H. texana	I	UC	CB
Side-blotched lizard	Uta stansburiana	I	VC	OM, (CB), (M), D, HM
Texas horned lizard	Phrynosoma cornutum	I	C	OM, M
Round-tailed horned lizard	P. modestum	I	UC	M
Western whiptail	Cnemidophorus tigris	I	VC	OM, CB, D, HM, M
Texas spotted whiptail	C. gularis	I	VC	CB
Six-lined racerunner	C. sexlineatus	I	UC	OM
Great Plains skink	Eumeces obsoletus	I	UC	OM, CB
Texas blind snake	Leptotyphlops dulcis	SV	UC	OM
Western hognose snake	Heterodon nasicus	I, SV	C	OM
Coachwhip	Masticophis flagellum	I, SV	C	OM, CB
Glossy snake	Arizona elegans	SV	C	OM
Bullsnake	Pituophis melanoleucus	SV	C	OM, CB
Long-nosed snake	Rhinocheilus lecontei	SV	UC	OM, CB
Night snake	Hypsiglena torquata	SV	UC	OM
Massasauga	Sistrurus catenatus	SV	UC	OM
Western diamondback rattlesnake	Crotalus atrox	SV	UC	OM, CB, M
Western rattlesnake	C. viridis	SV	VC	OM, CB, HM, D

[a]Key: P = plant tissue; F = fruit; I = invertebrates; SV = small vertebrates.
[b]Abundance: VC = very common; C = common; UC = uncommon.
[c]Habitat: OM = oak-mesquite associations; CB = creosote bush associations; M = mesa (mesquite grassland); D = dunes; HM = hummock mesquite associations; A = aquatic (stock pond or tank).

Lizards (11 species) are the most abundant and conspicuous reptiles, with the side-blotched lizard and the western whiptail common in most habitats. The Texas horned lizard is common in oak-mesquite associations and on the mesa. All species are diurnal and primarily insectivorous.

Several species of snakes are common in the area, including the western hognose snake, the coachwhip, and the western rattlesnake. Less common are the night snake, the long-nosed snake, and the massasauga. All species are carnivorous.

Terrestrial invertebrates

Important crop pests are the alfalfa caterpillar, cutworms, and aphids, which damage alfalfa; and the cotton boll worm and stinkbugs, which attack cotton. Grasshoppers are the principal range pest, destroying both domestic and wildlife forage. The fleas that transmit plague are the only important disease vectors.

Table H-62. Amphibians and Reptiles Potentially Inhabiting but Not Observed at, or in the Vicinity of, the WIPP Site

Common name	Scientific name
Amphibians	
Western spadefoot	Scaphiopus hammondi
Woodhouse's toad	Bufo woodhousei
Red-spotted toad	B. punctatus
Barking frog	Eleutherodactylus augisti
Cricket frog	Acris gryllus
Leopard frog	Rana pipiens
Bullfrog	R. catesbeiana
Reptiles	
Snapping turtles	Chelydra serpentina
Pond slider	Pseudemys scripta
Spiny soft-shelled turtle	Trionyx spiniferus
Eastern fence lizard	Sceloporus undulatus
Sagebrush lizard[a]	S. gracioisus
Checkered whiptail	Cnemidophorus tesselatus
Little striped whiptail	C. inornatus
Plain-bellied water snake	Natrix erythrogaster
Western hognose snake	Heterodon nasicus
Corn snake	Elaphe guttata
Common kingsnake	Lampropeltis getulus
Checkered garter snake	Thamnophis marcianus
Common garter snake	T. sirtalis
Ground snake	Sonora episcopa
Western hooked-nosed snake	Ficimia cana
Great Plains black-headed snake	Tantilla nigriceps

Sand crickets, ground beetles, darkling beetles, ants, and termites are the most abundant ground-dwelling insects found. Most of the arthropods collected are scavengers, plant feeders, and granivores. Predatory forms include scorpions, whiptails, spiders, praying mantids, and ants. Termites, ants, and grasshoppers are common in all plant communities. Termites are by far the most significant detritivores in the study area. They form large subterranean colonies in the stabilized dunes, on the mesa, and on the creosote bush flats. Their biomass is at least as large as that of the cattle grazing the surface.

Domestic livestock and range management

Domestic livestock. Ranching is the main agricultural enterprise in the region, and beef cattle are the principal livestock. Most of the cattle are kept on the range throughout the year and are given supplementary feed in winter. In summer, sudangrass, bermuda grass, and stubble are used for temporary grazing while native grasses rest during part of the growing season and produce seed for regrowth (SCS, 1971, 1974).

In 1969, there were about 123,000 beef cattle in Eddy and Lea Counties (BLM, 1973). Other livestock raised in the region are hogs (approximately 12,400 in 1969), sheep (approximately 42,300 in 1969), and a few thousand dairy cows (BLM, 1973). Horses are less common and are used mainly for ranching and recreation. Domestic-poultry farming is quite limited.

Range management. The WIPP site lies entirely within the Deep Sand and Sand Hills range sites (Table H-63). The site vicinity also includes Sandy, Rocky Land, Loamy, Salty Bottomland, and Bottomland range sites (SCS, 1971).

There are three BLM grazing allotments in the study area: 7032, 7027, and 7033 (BLM, 1978). The site itself is all on allotment 7032, which BLM classifies as in fair condition for livestock grazing. The recent licensed use of this allotment (BLM, State, and private land) has been, on the average, a little over six head per section. The carrying capacity of the allotments in the site region (an animal unit is defined as the amount of feed required to sustain one adult for a year) varies greatly from one section to the next and from one year to the next, depending on rainfall. In addition, allotment 7032 has an allotment-management plan that BLM revised in 1973. According to the plan, the actual qualifications for allotment 7032 are for 13,239 animal-unit months (a little over nine head per section). The plan specifies grazing deferments of various pastures for different lengths of time. Preliminary revised BLM data for allotment 7032 indicate a suggested stocking rate varying from 7 to 21 acres per animal-unit month, based on a 40% to 60% range utilization. This stocking rate is roughly equivalent to 7.6 to 2.5 head per section, assuming yearlong grazing.

Mesquite-control programs have been implemented in allotments 7033 and 7027, and, according to BLM (1977), have been fairly successful. After the spraying of mesquite, native grasses have increased, thus supporting the historical record that much of the area was once productive grassland.

Plants potentially poisonous to livestock occur throughout the area, but cause little trouble except in extreme weather conditions (BLM, 1977). Shinnery oak, which is poisonous to cattle during about 6 weeks in the spring, and snakeweed are common.

H.5.3 Aquatic Ecology

H.5.3.1 Two-county region

Aquatic habitats

The two-county region is in the basin of the Pecos River, which originates in the Sangre de Cristo Mountains in northern New Mexico. The Pecos River flows to the south through New Mexico and into the Red Bluff Reservoir, continues in a southeasterly direction across western Texas, eventually joining the Rio Grande. It has an overall length of about 500 miles and drains about 25,000 square miles in New Mexico and 17,000 square miles in Texas. The hydrologic characteristics of the region are discussed in Section 7.4.

Table H-63. Range Condition of the Land at the WIPP Site[a]

Soil mapping unit	Range site	Annual production (lb)[b]	Potential vegetation: Key decreases	Potential vegetation: Key increases	Potential vegetation: Key invaders
Berino complex, 0-3% slopes, eroded	Deep sand	400-2400	Little bluestem Sand bluestem Black grama Bush muhly Side-oats grama Plains bristle grass	Blue grama Hairy grama Sand dropseed Three-awn Mesquite Shinnery oak	Broom snakewood Annuals
Kermit-Berino sand, 0-3% slopes					
Kermit fine sand	Sand hill	800-3000	Bush muhly Little bluestem Black grama Sand bluestem Plains bristle grass Indian rice grass Switchgrass	Blue grama Red lovegrass Halls panicum Sand dropseed Tall dropseed Sand muhly Mesquite Little soaptree Yucca Shinnery oak Sand sagebrush Catclaw mimosa	Broom snakewood Ring muhly Annuals
Berino fine sand	Deep sand	400-2400	See Berino complex above	See Berino complex above	See Berino complex above

[a]Based on data from the Soil Conservation Service (SCS, 1971).

[b]Low numbers indicate average annual production of air-dry grazable forage on sites in poor condition; high numbers indicate production on sites in excellent condition.

The area is semiarid. Away from the river aquatic habitats are limited to intermittent streams and livestock-watering ponds. Poor water quality is characteristic of much of the Pecos River basin in the lower sections. Both surface water and groundwater contain salt from natural sources (salt springs, brine seeps, or gypsum overburden) and from human activities (e.g., irrigation return flow, potash mining). An important natural source of salt is the concentrated brine springs at Malaga Bend, which increase the salt content of the Pecos River by an estimated 340 tons per day. These sources progressively concentrate salts downstream.

Seasonally wet, shallow lakes (playas) and permanent salty lakes occur in the area. An example of the latter is the Laguna Grande de la Sal about 11 miles west-southwest of the WIPP site.

Aquatic biota

Because of high salinity due to natural brines and irrigation return flows, the lower Pecos River basin supports a depauperate flora and fauna. According to J. E. Sublette (personal communication, 1978), the aquatic fauna of the Pecos River and the Red Bluff Reservoir are probably the least known in New Mexico in both species and population density. Thirteen sampling stations have been established to study the faunal composition of aquatic habitats in the study area and nearby (Figure H-24).

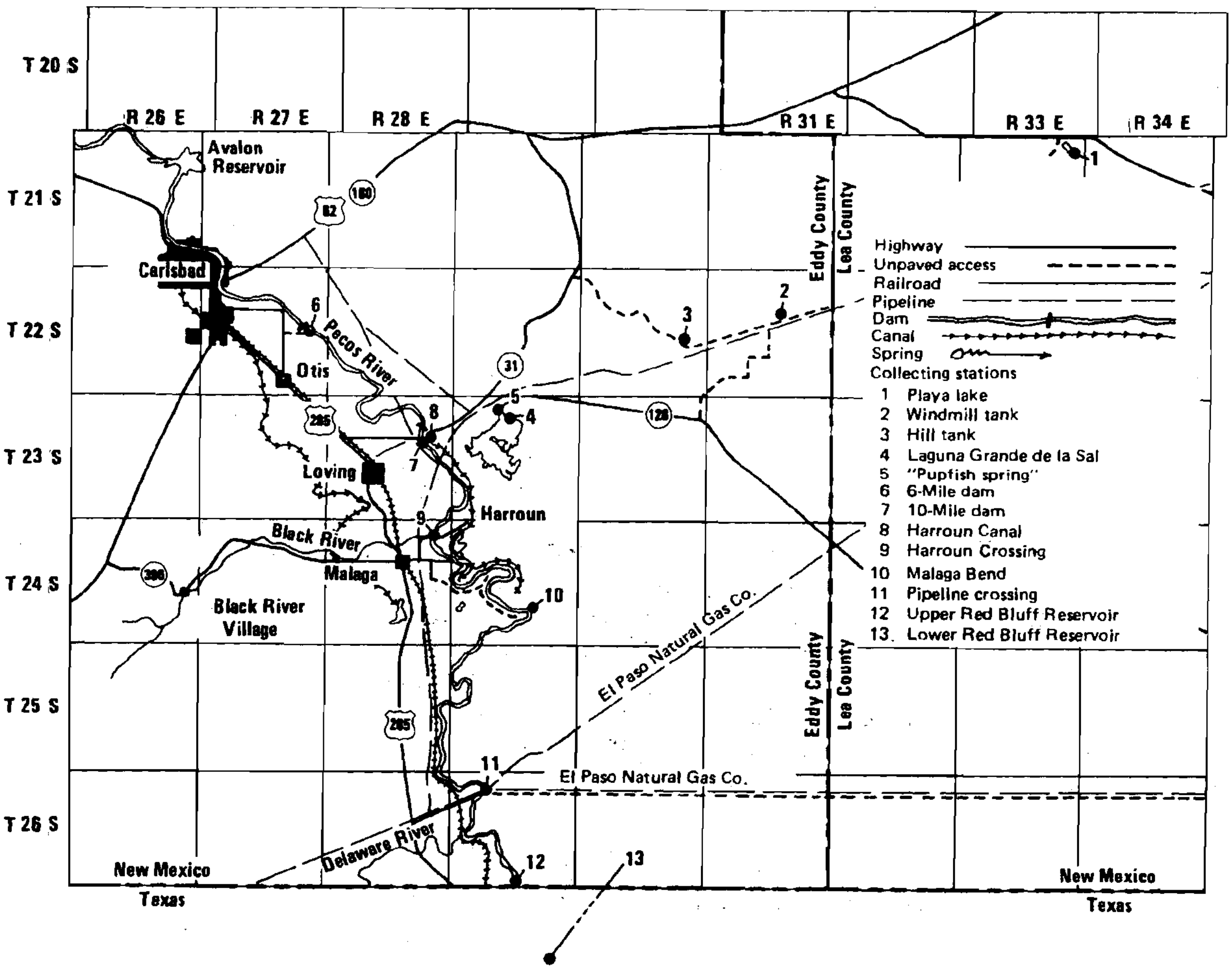


Figure H-24. Map of aquatic collecting stations.

Fish

Fish have been studied in more detail than other aquatic organisms in the region.

At present, there is no active commercial fishery in the site region (R. R. Patterson, New Mexico Game and Fish Department, personal communication, January 20, 1978), although several suitable species (carp, carpsucker, small-mouth buffalo) occur throughout the Pecos River basin.

A limited recreational fishery--based on such warm-water species as channel catfish, white bass, bluegill, green sunfish, and large-mouth bass--is located in the lower Pecos River basin. Because of the poor water quality of the lower Pecos mainstem, most of the recreational fishing activity is concentrated in impoundments on the upper reaches of the Pecos and its tributaries (R. R. Patterson, personal communication, January 20, 1978), although the Red Bluff Reservoir offers a modest sport fishery.

Both warm- and cold-water sport fish are stocked in Chaves, Eddy, and Lea Counties. In the 1973-1974 fiscal year, a total of 1,242,086 fish (trout, channel catfish, and walleye) were stocked (USDA, 1975).

Macroinvertebrates

Studies of the macroinvertebrate communities in the site region began in the spring of 1978. Chironomidae (nonbiting midges) were very abundant in many of the habitats investigated. At Harroun Crossing, the caddisfly family, Hydropsychidae, was also very abundant.

The invertebrate fauna of windmill-pumped water and playa lakes of eastern New Mexico and western Texas has been studied by Sublette and Sublette (1978). Most of the species that successfully invade the windmill-pumped waters are strong fliers and are able to travel considerable distances. The playa lakes contain many temporary pond forms, including the fairy, tadpole, and clam shrimps.

Microorganisms and plankters

Investigations of the microbial biochemistry of the site region include studies of surface waters, subterranean aquifers, and surface soils (Caldwell, 1978).

Diatoms are the principal planktonic producers in the fresh surface waters of the site region. The flora of Laguna Grande de la Sal consists of Halobacterium spp. and Dunaliella spp. A layer of cyanobacteria and photosynthetic sulfur bacteria is found below the salt crust surrounding the salt lake (Caldwell, 1978). Periphyton (epiphyton, epipelon, and filamentous algae) probably account for most of the production in the Pecos River. No blue-green algae were dominant in the Pecos River at certain sites and seasons (Sublette and Sublette, 1979).

Vascular plants

Other primary producers include the vascular aquatic plants. A rather extensive survey of vascular plants has been completed in Chaves, Eddy, and Lea Counties (Martin, cited by Sublette and Sublette, 1978).

H.5.3.2 Aquatic biota of the study area

Surface waters in the study area are limited to earthen livestock-watering ponds and metal stock tanks. Ephemeral surface waters (i.e., puddles) may form after a thunderstorm. This rainfall is generally of brief duration, but is occasionally intense. The temporary surface waters on the site provide minimal aquatic habitat.

The windmill tank (station 2, Figure H-24) and the hill tank (station 3) are being monitored for physical and for biotic characteristics. No macro-invertebrates were found in the February 1978 sampling of the windmill tank, but substantial numbers of seed shrimp (Ostracoda), nonbiting midges (Chironomidae), biting midges (Ceratopogonidae), fingernail clams (Sphaeriidae), aquatic worms (Oligochaeta), and copepods (Copepoda), were collected in the hill tank.

No fish species are known to occur within the study area.

H.5.4 Endangered and Threatened Species

H.5.4.1 Terrestrial species

Plants

The cactus Coryphantha sneedii var. leei, which is on the Federal list of endangered plants (FWS, 1976) in Eddy County, like most of the proposed species, is located in the Guadalupe Mountains. Proposed species include a milkwort (Polygala rimulicola), wild columbine (Aquilegia chaplinei), and bladderpod (Lesquerella valida). Another is a wild buckwheat (Eriogonum gypsophilum) that occurs on gypsum outcrops about 20 miles north of Carlsbad (Spellenberg, 1977). No species have been proposed for the Federal list of endangered plants for Lea County.

New Mexico does not have an official State list of rare, threatened, or endangered plant species. However, the New Mexico Plant Protection Act of 1953 protects all or some species in 23 plant families and includes some of the species proposed for the Federal list of endangered species in the State.

No plants proposed for the Federal list of endangered or threatened species have been observed within the study area, and the lack of suitable habitat makes their occurrence at the site unlikely.

Terrestrial vertebrates

Table H-64 lists the endangered terrestrial vertebrates that have been recently observed in the two-county region. Most of these species are associated with habitats that are not on or in the vicinity of the site.

Only two of these species, the bald eagle and the peregrine falcon, are included in the Federal list. Both species usually forage in the vicinity of large bodies of water like the Pecos River and associated reservoirs. It is unlikely that either species would be more than an occasional visitor at the site.

Table H-64. Endangered Terrestrial Vertebrates in the Region of the Site[a]

Common name	Scientific name	Status[b]
Mammals		
Nelson's pocket mouse	*Perognathus nelsoni canescens*	NM II
Birds		
Mississippi kite	*Ictinia mississippiensis*	NM II
Bald eagle	*Haliaeetus leucocephalus*	FE, NM II
Peregrine falcon	*Falco peregrinus anatum*	FE, NM I
Aplomado falcon	*F. femoralis septentrionalis*	NM I
Red-headed woodpecker	*Melanerpes ertyhrocephalus caurinis*	NM II
Varied bunting	*Passerina versicolor*	NM II
Baird's sparrow[c]	*Ammodramus bairdii*	NM II
McCown's longspur	*Calcarius mccownii*	NM II
Reptiles		
(Texas) slider turtle	*Chrysemys concinna texana*	NM II
(Sand dune) sagebrush lizard	*Sceloporus graciosus arenicolous*	NM II
(Blotched) plain-bellied water snake	*Natrix erythrogaster transversa*	NM II
(Pecos) western ribbon snake	*Thamnophis proximus diabolicus*	NM II
Amphibians		
(Eastern) barking frog	*Hylactophryne augusti latrans*	NM II
(Blanchard's cricket frog	*Acris crepitans blanchardi*	NM II

[a]Information on status and distribution from Hubbard et al. (1978).
[b]Key: FE = on the Federal list of endangered species; NM I = New Mexico endangered Group I; NM II = New Mexico endangered Group II.
[c]Observed in site vicinity during project field studies.

One mammal, eight bird, four reptile, and two amphibian species listed as endangered by the State of New Mexico may occur in the site region (Hubbard et al., 1978).

Nelson's pocket mouse is known from a single specimen collected 4 miles west of White City in western Eddy County (Webb, 1954). It is highly unlikely that the species inhabits the study area.

Three of the eight endangered bird species (Mississippi kite, bald eagle, and peregrine falcon) usually forage and nest near water and would not be expected to inhabit the study area. In New Mexico the red-headed woodpecker is strictly associated with planted groves of trees and lower-elevation riparian woodland (Hubbard et al., 1978). These habitats do not occur on, or in the vicinity of, the site. The four remaining species (Aplomado falcon, varied bunting, Baird's sparrow, and McCown's longspur) occupy habitats similar to those on and near the site and could occur there. In New Mexico the Aplomado falcon is typically found in areas with yucca grasslands and associated shrubby habitats at lower elevations. Baird's sparrow and McCown's longspur are grassland species. There is a recorded sighting of a single Baird's sparrow in the vicinity of the site on October 19, 1975.

Three of the four endangered reptiles inhabiting the site region (Texas slider turtle, blotched plain-bellied water snake, and Pecos western ribbon snake) are associated with aquatic environments and are not likely to be found in the study area. The fourth species, sand dune sagebrush lizard, occurs only on or near active sand dunes. Suitable habitat is available in the study area.

Both amphibian species listed as endangered in New Mexico are common elsewhere in their ranges. Blanchard's cricket frog inhabits moist terrestrial habitats associated with permanent water, like those along the Pecos River. The Eastern barking frog is associated with rocky ledges (usually limestone) and might inhabit the area along Livingston Ridge northwest of the site.

H.5.4.2 Aquatic species

Fish

A number of fish species in the Pecos River basin are considered to be threatened or endangered (Table H-65) because of their highly restricted distributions and dependence on unique habitats. Two categories of endangered species are recognized by the State of New Mexico: Group I includes those whose prospects of survival or recruitment in the State are in jeopardy; Group II includes species whose prospects of survival or recruitment in the State may be jeopardized in the foreseeable future. Nine species are known to occur in the region (or to have been extirpated within historical times).

The species in Group I include the blue sucker, the gray redhorse, the silverband shiner, and the Pecos shiner (bluntnose shiner). The blue sucker is known in New Mexico only from the lower Pecos drainage. Recent records of the blue sucker and the gray redhorse are from the Black River and the Pecos River south of Lake McMillan (Hubbard et al., 1978). The Pecos shiner occurs only in the Pecos River of New Mexico. Sublette (1975) collected two specimens of this species from Chaves County, and in 1977 considerable numbers were found below McMillan Dam in Eddy County (Hubbard et al., 1978). Hubbard et al. (1978) stress that reduced flows of the Pecos River have contributed to its reduction.

Four fish species belong to the New Mexico Group II of endangered species (Table H-65). Of these, the Pecos gambusia is perhaps the most widely publicized because of its Federal status as an endangered species (FWS, 1977). It occurs in seven isolated populations in the Bitter Lakes National Wildlife Refuge northeast of Roswell and in a 2-mile portion of Blue Spring (Bednarz, 1975).

Aquatic invertebrates

The only aquatic invertebrate presently listed in either group, the Socorro isopod (Exosphaeroma thermophilum), does not occur in the two-county region.

Table H-65. Endangered Fish in the Region of the Site[a]

Common name	Scientific name	Status[b]
Blue sucker	Cycleptus elongatus	NM I
Gray redhorse	Moxostoma congestum	NM I
Silverband shiner	Notropis shumardi	NM I
Bluntnose shiner	N. simus	NM I
Mexican tetra	Astyanax mexicanus	NM II
Greenthroat darter	Etheostoma lepidum	NM II
Pecos gambusia	Gambusia nobilis	FE[c], NM II
Bigscale logperch	Percina macrolepida	NM II

[a]Information from Hubbard et al. (1978) and F. H. Olson, New Mexico Department of Game and Fish (private communications).

[b]NM I = fish species whose prospects of survival or recruitment in New Mexico are in jeopardy; NM II = species whose prospects of survival or recruitment in New Mexico may be jeopardized in the foreseeable future.

[c]FE = species on the Federal list of endangered species (Federal Register, Vol. 42, pp. 36420-31, 1977).

H.5.5 Preexisting Environmental Stresses

Several natural and man-induced factors stress the terrestrial and aquatic ecosystems throughout the region.

Vegetation often undergoes water stress because of the variable and generally low rainfall in the area. In addition, the sandy soils in the site vicinity retain little water and are susceptible to wind erosion if vegetative cover is removed. The active dunes in the study area are probably a result of loss of cover due to overgrazing in the past near the James Ranch wells.

The great quantity of salt naturally occurring in the area is also a major ecological stress in the region. Surface water and groundwater are often salty. A lack of nearby good-quality watering areas is an important limiting factor for many of the wildlife species in the area. Adding to the natural salt loads are the brine effluent and dust (primarily potassium chloride, langbeinite, and potassium sulfate) from potash refineries. The potash industry uses approximately 12,000 acre-feet of fresh water annually and discharges approximately 10,000 acre-feet as brine. This waste commonly goes into tailings ponds from which some brine seeps into the ground. Estimated at about 200 million tons in 1976 and increasing at 14 million tons annually, these tailings consist principally of sodium chloride. Small quantities of these tailings are also airborne; however, the amount airborne is small compared to the 55 tons per day of dust emitted by the potash refineries in the site region.

Vegetation has been severely affected by the potash-mining operations, with a reduction or elimination of vegetation around potash plants, tailings piles, and tailings ponds. The soil under the tailings piles and brine-disposal areas is essentially sterile. The distance from the potash refinery to areas where salt no longer visibly affects vegetation varies, depending on such factors as the level of emission, prevailing wind direction, terrain, and soil types. The zone of effect ranges from no effect beyond the refinery site to effects observable nearly a mile away. At some refineries, all native vegetation within 0.25 mile has been killed. Beyond 0.25 mile, the salt-intolerant species (e.g., greythorn, allthorn, mesquite, and catclaw) have been defoliated, while salt-tolerant species such as saltbush appear to be growing well. These vegetational modifications in the area have, in turn, modified the wildlife habitat (BLM, 1975).

The most severe ecological stresses identified within the study area are heavy grazing by livestock and the limiting water supply. Historically many rangelands in the region have been subject to overgrazing and mismanagement ever since livestock were introduced into the area in the late 1800s (BLM, 1977; Humphrey, 1958). It has been estimated that overuse by livestock coupled with fire prevention has resulted in increased shrub densities. These factors, together with insect depredations and drought, have reduced forage production in the region to about half its potential (SCS, 1975). Persistent heavy grazing by livestock affects floristic composition and cover and thus influences available wildlife forage throughout the area. In addition, livestock can compete with herbivorous wildlife species such as deer, rodents, and granivorous birds for grasses, forbs, and palatable browse. However, direct competition is probably less important than changes in species composition that result from livestock mismanagement.

The construction of roads and the use of off-road vehicles has also affected the native vegetation and wildlife. Indiscriminate off-road use of vehicles has led to significant animal disturbance, vegetation damage, and soil erosion (BLM, 1977).

H.6 BACKGROUND RADIATION

This section discusses the existing background-radiation levels, presents the data currently available, and discusses additional information that will be obtained.

The major components of the external background radiation at any location are (a) cosmic rays, (b) terrestrial radiation sources like potassium-40 and the decay products of the uranium and thorium series in the earth's crust, and (c) global fallout from nuclear tests in the atmosphere. The background-radiation level can vary between geographical locations by more than twofold. At a specific location, it can also vary, to a lesser extent, over time and with weather conditions. Therefore, the natural variability of background-radiation levels at the site must be well documented to determine any facility contribution above this ambient level.

Some preliminary measurements of background radiation were begun at the WIPP site early in 1976, in conjunction with the on-site meteorological program. Direct measurements have been made with a Reuter-Stokes pressurized ionization chamber, and a number of thermoluminescent dosimeters (TLDs) have been emplaced in the area (Figure H-25). Sampling to determine the average gross beta-particle concentration in air has also begun. The results of these measurements are summarized in Tables H-66, H-67, and H-68; some have been discussed in a separate report (Metcalf and Brewer, 1977). Additional data will be required to permit accurate comparison of preoperational and operational dose contributions at specific locations or by specific pathways.

From data published by the National Council on Radiation Protection and Measurements (NCRP, 1975), the annual external whole-body exposure rates at the site from cosmic rays, terrestrial sources, and global fallout are estimated to be 37, 26, and 1 millirad, respectively, for a total of 64 millirads (or 64 millirem if a quality factor of 1 is assumed). These data were partly based on a flyover of an area that now includes the site. The aerial survey was part of the Aerial Radiological Measurement Surveys (ARMS), conducted for the U.S. Atomic Energy Commission during the period 1958 to 1963. A second aerial survey of the site area was made in September 1977 under the Aerial Measuring Systems Program, the successor to the ARMS program (Jobst, 1977). The second flyover was made both to verify the data collected by the first aerial survey and to locate any areas of abnormally high radiation levels (hot spots). The second survey covered only a small portion of the WIPP site, and no hot spots were located. The data tend to confirm the data taken on the surface with thermoluminescent dosimeters and the Reuter-Stokes instrument.

The data published by the NCRP (1975) and the latest flyover data can be compared with the background-radiation data presented in Tables H-66 and H-67, which were collected with ground-based monitoring equipment. For example, between August 22 and December 31, 1977, the average dose rate measured in the area with the Reuter-Stokes pressurized ionization chamber was 7.9 microroentgens per hour (approximately 69 milliroentgens per year), with a maximum of 14.8 microroentgens per hour and a minimum of 5.8 microroentgens per hour (Table H-66).

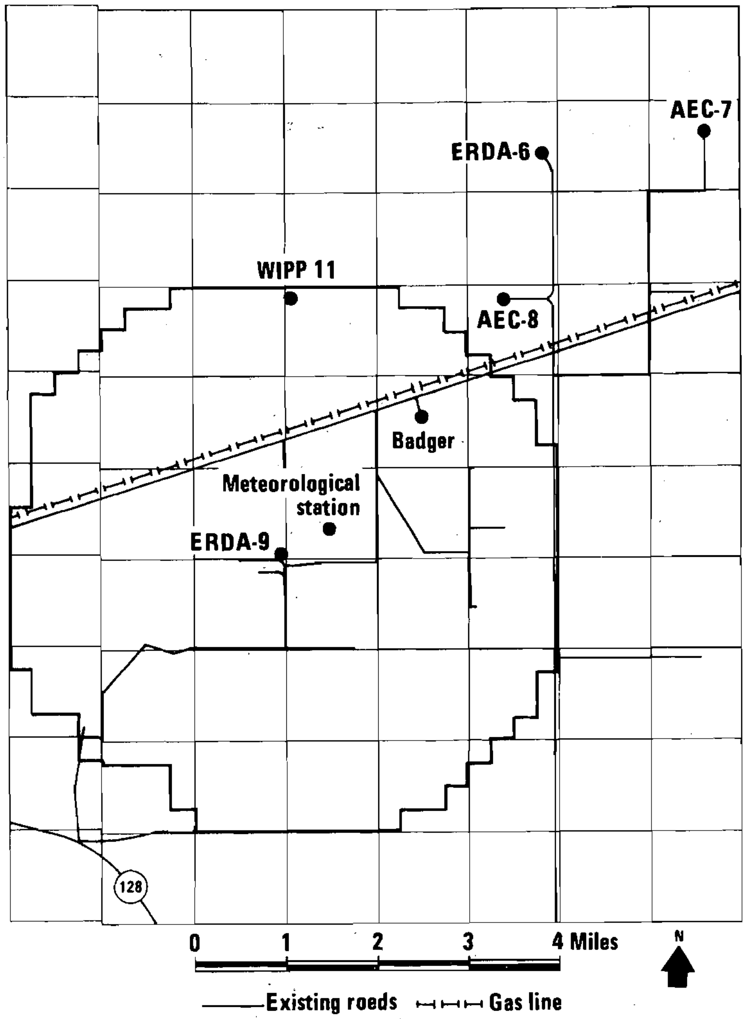


Figure H-25. Locations of thermoluminescent dosimeters in the site area.

The average dose rate compares favorably with the NCRP data. The dose rates measured by the thermoluminescent dosimeters (Table H-67) indicate a somewhat higher background-radiation level, but no significant differences are noted. Background-radiation levels at the WIPP site are expected to be similar to, or lower than, those in other parts of the Mountain States--lower especially than the levels at higher elevations, where cosmic-ray doses are greater.

Naturally occurring sources of radiation (e.g., potassium-40) are present in the human body and contribute an internal component to the total background-radiation dose. Thus, if an internal annual whole-body dose of 25 millirem (EPA, 1977) is added to the 64-millirem external dose, the estimated background-radiation whole-body dose at the site is approximately 90 millirem.

Table H-66. Background Radiation Measured in 1977 at the WIPP Site with a Reuter-Stokes Pressurized Ionization Chamber[a]

Exposure period		Radiation exposure (μR/hr)		
Begin	End	Average	Maximum	Minimum
8/22	8/28	7.83	9.30	6.82
8/29	9/4	7.74	10.27	6.52
9/5	9/11	7.78	9.73	6.30
9/12	9/18	7.83	9.66	6.36
9/19	9/25	7.77	9.57	6.33
9/26	10/2	7.88	9.64	6.69
10/3	10/9	7.99	11.58	6.84
10/10	10/16	7.81	9.02	6.52
10/17	10/23	8.04	11.30	6.54
10/24	10/30	7.93	10.24	6.86
10/31	11/6	7.89	10.71	5.98
11/7	11/13	7.97	11.45	5.94
11/14	11/20	8.01	12.12	5.79
11/21	11/27	8.00	12.29	6.12
11/28	12/4	8.04	12.39	6.28
12/5	12/11	8.14	14.18	6.68
12/12	12/18	8.06	12.95	6.65
12/19	12/25	7.99	14.80	6.47
12/26	12/31	8.11	10.78	6.58
Yearly average		7.94[b]	11.16	6.44

[a]Data for 1978 and 1979 have not yet been reduced.

[b]A similar average measurement in Albuquerque showed an exposure rate of about 15 microroentgens per hour, which illustrates the types of spatial variation that can be expected in the Mountain States, where elevations vary greatly.

In December 1961 a nuclear device was detonated at the Project Gnome site, 9 miles south-southwest of the WIPP site. Radioactive material vented during the explosion as well as various activities after the detonation contaminated nearby ground surfaces. Sampling programs conducted by the EPA have shown that there would be no significant radiological hazard to man from ingesting the meat of resident wild animals that were possibly affected by the Gnome event. The plume of vented material went to the northwest from the Gnome site; therefore the contribution of the Gnome event to the background-radiation levels at the WIPP site is negligible.

Table H-67. Thermoluminescent-Dosimeter Data Collected in the Area of the WIPP Site in 1977-1979

Location	First quarter		Second quarter		Third quarter		Fourth quarter	
	mR	μR/hr	mR	μR/hr	mR	μR/hr	mR	μR/hr
				1977				
Sandia office, Carlsbad	28.1±3.7	12.7±1.6	25.1±2.3	10.8±1.0	24.4±4.4	12.6±2.3	22.0±3.1	9.8±1.4
Meteorological station					18.6±3.9	9.6±2.0	19.0±2.7	8.4±1.2
Old Badger drill site	24.4±4.2	11.0±1.9	19.7±2.4	8.5±1.0	22.8±3.7	11.7±1.9	19.0±3.1	8.4±1.4
ERDA-6	25.7±3.6	11.6±1.6	19.9±2.6	8.5±1.1	21.3±3.8	11.0±2.0	21.5±3.3	9.5±1.5
AEC-7	24.9±3.7	11.3±1.7	22.5±2.8	9.7±1.2	21.4±3.6	11.0±1.9	19.7±3.0	8.7±1.3
AEC-8	24.4±4.1	11.0±1.9	20.1±2.4	8.6±1.0	18.0±3.2	9.3±1.6	16.7±3.1	7.4±1.4
ERDA-9	26.8±3.6	12.1±1.6	19.2±2.3	8.2±1.0	17.0±3.8	8.7±2.0	17.7±2.8	7.8±1.2
				1978				
Sandia office, Carlsbad	21.5±3.8	9.1±1.6	20.0±1.5	9.1±0.7	19.5±2.7	9.0±1.3	21.5±2.5	11.3±1.3
Meteorological station	17.3±3.5	7.4±1.5	14.8±1.0	6.7±0.5	14.8±2.6	6.9±1.2	16.5±2.1	8.7±1.1
Old Badger drill site	18.7±3.4	8.0±1.4	15.5±1.3	7.0±0.6	16.0±2.3	7.4±1.1	17.0±2.0	9.0±1.1
ERDA-6	18.0±3.3	7.7±1.4	16.0±1.2	7.2±0.5	16.2±2.2	7.5±1.0	16.5±2.1	8.7±1.1
AEC-7	20.0±3.4	8.5±1.4	17.3±1.2	7.8±0.5	17.1±2.2	7.9±1.0	18.5±2.3	9.8±1.2
AEC-8	18.7±3.6	8.0±1.5	15.6±1.2	7.1±0.5	15.5±2.3	7.2±1.1	17.0±2.0	9.0±1.1
ERDA-9	18.5±3.4	7.9±1.4	15.0±1.0	6.8±0.5	15.0±2.0	6.9±0.9	16.5±2.2	8.7±1.2
WIPP-11	18.2±3.4	7.7±1.4	15.0±1.1	6.8±0.5	14.8±2.0	6.9±0.9	16.5±2.5	8.7±1.3
				1979				
Meteorological station	14.8±2.3	6.0±0.9	15.2±1.5	6.8±0.7				
Old Badger drill site	--	--	16.2±1.5	7.3±0.7				
ERDA-6	15.6±2.5	6.3±1.0	14.4±1.5	6.5±0.7				
AEC-7	--	--	15.6±1.5	7.0±0.7				
AEC-8	15.5±2.4	6.3±1.0	16.9±1.5	7.6±0.7				
ERDA-9	16.9±2.7	6.8±1.1	14.3±1.5	6.4±0.7				
WIPP-11	15.2±2.4	6.1±1.0	14.1±1.5	6.3±0.7				

NOTES

1. The dates of collection for 1977 are as follows: first quarter, January 10 to April 12; second quarter, April 12 to July 18; third quarter, July 18 to October 7; fourth quarter, October 7 to January 9, 1978. The dates for 1978 are as follows: first quarter, January 9 to April 17; second quarter, April 17 to July 18; third quarter, July 18 to October 16; fourth quarter, October 16 to January 3, 1979. The first quarter in 1979 was January 3 to April 16; the second quarter, April 16 to July 18.

2. The reported precision of each measurement includes a statistical propagation of errors resulting from calibration procedures, the correction for dosimeter response during transit and storage, and variations in the TLD response of the five chips at each measurement location.

3. The differences between the TLD and ion-chamber data are probably due to differences in the wall thicknesses of the two systems (240 mg/cm^2 for TLDs and approximately 2400 mg/cm^2 for the ion chamber).

4. Variations in TLD data from quarter to quarter are probably due to the method of field installation of the TLD package. The dosimeters are exposed in a hollow pipe capped on the end that is above the ground. This pipe may act as a reservoir for radon and thoron emanations, increasing the local radiation field around the dosimeter package. This effect would be more apparent in the dry climate of the WIPP area, which has periods of precipitation alternating with dry periods.

5. The effects mentioned in notes 3 and 4 will be studied further in the 1979 calendar year.

6. Preliminary data for calendar year 1979 indicate that earlier TLD results are probably biased high, perhaps by 10 to 20%. This is especially true for quarters in which rainfall or snow cover was present in the WIPP area. The TLD results obtained after modifying the method of field installation show better agreement with the Reuter-Stokes data.

Table H-68. Monthly Average Gross Beta Concentrations in Air at the WIPP Site

Month	Average gross beta concentration (pCi/m^3)	Month	Average gross beta concentration (pCi/m^3)
		1976	
February	0.016	August	0.019
March	0.024	September	0.017
April	0.019	October	0.427[a]
May	0.020	November	0.226[a]
June	0.017	December	0.075[a]
July	0.012		
		1977	
January	0.041	July	0.101
February	0.048	August	0.045
March	0.082	September	0.753[b]
April	0.127	October	0.111
May	0.175	November	0.075
June	0.173	December	0.072
		1978	
January	0.074	July	0.035
February	0.058	August	0.028
March	0.124[c]	September	0.028
April	0.137[c]	October	0.035
May	0.083	November	0.024
June	0.056	December	0.027
		1979	
	January	0.044	
	February	0.032	
	March	0.008	

[a]Increase because of nuclear explosions in the atmosphere conducted by the People's Republic of China on September 26 and November 17, 1976.

[b]The People's Republic of China conducted a nuclear test in the atmosphere on September 17, 1977.

[c]The People's Republic of China conducted a nuclear test in the atmosphere on March 14, 1978.

H.7 NOISE BACKGROUND

The location of the site has been remote from human intrusion and thus from man-induced noise. Measurements indicate background noise levels in the range of 26 to 28 dBA. Noise sources were animals (birds, cattle), wind, occasional traffic, aircraft, intermittent use of heavy equipment, and (in the distance) potash-mine ventilation fans. The movement of drilling machinery to and from the site has led to the construction of a number of unimproved roads. The occasional use of these roads introduces a new, but minor, noise source to the area.

H.8 THE FUTURE OF THE SITE

H.8.1 Climatic Changes

Future climate changes cannot be predicted with great certainty at this time because of the complexity of atmospheric-oceanic-extraterrestrial interactions (Mitchell, 1968), complicated by the impacts of human activities. Although climatic experts have varying opinions, there appears to be a consensus (National Defense University, 1978) that there will not be a catastrophic climatic change during the next couple of decades. The long-term (thousands of years) natural trend is for another ice age (Keeling and Bacastow, 1977; Mitchell, 1978). However, man's impact on the climate could counterbalance this trend or result in a warming trend, possibly a global warming of 4.5 to 13°F or more, with greater aridity in the Western United States starting in the next century (Kukla and Matthews, 1972; Norwine, 1977). The possible climatic variability in the next 10,000 to 20,000 years in the site region, even allowing for man's influence, is similar to that experienced during the latter portion of the Pleistocene and the Holocene, as described in Section H.4.6. The climate of New Mexico may range from that associated with glaciers to the north (about 60% to 70% more rainfall than at present and summer temperatures about 20°F lower than at present) to that associated with interglacial periods (global temperatures about 3°F warmer and greater aridity in the Southwest than at present).

If continental glaciation returns, there is no possibility that the site itself will be glaciated, judging from the Pleistocene record; the increased rainfall, however, will increase the amount of water in the Pecos River, will increase the amount of vegetation in the region, and will cause the composition of the vegetation to shift toward prairie grasslands. If, on the other hand, man's influence causes a global warming, flow in the Pecos will decrease, the region will shift toward the flora of the Chihuahuan desert, and wind-driven processes will increase.

H.8.2 Demographic Changes

The population of the area is expected to change very little in the next few decades. It will grow slowly. The number of workers at nearby mines and at oil and gas wells in the area is not expected to change significantly. A ranch house will probably be built about 8 miles west-southwest of the site. A small trailer park is being built on private land along U.S. Highway 62-180 east of the intersection with N.M. Highway 360.

Population changes beyond the next few decades cannot be predicted in any detail. However, the return of glaciation would probably result in an increase in population and in intensity of land use as the mass of the human population is forced to move south. A global warming would be expected to induce little, if any, change in population.

H.8.3 Land-Use Changes

There is very little private land within 30 miles of the WIPP site. Most of the land is owned by the State or by the Federal Government. The dominant use of the land in and near the site is grazing, at levels of six to eight animals per square mile. There are also many active oil and gas wells. The only agricultural land within 30 miles is along the Pecos River near Carlsbad and Loving. With or without the WIPP, this pattern of land use is expected to change little in the near future.

Beyond the next few decades, the return of glaciation and the accompanying increase in rainfall would probably mean an increase in land use, perhaps including a shift from grazing to dry-land farming. A global warming would be expected to make little change in land use.

H.8.4 Geologic Changes

The last major tectonic activity at the WIPP site, the subsidence of the Delaware basin, ended in the Permian Period, about 225 million years ago. Evidence of lesser tectonic activity since then has been superimposed on the basin. Igneous activity in the vicinity of the site (9 miles northwest at the closest) is restricted to a dike or a series of dikes dated as being about 35 million years old. A gentle eastward tilting of the basin (1^{o}) that has occurred is broadly estimated as mid-Tertiary in age. This tilt may be contemporaneous with the initial formation of the west Texas salt-flat graben 70 miles to the southwest; the salt-flat graben is the closest structure to the site exhibiting geologic evidence of Quaternary or Recent tectonic activity. The tilting of the basin has also been postulated as a cause of deformation within the evaporite beds. Furthermore, the deposition of the Late Miocene-Pliocene Ogallala Formation indicates tectonic activity along the western margin of the Guadalupe-Sacramento Mountains 65 miles to the west. Thus the post-Permian tectonic history shows some gentle, broad effects of some tilting; intermittent periods of erosion indicate some relative uplift. Nearby recent tectonic changes are restricted to the salt-flat graben-Diablo Plateau area southwest of the site. The prognosis for the reasonably near geologic future is that the site may experience some erosion because of the slight relative uplift and that the salt-flat graben will be a source of earthquakes resulting in minor ground motion at the site.

Erosion and deposition as well as salt dissolution and collapse are responsible for many of the landforms at the site and in the region. In the past these processes and the resulting features have been significantly affected by changes in climate. Although there have been many small climatic cycles, past worldwide glacial-ice advances and interglacial periods have been alternating in 100,000-year cycles (Norwine, 1977). As indicated in Section H.4.6, the stage of the glacial-interglacial period cycle has a great effect on the climate of the Delaware basin. During interglacial times, the site has been warm and dry, while during glacial periods, the climate has been cooler and more humid. If, as Norwine (1977) suggests, the worldwide climate continues to move along 100,000-year cycles, two glacial periods and two interglacial periods are possible during the next 250,000 years.

Bachman (in preparation) infers, however, from the presence of Mescalero caliche at the site that the climate must have been semiarid since the formation of the caliche beginning about 500,000 years ago. The presence of this caliche is reasonable evidence that the average annual precipitation did not exceed 25 to 30 inches over any extended period during the last half million years.

It has been suggested that time and erosion could remove "evidence of a repository's existence, thereby increasing the potential violation of the site by drilling and mining." Burial by wind-blown sand might also conceal surface evidence of a repository.

Surface and near-surface processes can be used to some degree to estimate future erosion and deposition at the site. For the last million years, erosion at the site has exceeded deposition; however, the thickness of the resistant caliche cover at the site indicates that there has been no significant erosion since its formation 500,000 years ago. This layer will resist erosion while climatic conditions at the site are semiarid. If the site becomes more humid, water runoff will drain toward and along Nash Draw and San Simon Swale, increasing headward erosion in these areas. Since the site is adjacent to a low divide between these two features and has a very poorly developed drainage, it will not be significantly affected by fluvial erosion. Active and stabilized dunes in the area of the site mean that wind erosion can be expected to produce blowouts and dunes in the near future, though wind-induced features will be minor and local.

The process of salt dissolution and collapse can be expected to continue. The solution front at the Rustler-Salado interface will move over the site. From Bachman and Johnson's (1973) estimate of dissolution rates, it can be calculated that surface subsidence resulting from the dissolution of the top of the Salado will lower the land surface by about 125 feet over the next 250,000 years. (Bachman (in preparation) indicates that these rates are conservatively high because the dissolution that preceded Ogallala time was not taken into account in these estimates.) Related collapse features (sink holes, solution troughs, downwarps, fractured strata, and breccias) can be expected to form in future subsidence areas.

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ANNEX 1

METEOROLOGICAL TABLES

Contents

List of Tables

List of Tables (continued)

Table 1. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, June 1977

SPEED (MPS)		DIRECTION															
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		1	0	2	2	11	6	2	1	2	3	0	1	1	2	2	2	38
	(1)	0.3	0.0	0.6	0.6	3.2	1.7	0.6	0.3	0.6	0.9	0.0	0.3	0.3	0.6	0.6	0.6	11.0
	(2)	0.3	0.0	0.6	0.6	3.2	1.7	0.6	0.3	0.6	0.9	0.0	0.3	0.3	0.6	0.6	0.6	11.0
1.5- 3.0		10	3	6	5	29	27	12	8	6	9	2	4	2	2	5	0	130
	(1)	2.9	0.9	1.7	1.4	8.4	7.8	3.5	2.3	1.7	2.6	0.6	1.2	0.6	0.6	1.4	0.0	37.7
	(2)	2.9	0.9	1.7	1.4	8.4	7.8	3.5	2.3	1.7	2.6	0.6	1.2	0.6	0.6	1.4	0.0	37.7
3.1- 5.0		3	4	4	4	9	35	24	14	9	5	1	1	0	1	0	1	115
	(1)	0.9	1.2	1.2	1.2	2.6	10.1	7.0	4.1	2.6	1.4	0.3	0.3	0.0	0.3	0.0	0.3	33.3
	(2)	0.9	1.2	1.2	1.2	2.6	10.1	7.0	4.1	2.6	1.4	0.3	0.3	0.0	0.3	0.0	0.3	33.3
5.1- 8.0		1	1	1	3	2	23	14	2	1	0	0	0	0	0	1	0	49
	(1)	0.3	0.3	0.3	0.9	0.6	6.7	4.1	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	14.2
	(2)	0.3	0.3	0.3	0.9	0.6	6.7	4.1	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	14.2
8.1-10.4		0	1	0	1	0	4	3	0	0	0	0	0	1	0	0	0	10
	(1)	0.0	0.3	0.0	0.3	0.0	1.2	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.9
	(2)	0.0	0.3	0.0	0.3	0.0	1.2	0.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	2.9
OVER 10.4		0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	3
	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.9
	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.9
ALL SPEEDS		15	9	13	15	51	95	57	25	18	17	3	6	4	5	9	3	345
	(1)	4.3	2.6	3.8	4.3	14.8	27.5	16.5	7.2	5.2	4.9	0.9	1.7	1.2	1.4	2.6	0.9	100.0
	(2)	4.3	2.6	3.8	4.3	14.8	27.5	16.5	7.2	5.2	4.9	0.9	1.7	1.2	1.4	2.6	0.9	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

345 GOOD HRS 0 HRS (0.0 PCT) LESS THAN 0.3 MPS 720 HRS IN THE TIME PERIOD 47.9 PCT DATA RECOVERY

Table 2. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, July 1977

SPEED (MPS)		DIRECTION															
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		0	0	3	1	10	26	2	2	1	3	0	2	1	1	2	0	54
	(1)	0.0	0.0	0.5	0.2	1.6	4.1	0.3	0.3	0.2	0.5	0.0	0.3	0.2	0.2	0.3	0.0	8.6
	(2)	0.0	0.0	0.5	0.2	1.6	4.1	0.3	0.3	0.2	0.5	0.0	0.3	0.2	0.2	0.3	0.0	8.6
1.5- 3.0		2	8	2	4	27	79	17	5	7	7	3	3	1	2	4	1	172
	(1)	0.3	1.3	0.3	0.6	4.3	12.5	2.7	0.8	1.1	1.1	0.5	0.5	0.2	0.3	0.6	0.2	27.3
	(2)	0.3	1.3	0.3	0.6	4.3	12.5	2.7	0.8	1.1	1.1	0.5	0.5	0.2	0.3	0.6	0.2	27.3
3.1- 5.0		3	3	6	10	33	100	53	28	12	7	1	3	1	1	1	2	264
	(1)	0.5	0.5	1.0	1.6	5.2	15.9	8.4	4.4	1.9	1.1	0.2	0.5	0.2	0.2	0.2	0.3	41.9
	(2)	0.5	0.5	1.0	1.6	5.2	15.9	8.4	4.4	1.9	1.1	0.2	0.5	0.2	0.2	0.2	0.3	41.9
5.1- 8.0		0	2	3	7	9	33	61	7	3	0	0	0	0	0	0	1	126
	(1)	0.0	0.3	0.5	1.1	1.4	5.2	9.7	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	20.0
	(2)	0.0	0.3	0.5	1.1	1.4	5.2	9.7	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	20.0
8.1-10.4		0	1	0	0	1	2	9	0	0	0	0	0	0	0	0	0	13
	(1)	0.0	0.2	0.0	0.0	0.2	0.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
	(2)	0.0	0.2	0.0	0.0	0.2	0.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
OVER 10.4		0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	(1)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	(2)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
ALL SPEEDS		5	14	14	22	80	241	142	42	23	17	4	8	3	4	7	4	630
	(1)	0.8	2.2	2.2	3.5	12.7	38.3	22.5	6.7	3.7	2.7	0.6	1.3	0.5	0.6	1.1	0.6	100.0
	(2)	0.8	2.2	2.2	3.5	12.7	38.3	22.5	6.7	3.7	2.7	0.6	1.3	0.5	0.6	1.1	0.6	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

630 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   84.7 PCT DATA RECOVERY

Table 3. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, August 1977

SPEED (MPS)		DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		1	2	2	1	5	13	4	1	1	0	2	7	2	1	2	1	45
	(1)	0.1	0.3	0.3	0.1	0.7	1.9	0.6	0.1	0.1	0.0	0.3	1.0	0.3	0.1	0.3	0.1	6.6
	(2)	0.1	0.3	0.3	0.1	0.7	1.9	0.6	0.1	0.1	0.0	0.3	1.0	0.3	0.1	0.3	0.1	6.6
1.5- 3.0		3	4	6	3	36	69	17	13	16	3	5	6	2	3	10	6	202
	(1)	0.4	0.6	0.9	0.4	5.3	10.1	2.5	1.9	2.3	0.4	0.7	0.9	0.3	0.4	1.5	0.9	29.6
	(2)	0.4	0.6	0.9	0.4	5.3	10.1	2.5	1.9	2.3	0.4	0.7	0.9	0.3	0.4	1.5	0.9	29.6
3.1- 5.0		5	9	10	14	28	83	42	24	17	6	3	2	1	2	3	2	251
	(1)	0.7	1.3	1.5	2.0	4.1	12.2	6.1	3.5	2.5	0.9	0.4	0.3	0.1	0.3	0.4	0.3	36.7
	(2)	0.7	1.3	1.5	2.0	4.1	12.2	6.1	3.5	2.5	0.9	0.4	0.3	0.1	0.3	0.4	0.3	36.7
5.1- 8.0		2	2	12	7	11	33	60	26	2	2	0	0	2	0	0	1	160
	(1)	0.3	0.3	1.8	1.0	1.6	4.8	8.8	3.8	0.3	0.3	0.0	0.0	0.3	0.0	0.0	0.1	23.4
	(2)	0.3	0.3	1.8	1.0	1.6	4.8	8.8	3.8	0.3	0.3	0.0	0.0	0.3	0.0	0.0	0.1	23.4
8.1-10.4		0	1	6	4	3	1	4	1	0	0	0	0	0	0	0	0	20
	(1)	0.0	0.1	0.9	0.6	0.4	0.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
	(2)	0.0	0.1	0.9	0.6	0.4	0.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
OVER 10.4		0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	5
	(1)	0.0	0.0	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
	(2)	0.0	0.0	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
ALL SPEEDS		11	18	38	31	84	199	127	65	36	11	10	15	7	6	15	10	683
	(1)	1.6	2.6	5.6	4.5	12.3	29.1	18.6	9.5	5.3	1.6	1.5	2.2	1.0	0.9	2.2	1.5	100.0
	(2)	1.6	2.6	5.6	4.5	12.3	29.1	18.6	9.5	5.3	1.6	1.5	2.2	1.0	0.9	2.2	1.5	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

683 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   91.8 PCT DATA RECOVERY

Table 4. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, September 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	2	7	7	1	25	21	7	8	5	5	2	5	2	4	5	2	108
(1)	0.3	1.0	1.0	0.1	3.5	2.9	1.0	1.1	0.7	0.7	0.3	0.7	0.3	0.6	0.7	0.3	15.1
(2)	0.3	1.0	1.0	0.1	3.5	2.9	1.0	1.1	0.7	0.7	0.3	0.7	0.3	0.6	0.7	0.3	15.1
1.5- 3.0	11	16	13	6	25	30	21	13	15	19	11	17	4	9	12	8	230
(1)	1.5	2.2	1.8	0.8	3.5	4.2	2.9	1.8	2.1	2.7	1.5	2.4	0.6	1.3	1.7	1.1	32.2
(2)	1.5	2.2	1.8	0.8	3.5	4.2	2.9	1.8	2.1	2.7	1.5	2.4	0.6	1.3	1.7	1.1	32.2
3.1- 5.0	12	23	15	9	8	33	43	23	17	3	5	14	10	11	13	11	250
(1)	1.7	3.2	2.1	1.3	1.1	4.6	6.0	3.2	2.4	0.4	0.7	2.0	1.4	1.5	1.8	1.5	35.0
(2)	1.7	3.2	2.1	1.3	1.1	4.6	6.0	3.2	2.4	0.4	0.7	2.0	1.4	1.5	1.8	1.5	35.0
5.1- 8.0	2	4	8	5	1	12	27	9	8	5	10	7	2	1	3	5	109
(1)	0.3	0.6	1.1	0.7	0.1	1.7	3.8	1.3	1.1	0.7	1.4	1.0	0.3	0.1	0.4	0.7	15.2
(2)	0.3	0.6	1.1	0.7	0.1	1.7	3.8	1.3	1.1	0.7	1.4	1.0	0.3	0.1	0.4	0.7	15.2
8.1-10.4	0	0	0	3	0	1	3	0	0	0	4	4	0	0	0	1	16
(1)	0.0	0.0	0.0	0.4	0.0	0.1	0.4	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.1	2.2
(2)	0.0	0.0	0.0	0.4	0.0	0.1	0.4	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.1	2.2
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	27	50	43	24	59	97	101	53	45	32	32	47	18	25	33	27	713
(1)	3.8	7.0	6.0	3.4	8.3	13.6	14.1	7.4	6.3	4.5	4.5	6.6	2.5	3.5	4.6	3.8	99.7
(2)	3.8	7.0	6.0	3.4	8.3	13.6	14.1	7.4	6.3	4.5	4.5	6.6	2.5	3.5	4.6	3.8	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

715 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   99.3 PCT DATA RECOVERY

Table 5. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, October 1977

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	3	4	4	5	34	26	6	3	10	2	4	7	7	3	3	6	127
(1)	0.4	0.6	0.6	0.7	4.7	3.6	0.8	0.4	1.4	0.3	0.6	1.0	1.0	0.4	0.4	0.8	17.5
(2)	0.4	0.6	0.6	0.7	4.7	3.6	0.8	0.4	1.4	0.3	0.6	1.0	1.0	0.4	0.4	0.8	17.5
1.5- 3.0	4	8	7	5	30	51	35	35	33	11	9	10	10	5	12	4	269
(1)	0.6	1.1	1.0	0.7	4.1	7.0	4.8	4.8	4.5	1.5	1.2	1.4	1.4	0.7	1.7	0.6	37.1
(2)	0.6	1.1	1.0	0.7	4.1	7.0	4.8	4.8	4.5	1.5	1.2	1.4	1.4	0.7	1.7	0.6	37.1
3.1- 5.0	14	12	8	13	22	28	44	40	8	7	5	4	5	2	3	6	221
(1)	1.9	1.7	1.1	1.8	3.0	3.9	6.1	5.5	1.1	1.0	0.7	0.6	0.7	0.3	0.4	0.8	30.4
(2)	1.9	1.7	1.1	1.8	3.0	3.9	6.1	5.5	1.1	1.0	0.7	0.6	0.7	0.3	0.4	0.8	30.4
5.1- 8.0	4	5	1	13	3	8	16	6	0	0	8	6	2	1	0	0	73
(1)	0.6	0.7	0.1	1.8	0.4	1.1	2.2	0.8	0.0	0.0	1.1	0.8	0.3	0.1	0.0	0.0	10.1
(2)	0.6	0.7	0.1	1.8	0.4	1.1	2.2	0.8	0.0	0.0	1.1	0.8	0.3	0.1	0.0	0.0	10.1
8.1-10.4	0	3	1	1	0	1	4	0	0	0	3	5	0	0	0	0	18
(1)	0.0	0.4	0.1	0.1	0.0	0.1	0.6	0.0	0.0	0.0	0.4	0.7	0.0	0.0	0.0	0.0	2.5
(2)	0.0	0.4	0.1	0.1	0.0	0.1	0.6	0.0	0.0	0.0	0.4	0.7	0.0	0.0	0.0	0.0	2.5
OVER 10.4	0	4	2	0	0	0	0	0	0	0	0	2	0	0	0	0	8
(1)	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.1
(2)	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.1
ALL SPEEDS	25	36	23	37	89	114	105	84	51	20	29	34	24	11	18	16	716
(1)	3.4	5.0	3.2	5.1	12.3	15.7	14.5	11.6	7.0	2.8	4.0	4.7	3.3	1.5	2.5	2.2	98.6
(2)	3.4	5.0	3.2	5.1	12.3	15.7	14.5	11.6	7.0	2.8	4.0	4.7	3.3	1.5	2.5	2.2	98.6

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

726 GOOD HRS　　10 HRS (1.4 PCT) LESS THAN 0.3 MPS　　744 HRS IN THE TIME PERIOD　　97.6 PCT DATA RECOVERY

Table 6. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, November 1977

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	7	7	4	5	21	18	12	7	7	3	8	6	6	5	4	2	122
(1)	1.0	1.0	0.6	0.7	3.1	2.7	1.8	1.0	1.0	0.4	1.2	0.9	0.9	0.7	0.6	0.3	18.2
(2)	1.0	1.0	0.6	0.7	3.1	2.7	1.8	1.0	1.0	0.4	1.2	0.9	0.9	0.7	0.6	0.3	18.2
1.5- 3.0	14	13	6	13	24	41	26	26	17	10	5	3	6	7	10	21	242
(1)	2.1	1.9	0.9	1.9	3.6	6.1	3.9	3.9	2.5	1.5	0.7	0.4	0.9	1.0	1.5	3.1	36.1
(2)	2.1	1.9	0.9	1.9	3.6	6.1	3.9	3.9	2.5	1.5	0.7	0.4	0.9	1.0	1.5	3.1	36.1
3.1- 5.0	16	12	11	20	6	26	27	24	11	12	9	10	9	4	3	5	205
(1)	2.4	1.8	1.6	3.0	0.9	3.9	4.0	3.6	1.6	1.8	1.3	1.5	1.3	0.6	0.4	0.7	30.6
(2)	2.4	1.8	1.6	3.0	0.9	3.9	4.0	3.6	1.6	1.8	1.3	1.5	1.3	0.6	0.4	0.7	30.6
5.1- 8.0	7	3	7	5	0	2	4	1	2	6	3	6	2	1	7	7	63
(1)	1.0	0.4	1.0	0.7	0.0	0.3	0.6	0.1	0.3	0.9	0.4	0.9	0.3	0.1	1.0	1.0	9.4
(2)	1.0	0.4	1.0	0.7	0.0	0.3	0.6	0.1	0.3	0.9	0.4	0.9	0.3	0.1	1.0	1.0	9.4
8.1-10.4	0	0	5	2	0	0	0	0	0	5	1	6	1	1	2	4	27
(1)	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.9	0.1	0.1	0.3	0.6	4.0
(2)	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.9	0.1	0.1	0.3	0.6	4.0
OVER 10.4	0	0	3	0	0	0	0	0	0	0	0	1	0	0	1	5	10
(1)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.7	1.5
(2)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.7	1.5
ALL SPEEDS	44	35	36	45	51	87	69	58	37	36	26	32	24	18	27	44	669
(1)	6.6	5.2	5.4	6.7	7.6	13.0	10.3	8.6	5.5	5.4	3.9	4.8	3.6	2.7	4.0	6.6	99.7
(2)	6.6	5.2	5.4	6.7	7.6	13.0	10.3	8.6	5.5	5.4	3.9	4.8	3.6	2.7	4.0	6.6	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

671 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   93.2 PCT DATA RECOVERY

Table 7. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, December 1977

SPEED (MPS)		DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		7	6	10	5	14	23	9	7	5	5	3	6	6	3	3	5	117
	(1)	1.0	0.8	1.4	0.7	2.0	3.2	1.3	1.0	0.7	0.7	0.4	0.8	0.8	0.4	0.4	0.7	16.5
	(2)	1.0	0.8	1.4	0.7	2.0	3.2	1.3	1.0	0.7	0.7	0.4	0.8	0.8	0.4	0.4	0.7	16.5
1.5- 3.0		9	12	6	3	10	39	23	21	21	19	13	9	14	20	10	7	236
	(1)	1.3	1.7	0.8	0.4	1.4	5.5	3.2	3.0	3.0	2.7	1.8	1.3	2.0	2.8	1.4	1.0	33.2
	(2)	1.3	1.7	0.9	0.4	1.4	5.5	3.2	3.0	3.0	2.7	1.8	1.3	2.0	2.8	1.4	1.0	33.2
3.1- 5.0		10	5	8	6	4	19	47	15	8	15	32	26	12	11	9	9	236
	(1)	1.4	0.7	1.1	0.8	0.6	2.7	6.6	2.1	1.1	2.1	4.5	3.7	1.7	1.5	1.3	1.3	33.2
	(2)	1.4	0.7	1.1	0.8	0.6	2.7	6.6	2.1	1.1	2.1	4.5	3.7	1.7	1.5	1.3	1.3	33.2
5.1- 8.0		5	5	1	6	1	1	5	3	4	3	10	16	6	7	6	7	86
	(1)	0.7	0.7	0.1	0.8	0.1	0.1	0.7	0.4	0.6	0.4	1.4	2.3	0.8	1.0	0.8	1.0	12.1
	(2)	0.7	0.7	0.1	0.8	0.1	0.1	0.7	0.4	0.6	0.4	1.4	2.3	0.8	1.0	0.8	1.0	12.1
8.1-10.4		0	0	0	1	0	0	0	0	0	0	1	7	0	1	1	0	11
	(1)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	0.0	0.1	0.1	0.0	1.5
	(2)	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	0.0	0.1	0.1	0.0	1.5
OVER 10.4		0	0	2	2	0	0	0	0	0	0	1	8	6	0	0	0	19
	(1)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	0.8	0.0	0.0	0.0	2.7
	(2)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	0.8	0.0	0.0	0.0	2.7
ALL SPEEDS		31	28	27	23	29	82	84	46	38	42	60	72	44	42	29	28	705
	(1)	4.4	3.9	3.8	3.2	4.1	11.5	11.8	6.5	5.3	5.9	8.4	10.1	6.2	5.9	4.1	3.9	99.2
	(2)	4.4	3.9	3.8	3.2	4.1	11.5	11.8	6.5	5.3	5.9	8.4	10.1	6.2	5.9	4.1	3.9	99.2

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

711 GOOD HRS 6 HRS (0.8 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 95.6 PCT DATA RECOVERY

Table 8. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, January 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	4	4	6	9	3	15	12	3	3	4	3	3	3	5	3	3	83
(1)	0.6	0.6	0.9	1.4	0.5	2.3	1.9	0.5	0.5	0.6	0.5	0.5	0.5	0.8	0.5	0.5	12.9
(2)	0.6	0.6	0.9	1.4	0.5	2.3	1.9	0.5	0.5	0.6	0.5	0.5	0.5	0.8	0.5	0.5	12.9
1.5- 3.0	9	11	5	15	39	52	47	19	14	6	4	3	6	5	6	6	247
(1)	1.4	1.7	0.8	2.3	6.1	8.1	7.3	3.0	2.2	0.9	0.6	0.5	0.9	0.8	0.9	0.9	38.5
(2)	1.4	1.7	0.8	2.3	6.1	8.1	7.3	3.0	2.2	0.9	0.6	0.5	0.9	0.8	0.9	0.9	38.5
3.1- 5.0	11	5	6	13	21	29	47	30	7	3	7	3	5	4	10	7	208
(1)	1.7	0.8	0.9	2.0	3.3	4.5	7.3	4.7	1.1	0.5	1.1	0.5	0.8	0.6	1.6	1.1	32.4
(2)	1.7	0.8	0.9	2.0	3.3	4.5	7.3	4.7	1.1	0.5	1.1	0.5	0.8	0.6	1.6	1.1	32.4
5.1- 8.0	6	6	10	6	8	1	8	3	3	0	3	4	2	3	6	10	79
(1)	0.9	0.9	1.6	0.9	1.2	0.2	1.2	0.5	0.5	0.0	0.5	0.6	0.3	0.5	0.9	1.6	12.3
(2)	0.9	0.9	1.6	0.9	1.2	0.2	1.2	0.5	0.5	0.0	0.5	0.6	0.3	0.5	0.9	1.6	12.3
8.1-10.4	0	1	4	5	0	0	0	0	0	0	0	0	0	0	4	1	15
(1)	0.0	0.2	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	2.3
(2)	0.0	0.2	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	2.3
OVER 10.4	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	3
(1)	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
(2)	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
ALL SPEEDS	30	27	33	49	71	97	114	55	27	13	17	13	16	17	29	27	635
(1)	4.7	4.2	5.1	7.6	11.1	15.1	17.3	8.6	4.2	2.0	2.7	2.0	2.5	2.7	4.5	4.2	99.1
(2)	4.7	4.2	5.1	7.6	11.1	15.1	17.8	8.6	4.2	2.0	2.7	2.0	2.5	2.7	4.5	4.2	99.1

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

641 GOOD HRS   6 HRS (0.9 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   86.2 PCT DATA RECOVERY

Table 9. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, February 1978

SPEED (MPS)	DIRECTION																
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	3	2	4	9	7	7	8	7	8	7	4	5	6	4	3	86
(1)	0.4	0.6	0.4	0.8	1.7	1.3	1.3	1.5	1.3	1.5	1.3	0.8	0.9	1.1	0.8	0.6	16.3
(2)	0.4	0.6	0.4	0.8	1.7	1.3	1.3	1.5	1.3	1.5	1.3	0.8	0.9	1.1	0.8	0.6	16.3
1.5- 3.0	2	14	6	4	11	35	28	19	9	4	10	3	6	14	6	5	176
(1)	0.4	2.7	1.1	0.8	2.1	6.6	5.3	3.6	1.7	0.8	1.9	0.6	1.1	2.7	1.1	0.9	33.4
(2)	0.4	2.7	1.1	0.8	2.1	6.6	5.3	3.6	1.7	0.8	1.9	0.6	1.1	2.7	1.1	0.9	33.4
3.1- 5.0	6	7	8	12	7	31	34	8	4	7	2	5	5	2	7	8	153
(1)	1.1	1.3	1.5	2.3	1.3	5.9	6.5	1.5	0.8	1.3	0.4	0.9	0.9	0.4	1.3	1.5	29.0
(2)	1.1	1.3	1.5	2.3	1.3	5.9	6.5	1.5	0.8	1.3	0.4	0.9	0.9	0.4	1.3	1.5	29.0
5.1- 8.0	8	11	5	16	6	6	8	2	0	0	3	6	6	6	2	0	85
(1)	1.5	2.1	0.9	3.0	1.1	1.1	1.5	0.4	0.0	0.0	0.6	1.1	1.1	1.1	0.4	0.0	16.1
(2)	1.5	2.1	0.9	3.0	1.1	1.1	1.5	0.4	0.0	0.0	0.6	1.1	1.1	1.1	0.4	0.0	16.1
8.1-10.4	0	3	1	1	0	0	0	0	0	0	1	4	7	0	0	0	17
(1)	0.0	0.6	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.3	0.0	0.0	0.0	3.2
(2)	0.0	0.6	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.3	0.0	0.0	0.0	3.2
OVER 10.4	0	0	2	0	0	0	0	0	0	0	0	3	1	0	0	0	6
(1)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	1.1
(2)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	1.1
ALL SPEEDS	18	38	24	37	33	79	77	37	20	19	23	25	30	28	19	16	523
(1)	3.4	7.2	4.6	7.0	6.3	15.0	14.6	7.0	3.8	3.6	4.4	4.7	5.7	5.3	3.6	3.0	99.2
(2)	3.4	7.2	4.6	7.0	6.3	15.0	14.6	7.0	3.8	3.6	4.4	4.7	5.7	5.3	3.6	3.0	99.2

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

527 GOOD HRS 4 HRS (0.8 PCT) LESS THAN 0.3 MPS 672 HRS IN THE TIME PERIOD 78.4 PCT DATA RECOVERY

Table 10. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, March 1978

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	4	2	5	1	8	13	7	4	3	2	1	4	2	3	3	4	66
(1)	0.5	0.3	0.7	0.1	1.1	1.8	1.0	0.5	0.4	0.3	0.1	0.5	0.3	0.4	0.4	0.5	9.0
(2)	0.5	0.3	0.7	0.1	1.1	1.8	1.0	0.5	0.4	0.3	0.1	0.5	0.3	0.4	0.4	0.5	9.0
1.5- 3.0	3	11	10	13	20	48	29	23	16	8	12	7	11	11	9	8	239
(1)	0.4	1.5	1.4	1.8	2.7	6.6	4.0	3.1	2.2	1.1	1.6	1.0	1.5	1.5	1.2	1.1	32.7
(2)	0.4	1.5	1.4	1.8	2.7	6.6	4.0	3.1	2.2	1.1	1.6	1.0	1.5	1.5	1.2	1.1	32.7
3.1- 5.0	3	4	18	19	8	48	36	27	6	12	18	15	11	15	9	5	254
(1)	0.4	0.5	2.5	2.6	1.1	6.6	4.9	3.7	0.8	1.6	2.5	2.1	1.5	2.1	1.2	0.7	34.7
(2)	0.4	0.5	2.5	2.6	1.1	6.6	4.9	3.7	0.8	1.6	2.5	2.1	1.5	2.1	1.2	0.7	34.7
5.1- 8.0	7	1	11	19	3	16	8	0	3	5	9	21	9	4	5	11	132
(1)	1.0	0.1	1.5	2.6	0.4	2.2	1.1	0.0	0.4	0.7	1.2	2.9	1.2	0.5	0.7	1.5	18.1
(2)	1.0	0.1	1.5	2.6	0.4	2.2	1.1	0.0	0.4	0.7	1.2	2.9	1.2	0.5	0.7	1.5	18.1
8.1-10.4	1	0	4	3	0	1	5	3	1	0	3	4	5	1	3	1	35
(1)	0.1	0.0	0.5	0.4	0.0	0.1	0.7	0.4	0.1	0.0	0.4	0.5	0.7	0.1	0.4	0.1	4.8
(2)	0.1	0.0	0.5	0.4	0.0	0.1	0.7	0.4	0.1	0.0	0.4	0.5	0.7	0.1	0.4	0.1	4.8
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	5
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1	0.0	0.7
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1	0.0	0.7
ALL SPEEDS	18	18	48	55	39	126	85	57	29	27	43	55	38	34	30	29	731
(1)	2.5	2.5	6.6	7.5	5.3	17.2	11.6	7.8	4.0	3.7	5.9	7.5	5.2	4.7	4.1	4.0	100.0
(2)	2.5	2.5	6.6	7.5	5.3	17.2	11.6	7.8	4.0	3.7	5.9	7.5	5.2	4.7	4.1	4.0	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

731 GOOD HRS   0 HRS (0.0 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   98.3 PCT DATA RECOVERY

Table 11. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, April 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	2	3	2	8	12	3	6	0	7	3	1	3	2	4	2	60
(1)	0.3	0.3	0.5	0.3	1.2	1.8	0.5	0.9	0.0	1.1	0.5	0.2	0.5	0.3	0.6	0.3	9.2
(2)	0.3	0.3	0.5	0.3	1.2	1.8	0.5	0.9	0.0	1.1	0.5	0.2	0.5	0.3	0.6	0.3	9.2
1.5- 3.0	7	9	8	3	15	20	17	18	19	19	15	5	8	9	6	12	190
(1)	1.1	1.4	1.2	0.5	2.3	3.1	2.6	2.8	2.9	2.9	2.3	0.8	1.2	1.4	0.9	1.8	29.2
(2)	1.1	1.4	1.2	0.5	2.3	3.1	2.6	2.8	2.9	2.9	2.3	0.8	1.2	1.4	0.9	1.8	29.2
3.1- 5.0	10	16	5	4	7	26	20	15	17	6	12	17	8	10	8	10	191
(1)	1.5	2.5	0.8	0.6	1.1	4.0	3.1	2.3	2.6	0.9	1.8	2.6	1.2	1.5	1.2	1.5	29.4
(2)	1.5	2.5	0.8	0.6	1.1	4.0	3.1	2.3	2.6	0.9	1.8	2.6	1.2	1.5	1.2	1.5	29.4
5.1- 8.0	2	5	4	6	1	20	13	10	12	7	21	20	4	10	0	10	145
(1)	0.3	0.8	0.6	0.9	0.2	3.1	2.0	1.5	1.8	1.1	3.2	3.1	0.6	1.5	0.0	1.5	22.3
(2)	0.3	0.8	0.6	0.9	0.2	3.1	2.0	1.5	1.8	1.1	3.2	3.1	0.6	1.5	0.0	1.5	22.3
8.1-10.4	0	0	3	3	0	3	5	1	1	2	14	17	7	1	0	0	57
(1)	0.0	0.0	0.5	0.5	0.0	0.5	0.8	0.2	0.2	0.3	2.2	2.6	1.1	0.2	0.0	0.0	8.8
(2)	0.0	0.0	0.5	0.5	0.0	0.5	0.8	0.2	0.2	0.3	2.2	2.6	1.1	0.2	0.0	0.0	8.8
OVER 10.4	0	0	0	0	0	1	0	0	0	0	2	2	1	0	0	0	6
(1)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.3	0.2	0.0	0.0	0.0	0.9
(2)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.3	0.3	0.2	0.0	0.0	0.0	0.9
ALL SPEEDS	21	32	23	18	31	82	58	50	49	41	67	62	31	32	18	34	649
(1)	3.2	4.9	3.5	2.8	4.8	12.6	8.9	7.7	7.5	6.3	10.3	9.5	4.8	4.9	2.8	5.2	99.8
(2)	3.2	4.9	3.5	2.8	4.8	12.6	8.9	7.7	7.5	6.3	10.3	9.5	4.8	4.9	2.8	5.2	99.8

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

650 GOOD HRS   1 HRS (0.2 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   90.3 PCT DATA RECOVERY

Table 12. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, May 1978

SPEED (MPS)		DIRECTION																
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		2	3	3	2	2	11	7	9	4	6	4	4	4	2	3	2	68
	(1)	0.3	0.5	0.5	0.3	0.3	1.7	1.1	1.4	0.6	0.9	0.6	0.6	0.6	0.3	0.5	0.3	10.3
	(2)	0.3	0.5	0.5	0.3	0.3	1.7	1.1	1.4	0.6	0.9	0.6	0.6	0.6	0.3	0.5	0.3	10.3
1.5- 3.0		6	5	7	3	19	27	14	18	12	11	9	5	5	6	5	6	158
	(1)	0.9	0.8	1.1	0.5	2.9	4.1	2.1	2.7	1.8	1.7	1.4	0.8	0.8	0.9	0.8	0.9	23.9
	(2)	0.9	0.8	1.1	0.5	2.9	4.1	2.1	2.7	1.8	1.7	1.4	0.8	0.8	0.9	0.8	0.9	23.9
3.1- 5.0		4	5	9	6	7	33	36	31	7	11	14	19	7	8	10	10	217
	(1)	0.6	0.8	1.4	0.9	1.1	5.0	5.4	4.7	1.1	1.7	2.1	2.9	1.1	1.2	1.5	1.5	32.8
	(2)	0.6	0.8	1.4	0.9	1.1	5.0	5.4	4.7	1.1	1.7	2.1	2.9	1.1	1.2	1.5	1.5	32.8
5.1- 8.0		0	2	11	5	4	28	34	15	4	9	11	27	8	1	4	7	170
	(1)	0.0	0.3	1.7	0.8	0.6	4.2	5.1	2.3	0.6	1.4	1.7	4.1	1.2	0.2	0.6	1.1	25.7
	(2)	0.0	0.3	1.7	0.8	0.6	4.2	5.1	2.3	0.6	1.4	1.7	4.1	1.2	0.2	0.6	1.1	25.7
8.1-10.4		1	1	0	6	1	3	5	0	1	5	6	8	0	2	1	2	42
	(1)	0.2	0.2	0.0	0.9	0.2	0.5	0.8	0.0	0.2	0.8	0.9	1.2	0.0	0.3	0.2	0.3	6.3
	(2)	0.2	0.2	0.0	0.9	0.2	0.5	0.8	0.0	0.2	0.8	0.9	1.2	0.0	0.3	0.2	0.3	6.3
OVER 10.4		0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	4
	(1)	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6
	(2)	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6
ALL SPEEDS		13	16	33	22	33	102	96	73	28	42	44	64	24	19	23	27	659
	(1)	2.0	2.4	5.0	3.3	5.0	15.4	14.5	11.0	4.2	6.3	6.6	9.7	3.6	2.9	3.5	4.1	99.5
	(2)	2.0	2.4	5.0	3.3	5.0	15.4	14.5	11.0	4.2	6.3	6.6	9.7	3.6	2.9	3.5	4.1	99.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

662 GOOD HRS   3 HRS (0.5 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   89.0 PCT DATA RECOVERY

Table 13. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, June 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	3	3	2	4	7	10	2	2	3	3	2	1	1	2	2	1	48
(1)	0.4	0.4	0.3	0.6	1.0	1.4	0.3	0.3	0.4	0.4	0.3	0.1	0.1	0.3	0.3	0.1	6.8
(2)	0.4	0.4	0.3	0.6	1.0	1.4	0.3	0.3	0.4	0.4	0.3	0.1	0.1	0.3	0.3	0.1	6.8
1.5- 3.0	5	4	6	7	14	46	20	9	8	3	2	2	5	6	10	6	153
(1)	0.7	0.6	0.8	1.0	2.0	6.5	2.8	1.3	1.1	0.4	0.3	0.3	0.7	0.8	1.4	0.8	21.5
(2)	0.7	0.6	0.8	1.0	2.0	6.5	2.8	1.3	1.1	0.4	0.3	0.3	0.7	0.8	1.4	0.8	21.5
3.1- 5.0	3	12	13	12	12	69	53	47	9	1	0	1	0	5	6	7	250
(1)	0.4	1.7	1.8	1.7	1.7	9.7	7.5	6.6	1.3	0.1	0.0	0.1	0.0	0.7	0.8	1.0	35.2
(2)	0.4	1.7	1.8	1.7	1.7	9.7	7.5	6.6	1.3	0.1	0.0	0.1	0.0	0.7	0.8	1.0	35.2
5.1- 8.0	3	6	7	13	3	61	87	14	4	0	1	1	0	1	1	2	204
(1)	0.4	0.8	1.0	1.8	0.4	8.6	12.3	2.0	0.6	0.0	0.1	0.1	0.0	0.1	0.1	0.3	28.7
(2)	0.4	0.8	1.0	1.8	0.4	8.6	12.3	2.0	0.6	0.0	0.1	0.1	0.0	0.1	0.1	0.3	28.7
8.1-10.4	1	5	3	5	0	11	23	0	0	0	0	0	0	0	0	0	48
(1)	0.1	0.7	0.4	0.7	0.0	1.5	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8
(2)	0.1	0.7	0.4	0.7	0.0	1.5	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8
OVER 10.4	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	1	5
(1)	0.0	0.0	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7
(2)	0.0	0.0	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7
ALL SPEEDS	15	30	33	42	36	198	185	72	24	7	5	5	6	14	19	17	708
(1)	2.1	4.2	4.6	5.9	5.1	27.9	26.1	10.1	3.4	1.0	0.7	0.7	0.8	2.0	2.7	2.4	99.7
(2)	2.1	4.2	4.6	5.9	5.1	27.9	26.1	10.1	3.4	1.0	0.7	0.7	0.8	2.0	2.7	2.4	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

710 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   98.6 PCT DATA RECOVERY

Table 14. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, July 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	1	0	2	1	9	13	7	5	6	4	3	0	0	0	0	0	51
(1)	0.1	0.0	0.3	0.1	1.3	1.9	1.0	0.7	0.9	0.6	0.4	0.0	0.0	0.0	0.0	0.0	7.5
(2)	0.1	0.0	0.3	0.1	1.3	1.9	1.0	0.7	0.9	0.6	0.4	0.0	0.0	0.0	0.0	0.0	7.5
1.5- 3.0	7	5	7	7	39	83	22	30	9	1	1	0	0	0	4	6	221
(1)	1.0	0.7	1.0	1.0	5.7	12.2	3.2	4.4	1.3	0.1	0.1	0.0	0.0	0.0	0.6	0.9	32.5
(2)	1.0	0.7	1.0	1.0	5.7	12.2	3.2	4.4	1.3	0.1	0.1	0.0	0.0	0.0	0.6	0.9	32.5
3.1- 5.0	2	4	8	13	15	107	87	26	5	1	1	0	0	0	0	2	271
(1)	0.3	0.6	1.2	1.9	2.2	15.7	12.8	3.8	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.3	39.8
(2)	0.3	0.6	1.2	1.9	2.2	15.7	12.8	3.8	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.3	39.8
5.1- 8.0	0	8	6	5	1	38	64	1	0	0	0	0	0	0	0	1	124
(1)	0.0	1.2	0.9	0.7	0.1	5.6	9.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	18.2
(2)	0.0	1.2	0.9	0.7	0.1	5.6	9.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	18.2
8.1-10.4	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	10
(1)	0.0	0.0	0.4	0.1	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
(2)	0.0	0.0	0.4	0.1	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
OVER 10.4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
(1)	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
(2)	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
ALL SPEEDS	10	18	26	28	64	244	183	62	20	6	5	0	0	0	4	9	679
(1)	1.5	2.6	3.8	4.1	9.4	35.8	26.9	9.1	2.9	0.9	0.7	0.0	0.0	0.0	0.6	1.3	99.7
(2)	1.5	2.6	3.8	4.1	9.4	35.8	26.9	9.1	2.9	0.9	0.7	0.0	0.0	0.0	0.6	1.3	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

681 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   91.5 PCT DATA RECOVERY

Table 15. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, August 1978

SPEED (MPS)		DIRECTION															
		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		2	5	1	1	10	9	4	4	7	4	3	2	6	0	5	4	67
	(1)	0.3	0.8	0.2	0.2	1.6	1.4	0.6	0.6	1.1	0.6	0.5	0.3	0.9	0.0	0.8	0.6	10.6
	(2)	0.3	0.8	0.2	0.2	1.6	1.4	0.6	0.6	1.1	0.6	0.5	0.3	0.9	0.0	0.8	0.6	10.6
1.5- 3.0		3	5	5	6	15	37	24	33	25	10	11	7	5	8	6	9	209
	(1)	0.5	0.8	0.8	0.9	2.4	5.9	3.8	5.2	4.0	1.6	1.7	1.1	0.8	1.3	0.9	1.4	33.1
	(2)	0.5	0.8	0.8	0.9	2.4	5.9	3.8	5.2	4.0	1.6	1.7	1.1	0.8	1.3	0.9	1.4	33.1
3.1- 5.0		4	14	13	8	1	36	62	54	7	3	5	5	6	10	6	5	239
	(1)	0.6	2.2	2.1	1.3	0.2	5.7	9.8	8.5	1.1	0.5	0.8	0.8	0.9	1.6	0.9	0.8	37.8
	(2)	0.6	2.2	2.1	1.3	0.2	5.7	9.8	8.5	1.1	0.5	0.8	0.8	0.9	1.6	0.9	0.8	37.8
5.1- 8.0		0	3	18	9	6	7	47	12	1	1	0	1	1	1	0	2	109
	(1)	0.0	0.5	2.8	1.4	0.9	1.1	7.4	1.9	0.2	0.2	0.0	0.2	0.2	0.2	0.0	0.3	17.2
	(2)	0.0	0.5	2.8	1.4	0.9	1.1	7.4	1.9	0.2	0.2	0.0	0.2	0.2	0.2	0.0	0.3	17.2
8.1-10.4		0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	[illegible]
	(1)	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
	(2)	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
OVER 10.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS		9	27	40	24	32	89	138	103	40	18	19	15	18	19	17	20	628
	(1)	1.4	4.3	6.3	3.8	5.1	14.1	21.8	16.3	6.3	2.8	3.0	2.4	2.8	3.0	2.7	3.2	99.4
	(2)	1.4	4.3	6.3	3.8	5.1	14.1	21.8	16.3	6.3	2.8	3.0	2.4	2.8	3.0	2.7	3.2	99.4

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

632 GOOD HRS 4 HRS (0.6 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 84.9 PCT DATA RECOVERY

Table 16. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, September 1978

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	3	10	1	3	2	9	6	9	7	4	3	8	7	4	7	4	87
(1)	0.5	1.6	0.2	0.5	0.3	1.4	0.9	1.4	1.1	0.6	0.5	1.3	1.1	0.6	1.1	0.6	13.7
(2)	0.5	1.6	0.2	0.5	0.3	1.4	0.9	1.4	1.1	0.6	0.5	1.3	1.1	0.6	1.1	0.6	13.7
1.5- 3.0	10	15	9	13	15	41	30	18	14	11	11	6	5	10	11	7	226
(1)	1.6	2.4	1.4	2.1	2.4	6.5	4.7	2.8	2.2	1.7	1.7	0.9	0.8	1.6	1.7	1.1	35.6
(2)	1.6	2.4	1.4	2.1	2.4	6.5	4.7	2.8	2.2	1.7	1.7	0.9	0.8	1.6	1.7	1.1	35.6
3.1- 5.0	8	6	8	15	12	72	40	10	17	7	4	5	2	6	8	6	226
(1)	1.3	0.9	1.3	2.4	1.9	11.4	6.3	1.6	2.7	1.1	0.6	0.8	0.3	0.9	1.3	0.9	35.6
(2)	1.3	0.9	1.3	2.4	1.9	11.4	6.3	1.6	2.7	1.1	0.6	0.8	0.3	0.9	1.3	0.9	35.6
5.1- 8.0	2	6	16	6	0	20	9	2	1	3	6	12	0	0	1	0	84
(1)	0.3	0.9	2.5	0.9	0.0	3.2	1.4	0.3	0.2	0.5	0.9	1.9	0.0	0.0	0.2	0.0	13.2
(2)	0.3	0.9	2.5	0.9	0.0	3.2	1.4	0.3	0.2	0.5	0.9	1.9	0.0	0.0	0.2	0.0	13.2
8.1-10.4	0	0	3	0	0	1	2	1	0	0	0	2	0	0	0	0	9
(1)	0.0	0.0	0.5	0.0	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.4
(2)	0.0	0.0	0.5	0.0	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.4
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	23	37	37	37	29	143	87	40	39	25	24	33	14	20	27	17	632
(1)	3.6	5.8	5.8	5.8	4.6	22.6	13.7	6.3	6.2	3.9	3.8	5.2	2.2	3.2	4.3	2.7	99.7
(2)	3.6	5.8	5.8	5.8	4.6	22.6	13.7	6.3	6.2	3.9	3.8	5.2	2.2	3.2	4.3	2.7	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

634 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   88.1 PCT DATA RECOVERY

Table 17. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, October 1978

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	7	4	6	8	9	6	6	5	7	5	6	2	6	2	8	89
(1)	0.3	1.0	0.6	0.8	1.1	1.3	0.8	0.8	0.7	1.0	0.7	0.8	0.3	0.8	0.3	1.1	12.4
(2)	0.3	1.0	0.6	0.8	1.1	1.3	0.8	0.8	0.7	1.0	0.7	0.8	0.3	0.8	0.3	1.1	12.4
1.5- 3.0	2	4	2	12	31	50	36	29	21	8	11	10	5	13	10	6	250
(1)	0.3	0.6	0.3	1.7	4.3	7.0	5.0	4.1	2.9	1.1	1.5	1.4	0.7	1.8	1.4	0.8	34.9
(2)	0.3	0.6	0.3	1.7	4.3	7.0	5.0	4.1	2.9	1.1	1.5	1.4	0.7	1.8	1.4	0.8	34.9
3.1- 5.0	6	10	14	0	51	80	32	30	19	5	4	2	2	12	6	9	282
(1)	0.8	1.4	2.0	0.0	7.1	11.2	4.5	4.2	2.7	0.7	0.6	0.3	0.3	1.7	0.8	1.3	39.4
(2)	0.8	1.4	2.0	0.0	7.1	11.2	4.5	4.2	2.7	0.7	0.6	0.3	0.3	1.7	0.8	1.3	39.4
5.1- 8.0	4	4	7	4	0	19	9	16	3	0	2	2	0	0	0	9	79
(1)	0.6	0.6	1.0	0.6	0.0	2.7	1.3	2.2	0.4	0.0	0.3	0.3	0.0	0.0	0.0	1.3	11.0
(2)	0.6	0.6	1.0	0.6	0.0	2.7	1.3	2.2	0.4	0.0	0.3	0.3	0.0	0.0	0.0	1.3	11.0
8.1-10.4	1	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	11
(1)	0.1	0.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
(2)	0.1	0.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
OVER 10.4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
(1)	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
(2)	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
ALL SPEEDS	15	29	36	22	90	158	83	81	48	20	22	20	9	31	18	32	714
(1)	2.1	4.1	5.0	3.1	12.6	22.1	11.6	11.3	6.7	2.8	3.1	2.8	1.3	4.3	2.5	4.5	99.7
(2)	2.1	4.1	5.0	3.1	12.6	22.1	11.6	11.3	6.7	2.8	3.1	2.8	1.3	4.3	2.5	4.5	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

716 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   96.2 PCT DATA RECOVERY

Table 18. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, November 1978

SPEED (MPS)		DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4		9	8	4	6	5	9	14	10	8	2	5	4	4	4	2	5	99
	(1)	1.3	1.1	0.6	0.9	0.7	1.3	2.0	1.4	1.1	0.3	0.7	0.6	0.6	0.6	0.3	0.7	14.2
	(2)	1.3	1.1	0.6	0.9	0.7	1.3	2.0	1.4	1.1	0.3	0.7	0.6	0.6	0.6	0.3	0.7	14.2
1.5- 3.0		10	12	8	9	31	52	36	33	10	4	4	11	11	15	10	16	272
	(1)	1.4	1.7	1.1	1.3	4.4	7.4	5.2	4.7	1.4	0.6	0.6	1.6	1.6	2.1	1.4	2.3	39.0
	(2)	1.4	1.7	1.1	1.3	4.4	7.4	5.2	4.7	1.4	0.6	0.6	1.6	1.6	2.1	1.4	2.3	39.0
3.1- 5.0		10	19	20	10	41	43	21	11	8	7	9	5	11	7	5	2	229
	(1)	1.4	2.7	2.9	1.4	5.9	6.2	3.0	1.6	1.1	1.0	1.3	0.7	1.6	1.0	0.7	0.3	32.8
	(2)	1.4	2.7	2.9	1.4	5.9	6.2	3.0	1.6	1.1	1.0	1.3	0.7	1.6	1.0	0.7	0.3	32.8
5.1- 8.0		3	6	11	5	5	18	19	0	2	3	3	4	3	0	0	0	82
	(1)	0.4	0.9	1.6	0.7	0.7	2.6	2.7	0.0	0.3	0.4	0.4	0.6	0.4	0.0	0.0	0.0	11.7
	(2)	0.4	0.9	1.6	0.7	0.7	2.6	2.7	0.0	0.3	0.4	0.4	0.6	0.4	0.0	0.0	0.0	11.7
8.1-10.4		0	3	7	1	0	1	0	0	0	0	0	3	0	0	0	0	15
	(1)	0.0	0.4	1.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	2.1
	(2)	0.0	0.4	1.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	2.1
OVER 10.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS		32	48	50	31	82	123	90	54	28	16	21	27	29	26	17	23	697
	(1)	4.6	6.9	7.2	4.4	11.7	17.6	12.9	7.7	4.0	2.3	3.0	3.9	4.2	3.7	2.4	3.3	99.9
	(2)	4.6	6.9	7.2	4.4	11.7	17.6	12.9	7.7	4.0	2.3	3.0	3.9	4.2	3.7	2.4	3.3	99.9

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

698 GOOD HRS 1 HRS (0.1 PCT) LESS THAN 0.3 MPS 720 HRS IN THE TIME PERIOD 96.9 PCT DATA RECOVERY

Table 19. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, December 1978

SPEED (MPS)	DIRECTION																
	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	3	5	4	8	7	5	9	6	4	5	3	4	3	2	4	79
(1)	0.3	1.2	0.7	0.6	1.2	1.0	0.7	1.3	0.9	0.6	0.7	0.4	0.6	0.4	0.3	0.6	11.5
(2)	0.3	1.2	0.7	0.6	1.2	1.0	0.7	1.3	0.9	0.6	0.7	0.4	0.6	0.4	0.3	0.6	11.5
1.5- 3.0	16	15	8	8	17	40	32	24	12	13	10	7	9	9	7	13	240
(1)	2.3	2.2	1.2	1.2	2.5	5.8	4.7	3.5	1.8	1.9	1.5	1.0	1.3	1.3	1.0	1.9	35.0
(2)	2.3	2.2	1.2	1.2	2.5	5.8	4.7	3.5	1.8	1.9	1.5	1.0	1.3	1.3	1.0	1.9	35.0
3.1- 5.0	17	18	18	21	16	20	21	27	24	17	7	8	5	5	15	7	246
(1)	2.5	2.6	2.6	3.1	2.3	2.9	3.1	3.9	3.5	2.5	1.0	1.2	0.7	0.7	2.2	1.0	35.9
(2)	2.5	2.6	2.6	3.1	2.3	2.9	3.1	3.9	3.5	2.5	1.0	1.2	0.7	0.7	2.2	1.0	35.9
5.1- 8.0	4	6	11	9	0	1	5	11	6	13	4	6	6	7	2	6	97
(1)	0.6	0.9	1.6	1.3	0.0	0.1	0.7	1.6	0.9	1.9	0.6	0.9	0.9	1.0	0.3	0.9	14.2
(2)	0.6	0.9	1.6	1.3	0.0	0.1	0.7	1.6	0.9	1.9	0.6	0.9	0.9	1.0	0.3	0.9	14.2
8.1-10.4	0	0	5	2	0	0	0	0	1	5	1	0	0	4	0	1	19
(1)	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.1	0.7	0.1	0.0	0.0	0.6	0.0	0.1	2.8
(2)	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.1	0.7	0.1	0.0	0.0	0.6	0.0	0.1	2.8
OVER 10.4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3
ALL SPEEDS	39	47	47	44	41	68	63	71	49	52	29	24	24	28	26	31	683
(1)	5.7	6.9	6.9	6.4	6.0	9.9	9.2	10.4	7.2	7.6	4.2	3.5	3.5	4.1	3.8	4.5	99.7
(2)	5.7	6.9	6.9	6.4	6.0	9.9	9.2	10.4	7.2	7.6	4.2	3.5	3.5	4.1	3.8	4.5	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

685 GOOD HRS 2 HRS (0.3 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 92.1 PCT DATA RECOVERY

Table 20. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, January 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	2	3	2	2	8	8	12	6	5	5	1	2	3	1	2	3	65
(1)	0.3	0.4	0.3	0.3	1.2	1.2	1.8	0.9	0.7	0.7	0.1	0.3	0.4	0.1	0.3	0.4	9.6
(2)	0.3	0.4	0.3	0.3	1.2	1.2	1.8	0.9	0.7	0.7	0.1	0.3	0.4	0.1	0.3	0.4	9.6
1.5- 3.0	4	2	8	19	19	45	44	36	20	5	5	6	7	3	3	2	228
(1)	0.6	0.3	1.2	2.8	2.8	6.6	6.5	5.3	2.9	0.7	0.7	0.9	1.0	0.4	0.4	0.3	33.6
(2)	0.6	0.3	1.2	2.8	2.8	6.6	6.5	5.3	2.9	0.7	0.7	0.9	1.0	0.4	0.4	0.3	33.6
3.1- 5.0	14	6	8	11	17	39	48	38	10	3	5	13	11	3	2	3	231
(1)	2.1	0.9	1.2	1.6	2.5	5.7	7.1	5.6	1.5	0.4	0.7	1.9	1.6	0.4	0.3	0.4	34.0
(2)	2.1	0.9	1.2	1.6	2.5	5.7	7.1	5.6	1.5	0.4	0.7	1.9	1.6	0.4	0.3	0.4	34.0
5.1- 8.0	7	1	8	3	6	26	10	10	4	1	3	14	8	4	3	8	116
(1)	1.0	0.1	1.2	0.4	0.9	3.8	1.5	1.5	0.6	0.1	0.4	2.1	1.2	0.6	0.4	1.2	17.1
(2)	1.0	0.1	1.2	0.4	0.9	3.8	1.5	1.5	0.6	0.1	0.4	2.1	1.2	0.6	0.4	1.2	17.1
8.1-10.4	0	2	0	0	0	0	0	0	0	0	2	13	4	0	2	3	26
(1)	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9	0.6	0.0	0.3	0.4	3.8
(2)	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9	0.6	0.0	0.3	0.4	3.8
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	7	2	0	2	0	11
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.3	0.0	1.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.3	0.0	1.6
ALL SPEEDS	27	14	26	35	50	118	114	90	39	14	16	55	35	11	14	19	677
(1)	4.0	2.1	3.8	5.2	7.4	17.4	16.8	13.3	5.7	2.1	2.4	8.1	5.2	1.6	2.1	2.8	99.7
(2)	4.0	2.1	3.8	5.2	7.4	17.4	16.8	13.3	5.7	2.1	2.4	8.1	5.2	1.6	2.1	2.8	99.7

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

679 GOOD HRS   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   744 HRS IN THE TIME PERIOD   91.3 PCT DATA RECOVERY

Table 21. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, February 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	5	6	5	4	8	6	3	6	4	9	6	9	4	2	5	8	90
(1)	0.9	1.0	0.9	0.7	1.4	1.0	0.5	1.0	0.7	1.5	1.0	1.5	0.7	0.3	0.9	1.4	15.4
(2)	0.9	1.0	0.9	0.7	1.4	1.0	0.5	1.0	0.7	1.5	1.0	1.5	0.7	0.3	0.9	1.4	15.4
1.5- 3.0	5	14	10	4	12	36	38	26	13	11	12	4	1	8	5	10	209
(1)	0.9	2.4	1.7	0.7	2.1	6.2	6.5	4.5	2.2	1.9	2.1	0.7	0.2	1.4	0.9	1.7	35.8
(2)	0.9	2.4	1.7	0.7	2.1	6.2	6.5	4.5	2.2	1.9	2.1	0.7	0.2	1.4	0.9	1.7	35.8
3.1- 5.0	12	18	14	7	17	23	24	14	5	4	12	6	3	10	5	5	179
(1)	2.1	3.1	2.4	1.2	2.9	3.9	4.1	2.4	0.9	0.7	2.1	1.0	0.5	1.7	0.9	0.9	30.7
(2)	2.1	3.1	2.4	1.2	2.9	3.9	4.1	2.4	0.9	0.7	2.1	1.0	0.5	1.7	0.9	0.9	30.7
5.1- 8.0	3	6	5	3	3	7	14	9	2	2	4	7	6	2	6	2	81
(1)	0.5	1.0	0.9	0.5	0.5	1.2	2.4	1.5	0.3	0.3	0.7	1.2	1.0	0.3	1.0	0.3	13.9
(2)	0.5	1.0	0.9	0.5	0.5	1.2	2.4	1.5	0.3	0.3	0.7	1.2	1.0	0.3	1.0	0.3	13.9
8.1-10.4	0	0	4	0	0	0	0	0	0	0	3	3	1	2	4	0	17
(1)	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.2	0.3	0.7	0.0	2.9
(2)	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.2	0.3	0.7	0.0	2.9
OVER 10.4	0	0	2	2	0	0	0	0	0	0	0	2	1	0	0	0	7
(1)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	1.2
(2)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	1.2
ALL SPEEDS	25	44	40	20	40	72	79	55	24	26	37	31	16	24	25	25	583
(1)	4.3	7.5	6.8	3.4	6.8	12.3	13.5	9.4	4.1	4.5	6.3	5.3	2.7	4.1	4.3	4.3	99.8
(2)	4.3	7.5	6.8	3.4	6.8	12.3	13.5	9.4	4.1	4.5	6.3	5.3	2.7	4.1	4.3	4.3	99.8

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

584 GOOD HRS   1 HRS (0.2 PCT) LESS THAN 0.3 MPS   672 HRS IN THE TIME PERIOD   86.9 PCT DATA RECOVERY

Table 22. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, March 1979

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	5	4	2	4	5	6	7	5	5	2	7	1	5	1	1	5	65
(1)	0.7	0.5	0.3	0.5	0.7	0.8	1.0	0.7	0.7	0.3	1.0	0.1	0.7	0.1	0.1	0.7	8.9
(2)	0.7	0.5	0.3	0.5	0.7	0.8	1.0	0.7	0.7	0.3	1.0	0.1	0.7	0.1	0.1	0.7	8.9
1.5- 3.0	12	14	4	8	12	29	35	22	17	17	11	11	5	3	6	16	222
(1)	1.6	1.9	0.5	1.1	1.6	4.0	4.8	3.0	2.3	2.3	1.5	1.5	0.7	0.4	0.8	2.2	30.4
(2)	1.6	1.9	0.5	1.1	1.6	4.0	4.8	3.0	2.3	2.3	1.5	1.5	0.7	0.4	0.8	2.2	30.4
3.1- 5.0	4	4	10	17	24	36	37	19	7	8	12	14	6	12	7	3	220
(1)	0.5	0.5	1.4	2.3	3.3	4.9	5.1	2.6	1.0	1.1	1.6	1.9	0.8	1.6	1.0	0.4	30.1
(2)	0.5	0.5	1.4	2.3	3.3	4.9	5.1	2.6	1.0	1.1	1.6	1.9	0.8	1.6	1.0	0.4	30.1
5.1- 8.0	2	2	5	36	17	25	7	11	0	3	15	31	6	0	3	4	167
(1)	0.3	0.3	0.7	4.9	2.3	3.4	1.0	1.5	0.0	0.4	2.1	4.2	0.8	0.0	0.4	0.5	22.9
(2)	0.3	0.3	0.7	4.9	2.3	3.4	1.0	1.5	0.0	0.4	2.1	4.2	0.8	0.0	0.4	0.5	22.9
8.1-10.4	0	1	1	10	0	0	5	0	0	0	6	13	2	0	0	2	40
(1)	0.0	0.1	0.1	1.4	0.0	0.0	0.7	0.0	0.0	0.0	0.8	1.8	0.3	0.0	0.0	0.3	5.5
(2)	0.0	0.1	0.1	1.4	0.0	0.0	0.7	0.0	0.0	0.0	0.8	1.8	0.3	0.0	0.0	0.3	5.5
OVER 10.4	0	0	0	0	0	0	0	0	0	0	4	5	4	0	0	0	13
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.5	0.0	0.0	0.0	1.8
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.5	0.0	0.0	0.0	1.8
ALL SPEEDS	23	25	22	75	58	96	91	57	29	30	55	75	28	16	17	30	727
(1)	3.2	3.4	3.0	10.3	7.9	13.2	12.5	7.8	4.0	4.1	7.5	10.3	3.8	2.2	2.3	4.1	99.6
(2)	3.2	3.4	3.0	10.3	7.9	13.2	12.5	7.8	4.0	4.1	7.5	10.3	3.8	2.2	2.3	4.1	99.6

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

730 GOOD HRS 3 HRS (0.4 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 98.1 PCT DATA RECOVERY

Table 23. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, April 1979

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	4	0	3	3	4	7	2	2	2	4	1	3	4	1	3	1	44
(1)	0.6	0.0	0.4	0.4	0.6	1.0	0.3	0.3	0.3	0.6	0.1	0.4	0.6	0.1	0.4	0.1	6.5
(2)	0.6	0.0	0.4	0.4	0.6	1.0	0.3	0.3	0.3	0.6	0.1	0.4	0.6	0.1	0.4	0.1	6.5
1.5- 3.0	4	8	5	10	21	19	13	27	10	11	12	3	3	7	10	4	167
(1)	0.6	1.2	0.7	1.5	3.1	2.8	1.9	4.0	1.5	1.6	1.8	0.4	0.4	1.0	1.5	0.6	24.8
(2)	0.6	1.2	0.7	1.5	3.1	2.8	1.9	4.0	1.5	1.6	1.8	0.4	0.4	1.0	1.5	0.6	24.8
3.1- 5.0	2	7	12	12	43	61	31	17	10	7	10	5	9	3	3	3	235
(1)	0.3	1.0	1.8	1.8	6.4	9.1	4.6	2.5	1.5	1.0	1.5	0.7	1.3	0.4	0.4	0.4	34.9
(2)	0.3	1.0	1.8	1.8	6.4	9.1	4.6	2.5	1.5	1.0	1.5	0.7	1.3	0.4	0.4	0.4	34.9
5.1- 8.0	8	3	13	20	18	34	15	3	1	10	7	6	4	0	7	4	153
(1)	1.2	0.4	1.9	3.0	2.7	5.0	2.2	0.4	0.1	1.5	1.0	0.9	0.6	0.0	1.0	0.6	22.7
(2)	1.2	0.4	1.9	3.0	2.7	5.0	2.2	0.4	0.1	1.5	1.0	0.9	0.6	0.0	1.0	0.6	22.7
8.1-10.4	0	0	11	3	0	5	4	0	0	1	7	9	5	2	3	0	50
(1)	0.0	0.0	1.6	0.4	0.0	0.7	0.6	0.0	0.0	0.1	1.0	1.3	0.7	0.3	0.4	0.0	7.4
(2)	0.0	0.0	1.6	0.4	0.0	0.7	0.6	0.0	0.0	0.1	1.0	1.3	0.7	0.3	0.4	0.0	7.4
OVER 10.4	0	0	0	0	0	0	0	0	0	0	6	11	4	0	3	0	24
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.6	0.6	0.0	0.4	0.0	3.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.6	0.6	0.0	0.4	0.0	3.6
ALL SPEEDS	18	18	44	48	86	126	65	49	23	33	43	37	29	13	29	12	673
(1)	2.7	2.7	6.5	7.1	12.8	18.7	9.6	7.3	3.4	4.9	6.4	5.5	4.3	1.9	4.3	1.8	99.9
(2)	2.7	2.7	6.5	7.1	12.8	18.7	9.6	7.3	3.4	4.9	6.4	5.5	4.3	1.9	4.3	1.8	99.9

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

674 GOOD HRS   1 HRS (0.1 PCT) LESS THAN 0.3 MPS   720 HRS IN THE TIME PERIOD   93.6 PCT DATA RECOVERY

Table 24. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, May 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	3	1	4	3	3	3	5	2	5	3	1	2	3	1	1	2	42
(1)	0.5	0.2	0.6	0.5	0.5	0.5	0.8	0.3	0.8	0.5	0.2	0.3	0.5	0.2	0.2	0.3	6.5
(2)	0.5	0.2	0.6	0.5	0.5	0.5	0.8	0.3	0.8	0.5	0.2	0.3	0.5	0.2	0.2	0.3	6.5
1.5- 3.0	6	13	6	10	20	23	21	23	18	6	9	6	7	5	6	13	192
(1)	0.9	2.0	0.9	1.5	3.1	3.6	3.2	3.6	2.8	0.9	1.4	0.9	1.1	0.8	0.9	2.0	29.7
(2)	0.9	2.0	0.9	1.5	3.1	3.6	3.2	3.6	2.8	0.9	1.4	0.9	1.1	0.8	0.9	2.0	29.7
3.1- 5.0	10	5	1	13	36	49	33	23	19	11	3	16	7	6	10	9	251
(1)	1.5	0.8	0.2	2.0	5.6	7.6	5.1	3.6	2.9	1.7	0.5	2.5	1.1	0.9	1.5	1.4	38.8
(2)	1.5	0.8	0.2	2.0	5.6	7.6	5.1	3.6	2.9	1.7	0.5	2.5	1.1	0.9	1.5	1.4	38.8
5.1- 8.0	7	3	1	4	15	42	17	5	12	6	4	6	3	2	3	11	141
(1)	1.1	0.5	0.2	0.6	2.3	6.5	2.6	0.8	1.9	0.9	0.6	0.9	0.5	0.3	0.5	1.7	21.8
(2)	1.1	0.5	0.2	0.6	2.3	6.5	2.6	0.8	1.9	0.9	0.6	0.9	0.5	0.3	0.5	1.7	21.8
8.1-10.4	0	1	1	0	0	3	1	0	7	5	3	0	0	0	0	0	21
(1)	0.0	0.2	0.2	0.0	0.0	0.5	0.2	0.0	1.1	0.8	0.5	0.0	0.0	0.0	0.0	0.0	3.2
(2)	0.0	0.2	0.2	0.0	0.0	0.5	0.2	0.0	1.1	0.8	0.5	0.0	0.0	0.0	0.0	0.0	3.2
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	26	23	13	30	74	120	77	53	61	31	20	30	20	14	20	35	647
(1)	4.0	3.6	2.0	4.6	11.4	18.5	11.9	8.2	9.4	4.8	3.1	4.6	3.1	2.2	3.1	5.4	100.0
(2)	4.0	3.6	2.0	4.6	11.4	18.5	11.9	8.2	9.4	4.8	3.1	4.6	3.1	2.2	3.1	5.4	100.0

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

647 GOOD HRS 0 HRS (0.0 PCT) LESS THAN 0.3 MPS 744 HRS IN THE TIME PERIOD 87.0 PCT DATA RECOVERY

Table 25. Distribution of Wind Directions and Speeds at the WIPP Site, Stability A, June 1, 1977-May 31, 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
								DIRECTION									
0.3- 1.4	13	10	17	12	20	26	28	34	35	39	27	28	23	25	17	12	366
(1)	0.2	0.2	0.3	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.5	0.5	0.4	0.4	0.3	0.2	6.3
(2)	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	2.3
1.5- 3.0	44	39	39	45	109	191	153	223	212	121	92	76	67	86	79	64	1640
(1)	0.8	0.7	0.7	0.8	1.9	3.3	2.6	3.9	3.7	2.1	1.6	1.3	1.2	1.5	1.4	1.1	28.4
(2)	0.3	0.2	0.2	0.3	0.7	1.2	1.0	1.4	1.3	0.8	0.6	0.5	0.4	0.5	0.5	0.4	10.4
3.1- 5.0	51	58	65	97	95	254	390	415	218	105	102	98	64	97	70	55	2234
(1)	0.9	1.0	1.1	1.7	1.6	4.4	6.7	7.2	3.8	1.8	1.8	1.7	1.1	1.7	1.2	1.0	38.6
(2)	0.3	0.4	0.4	0.6	0.6	1.6	2.5	2.6	1.4	0.7	0.6	0.6	0.4	0.6	0.4	0.3	14.2
5.1- 8.0	45	41	64	66	23	116	214	145	66	58	91	115	36	22	34	59	1195
(1)	0.8	0.7	1.1	1.1	0.4	2.0	3.7	2.5	1.1	1.0	1.6	2.0	0.6	0.4	0.6	1.0	20.7
(2)	0.3	0.3	0.4	0.4	0.1	0.7	1.4	0.9	0.4	0.4	0.6	0.7	0.2	0.1	0.2	0.4	7.6
8.1-10.4	2	7	15	8	2	12	15	5	10	18	45	77	16	12	13	5	262
(1)	0.0	0.1	0.3	0.1	0.0	0.2	0.3	0.1	0.2	0.3	0.8	1.3	0.3	0.2	0.2	0.1	4.5
(2)	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.3	0.5	0.1	0.1	0.1	0.0	1.7
OVER 10.4	0	3	2	1	0	1	0	0	0	0	13	35	11	0	6	3	75
(1)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.2	0.0	0.1	0.1	1.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.5
ALL SPEEDS	155	158	202	229	249	600	800	822	541	341	373	429	217	242	219	198	5772
(1)	2.7	2.7	3.5	4.0	4.3	10.4	13.8	14.2	9.4	5.9	6.4	7.4	3.8	4.2	3.8	3.4	99.8
(2)	1.0	1.0	1.3	1.5	1.6	3.8	5.1	5.2	3.4	2.2	2.3	2.7	1.4	1.5	1.4	1.3	36.6

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

5782 HRS ON THIS PAGE 10 HRS (0.2 PCT) LESS THAN 0.3 MPS (0.1 PCT OF ALL HRS)

Table 26. Distribution of Wind Directions and Speeds at the WIPP Site, Stability B, June 1, 1977-May 31, 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	1	1	1	0	0	3	2	2	3	1	3	4	1	3	3	2	30
(1)	0.6	0.6	0.6	0.0	0.0	1.7	1.1	1.1	1.7	0.6	1.7	2.3	0.6	1.7	1.7	1.1	17.2
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1.5- 3.0	4	0	1	5	6	5	5	6	1	3	0	6	4	3	4	3	56
(1)	2.3	0.0	0.6	2.9	3.4	2.9	2.9	3.4	0.6	1.7	0.0	3.4	2.3	1.7	2.3	1.7	32.2
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
3.1- 5.0	1	2	9	6	4	9	8	4	0	2	0	1	0	0	0	0	46
(1)	0.6	1.1	5.2	3.4	2.3	5.2	4.6	2.3	0.0	1.1	0.0	0.6	0.0	0.0	0.0	0.0	26.4
(2)	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
5.1- 8.0	2	0	2	5	2	3	5	0	1	2	0	1	0	1	1	3	28
(1)	1.1	0.0	1.1	2.9	1.1	1.7	2.9	0.0	0.6	1.1	0.0	0.6	0.0	0.6	0.6	1.7	16.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
8.1-10.4	0	0	2	3	1	1	0	0	0	0	0	1	1	0	0	0	9
(1)	0.0	0.0	1.1	1.7	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	5.2
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
OVER 10.4	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	4
(1)	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6	2.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	8	3	16	20	13	21	20	12	5	8	3	14	6	7	8	9	173
(1)	4.6	1.7	9.2	11.5	7.5	12.1	11.5	6.9	2.9	4.6	1.7	8.0	3.4	4.0	4.6	5.2	99.4
(2)	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.1	1.1

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

174 HRS ON THIS PAGE 1 HRS (0.6 PCT) LESS THAN 0.3 MPS (0.0 PCT OF ALL HRS)

Table 27. Distribution of Wind Directions and Speeds at the WIPP Site, Stability C, June 1, 1977-May 31, 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
								DIRECTION									
0.3- 1.4	1	0	0	0	0	0	0	1	0	2	1	1	1	0	0	0	7
(1)	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	2.2	1.1	1.1	1.1	0.0	0.0	0.0	7.5
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5- 3.0	1	5	0	0	2	4	4	3	2	2	1	1	0	2	2	1	30
(1)	1.1	5.4	0.0	0.0	2.2	4.3	4.3	3.2	2.2	2.2	1.1	1.1	0.0	2.2	2.2	1.1	32.3
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
3.1- 5.0	3	4	3	2	3	5	5	2	2	1	1	1	0	1	0	1	34
(1)	3.2	4.3	3.2	2.2	3.2	5.4	5.4	2.2	2.2	1.1	1.1	1.1	0.0	1.1	0.0	1.1	36.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
5.1- 8.0	3	0	2	3	1	0	0	0	0	2	0	2	0	1	0	0	14
(1)	3.2	0.0	2.2	3.2	1.1	0.0	0.0	0.0	0.0	2.2	0.0	2.2	0.0	1.1	0.0	0.0	15.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
8.1-10.4	0	0	2	2	0	1	0	0	0	1	1	0	0	0	0	0	7
(1)	0.0	0.0	2.2	2.2	0.0	1.1	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	7.5
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 10.4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	1.1
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	8	9	7	7	6	10	9	6	4	8	4	6	1	4	2	2	93
(1)	8.6	9.7	7.5	7.5	6.5	10.8	9.7	6.5	4.3	8.6	4.3	6.5	1.1	4.3	2.2	2.2	100.0
(2)	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

93 HRS ON THIS PAGE 0 HRS (0.0 PCT) LESS THAN 0.3 MPS (0.0 PCT OF ALL HRS)

Table 28. Distribution of Wind Directions and Speeds at the WIPP Site, Stability D, June 1, 1977-May 31, 1979

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	4	3	5	2	5	2	6	5	5	8	7	5	7	3	4	4	75
(1)	0.6	0.4	0.7	0.3	0.7	0.3	0.9	0.7	0.7	1.2	1.0	0.7	1.0	0.4	0.6	0.6	11.2
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5
1.5- 3.0	5	8	7	13	24	25	20	15	18	9	8	2	4	6	5	5	174
(1)	0.7	1.2	1.0	1.9	3.6	3.7	3.0	2.2	2.7	1.3	1.2	0.3	0.6	0.9	0.7	0.7	26.0
(2)	0.0	0.1	0.0	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	1.1
3.1- 5.0	13	13	27	27	27	31	25	28	8	4	4	6	2	1	1	1	218
(1)	1.9	1.9	4.0	4.0	4.0	4.6	3.7	4.2	1.2	0.6	0.6	0.9	0.3	0.1	0.1	0.1	32.6
(2)	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
5.1- 8.0	9	7	25	32	14	11	15	7	2	2	7	7	1	4	2	5	150
(1)	1.3	1.0	3.7	4.8	2.1	1.6	2.2	1.0	0.3	0.3	1.0	1.0	0.1	0.6	0.3	0.7	22.5
(2)	0.1	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
8.1-10.4	1	2	11	10	2	2	2	1	0	1	2	1	1	0	1	0	37
(1)	0.1	0.3	1.6	1.5	0.3	0.3	0.3	0.1	0.0	0.1	0.3	0.1	0.1	0.0	0.1	0.0	5.5
(2)	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
OVER 10.4	0	0	6	1	1	0	0	0	0	0	0	2	1	0	0	1	12
(1)	0.0	0.0	0.9	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.1	1.8
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ALL SPEEDS	32	33	81	85	73	71	68	56	33	24	28	23	16	14	13	16	666
(1)	4.8	4.9	12.1	12.7	10.9	10.6	10.2	8.4	4.9	3.6	4.2	3.4	2.4	2.1	1.9	2.4	99.7
(2)	0.2	0.2	0.5	0.5	0.5	0.5	0.4	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	4.2

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

668 HRS ON THIS PAGE   2 HRS (0.3 PCT) LESS THAN 0.3 MPS   (0.0 PCT OF ALL HRS)

Table 29. Distribution of Wind Directions and Speeds at the WIPP Site, Stability E, June 1, 1977-May 31, 1979

SPEED (MPS)	DIRECTION NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	4	6	7	7	10	17	11	7	9	6	9	7	9	4	10	9	132
(1)	0.3	0.4	0.5	0.5	0.7	1.2	0.8	0.5	0.6	0.4	0.6	0.5	0.6	0.3	0.7	0.6	9.1
(2)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.8
1.5- 3.0	11	15	12	20	49	68	31	43	17	9	8	7	4	16	12	12	334
(1)	0.8	1.0	0.8	1.4	3.4	4.7	2.1	3.0	1.2	0.6	0.6	0.5	0.3	1.1	0.8	0.8	23.0
(2)	0.1	0.1	0.1	0.1	0.3	0.4	0.2	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	2.1
3.1- 5.0	31	42	34	38	62	111	62	42	8	11	3	7	2	7	14	22	496
(1)	2.1	2.9	2.3	2.6	4.3	7.6	4.3	2.9	0.6	0.8	0.2	0.5	0.1	0.5	1.0	1.5	34.2
(2)	0.2	0.3	0.2	0.2	0.4	0.7	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	3.1
5.1- 8.0	17	27	40	41	40	61	56	9	4	4	4	16	4	4	5	19	351
(1)	1.2	1.9	2.8	2.8	2.8	4.2	3.9	0.6	0.3	0.3	0.3	1.1	0.3	0.3	0.3	1.3	24.2
(2)	0.1	0.2	0.3	0.3	0.3	0.4	0.4	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	2.2
8.1-10.4	1	9	31	19	0	10	13	0	0	2	3	3	7	2	1	5	106
(1)	0.1	0.6	2.1	1.3	0.0	0.7	0.9	0.0	0.0	0.1	0.2	0.2	0.5	0.1	0.1	0.3	7.3
(2)	0.0	0.1	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
OVER 10.4	0	3	11	5	0	1	2	0	0	0	0	4	2	0	2	0	30
(1)	0.0	0.2	0.8	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.1	0.0	2.1
(2)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
ALL SPEEDS	64	102	135	130	161	268	175	101	38	32	27	44	28	33	44	67	1449
(1)	4.4	7.0	9.3	9.0	11.1	18.5	12.1	7.0	2.6	2.2	1.9	3.0	1.9	2.3	3.0	4.6	99.9
(2)	0.4	0.6	0.9	0.8	1.0	1.7	1.1	0.6	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.4	9.2

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1451 HRS ON THIS PAGE   2 HRS (0.1 PCT) LESS THAN 0.3 MPS   (0.0 PCT OF ALL HRS)

Table 30. Distribution of Wind Directions and Speeds at the WIPP Site, Stability F, June 1, 1977-May 31, 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	6	10	5	4	22	16	10	6	7	5	0	2	8	3	5	13	122
(1)	0.3	0.5	0.3	0.2	1.1	0.8	0.5	0.3	0.4	0.3	0.0	0.1	0.4	0.2	0.3	0.7	6.2
(2)	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.8
1.5- 3.0	9	22	9	23	94	132	39	17	7	11	6	7	6	4	7	19	412
(1)	0.5	1.1	0.5	1.2	4.8	6.7	2.0	0.9	0.4	0.6	0.3	0.4	0.3	0.2	0.4	1.0	21.0
(2)	0.1	0.1	0.1	0.1	0.6	0.8	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.6
3.1- 5.0	15	27	33	36	97	224	140	45	4	0	9	9	6	4	17	11	677
(1)	0.8	1.4	1.7	1.8	4.9	11.4	7.1	2.3	0.2	0.0	0.5	0.5	0.3	0.2	0.9	0.6	34.5
(2)	0.1	0.2	0.2	0.2	0.6	1.4	0.9	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	4.3
5.1- 8.0	7	15	31	48	26	198	229	6	0	3	8	28	13	11	2	12	637
(1)	0.4	0.8	1.6	2.4	1.3	10.1	11.7	0.3	0.0	0.2	0.4	1.4	0.7	0.6	0.1	0.6	32.5
(2)	0.0	0.1	0.2	0.3	0.2	1.3	1.5	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.0	0.1	4.0
8.1-10.4	0	4	10	4	0	14	41	0	0	1	3	8	4	0	4	4	97
(1)	0.0	0.2	0.5	0.2	0.0	0.7	2.1	0.0	0.0	0.1	0.2	0.4	0.2	0.0	0.2	0.2	4.9
(2)	0.0	0.0	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.6
OVER 10.4	0	2	0	0	0	1	0	0	0	0	2	3	5	0	0	1	14
(1)	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.1	0.7
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
ALL SPEEDS	37	80	88	115	239	585	459	74	18	20	28	57	42	22	35	60	1959
(1)	1.9	4.1	4.5	5.9	12.2	29.8	23.4	3.8	0.9	1.0	1.4	2.9	2.1	1.1	1.8	3.1	99.9
(2)	0.2	0.5	0.6	0.7	1.5	3.7	2.9	0.5	0.1	0.1	0.2	0.4	0.3	0.1	0.2	0.4	12.4

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

1961 HRS ON THIS PAGE 2 HRS (0.1 PCT) LESS THAN 0.3 MPS (0.0 PCT OF ALL HRS)

Table 31. Distribution of Wind Directions and Speeds at the WIPP Site, Stability G, June 1, 1977–May 31, 1979

SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
	DIRECTION																
0.3- 1.4	47	65	51	54	170	223	94	70	52	38	32	44	36	24	31	37	1068
(1)	0.8	1.2	0.9	1.0	3.0	4.0	1.7	1.2	0.9	0.7	0.6	0.8	0.6	0.4	0.6	0.7	19.0
(2)	0.3	0.4	0.3	0.3	1.1	1.4	0.6	0.4	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	6.8
1.5- 3.0	90	136	92	84	247	594	385	221	105	71	82	49	53	63	74	88	2434
(1)	1.6	2.4	1.6	1.5	4.4	10.5	6.8	3.9	1.9	1.3	1.5	0.9	0.9	1.1	1.3	1.6	43.2
(2)	0.6	0.9	0.6	0.5	1.6	3.8	2.4	1.4	0.7	0.5	0.5	0.3	0.3	0.4	0.5	0.6	15.4
3.1- 5.0	75	82	76	63	157	492	312	59	23	45	62	77	62	40	47	47	1719
(1)	1.3	1.5	1.3	1.1	2.8	8.7	5.5	1.0	0.4	0.8	1.1	1.4	1.1	0.7	0.8	0.8	30.5
(2)	0.5	0.5	0.5	0.4	1.0	3.1	2.0	0.4	0.1	0.3	0.4	0.5	0.4	0.3	0.3	0.3	10.9
5.1- 8.0	4	11	18	20	17	92	42	11	5	8	17	34	26	8	16	10	339
(1)	0.1	0.2	0.3	0.4	0.3	1.6	0.7	0.2	0.1	0.1	0.3	0.6	0.5	0.1	0.3	0.2	6.0
(2)	0.0	0.1	0.1	0.1	0.1	0.6	0.3	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.1	0.1	2.2
8.1-10.4	0	2	3	6	0	0	6	0	1	0	1	8	4	0	1	1	33
(1)	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.6
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2
OVER 10.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL SPEEDS	216	296	240	228	591	1401	839	361	166	162	194	212	181	135	169	183	5594
(1)	3.8	5.3	4.3	4.0	10.5	24.9	14.9	6.4	3.3	2.9	3.4	3.8	3.2	2.4	3.0	3.2	99.3
(2)	1.4	1.9	1.5	1.4	3.7	8.9	5.3	2.3	1.2	1.0	1.2	1.3	1.1	0.9	1.1	1.2	35.5

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

5633 HRS ON THIS PAGE   39 HRS (0.7 PCT) LESS THAN 0.3 MPS   (0.2 PCT OF ALL HRS)

Table 32. Distribution of Wind Directions and Speeds at the WIPP Site, All Stabilities Combined, June 1, 1977-May 31, 1979

	DIRECTION																
SPEED (MPS)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	TOTAL
0.3- 1.4	76	95	86	79	227	287	151	125	111	99	79	91	85	62	70	77	1800
(1)	0.5	0.6	0.5	0.5	1.4	1.8	1.0	0.8	0.7	0.6	0.5	0.6	0.5	0.4	0.4	0.5	11.4
(2)	0.5	0.6	0.5	0.5	1.4	1.8	1.0	0.8	0.7	0.6	0.5	0.6	0.5	0.4	0.4	0.5	11.4
1.5- 3.0	164	225	160	190	531	1019	637	528	362	226	197	148	138	180	183	192	5080
(1)	1.0	1.4	1.0	1.2	3.4	6.5	4.0	3.3	2.3	1.4	1.2	0.9	0.9	1.1	1.2	1.2	32.2
(2)	1.0	1.4	1.0	1.2	3.4	6.5	4.0	3.3	2.3	1.4	1.2	0.9	0.9	1.1	1.2	1.2	32.2
3.1- 5.0	189	228	247	269	445	1126	942	595	263	168	181	199	136	150	149	137	5424
(1)	1.2	1.4	1.6	1.7	2.8	7.1	6.0	3.8	1.7	1.1	1.1	1.3	0.9	1.0	0.9	0.9	34.4
(2)	1.2	1.4	1.6	1.7	2.8	7.1	6.0	3.8	1.7	1.1	1.1	1.3	0.9	1.0	0.9	0.9	34.4
5.1- 8.0	87	101	162	215	123	481	561	176	78	79	127	203	80	51	60	108	2714
(1)	0.6	0.6	1.2	1.4	0.8	3.1	3.6	1.1	0.5	0.5	0.8	1.3	0.5	0.3	0.4	0.7	17.2
(2)	0.6	0.6	1.2	1.4	0.8	3.1	3.6	1.1	0.5	0.5	0.8	1.3	0.5	0.3	0.4	0.7	17.2
8.1-10.4	4	24	74	52	5	40	77	6	11	23	55	98	33	14	20	15	551
(1)	0.0	0.2	0.5	0.3	0.0	0.3	0.5	0.0	0.1	0.1	0.3	0.6	0.2	0.1	0.1	0.1	3.5
(2)	0.0	0.2	0.5	0.3	0.0	0.3	0.5	0.0	0.1	0.1	0.3	0.6	0.2	0.1	0.1	0.1	3.5
OVER 10.4	0	8	20	9	1	3	2	0	0	0	15	46	19	0	8	6	137
(1)	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.1	0.0	0.9
(2)	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.1	0.0	0.9
ALL SPEEDS	520	681	769	814	1332	2956	2370	1432	825	595	654	785	491	457	490	535	15706
(1)	3.3	4.3	4.9	5.2	8.5	18.8	15.0	9.1	5.2	3.8	4.1	5.0	3.1	2.9	3.1	3.4	99.6
(2)	3.3	4.3	4.9	5.2	8.5	18.8	15.0	9.1	5.2	3.8	4.1	5.0	3.1	2.9	3.1	3.4	99.6

(1)=PERCENT OF ALL GOOD OBS FOR THIS PAGE
(2)=PERCENT OF ALL GOOD OBS FOR THE PERIOD

15762 GOOD HRS 56 HRS (0.4 PCT) LESS THAN 0.3 MPS 17520 HRS IN THE TIME PERIOD 90.0 PCT DATA RECOVERY

Table 33. One-Hour Frequency Distribution X/Q Values for the WIPP Site

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	805	0.110E-02	0.284E-03	0.606E-04
SW	805	0.110E-02	0.276E-03	0.621E-04
WSW	805	0.110E-02	0.265E-03	0.421E-04
W	805	0.110E-02	0.276E-03	0.543E-04
WNW	805	0.110E-02	0.329E-03	0.633E-04
NW	805	0.110E-02	0.259E-03	0.619E-04
NNW	805	0.110E-02	0.230E-03	0.569E-04
N	805	0.110E-02	0.231E-03	0.279E-04
NNE	805	0.110E-02	0.253E-03	0.155E-04
NE	805	0.110E-02	0.263E-03	0.302E-04
ENE	805	0.110E-02	0.277E-03	0.244E-04
E	805	0.110E-02	0.251E-03	0.255E-04
ESE	805	0.822E-03	0.268E-03	0.508E-04
SE	805	0.110E-02	0.257E-03	0.452E-04
SSE	805	0.110E-02	0.276E-03	0.519E-04
S	805	0.110E-02	0.250E-03	0.580E-04
ALL		0.110E-02	0.263E-03	0.581E-04

Table 33. One-Hour Frequency Distribution X/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	2414	0.450E-03	0.111E-03	0.139E-04
SW	2414	0.450E-03	0.954E-04	0.156E-04
WSW	2414	0.450E-03	0.930E-04	0.857E-05
W	2414	0.450E-03	0.902E-04	0.104E-04
WNW	2414	0.450E-03	0.133E-03	0.192E-04
NW	2414	0.450E-03	0.927E-04	0.153E-04
NNW	2414	0.450E-03	0.740E-04	0.108E-04
N	2414	0.450E-03	0.820E-04	0.425E-05
NNE	2414	0.450E-03	0.940E-04	0.175E-05
NE	2414	0.450E-03	0.953E-04	0.496E-05
ENE	2414	0.450E-03	0.844E-04	0.405E-05
E	2414	0.450E-03	0.839E-04	0.432E-05
ESE	2414	0.338E-03	0.905E-04	0.106E-04
SE	2414	0.450E-03	0.800E-04	0.917E-05
SSE	2414	0.450E-03	0.904E-04	0.113E-04
S	2414	0.450E-03	0.820E-04	0.116E-04
ALL		0.450E-03	0.908E-04	0.114E-04

Table 33. One-Hour Frequency Distribution χ/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q (SEC PER CUBIC METER)	5 PCT CHI/Q (SEC PER CUBIC METER)	50 PCT CHI/Q (SEC PER CUBIC METER)
SSW	4023	0.293E-03	0.697E-04	0.703E-05
SW	4023	0.293E-03	0.615E-04	0.797E-05
WSW	4023	0.293E-03	0.586E-04	0.412E-05
W	4023	0.293E-03	0.563E-04	0.500E-05
WNW	4023	0.293E-03	0.880E-04	0.104E-04
NW	4023	0.293E-03	0.592E-04	0.780E-05
NNW	4023	0.293E-03	0.470E-04	0.518E-05
N	4023	0.293E-03	0.521E-04	0.179E-05
NNE	4023	0.293E-03	0.583E-04	0.693E-06
NE	4023	0.293E-03	0.613E-04	0.223E-05
ENE	4023	0.293E-03	0.550E-04	0.130E-05
E	4023	0.293E-03	0.513E-04	0.198E-05
ESE	4023	0.220E-03	0.566E-04	0.515E-05
SE	4023	0.293E-03	0.506E-04	0.449E-05
SSE	4023	0.293E-03	0.569E-04	0.554E-05
S	4023	0.293E-03	0.515E-04	0.566E-05
ALL		0.293E-03	0.580E-04	0.554E-05

Table 33. One-Hour Frequency Distribution χ/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	5633	0.219E-03	0.521E-04	0.454E-05
SW	5633	0.219E-03	0.453E-04	0.517E-05
WSW	5633	0.219E-03	0.434E-04	0.255E-05
W	5633	0.219E-03	0.419E-04	0.314E-05
WNW	5633	0.219E-03	0.679E-04	0.698E-05
NW	5633	0.219E-03	0.443E-04	0.512E-05
NNW	5633	0.219E-03	0.338E-04	0.323E-05
N	5633	0.219E-03	0.389E-04	0.104E-05
NNE	5633	0.219E-03	0.427E-04	0.410E-06
NE	5633	0.219E-03	0.450E-04	0.130E-05
ENE	5633	0.219E-03	0.400E-04	0.107E-05
E	5633	0.219E-03	0.381E-04	0.118E-05
ESE	5633	0.164E-03	0.420E-04	0.323E-05
SE	5633	0.219E-03	0.391E-04	0.277E-05
SSE	5633	0.219E-03	0.428E-04	0.359E-05
S	5633	0.219E-03	0.372E-04	0.359E-05
ALL		0.219E-03	0.434E-04	0.350E-05

Table 33. One-Hour Frequency Distribution X/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	7242	0.176E-03	0.423E-04	0.315E-05
SW	7242	0.176E-03	0.377E-04	0.370E-05
WSW	7242	0.176E-03	0.349E-04	0.180E-05
W	7242	0.176E-03	0.326E-04	0.223E-05
WNW	7242	0.176E-03	0.524E-04	0.526E-05
NW	7242	0.176E-03	0.356E-04	0.367E-05
NNW	7242	0.176E-03	0.265E-04	0.230E-05
N	7242	0.176E-03	0.303E-04	0.685E-06
NNE	7242	0.176E-03	0.333E-04	0.256E-06
NE	7242	0.176E-03	0.363E-04	0.381E-06
ENE	7242	0.176E-03	0.311E-04	0.725E-06
E	7242	0.176E-03	0.297E-04	0.825E-06
ESE	7242	0.132E-03	0.327E-04	0.229E-05
SE	7242	0.176E-03	0.309E-04	0.178E-05
SSE	7242	0.176E-03	0.333E-04	0.257E-05
S	7242	0.176E-03	0.292E-04	0.259E-05
ALL		0.176E-03	0.341E-04	0.249E-05

Table 33. One-Hour Frequency Distribution X/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	12070	0.111E-03	0.275E-04	0.164E-05
SW	12070	0.111E-03	0.235E-04	0.192E-05
WSW	12070	0.111E-03	0.223E-04	0.891E-06
W	12070	0.111E-03	0.198E-04	0.113E-05
WNW	12070	0.111E-03	0.346E-04	0.283E-05
NW	12070	0.111E-03	0.224E-04	0.194E-05
NNW	12070	0.111E-03	0.164E-04	0.117E-05
N	12070	0.111E-03	0.192E-04	0.298E-06
NNE	12070	0.111E-03	0.212E-04	0.115E-06
NE	12070	0.111E-03	0.226E-04	0.404E-06
ENE	12070	0.111E-03	0.214E-04	0.326E-06
E	12070	0.111E-03	0.186E-04	0.384E-06
ESE	12070	0.835E-04	0.200E-04	0.115E-05
SE	12070	0.111E-03	0.194E-04	0.981E-06
SSE	12070	0.111E-03	0.213E-04	0.130E-05
S	12070	0.111E-03	0.184E-04	0.131E-05
ALL		0.111E-03	0.218E-04	0.127E-05

Table 33. One-Hour Frequency Distribution X/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	24140	0.599E-04	0.139E-04	0.692E-06
SW	24140	0.599E-04	0.123E-04	0.803E-06
WSW	24140	0.599E-04	0.116E-04	0.363E-06
W	24140	0.599E-04	0.102E-04	0.471E-06
WNW	24140	0.599E-04	0.182E-04	0.126E-05
NW	24140	0.599E-04	0.117E-04	0.831E-06
NNW	24140	0.599E-04	0.852E-05	0.493E-06
N	24140	0.599E-04	0.100E-04	0.101E-06
NNE	24140	0.599E-04	0.111E-04	0.398E-07
NE	24140	0.599E-04	0.114E-04	0.145E-06
ENE	24140	0.599E-04	0.111E-04	0.111E-06
E	24140	0.599E-04	0.945E-05	0.148E-06
ESE	24140	0.450E-04	0.105E-04	0.479E-06
SE	24140	0.599E-04	0.997E-05	0.395E-06
SSE	24140	0.599E-04	0.111E-04	0.526E-06
S	24140	0.599E-04	0.957E-05	0.534E-06
ALL		0.599E-04	0.114E-04	0.527E-06

Table 33. One-Hour Frequency Distribution χ/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
			(SEC PER CUBIC METER)	
SSW	40233	0.383E-04	0.878E-05	0.368E-06
SW	40233	0.383E-04	0.803E-05	0.445E-06
WSW	40233	0.383E-04	0.763E-05	0.195E-06
W	40233	0.383E-04	0.649E-05	0.256E-06
WNW	40233	0.383E-04	0.114E-04	0.711E-06
NW	40233	0.383E-04	0.779E-05	0.466E-06
NNW	40233	0.383E-04	0.536E-05	0.269E-06
N	40233	0.383E-04	0.647E-05	0.472E-07
NNE	40233	0.383E-04	0.706E-05	0.174E-07
NE	40233	0.383E-04	0.749E-05	0.714E-07
ENE	40233	0.383E-04	0.706E-05	0.513E-07
E	40233	0.383E-04	0.603E-05	0.740E-07
ESE	40233	0.287E-04	0.641E-05	0.249E-06
SE	40233	0.383E-04	0.644E-05	0.210E-06
SSE	40233	0.383E-04	0.71[illegible]E-05	0.279E-06
S	40233	0.383E-04	0.646E-05	0.289E-06
ALL		0.383E-04	0.746E-05	0.286E-06

Table 33. One-Hour Frequency Distribution χ/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	56327	0.288E-04	0.659E-05	0.251E-06
SW	56327	0.288E-04	0.603E-05	0.297E-06
WSW	56327	0.288E-04	0.552E-05	0.130E-06
W	56327	0.288E-04	0.478E-05	0.174E-06
WNW	56327	0.288E-04	0.854E-05	0.490E-06
NW	56327	0.288E-04	0.570E-05	0.322E-06
NNW	56327	0.288E-04	0.398E-05	0.182E-06
N	56327	0.288E-04	0.481E-05	0.274E-07
NNE	56327	0.288E-04	0.522E-05	0.109E-07
NE	56327	0.288E-04	0.542E-05	0.445E-07
ENE	56327	0.288E-04	0.513E-05	0.298E-07
E	56327	0.288E-04	0.443E-05	0.477E-07
ESE	56327	0.216E-04	0.481E-05	0.169E-06
SE	56327	0.288E-04	0.495E-05	0.138E-06
SSE	56327	0.288E-04	0.525E-05	0.185E-06
S	56327	0.288E-04	0.472E-05	0.192E-06
ALL		0.288E-04	0.540E-05	0.192E-06

Table 33. One-Hour Frequency Distribution χ/Q Values for the WIPP Site (Continued)

DOWNWIND SECTOR	DISTANCE (METERS)	MAXIMUM CHI/Q	5 PCT CHI/Q	50 PCT CHI/Q
		(SEC PER CUBIC METER)		
SSW	72420	0.234E-04	0.532E-05	0.182E-06
SW	72420	0.234E-04	0.504E-05	0.221E-06
WSW	72420	0.234E-04	0.468E-05	0.961E-07
W	72420	0.234E-04	0.380E-05	0.132E-06
WNW	72420	0.234E-04	0.691E-05	0.382E-06
NW	72420	0.234E-04	0.481E-05	0.243E-06
NNW	72420	0.234E-04	0.324E-05	0.138E-06
N	72420	0.234E-04	0.384E-05	0.192E-07
NNE	72420	0.234E-04	0.427E-05	-0.999E 10
NE	72420	0.234E-04	0.423E-05	0.328E-07
ENE	72420	0.234E-04	0.417E-05	0.213E-07
E	72420	0.234E-04	0.364E-05	0.353E-07
ESE	72420	0.176E-04	0.387E-05	0.125E-06
SE	72420	0.234E-04	0.390E-05	0.101E-06
SSE	72420	0.234E-04	0.420E-05	0.135E-06
S	72420	0.234E-04	0.376E-05	0.145E-06
ALL		0.234E-04	0.453E-05	0.144E-06

Appendix I

CORRESPONDENCE ON ARCHAEOLOGY, HISTORIC SITES, PRIME FARMLAND, AND ENDANGERED SPECIES

Appendix I

CORRESPONDENCE ON ARCHAEOLOGY, HISTORIC SITES, PRIME FARMLAND, AND ENDANGERED SPECIES

The preparation of this environmental impact statement has required consultation with government agencies about the archaeological, historic, and agricultural values of the land in the area of the WIPP site and about the endangered species of plants and animals that might be found there. This appendix contains copies of the official correspondence through which the consultation was carried out.

From	To	Date
M. L. Merritt Sandia Laboratories	Thomas W. Merlan New Mexico State Historic Preservation Officer	November 15, 1976
Thomas W. Merlan New Mexico State Historic Preservation Officer	M. L. Merritt Sandia Laboratories	February 16, 1977
Colin A. Heath, Manager DOE WIPP Program	William J. Murtagh Keeper of the National Register	No date
William J. Murtagh Keeper of the National Register	Thomas W. Merlan New Mexico State Historic Preservation Officer	No date
Thomas W. Merlan New Mexico State Historic Preservation Officer	William J. Murtagh Keeper of the National Register	April 28, 1978
William J. Murtagh Keeper of the National Register	Colin A. Heath, Manager DOE WIPP Program	No date
D. T. Schueler, Manager DOE WIPP Project	Thomas W. Merlan New Mexico State Historic Preservation Officer	November 8, 1978
Thomas W. Merlan New Mexico State Historic Preservation Officer	D. T. Schueler, Manager DOE WIPP Project	November 30, 1979

From	To	Date
D. T. Schueler, Manager DOE WIPP Project	Thomas W. Merlan New Mexico State Historic Preservation Officer	March 21, 1980
Thomas W. Merlan New Mexico State Historic Preservation Officer	D. T. Schueler, Manager DOE WIPP Project	April 10, 1980
Thomas W. Merlan New Mexico State Historic Preservation Officer	D. T. Schueler, Manager DOE WIPP Project	May 8, 1980
D. T. Schueler, Manager DOE WIPP Project	Louis S. Wall, Chief Western Division of Project Review Advisory Council on Historic Preservation	May 20, 1980
M. L. Merritt Sandia Laboratories	Albert W. Hamelstrom State Conservationist U.S. Department of Agriculture	November 3, 1976
Albert W. Hamelstrom State Conservationist U.S. Department of Agriculture	M. L. Merritt Sandia Laboratories	November 11, 1976
D. T. Schueler, Manager DOE WIPP Project	W. O. Nelson, Jr. Regional Director Endangered Species Office U.S. Fish and Wildlife Service	October 17, 1979
Jerry L. Stegman Acting Regional Director Endangered Species Office U.S. Fish and Wildlife Service	D. T. Schueler, Manager DOE WIPP Project	November 15, 1979
Harold F. Olson, Director New Mexico Department of Game and Fish	D. T. Schueler, Manager DOE WIPP Project	April 7, 1980

Sandia Laboratories

Albuquerque, New Mexico 87115

November 15, 1976

Mr. Thomas W. Merlan
State Historic Preservation Officer
State Planning Office
505 Don Gaspar
Santa Fe, New Mexico 87503

Dear Sir:

I am working on the environmental assessment for the proposed Waste Isolation Pilot Plant east of Carlsbad. It has come to my attention that we need a determination from you as State Historic Preservation Officer on the existence of any cultural resources that may exist on or near the proposed project, and that the project may impact, and in particular we need to know about the existence of any sites on the State Register or being considered for the register on or near our location.

I enclose a xerox copy of the report on the archaeological survey of the central four sections of the area under consideration, made by the Agency of Conservation Archaeology, Eastern New Mexico University (ENMU), and will send you a copy of the formal report when it is printed. We have not yet had an archaeological survey made of the necessary rights of way, but intend to have one made in the near future.

I also enclose two maps of the area, showing the proposed withdrawal area for the projects and the rights of way that will be required for highway, railroad, and electric power line access (other utilities will be routed over one or the other of these rights of way). I should add that most of the 28 square miles of withdrawal area is to be used merely as a buffer zone with no change in surface use. Only in the central three square miles (included within the four square miles of the ENMU survey) will there be mining, and all surface facilities will be in a 100-acre plot on the edge of this core area.

Yours,

M. L. Merritt

M. L. Merritt, Supv.
Environmental Assessment
Division 1151

MLM:1151:vf
Enclosure
Copy to:
ALO W. P. Armstrong, wo/enc.
ALO J. D. Shaykin, wo/enc.
1140 W. D. Weart, wo/enc.

STATE OF NEW MEXICO

STATE PLANNING OFFICE

GREER BUILDING
505 DON GASPER
SANTA FE, 87503
(505) 827-2073

GRACIELA (GRACE) OLIVAREZ
STATE PLANNING OFFICER

JERRY APODACA
GOVERNOR

February 16, 1977

Mr. M.L. Merritt, Supervisor
Environmental Assessment Division, 1115
Sandia Laboratories
Albuquerque, New Mexico 87115

Dear Mr. Merritt:

With reference to your request for comments on cultural resources which may be affected by the proposed Waste Isolation Pilot Plant east of Carlsbad the report: An Archaeological Reconnaissance of Sandia Laboratories' Los Medanos Nuclear Waste Disposal Facility, Eddy County, New Mexico by Jeffrey Nielsen has been reviewed by this office.

The recommendations for mitigation of adverse effects on cultural resources located by this survey should be followed and avoidance of sites accomplished whenever possible. Sites which cannot be avoided should be excavated or tested as indicated in these recommendations before clearance can be granted. Those rights of way which have not yet been surveyed should be surveyed as soon as possible so that recommendations for the mitigation of adverse effects on any resources located within these areas may be included in the overall mitigation proposal.

Several of the sites located by the survey may meet the criteria for eligibility for nomination to the National Register of Historic Places. However, there are currently no sites located within the 28 square mile withdrawal which are entered in either the National Register or the State Register of Cultural Properties.

Should you have any further questions regarding this matter, please do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan
State Historic
Preservation Officer

TWM:jf

Department of Energy
Washington, D.C. 20545

Dr. William Murtagh
Keeper of the National Register
Heritage, Conservation and Recreation Service
U. S. Department of the Interior
Washington, D. C. 20240

Dear Dr. Murtagh:

Your opinion respecting the eligibility of certain sites associated with the proposed Waste Isolation Pilot Plant (WIPP), for inclusion in the National Register, is hereby requested under the provisions of 36 CFR 800.4(a)(2).

The Department of Energy (DOE) has been investigating a site in southeastern New Mexico for a deep geological repository. DOE will seek congressional authorization for the WIPP and legislative action to acquire land and rights-of-way needed. The WIPP will be licensed by the Nuclear Regulatory Commission.

The WIPP will be used for the demonstration of safe permanent disposal of transuranic wastes produced as a result of the United States defense program. The WIPP will also be used for experiments related to the permanent disposal of solidified high level radioactive wastes.

The WIPP plans call for the use of 17,200 acres of Federal land and 1760 acres of State land for the site (and 691 acres for rights-of-way). Construction would remove 487 acres of land from grazing temporarily and 448 acres for an extended period of time. Surface facilities for radioactive waste handling will require about 100 acres above ground. There will also be extensive underground handling and storage facilities in the salt formation at the WIPP site.

Mr. Thomas W. Merlan, State Historic Preservation Officer, State of New Mexico, State Planning Office, Greer Building, 505 Don Gaspar, Sante Fe, New Mexico, 87503, can be contacted for details concerning the review performed by the State of New Mexico. T. Merlan stated, in a letter to M. Merritt, Sandia Laboratories, on February 16, 1977 - "Several of the sites located by the survey may meet the criteria for eligibility for nomination to the National Register of Historic Places. However, there are currently no sites located within the 28 square mile withdrawal which are entered in either the National Register or the State Register of Cultural Properties."

Report SAND77-7024, "An Archaeological Reconnaissance of a Proposed Site for the Waste Isolation Pilot Plant (WIPP)," October 1977, by Jeffrey Nielsen, Agency of Conservation Archaeology, Eastern New Mexico University, Portales, New Mexico, is enclosed for your use.

Your opinion concerning the eligibility of the sites associated with the WIPP will be included in the Draft Environmental Impact Statement now being prepared by DOE for issuance in October 1978. If there are any questions, we would be pleased to respond.

Sincerely,

Colin A. Heath
WIPP Program Manager
Division of Waste Management

Enclosure:
Report SAND77-7024

cc w/o encl:
T. W. Merlan, State Historic
Preservation Officer, NM

United States Department of the Interior

NATIONAL PARK SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:
H32-880

Mr. Thomas W. Merlan, SHPO
State Planning Office
Santa Fe, New Mexico 87503

Dear State Historic Preservation Officer:

As you will note from the enclosed letter, we have received a request for a determination of eligibility for inclusion in the National Register, pursuant to Executive Order 11593 or the National Historic Preservation Act of 1966, as amended, as implemented by the procedures of the Advisory Council on Historic Preservation (36 CFR 800).

Since determinations of eligibility are made in consultation with the State Historic Preservation Officer, we would appreciate receiving your opinion on the eligibility of the property(s) which appear in the enclosed material along with any documentation which you have on it and its significance within three weeks of receipt of this letter. Copies of documentation submitted with the request(s) are enclosed for your review, as appropriate.

We look forward to hearing from you in the near future. Please do not hesitate to consult the National Register staff if you have any questions concerning this property.

We appreciate your assistance in this matter.

Sincerely yours,

William J. Murtagh
Keeper of the National Register

Enclosure(s)

cc: Mr. Colin A. Heath
WIPP Program Manager
Division of Waste Management
Department of Energy
Washington, D.C. 20545

Mr. Gregory J. Cavanaugh, Director
Division of Real Estate and Facilities Management
Department of Energy
Washington, D.C. 20545
Attn: Mr. William R. Cochran

Advisory Council on Historic Preservation
Denver Office
Box 25085
Denver, Colorado 80225
Attn: Louis Wall

HISTORIC PRESERVATION PROGRAM
Department of Educational Finance & Cultural Affairs
c/o New Mexico State Library
P.O. Box 1[illegible]
Santa Fe, New Mexico 87503
(505) 827-2108

April 28, 1978

Dr. William J. Murtagh
Keeper of the National Register
National Park Service
1100 L Street, N.W. - Room 3209
Washington, D.C. 20005

Dear Dr. Murtagh:

This office has been requested by the Department of Energy to provide an opinion on the eligibility for nomination to the National Register of Historic Places of several archaeological sites located in southeastern New Mexico.

The sites in question were located by an archaeological survey of a four section area and related right-of-way which constitutes the core area of the proposed Waste Isolation Pilot Plant project. Information on the survey area, survey techniques, and descriptions of the individual sites is included in the report entitled An Archaeological Reconnaissance of a Proposed Site fro the Waste Isolation Pilot Plant (WIPP) By Jeffrey Nielsen, Agency of Conservation Archaeology, Eastern New Mexico University, July, 1976.

All of the 33 sites located by this survey appear, on the basis of survey data, to be associated culturally and temporally, and related to a specific economic activity. The archaeological investigation of this group of sites is in our opinion likely to yield significant information on the prehistoric occupation and utilization of the Los Medanos region. Some theoretical considerations for such a study are outlined in the above referenced report.

Therefore, we believe that the 33 sites because of their relationship, are contributing elements of an archaeological district meeting the criteria of eligibility for nomination to the National Register. The significance of the information which can be obtained through the scientific investigation of these sites becomes even more important in view of the so far poorly defined prehistory of this area.

The boundaries of the archaeological district can be arbitrarily defined as the approximately 2,600 acre, four section, core area and right-of-way covered by the archaeological survey. Indications from subsequent archaeological surveys of drill pad, access roads, and test plots are that similar archaeological sites can be expexted to occur throughout the 18,960 acre withdrawal area.

Should you have any questions regarding our opinion regarding the significance of these archaeological sites, do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan

Thomas W. Merlan
State Historic Preservation Officer

TWM:jf

cc: Smokey O'Connor
Colin A. Heath

United States Department of the Interior

HERITAGE CONSERVATION AND RECREATION SERVICE
WASHINGTON, D.C. 20240

IN REPLY REFER TO:
H32-NR

Mr. Colin A. Heath
WIPP Program Manager
Division of Waste Management
Department of Energy
Washington, D.C. 20545

Dear Mr. Heath:

Thank you for your letter requesting a determination of eligibility for inclusion in the National Register pursuant to Executive Order 11593 or the National Historic Preservation Act of 1966, as amended. Our determination appears on the enclosed material.

As you understand, your request for our professional judgment constitutes a part of the Federal planning process. We urge that this information be integrated into the National Environmental Policy Act analysis in order to bring about the best possible program decisions. This determination does not serve in any manner as a veto to uses of property, with or without Federal participation or assistance. Any decision on the property in question and the responsibility for program planning concerning such properties lie with the agency or block grant recipient after the Advisory Council on Historic Preservation has had an opportunity to comment.

We are pleased to be of assistance in the consideration of historic resources in the planning process.

Sincerely yours,

William J. Murtagh
Keeper of the National Register

Enclosure

DETERMINATION OF ELICIBILITY
NOTIFICATION DISTRIBUTION

cc: State Historic Preservation Officer: Mr. Thomas W. Merlan, New Mexico

Federal Representative: Mr. Gregory J. Cavanaugh

Bureau Liason:

Advisory Council on Historic Preservation: Denver

Mr. George Sherwood
Acting Chief
Environmental Safety
& Effects Division
Reactor, Research and Technology
US. Department of Energy
Washington, D.C. 20545

E.O.11593

DETERMINATION OF ELIGIBILITY NOTIFICATION

NATIONAL REGISTER OF HISTORIC PLACES

OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION

HERITAGE CONSERVATION AND RECREATION SERVICE

Request submitted by: DOE Colin A. Heath

Date request received: 2/24/78 additional information received 5/5/78

Name of property: Archeological Sites, Waste Isolation Pilot Plant State: New Mexico

Location: S.E. of Carlsbad, New Mexico

Opinion of the State Historic Preservation Officer:

(x) Eligible ( ) Not eligible ( ) No response

Comments: "All of the 33 sites located by this survey appear, on the basis of survey data, to be associated culturally and temporally, and related to a specific economic activity... (and are) likely to yield significant information on the prehistoric occupation and utilization of the Los Medanos region... we believe that the 33 sites, because of their relationship, are contributing elements of an archaeological district..."

The Secretary of the Interior has determined that this property is:

(x) Eligible Applicable criteria: D

Comments: 36 CFR Part 63.3 Determination

( ) Not eligible

Comments:

( ) Documentation insufficient (see accompanying sheet explaining additional materials required)

William J. Murtagh (Sgd.)

Keeper of the National Register

Date: MAY 24 1978

WASO-185
9/75

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

NOV 8 1979

Mr. Thomas W. Merlan
State Historic Preservation Officer
State Planning Office
Santa Fe, New Mexico 87503

Dear Mr. Merlan:

The Department of Energy (DOE) is submitting this letter to appraise you of our intention to construct site verification shafts and an underground (in-situ) experimentation facility at the site proposed for the Waste Isolation Pilot Plant (WIPP) near Carlsbad (Figure 1). This construction program, herein referred to as the SPDV (Site Preliminary Design Verification), is an extension of the earlier site characterization program and is intended to provide the additional data necessary before a final site commitment can be made. We request your concurrence in determination of effect for archaeological sites affected by the SPDV. The locations of the shafts and attendant facilities are indicated on the enclosed Figure 2. The access road to the site was previously constructed for borehole drilling (ERDA-9).

Three major archaeological surveys have been conducted by the Agency for Conservation Archaeology of Eastern New Mexico University on the entire proposed WIPP site:

- J. Nielson conducted a reconnaissance of the core area (Sections 20, 21, 29, and 28) and tentative rights-of-way in 1976.
- S. C. Schermer conducted a survey of 27 miles of seismic survey lines in 1978.
- R. B. Maclennan and S. C. Schermer conducted a survey of proposed access roads and railroad rights-of-way in 1979.

The first report was forwarded to you on November 15, 1976. The latter two are enclosed. In addition, archaeological surveys have been conducted for each of the borehole drilling pads and access roads constructed as part of the overall WIPP Project.

All archaeological sites discovered in the site area during these surveys are indicated on Figure 2. Table 1 summarizes site descriptions and recommended mitigation measures for those sites which will be affected or possibly affected by construction of the SPDV.

Prior to the start of construction of the SPDV facilities, all sites affected by construction and "borderline" sites will be accurately mapped by a field surveying crew. Fences will then be constructed around each of the archaeological sites. DOE and its contractors will supply the needed support to the State Historic Preservation Officer and/or his designees to allow proper removal of artifacts from all affected sites. We believe these mitigation measures will preserve the archaeological resources present, yet allow construction of the SPDV facilities to proceed.

In previous correspondence with Dr. William Murtagh, Keeper of the National Register, and yourself, on May 24, 1978, the 33 sites located in the 1976 Nielson survey were determined eligible for nomination to the National Register of Historic Places under applicable Criterion D of 36 CFR Part 63.3. DOE plans to conduct further archaeological surveys as soon as practicable including sample surveys throughout the remaining outer Control Zones of the site. Upon completion of those surveys and prior to construction of the full WIPP repository, DOE will consult with you to comply with the requirements of Section 106 of the National Historic Preservation Act as detailed in regulations detailed in the January 30, 1979 Federal Register (Title 36, Chapter VIII, Part 800) to identify any additional eligible properties, request a determination of effect and implement a consultation process to mitigate or minimize any adverse effects from full repository construction.

We request your formal comments on our proposed plan for the SPDV program with regard to archaeological resources and the mitigation of any adverse impacts. A response by December 14, 1979 would be appreciated.

If you require further information or clarification, please contact Mr. J.M. McGough of my staff (505-766-3884).

Sincerely,

D.T. Schueler
Project Manager
WIPP Project Office

WIP:JMM(2570)

Enclosures

STATE OF NEW MEXICO

DEPARTMENT OF FINANCE AND ADMINISTRATION PLANNING DIVISION

BRUCE KING
GOVERNOR

DAVID W. KING
SECRETARY

ANITA HISENBERG
DIRECTOR

505 DON GASPAR AVENUE
SANTA FE, NEW MEXICO 87503
(505) 827-2073
(505) 827-5191
827-2108

November 30, 1979

Dr. D.T. Schueler, Project Manager
WIPP Project Office
Department of Energy
Post Office Box 5400
Albuquerque, New Mexico 87115

Dear Dr. Schueler:

Your proposal for the mitigation of adverse effects resulting from construction of Site Preliminary Design Verification facilities at the Waste Isolation Pilot Plant has been reviewed by this office.

We concur with your determination that several significant archeological resources will be affected by construction of the SPDV facilities, that these effects have been identified as being adverse, and that measures will be required to mitigate adverse effects.

We also concur with the procedures you propose to accomplish the required mitigation with the understanding that several additional steps are to be accomplished before the mitigation proposal is submitted to the Advisory Council. These include:

1. Accurate mapping of the site locations in relation to the SPDV facilities.
2. Site specific determination of effect and proposed mitigation procedure. (protection and avoidance or data recovery.)
3. Preparation of a statement of problem orientation and research design for the data recovery program for those sites which cannot be avoided.

Upon submission of the detailed mitigation plan, we are prepared to request a determination of no adverse effect thru satisfactory mitigation.

We will be looking forward to receiving your completed mitigation proposal. If you have any questions regarding our recommendations do not hesitate to contact us.

Sincerely,

Jane Stelser

for Thomas W. Merlan
State Historic Preservation Officer
Historic Preservation Bureau

TWM:DER:dg
cc: Jack Mobley

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

MAR 21 1980

Mr. Thomas Merlan
State Historic Preservation Officer
State Planning Office
Santa Fe, NM 87503

Dear Mr. Merlan:

ARCHAEOLOGICAL MITIGATION PLAN FOR SITE & PRELIMINARY DESIGN VALIDATION AT WIPP SITE

As requested by your letter of November 30, 1979, the WIPP Project Office has prepared a plan to mitigate adverse impacts to archaeological resources resulting from Site and Preliminary Design Validation (SPDV) activities for the Waste Isolation Pilot Plant (WIPP). This mitigation plan is based on the results of an archaeological survey conducted by Mr. Scott Schermer of the Agency for Conservation Archaeology at Eastern New Mexico University. This survey covered the four square mile area surrounding the ERDA-9 drill-hole at the WIPP Site.

Subsequent to the submittal of Mr. Schermer's findings, DOE modified SPDV surface design features so as to avoid impacts to some of the archaeological sites. Furthermore, DOE plans to impose administrative controls at the site to lessen the adverse impacts of human presence near archaeological resources. Artifacts will be collected and analyzed at some sites as well. Details are given in the enclosed "Plan to Mitigate Effects on Archaeological Sites."

Included as an appendix to this report is a copy of Mr. Schermer's letter of March 3, 1980, in which he states his concurrence with the DOE proposed mitigative actions. Also enclosed is one copy of the findings of Mr. Schermer's survey "A Report on the Archaeological Site Locations in the WIPP Core Area with Mitigation Recommendations."

We request your review of the proposed mitigation plan and accompanying materials to ensure full DOE compliance with the requirements of Section 106 of the Nationa Historic Preservation Act. We will contact you soon to arrange a meeting on the mitigation plan.

Sincerely,
ORIGINAL SIGNED BY
D. T. SCHUELER
D. T. Schueler
Project Manager

WIP:JMM(2853)

See page 2

Enclosures:
1. SPDV Mitigation Plan
2. Archaeological Site Locations In the WIPP Core Area with Mitigation Recommendations

cc w/encl # 1 only:
J. McGough, DOE, WIPP
J. Gervers, Governor's Task Force for WIPP, SF
R. Neill, EEG, SF

cc wo/encl: G. Hohmann, Westinghouse WIPP

BRUCE KING
GOVERNOR

DAVID W. KING
SECRETARY

STATE OF NEW MEXICO

**DEPARTMENT OF
FINANCE AND ADMINISTRATION
PLANNING DIVISION**

ANITA HISENBERG
DIRECTOR

505 DON GASPAR AVENUE
SANTA FE, NEW MEXICO 87503
(505) 827-2073
(505) 827-5191
827-2108

April 10, 1980

Dr. D.T. Schueler
Project Manager
Waste Isolation Pilot Plant
Department of Energy
Post Office Box 5400
Albuquerque, New Mexico 87115

Dear Dr. Schueler:

The Plan to Mitigate Effects on Archeological Resources; Site and Preliminary Design Validation (SPDV), Waste Isolation Pilot Plant, Eddy County, New Mexico by J.S. Hart and L.M. Brausch has been reviewed by this office.

It is our opinion that procedures outlined in the plan are adequate to mitigate direct and indirect adverse effects of the SPDV facility on significant cultural resources. This determination is applicable only to the SPDV facility as presently designed. A decision to proceed with full development of WIPP will of course require consideration of additional mitigative actions.

We also believe that data recovery and analysis procedures to be employed at those sites to be collected, tested, or excavated are appropriate and will insure the preservation of archeological information contained within sites which cannot be protected by other means.

Scott C. Schermer's A Report on the Archeological Site Locations in the WIPP Core Area with Mitigation Recommendations for Bechtel National, Inc. was also reviewed with interest. The information contained in this report satisfies certain inadequacies previously noted in the archeological program for WIPP. We are pleased with your efforts to insure that archeological information in the WIPP area is adequately recorded and understood.

Should you have any questions regarding our comments on the SPDV mitigation plan, do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan

Thomas W. Merlan
State Historic Preservation Officer
Historic Preservation Bureau

TWM:DER:dg
cc: Louis S. Wall
John Gervers

Bruce King
Governor

David W. King
Secretary

State of New Mexico

**DEPARTMENT OF
FINANCE AND ADMINISTRATION
PLANNING DIVISION**

Anita Hisenberg
Director

505 Don Gaspar Avenue
Santa Fe, New Mexico 87503
(505) 827-2073
(505) 827-5191

May 8, 1980

Dr. D.T. Schueler
Project Manager
WIPP Project Office
Albuquerque Operations Office
Department of Energy
Post Office Box 5400
Albuquerque, New Mexico 87115

Dear Dr. Schueler:

As I stated in My April 10, 1980 letter, it is my opinion that the Plan to Mitigate Effects on Archeological Resources; Site and Preliminary Design Validation (SPDV), Waste Isolation Pilot Plant contains adequate data recovery and protection measures to satisfactorily mitigate adverse effects on significant cultural resources.

I therefore concur with your determination of no adverse effect for this undertaking provided that the mitigation plan is implemented as stated. It is my opinion that the criteria and requirements set forth in Parts I and II of the Advisory Council's Guidelines for Making "Adverse Effect" and No Adverse Effect Determinations for Archeological Resources in Accordance with 36 CFR Part 800 are being met. Specifically, I can certify that the affected archeological resources meet Part I: Criteria 2 and 3a, b, and c.

Should you have any questions regarding my concurrence with this determination, do not hesitate to contact this office.

Sincerely,

Thomas W. Merlan
State Historic Preservation Officer

TWM:DER;dg
cc: Louis S. Wall
John Gervers

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

MAY 2 0 1980

Mr. Louis S. Wall, Chief
Western Division of Project Review
Advisory Council on Historic Preservation
44 Union Boulevard, Suite 616
Lakewood, Colorado 80226

Dear Mr. Wall:

REQUEST FOR COUNCIL COMMENTS

Enclosed are three (3) copies of the "Plan to Mitigate Effects on Archaeological Resources," for the Site and Preliminary Design Validation Program for the Waste Isolation Pilot Plant Site in Eddy County, New Mexico. This report was prepared to comply with the requirements of Section 106 of the National Historic Preservation Act of 1966 and Section 2(b) of Executive Order 11593.

Correspondence documenting approval of the plan by Mr. Thomas W. Merlan, the New Mexico State Historic Preservation Officer, is included as Appendix A of the report. Also included in Appendix A are letters from Mr. Merlan and Mr. Scott Schermer of the Agency for Conservation Archaeology supporting a determination of "No Adverse Effect" to archaeological resources as a result of SPDV activities at the WIPP Site. Appendix B of the report consists of specific responses to the information requirements required by 36 CFR 800.13(a).

Also enclosed are two (2) copies of Scott Schermer's "A Report on the Archaeological Site Locations in the WIPP Core Area with Recommendations for Bechtel National, Inc." This document details characteristics of the archaeological sites discussed in our mitigation plan.

We believe that this information meets our responsibilities for documentation of a determination of "No Adverse Effect" to archaeological resources. We request that the Advisory Council on Historic Preservation comment on this determination pursuant to 36 CFR 800.6.

Sincerely,

ORIGINAL SIGNED BY
D. T. SCHUELER

D. T. Schueler
Project Manager
WIPP Project Office

WIP:JMM

Enclosures:
1. "Plan to Mitigate Effects on Archaeological Resources for SPDV" (3 copies)
2. "A Report on the Archaeological Site Locations in the WIPP Core Area with Mitigation Recommendations" (2 copies)

cc w/encl no. 1 (1 copy). J. McGough, WIPP P/O, ALO
J. Gervers, WIPP Task Force
R. Neill, EEG, Santa Fe
A. Zimmerman, BLM, Santa Fe
A. Ramage, BLM, Roswell

cc w/o encl: G. Hohmann, W-WIPP Proj.

Sandia Laboratories
Albuquerque, New Mexico 87115

November 3, 1976

Mr. Albert W. Hamelstrom
517 Gold Avenue SW
P. O. Box 2007
Albuquerque, NM 87103

Dear Sir:

I am in the process of preparing inputs for a Draft Environmental Impact Statement on the proposed Waste Isolation Pilot Plant to be used for experiments related to the storage of low and intermediate level nuclear wastes in the bedded salt of the Delaware Basin, east of Carlsbad, New Mexico.

I have just been informed that I must solicit a determination from the USDA Rural Development Committee on whether there are any "prime or unique farmlands" located within the project area. I would be very much surprised if there were, but nevertheless I need a formal statement on the subject.

The area proposed includes all or part of Sections 7-11, 14-23, 26-35 of T. 22 S., R. 33 E.; Sections 2-6 of T. 23 S., R. 31 E.; Sections 12-13, 24-25, 36 of T. 22 S., R. 30 E.; and Section 1, T. 23 S., R. 30 E. Most of this land will merely be buffer zone; the area which would overlie the underground workings includes only Sections 20-21 and 28-29, T. 22 S., R. 31 E. All the land mentioned is in Eddy County, New Mexico--see map enclosed.

If there are any further questions, please phone me at 264-3540. Thank you for your cooperation.

Yours,

M. L. Merritt

M. L. Merritt, Supervisor
Environmental Assessment Div. 1151

MLM:1151:jeh

Enclosure

Copy to:
SAO L. P. Apodaca w/encl.
ALO W. P. Armstrong w/encl.
1140 W. D. Weart w/encl.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Box 2007, Albuquerque, NM 87103

November 11, 1976

Mr. M. L. Merritt, Supervisor
Environmental Assessment Division 1151
Sandia Laboratories
Albuquerque, NM 87115

Dear Mr. Merritt:

In response to your request of November 3, 1976, the site and buffer zone for the proposed Waste Isolation Pilot Plant in Eddy County, New Mexico, does not include prime or unique farm lands according to Soil Conservation Service criteria. The area considered was that shown on the map provided with your letter.

Sincerely,

AW Hamelstrom

A. W. Hamelstrom
State Conservationist

P I N K   C O P Y

OCT 17 1979

Mr. W. O. Nelson, Jr.
Regional Director
U. S. Fish & Wildlife Service
Endangered Species Office
P. O. Box 1306
Albuquerque, NM 87103

Dear Mr. Nelson:

REQUEST FOR LIST OF ENDANGERED SPECIES AFFECTED BY WIPP SITE

The Department of Energy (DOE) is considering the construction of a Waste Isolation Pilot Plant (WIPP) at a site near Carlsbad, New Mexico. The WIPP will be a permanent repository for low- and intermediate-level defense related nuclear wastes which will be emplaced in a bedded salt formation underlying the site. As a part of this program, the Sandia Laboratories, under contract to the DOE, has funded extensive studies of the environmental biology of the site. These studies are intended to provide information for use in the Environmental Impact Statement as well as to establish Baseline data for the long-term ecological monitoring of the site.

This letter constitutes a formal request for your Office to provide a list of threatened and endangered species that may be affected by the proposed WIPP facility, as required by Section 7 of the 1978 amendments to the Endangered Species Act of 1973.

You may find the following information useful in assembling such a list.

The WIPP site is about 25 miles east of Carlsbad in Eddy County, New Mexico and covers an area of 18,960 acres, all federal and state land. Biological studies have encompassed a somewhat larger area. The floral associations on the site are characteristic of the Chihuahuan Regions of the Desert Shrub and Grassland Formations. Some Plains Region components are present as well.* The site region is grazed by cattle throughout the year and is stocked at a level of about six head per section.

*Donart, G. B., D. D. Sylvester, and W. C. Hickey, 1978. Potential Natural Vegetation of New Mexico. U. S. Department of the Interior, Soil Conservation Service, Portland, Oregon.

WIPP SAFETY ASSESS	WIPP PROJ CONTROL	WIPP FIN MGMT BR	WIPP DEP PROJ MGR	WIPP PROJ MGR
McGough:srk	Bellows	Dintaman	Rudolph	Schueler
10/17/79	10/ /79	10/ /79	10/ /79	10/ /79

Proposed construction at the site consists of surface and underground facilities. Surface structures will include, in addition to buildings, a storage pile for the mined rock (much of which will be salt), an evaporation pond for sewage-treatment effluents, a disposal area for construction spoils, and a sanitary landfill. Also planned are a railroad spur, paved access roads, and a power line. The proposed locations of these facilities are shown on the accompanying map.

The portion of the Draft Environmental Impact Statement (DOE/EIS-0026-D) is enclosed that details the information available to us concerning threatened and endangered species on or near the site. Field data obtained since the DEIS was prepared necessitates some modifications of the statements concerning threatened and endangered fish species. Dr. James Sublette of Eastern New Mexico University (ENMU) in Portales, NM, the principal investigator for the aquatic studies portion of the WIPP Biology Program, has conducted field studies in 1978 and 1979 at eight sampling stations on the Pecos River between Six Mile Dam and Red Bluff Reservoir. His 1978 findings (summarized in the table attached) included the following information. Of the nineteen species of fish in the length of the Pecos River under study, three are currently listed by the State of New Mexico as being threatened or endangered. They are: the Pecos River Pupfish, the Rainwater fish, and the Gray Redhorse. Dr. Sublette found several thriving populations of the first two species and has recommended that they be "delisted." The third is rare in the Pecos but moderate populations are found in the Black River drainage. The Black river joins the Pecos near Malaga west-southwest of the WIPP site.

Five additional species of fish on the state list were found to occur in the Black River drainage but not in the Pecos. They are: the Blue Sucker, the Banded Tetra, the Blunt Nose Minnow, the Green-throated Darter, and the Pecos Gambusia. The last two occur only in the Blue Spring Run; the last species is also on the federal list of threatened and endangered species.

To our knowledge, the Pecos Gambusia is the only federally listed species of threatened and endangered fish that is found anywhere near the WIPP site. The only known populations within the aquatic study area are in the Black River drainage, which is well buffered from any direct association with drainage from the WIPP site into the Pecos.

The foregoing information is contained in the FY78 annual report of the WIPP Biology Program soon to be published as Sandia document (SAND79-0368). Your office has been placed on the mailing list for distribution.

With regard to the avifuana, it should be emphasized that the single sighting of Baird's sparrow (New Mexico endangered species) mentioned in the DEIS (Vol. 2, page H-90) is questionable. The sighting, made by a graduate student of Dr. A. L. Gennaro of ENMU, did not permit a truly positive identification (A. L. Gennaro, personal communication; Dr. Gennaro has conducted the mammalian and reptilian portions of the WIPP studies for several years). Dr. David Ligon of the University of New Mexico is now responsible for avian studies.

The terminology used in the DEIS may require some clarification. "The region of the site" refers to the large area consisting of those parts of Eddy and Lea counties east of the Pecos. The term "the site vicinity" is more restrictive and refers to the area within a 5-mile radius of the center of the proposed WIPP site. Species checklists assembled for the "region of the site" understandably contain species never sighted in the "vicinity of the site" because the range of habitats in the larger area is, of course, more diverse than those encountered in the immediate neighborhood of the WIPP site. Similarly, the aquatic species discussed in the DEIS are those that occur within the "site region" whereas the aquatic study area is confined to water bodies close to the site (tanks, playas, etc.) and to that region of the Pecos which may receive drainage from the site and continuing downstream to Red Bluff Reservoir.

A copy of the entire DEIS is being mailed to you under separate cover for your information.

If you require further information on these biological studies, please contact Sieglinde Neuhauser (264-5364) or M. L. Merritt (264-3540) at Sandia Laboratories. Questions concerning the project itself should be addressed to me at 766-3884.

Sincerely,

Original Signed by
D. T. SCHUELER
D. T. Schueler
Project Manager
WIPP Project Office

WIP:JMM(2527)

Enclosures:
1. Map of WIPP Site Area
2. Section H.5.4 of DEIS
3. List of Threatened & Endangered Species of Fish

cc w/o encl. K. Neuhauser, Org. 4514, SLA
M. Merritt, Org. 4514, SLA
G. Hohmann, Westinghouse WIPP Proj
J. McGough, WIPP Proj Ofc, ALO

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

SE

POST OFFICE BOX 1306
ALBUQUERQUE, NEW MEXICO 87103

WIPP PROJECT OFFICE

	Act	Info	Init	Date
Schueler				
[illegible]				
[illegible]				
[illegible]				
Bellows				
Carlsbad [illegible]				
SE Office				
FILE				

November 15, 1979

Mr. D. T. Schueler
Project Manager, WIPP Project Office
Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Schueler:

This is in reply to your October 17, 1979 letter which requested information about species which are listed or proposed to be listed as threatened or endangered as provided by the Endangered Species Act. Your area of interest is the Waste Isolation Pilot Plant site 25 miles east of Carlsbad, Eddy County, New Mexico.

As provided by Section 7(c) of the Endangered Species Act Amendments of 1978, the Fish and Wildlife Service is required to furnish a list of those species, both proposed and listed, that may be or are present in the area involving Federal construction activities.

Upon receipt of the Fish and Wildlife Service's species list, the Federal agency authorizing, funding, or carrying out the construction action is required to conduct a biological assessment for the purpose of identifying listed species which are likely to be affected by such action. Proposed species are included on the list even though they do not have legal protection under the Act. Their inclusion recognizes that they may be listed anytime and have the portent to cause delays or modifications to the proposed action. In light of this, we recommend that those species be included in the biological assessment.

The biological assessment shall be completed within 180 days after receipt of the species list, unless it is mutually agreed to extend this period. The biological assessment should include: 1) the results of a comprehensive survey; 2) results of any studies undertaken to determine the nature and extent of any impacts on identified species; 3) consideration of the cumulative effects upon the species or its critical habitat; 4) study methods used; 5) difficulties encountered in obtaining data and completing the proposed study; 6) conclusions including recommendations as to further studies, and 7) any other relevant information.

For purposes of providing interim guidance, the Fish and Wildlife Service considers construction projects to be any action conducted or contracted by the Federal agency designed primarily to result in the building or erection of man-made structures, such as dams, buildings, roads, pipelines, and the like. This includes consideration of major Federal actions such as permits, grants, licenses, or other forms of Federal authorization or approval which may result in construction and which significantly affect the quality of the human environment. In addition, other actions that have the potential of becoming or are controversial, may be considered as construction.

If the biological assessment reveals that the proposed project may affect listed species, the formal consultation process shall be initiated by writing to the Regional Director, Region 2, U.S. Fish and Wildlife Service, P.O. Box 1306, Albuquerque, New Mexico 87103. If no affect is evident, there is no need for further consultation. We would, however, appreciate the opportunity to review your biological assessment.

The attached sheet provides information on species which may occur in the proposed project area. If we may be of further assistance, do not hesitate to call upon us (505-766-3972; FTS 474-3972).

Sincerely yours,

Acting Regional Director

Attachment

cc: Phoenix Area Office (SE), Phoenix, Arizona
Ecological Services Field Office, Albuquerque, New Mexico

WASTE ISOLATION PILOT PLANT
Eddy County, New Mexico

LISTED SPECIES

BIRDS

Peregrine falcon (*Falco peregrinus*) - Medium sized falcon, slate gray above, dark head with "mustaches" below each eye. Long pointed wings. May occur as a spring or winter migrant.

Bald eagle (*Haliaeetus leucocephalus*) - Large eagle with white head and tail in the adult. Immatures are dark, feet bare of feathers. May occur as a spring or fall migrant. Winters around lakes and along rivers in project area.

MAMMALS

Black-footed ferret (*Mustela nigripes*) - Extremely rare and possibly extinct in area. Generally found in association with prairie dog towns.

FISH

Pecos gambusia (*Gambusia nobilis*) - Known from several locations near the project area. Found in springs and free-flowing streams.

PLANTS

Lee pincushion cactus (*Coryphantha sneedii leei*) - Listed as threatened effective November 26, 1979 (*FR* 10/25/79, Vol. 44, #208, 61554). A small pincushion-like cactus with white spines. Known only from the eastern edge of the Guadalupe Mountains in southwest Eddy County, New Mexico within Carlsbad Caverns National Park.

PROPOSED SPECIES

None.

CRITICAL HABITAT

None.

State of New Mexico

DEPARTMENT OF GAME AND FISH

STATE CAPITOL
SANTA FE
87503

April 7, 1980

Mr. D. T. Schueler
Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Schueler:

We have reviewed the "Biological Assessment. Potential Impacts on State-designated Endangered Species from the Proposed Construction and Operation of the Waste Isolation Pilot Plant (WIPP)" and find it a generally acceptable treatment of the subject. I would like to request any specific information on the least tern occurrence (p. 29 in Table 5) for our records. In addition, we question the occurrence of Bendire's thrasher (p. 30 in Table 5) in the area, as it is not verified from eastern New Mexico.

As for the FEIS, we have comments as follows:

- p. H-126 - add Ross' Goose and white-winged dove to the table.
- p. H-127 - (also p. 28 in TME 3010) - Butorides veresans = virescens; Spatula = Anas
- p. H-128 - (also p. 29 in TME 3010) - Totanus = Tringa; Erolia = Calidris; Ereunetes = Calidris
- pp. H-129/H-130 - these pages are reversed in sequence.
- p. H-134 - Elsewhere the ferruginous hawk is listed as yearlong (e.g. H-127; p. 30 in TME 3010), but here the data show winter occurrences only. The latter status is more likely to be correct.
- p. H-135 - The lesser nighthawk is listed here but not elsewhere in the reports.
- p. H-136 - Oregon = dark-eyed junco.
- p. H-145 - Some of the species were delisted in May 1979, i.e. little blue heron and osprey; the bald eagle is now NM II.
- p. H-147 - Some of the species were delisted in May 1979, i.e. American eel, roundnose minnow, Pecos pupfish, and rainwater killifish; the Pecos gambusia, now NM II, is not listed here.

We have not reviewed the plant occurrences and related aspects in detail, but I shall request this from the New Mexico Heritage Program. If they have comments, they can write to you direct.

Sincerely,

Harold F. Olson

Harold F. Olson
Director

cc: Bill Huey

Appendix J

EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Appendix J

EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

This appendix discusses the materials and methods used to collect the data presented in this report. It also discusses the proposed monitoring programs for assessing the environmental impacts of the WIPP.

J.1 PREOPERATIONAL ENVIRONMENTAL PROGRAMS

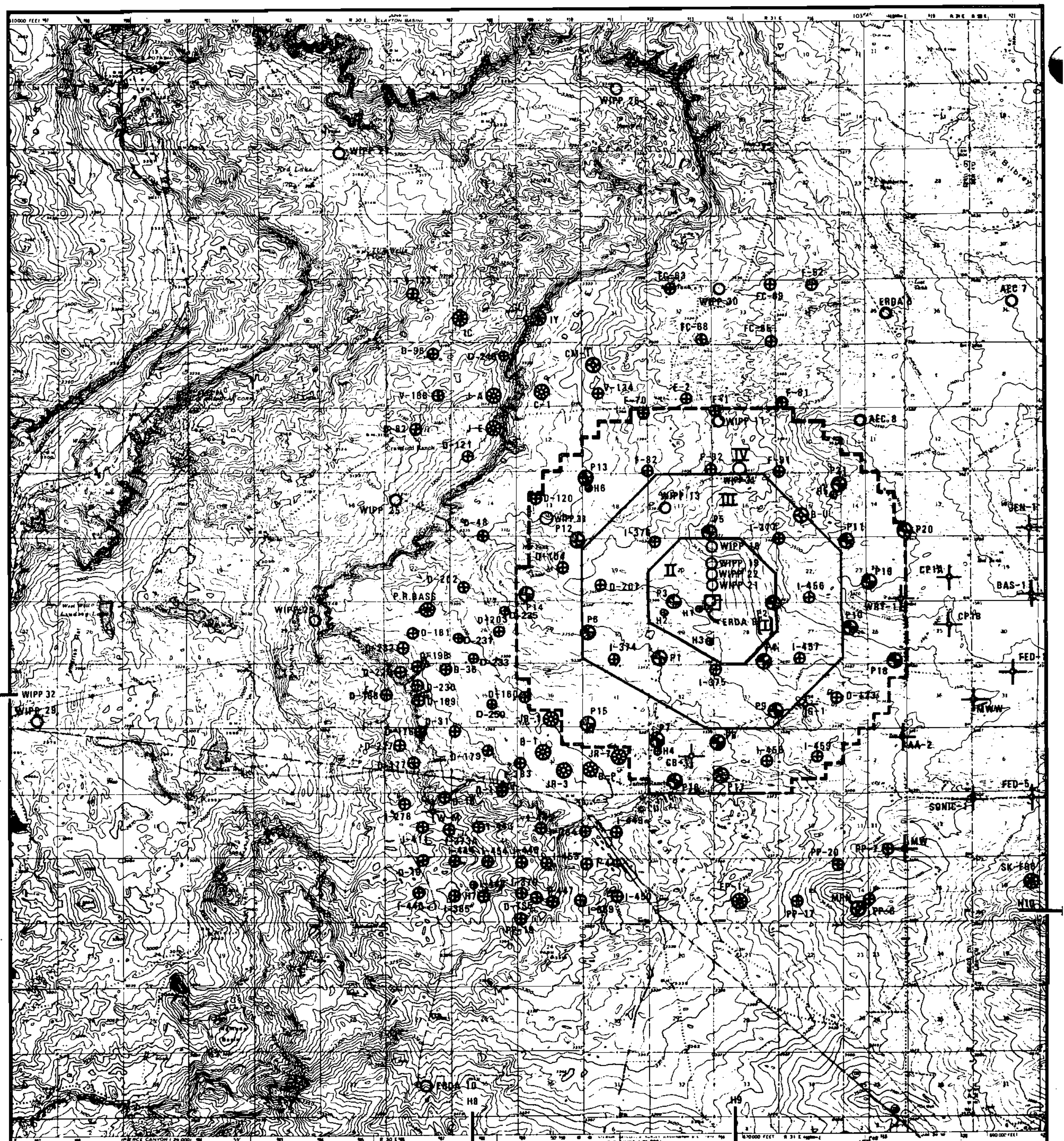
The preoperational survey programs have been designed to describe the existing geologic, hydrologic, meteorologic, biologic, and radiologic characteristics of the region surrounding the WIPP site in Eddy County, New Mexico.

J.1.1 Geology

The purposes of the site geologic studies and the geology sections presented in this report are given in Section 7.3. Investigation methods for geology and seismology are discussed in more detail in the Geological Characterization Report (Powers et al., 1978).

Geologic studies for the site fall into three different phases: preliminary site-selection activities, site characterization, and studies on long-range geologic processes affecting a repository. Site characterization at the present site began in 1975 with the drilling of a hole at the center of the site and the start of seismic reflection work. Site characterization is intended to provide data concerning the geologic acceptability of the site. Results up to late 1978 have been reported in the Geological Characterization Report (Powers et al., 1978). Studies of long-term processes that might affect the integrity of a repository are now the major geotechnical activity of the project personnel. These studies are concerned with the age of significant features and the rates and processes that have produced them.

This section summarizes the geophysical and geologic methods used in characterizing the New Mexico study area. Sixteen stratigraphic holes have been drilled to date (June 1980) in support of this program; one (ERDA-9) is at the center of the site. Figure J-1 shows boreholes within and near the site. Table J-1 has the location, depth, and purpose of boreholes drilled specifically for the WIPP. These boreholes were extensively logged, cored, and drill-stem tested in the evaporite section. The cores form the basis for several continuing laboratory studies important to an understanding of the physical and chemical phenomena associated with the site and contributing to general knowledge about the formation of evaporites. Two boreholes have been drilled well outside the immediate area to obtain data on salt dissolution.



TD Total depth

TA Temporarily abandoned

⊛ Deep producing gas

-|- Abandoned well

⊗ Deep and abandoned

⊕ Potash drill holes

○ Geologic holes

• Hydrologic holes

⊕ ERDA potash drill holes

Figure J-1. Exploratory drill holes in the WIPP site.

Table J-1. Exploratory Drill Holes in the Vicinity of the Site

Designation	Start date	Purpose	Total depth (ft)
AEC-7	3-74	Stratigraphic	3918
AEC-7	3-74	Stratigraphic	3918
AEC-8	5-74	Stratigraphic	
(deepened)	6-76	Deep hydrologic	4910
ERDA-6	6-13-75	Stratigraphic	2776
ERDA-9	4-28-76	Stratigraphic	2886
ERDA-10	8-18-77	Deep dissolution	4431.5
P-1	8-23-76	Potash	1591
P-2	8-25-76	Potash	1895
P-3	8-26-76	Potash	1676
P-4	8-27-76	Potash	1857
P-5	9-10-76	Potash	1830
P-6	9-3-76	Potash	1573
P-7	9-4-76	Potash	1574
P-8	9-8-76	Potash	1660
P-9	9-16-76	Potash	1796
P-10	9-24-76	Potash	2009
P-11	9-24-76	Potash	1940
P-12	9-17-76	Potash	1598
P-13	9-17-76	Potash	1576
P-14	9-24-76	Potash and hydrologic	1545
P-15	10-4-76	Potash and hydrologic	1465
P-16	9-27-76	Potash	1585
P-17	10-18-76	Potash and hydrologic	1660
P-18	10-19-76	Potash and hydrologic	1998
P-19	10-19-76	Potash	2000
P-20	10-6-76	Potash	1995
P-21	10-15-76	Potash	1915
H-1	5-20-76	Hydrologic	856
H-2A	2-14-77	Hydrologic	563
H-2B	2-7-77	Hydrologic	661
H-2C	2-28-77	Hydrologic	795
H-3	7-25-76	Hydrologic	902
H-4A	5-16-78	Hydrologic	415
H-4B	5-14-78	Hydrologic	529
H-4C	4-30-78	Hydrologic	661
H-5A	6-13-78	Hydrologic	824
H-5B	6-4-78	Hydrologic	925
H-5C	6-24-78	Hydrologic	1076

Table J-1. Exploratory Drill Holes in the Vicinity of the Site (continued)

Designation	Start date	Purpose	Total Depth (ft)
H-6A	7-7-78	Hydrologic	525
H-6B	6-28-78	Hydrologic	640
H-6C	6-21-78	Hydrologic	741
H-7A	9-18-79	Hydrologic	154
H-7B	9-13-79	Hydrologic	286
H-7C	9-6-79	Hydrologic	420
H-8A	9-7-79	Hydrologic	505
H-8B	8-6-79	Hydrologic	624
H-8C	7-27-79	Hydrologic	808
H-9A	7-9-79	Hydrologic	559
H-9B	8-14-79	Hydrologic	708
H-9C	8-1-79	Hydrologic	816
H-10A	8-21-79	Hydrologic	1318
H-10B	10-7-79	Hydrologic	1398
H-10C	8-11-79	Hydrologic	1538
WIPP-11	2-5-78	Stratigraphic	3577
WIPP-12	11-9-78	Stratigraphic	2790
WIPP-13	7-26-78	Stratigraphic	1025
WIPP-15	2-8-78	Paleoclimatologic	810
WIPP-16	1-11-80	Stratigraphic	1330
WIPP-18	2-13-78	Stratigraphic	1060
WIPP-19	4-5-78	Stratigraphic	1038
WIPP-21	5-24-78	Stratigraphic	1045
WIPP-22	5-8-78	Stratigraphic	1450
WIPP-25	8-28-78	ND-1 Hydrologic	655
WIPP-26	8-28-78	ND-2 Hydrologic	503
WIPP-27	9-12-78	ND-3 Hydrologic	592
WIPP-28	8-7-78	ND-4 Hydrologic	801
WIPP-29	10-3-78	ND-5 Hydrologic	376
WIPP-30	9-8-78	ND-6 Hydrologic	913
WIPP-31	9-18-78	Stratigraphic	810
WIPP-32	8-7-79	Stratigraphic	390
WIPP-33	7-13-79	Stratigraphic	840
WIPP-34	8-16-79	Stratigraphic	1820
B-25	12-1-78	Stratigraphic	902

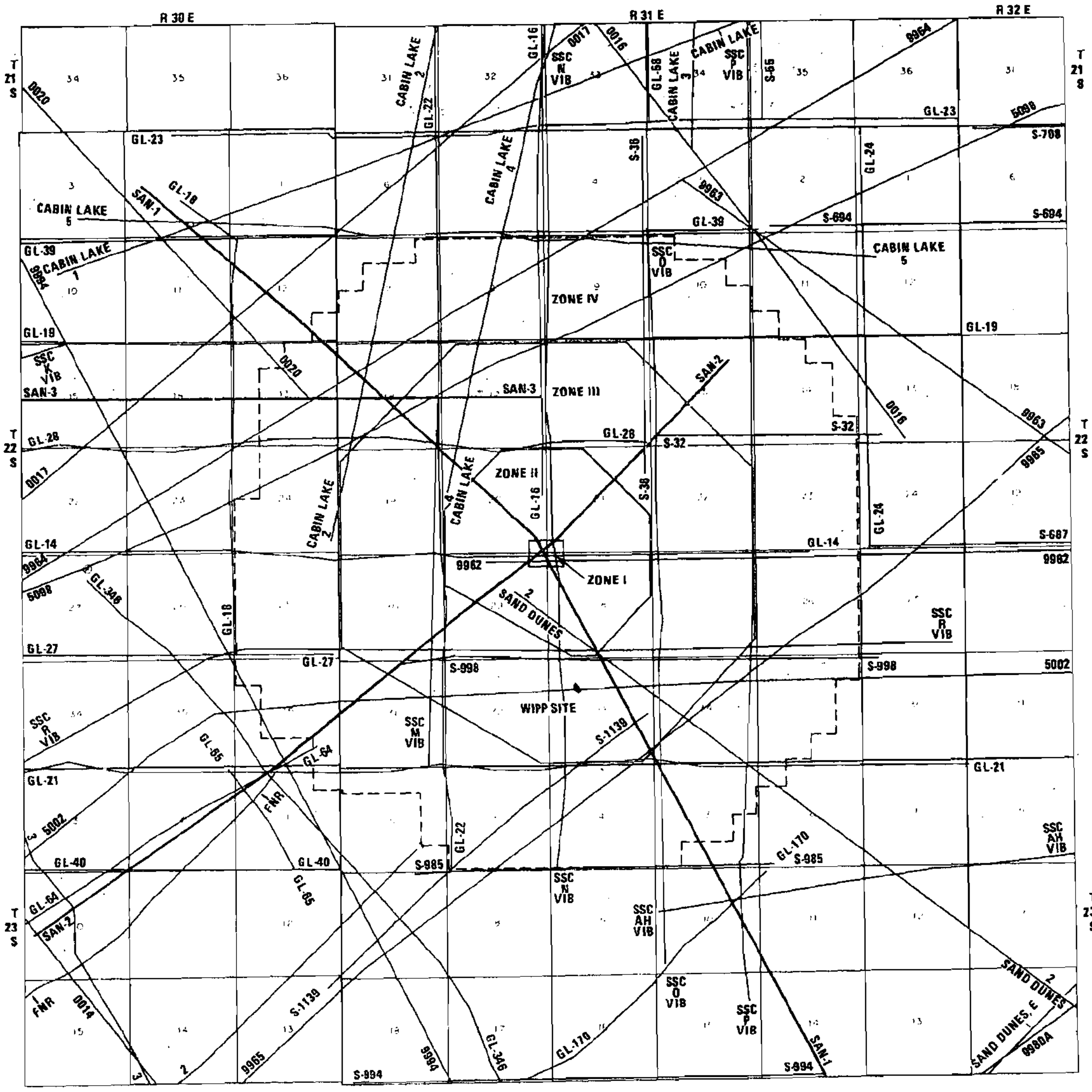


Figure J-2. Industry seismic data and WIPP data from 1976.

Many line-miles of seismic reflection data were available for the study area from petroleum companies, and 26 line-miles of such data were initially obtained by the DOE (Figure J-2), using standard techniques for the petroleum industry. The data are excellent for interpreting deeper structure, but are not as useful for showing reflecting interfaces in the upper 3000 feet. In 1977 about 48 line-miles of new data (Figure J-3) were obtained using shorter spacings for geophones, higher frequencies from Vibroseis units, and higher rates of data sampling. These data show much improved reflections from, and better resolution in, the shallow depths of interest. Resistivity has also been extensively used. Field tests indicate that resistivity can detect certain types of solution features; more than 9000 measurements have been taken in the study area to search for such features (Figure J-4). Additional measurements of resistivity using expander arrays have been made to study resistivity changes with depth and to help interpret the detailed measurements (Figure J-5).

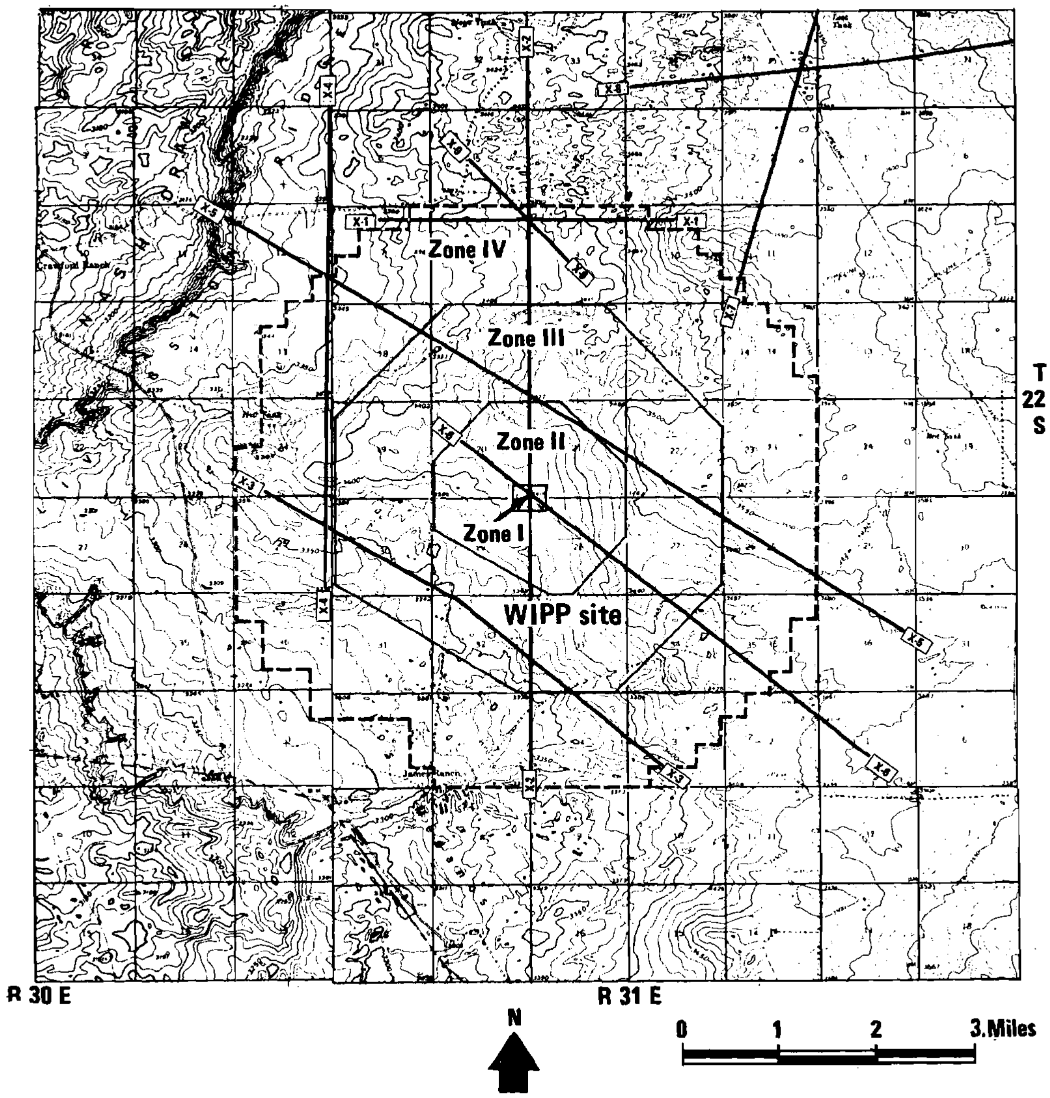


Figure J-3. Seismic program, 1977.

Investigation methods used at the site fall into the major categories of field geology, geophysics, geochemistry, and rock mechanics. The application of these disciplines to studies relevant to the WIPP is outlined below.

Field geology

While all the methods to be discussed may be considered fundamental in the geologic sciences, the term "field geology" is here restricted to the investigations and correlations of regional and local features that are available to the geologist through surface mapping, aerial photography, satellite imagery, and interpretation of borehole and other subsurface data.

The basic starting point of the present investigations was the preparation of a good base map on which the topographic, geomorphologic, and surface-geologic characteristics could be displayed. Existing USGS topographic

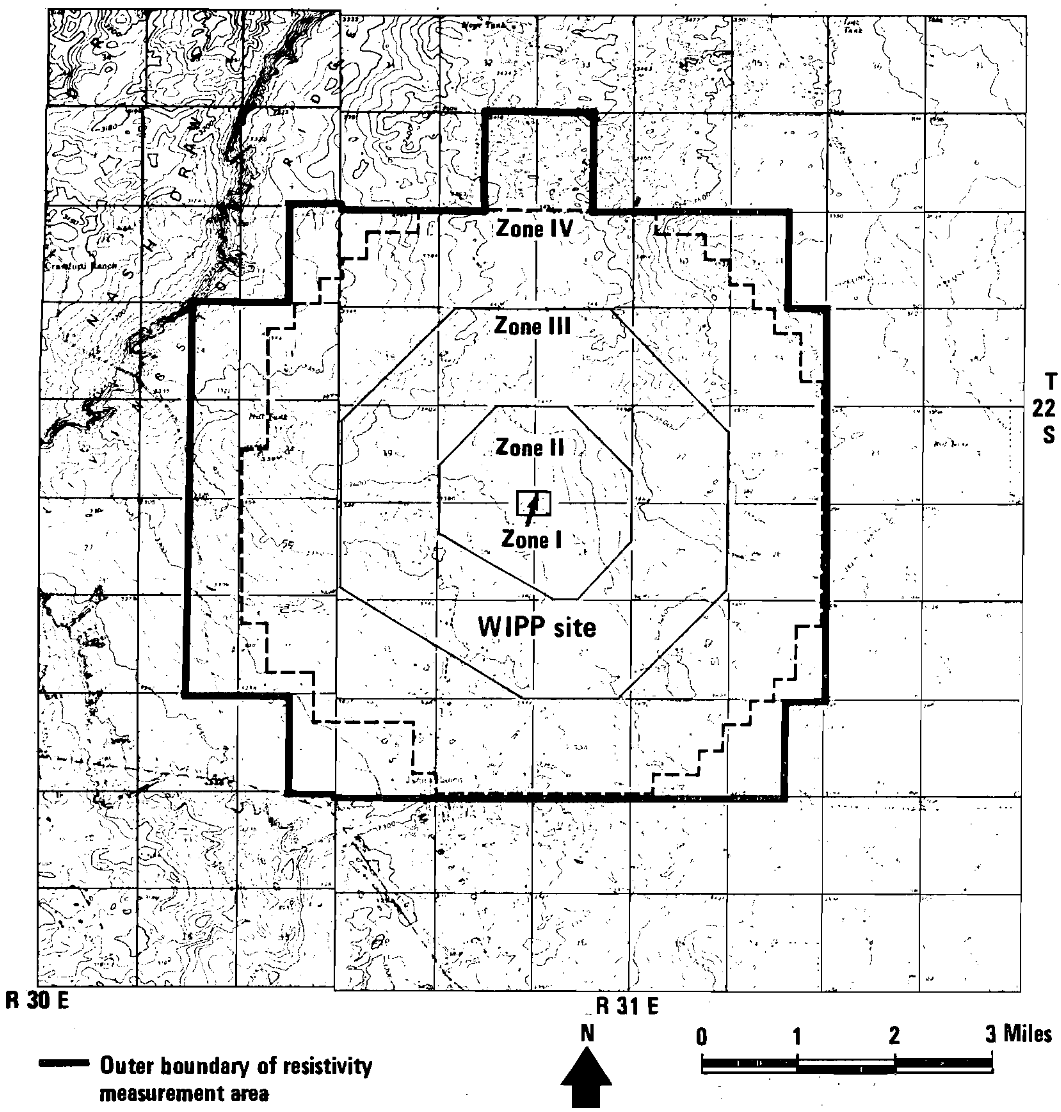


Figure J-4. Location map of gradient resistivity array.

quadrangle maps and aerial photographs were used for this purpose. Aerial photographs, in both color and black and white, were used for the surface mapping of geologic features. Larger-scale features were derived from satellite imagery in reconnaissance style for the southern New Mexico-west Texas area.

Data on surface geology were compiled starting with reports on earlier investigations of the area. It was necessary to supplement this work with more detailed mapping of geologic units in the immediate vicinity of the site. Visual inspection and identification of rock units is necessary at this stage and requires months of field work. Observations of geomorphology and vegetation changes were useful in identifying geologic features for mapping.

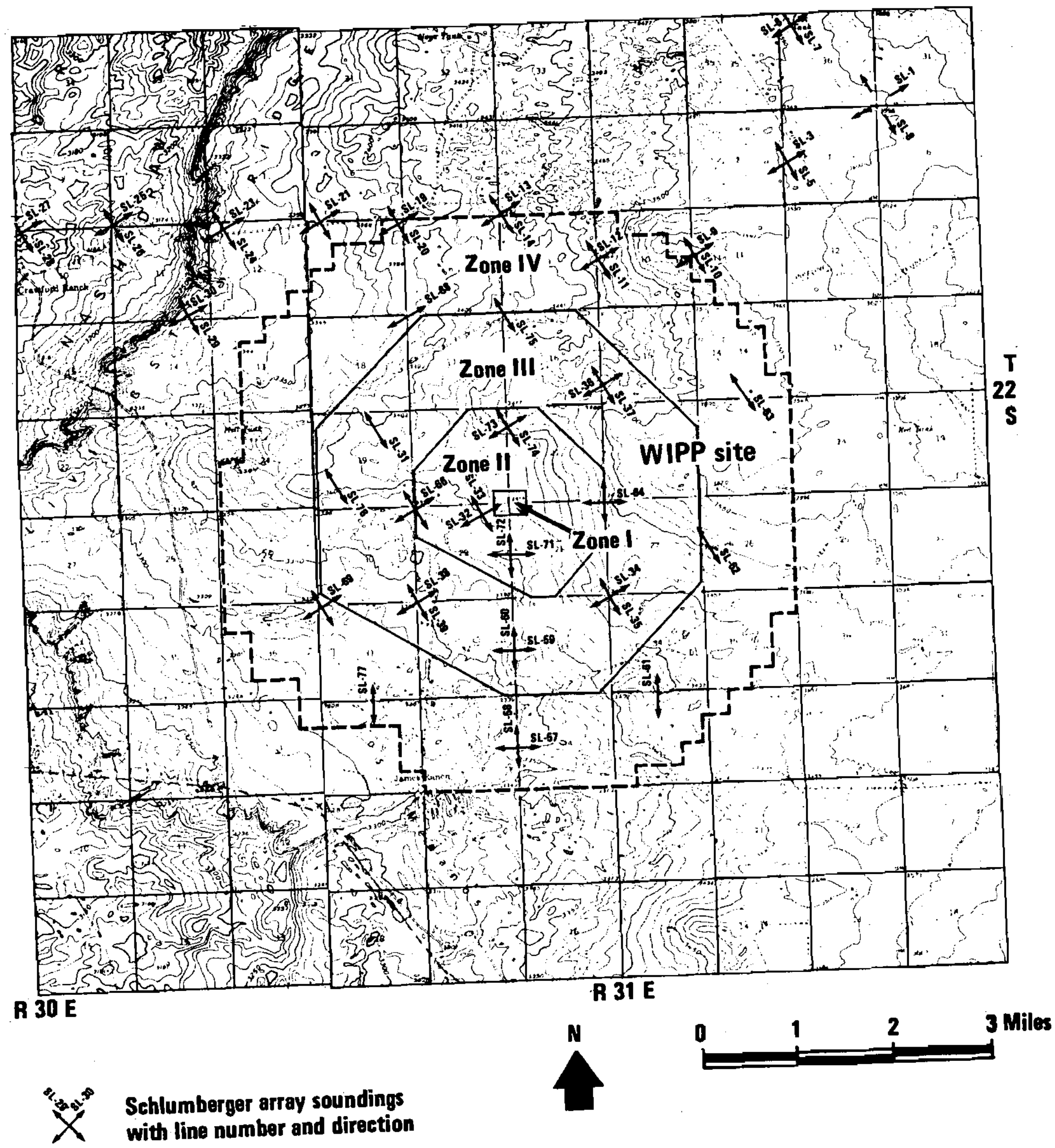


Figure J-5. Location map for resistivity soundings.

Subsurface geology was established using several lines of evidence. Data reported in the literature were the starting point. These were supplemented, and sometimes amended, by proprietary data from petroleum and potash companies that have conducted exploration in the region. Vast quantities of information exist on southeastern New Mexico, both from drill-hole and geophysical tests. Final details were provided by drilling and coring holes for stratigraphic information and conducting geophysical studies to help map formations between boreholes. Cores from boreholes were measured and located relative to the ground surface, described and identified in field notes, and photographed. Lithologic and stratigraphic logs were prepared from examination of the samples. Portions not used in subsequent analyses and tests were sealed in plastic bags, labeled, and stored. All this information is assembled into structural contour and isopach maps for the different geologic formations of interest.

Geomorphologic, topographic, surface, and subsurface geologic maps are all used to interpret the geologic history and tectonic setting of the area. In certain instances, paleontological or paleobotanical information is useful in establishing the chronology of events. Micropaleontology is being used to provide a more thorough understanding of solutioning processes and their rates since Pleistocene time. Samples are obtained by coring deposits in solution sinks in the Delaware basin. Coupled with the physical and geochemical studies, a chronology of events can be developed that allows an estimate of process rates and provides some confidence that forecasts into the near geologic future will not be unreasonable.

Geophysics

Early in the preliminary site evaluation, 1500 line-miles of petroleum-company reflection data were examined for evidence of major faults and other structures in the deep (over 4000 feet) formations. The nature of the data limited its usefulness for the examination of shallow (less than 4000 feet) horizons. Information on shallow horizons was acquired by special seismic reflection surveys. Conventional oil-field gear (Vibroseis) was used, with geophone spacing and instrument recording adjusted to provide better resolution at depths of less than 5000 feet. Experience has shown that this technique can provide good information on reflectors in the Castile Formation and below but must be used with a great deal of caution in attempting to define the attitude of the top of the Salado. Reflections from this horizon and depth are erratic.

Only a limited amount of seismic refraction work was carried out to determine weathering conditions for the reflection work. Where possible, sonic logs or uphole surveys were preferred for this purpose.

Electrical resistivity proved to be a valuable tool in searching for dissolution-related features in the Delaware basin. Resistivity surveys over known solution features, such as "breccia pipes," give characteristic signatures. Consequently, closely spaced resistivity surveys were made over the site to examine it for these anomalies. Indicated anomalies were then confirmed or denied by test drilling. The surveys were run along lines 500 feet apart over the entire 30 square miles of the site area and resulted in about 9000 data points. Two different measurement configurations were used. The modified Werner electrode placement was used for the areal survey described above, and an "expander" array was used to investigate changes in resistivity with depth at a given location. The latter configuration was used to determine whether low resistivities were associated with the presence of the shallow-dissolution zone.

Magnetic methods were employed to search for both regional and local features expected to show magnetic contrast. Existing aeromagnetics of the Delaware basin was examined for indications of major faulting or igneous intrusions. An igneous dike 9 miles northwest of the site was all that was observable in these data; a higher-resolution survey will be used to examine the region near the site for similar but less evident intrusives. Ground surveys and detailed aeromagnetic surveys were tried but were found to be ambiguous in detecting solution-collapse features.

Gravity data for the Delaware basin were examined for indications of major geologic structures and for their utility in detecting collapse features. The absence of the former in the site and the failure of collapse features to exhibit significant density differentials limited the usefulness of the gravity technique.

First-order level-line surveys tied into the national grid established by the National Geodetic Survey (NGS) were made by NGS within the region and locally, in a more dense pattern, in and near the site. These permanent stations will be periodically reoccupied to detect tectonic movements and subsidence due to dissolution and potash mining.

Geochemistry

Geochemical measurements include techniques used to determine the mineral composition, chemical composition, fluid content and composition, age of rocks, and postdepositional history of recrystallization. Mineral composition has been determined through visual inspection, petrographic microscope examination, and X-ray diffraction. When large numbers of samples are involved, X-ray diffraction has been the preferred technique.

Chemical composition has been obtained by analytical-chemistry and atomic-absorption methods. For most purposes atomic absorption is satisfactory and more rapid than wet-chemistry techniques.

Fluid inclusions in salt are counted by microscopic examination. The mass of the fluid is determined by crushing, heating, and recording the weight loss of the sample. In favorable samples the effluent is analyzed by gas chromatography or mass spectrometry. Inferences on fluid-inclusion composition are also obtained by cooling the sample and observing the "freezing" point.

Brines are studied for clues to their past history by applying mass spectrometry to obtain oxygen-18/oxygen-16 and deuterium/hydrogen ratios.

Age dating of evaporites may be attempted by examining rubidium/strontium ratios. Dating of old brines has been attempted through analysis of the uranium-234/uranium-238 disequilibrium. Satisfactory age-dating techniques for old brines and evaporites are not well developed.

Rock mechanics

The rock-mechanics methods described here include both physical and thermal tests applied to rock specimens.

The elastic and strength properties of the salt and other rock samples are determined by stressing machined specimens under conditions of both uniaxial and triaxial stress. Special creep-test apparatus has been built to test rheological properties as a function of temperature and pressure applied over long periods of time.

The permeability of salt to various gases (helium, nitrogen, hydrogen) has been established by laboratory tests on single crystals and on rock cores. Variations in permeability as a function of pressure are also measured. In-situ tests will be conducted in potash mines in the future.

Thermal properties have been measured on laboratory samples and at bench scale. Parameters determined are thermal conductivity, thermal diffusivity, thermal expansion coefficient, and specific heat capacity. Radiant heat transfer has also been examined and found to be relatively minor. These properties are determined by standard laboratory techniques. On larger, bench-scale samples, holes are drilled into the block for heater elements, thermocouples, and strain gauges. These tests allow the determination of average properties more representative of in-situ conditions.

Radiation effects on salt have also been examined in laboratory tests. Induced crystal-lattice defects resulting in "stored energy" are found to be similar in magnitude to those described in the literature for other salts.

Seismology

Information about the regional seismicity around the site falls into two groups. The first includes information obtained before 1962, when no specialized instrumentation existed close to the area. During that period, there were not enough seismic stations in the southwestern United States to provide instrumental coverage of southeastern New Mexico. Therefore, these data describe earthquakes that people felt and that were reported in the technical literature, including the annual publication U.S. Earthquakes. Sanford and Toppozada (1974) gathered other information from newspaper accounts, recollections of long-time residents, records of museums, historical societies, and the like. The principal weakness of these early seismic data is that they are partly a function of population density.

The second group of data began to be collected after instrumentation was established in 1960 and 1962 at Socorro by the New Mexico Institute of Mining and Technology and at Sandia Base near Albuquerque by the Atomic Energy Commission and the Coast and Geodetic Survey. Additional Coast and Geodetic Survey stations, established in 1962 in Las Cruces, New Mexico; Payson, Arizona; and Fort Sill, Oklahoma, permitted epicenters to be determined for local events. Since April 1974, A. R. Sanford of the New Mexico Institute of Mining and Technology has operated a vertical, single-component, continuously recording seismograph station (CLN), 4 miles east-northeast of the site, to monitor seismicity near the site. An array of several additional stations is being deployed at and around the WIPP site in fiscal year 1980 to provide additional information on the rare seismic events within 40 miles of the site. Useful information has also been obtained from a seismograph station operated at Fort Stockton, Texas, from June 21, 1964, to April 12, 1965, as part of the federally sponsored Long Range Seismic Measurement (LRSM) system. From November 1975 to October 1979, the USGS operated a 10-station seismic array near Kermit, Texas, about 60 miles southeast of the site, to monitor seismicity in the Central Basin platform.

J.1.2 Hydrology

Hydrology is a major consideration in examining the feasibility of a site for radioactive-waste disposal. Two factors are directly related to hydrology: (1) the geologic stability of the formation in which the waste will be stored and (2) the presence of groundwater as a transport medium. Because unsaturated waters migrating along the surfaces of salt beds will dissolve salts, an examination of the integrity of the Salado Formation is directed into three study areas: (1) the Rustler-Salado contact beneath the site, to determine whether dissolution is presently occurring; (2) the front of the shallow-dissolution zone in Nash Draw, to more precisely map active dissolution boundaries; and (3) the estimated rates of dissolution at the top and the bottom of the salt, to refine analyses of hazards to the site. Further definition of the hydraulic gradients and rates of fluid movement in the fluid-bearing zones that overlie the Salado will aid in refining the estimates of potential groundwater transport of radionuclides.

Inventory of test holes

The objectives of the hydrologic testing program at the WIPP site are to determine the potentiometric head, the hydraulic character of the rock strata, and the chemistry of formation waters. These hydrologic tests are commonly made in exploratory test holes either during drilling or after the holes have been drilled to total depth.

As of June 1980, hydrologic tests had been conducted at 16 locations in exploratory test holes at the site. Of the 16 locations investigated, ten were specifically designed for hydrologic testing: H-1 through H-10 (Figure J-6). The first three of these were drilled in a triangular array 0.5 mile on a side for the purpose of determining hydraulic gradients in the fluid-bearing zones above the Salado Formation near ERDA-9.

The potash test holes P-14, P-15, P-17, and P-18 shown in Figure J-6 were not drilled specifically for hydrologic testing, but for exploring potash mineral deposits. These holes have been used, however, for determinations of potentiometric head in the fluid-bearing zones above the salt under the southern perimeter of the site.

Two other holes, AEC-8 and ERDA-10, were used for testing fluid-bearing zones below the Salado salt section. The AEC-8 hole, drilled before the WIPP project began, was deepened for testing fluid-bearing zones in the Castile Formation and the Delaware Mountain Group. Similar testing of the Delaware Mountain Group was conducted in ERDA-10.

After drilling and testing holes H-1 through H-3, eight triangular arrays--at locations H-2 and H-4--were designed and drilled at a spacing of about 100 feet. These three-hole complexes, in addition to providing long-term open-hole testing, permit static fluid-level monitoring and pump testing to check for vertical or horizontal communications between fluid-bearing zones. Together with P-14, P-15, P-17, and P-18, the three-hole complexes form part of a network of holes, 2 to 3 miles apart, completely encircling the site.

Finally, six holes (WIPP-25 through WIPP-30) have been drilled in Nash Draw to the west. Their purpose is to define the hydrologic character of Nash Draw in relation to that of the WIPP site. They are being tested now; testing will be complete by October 1980.

General methods used in drilling

Air-rotary drilling was used to drill the holes designed specifically for hydrologic testing at the site. This method differs from standard rotary drilling in that the fluid or mud gel usually used to cool the bit and remove cuttings is replaced by compressed air. The air method was used to make it

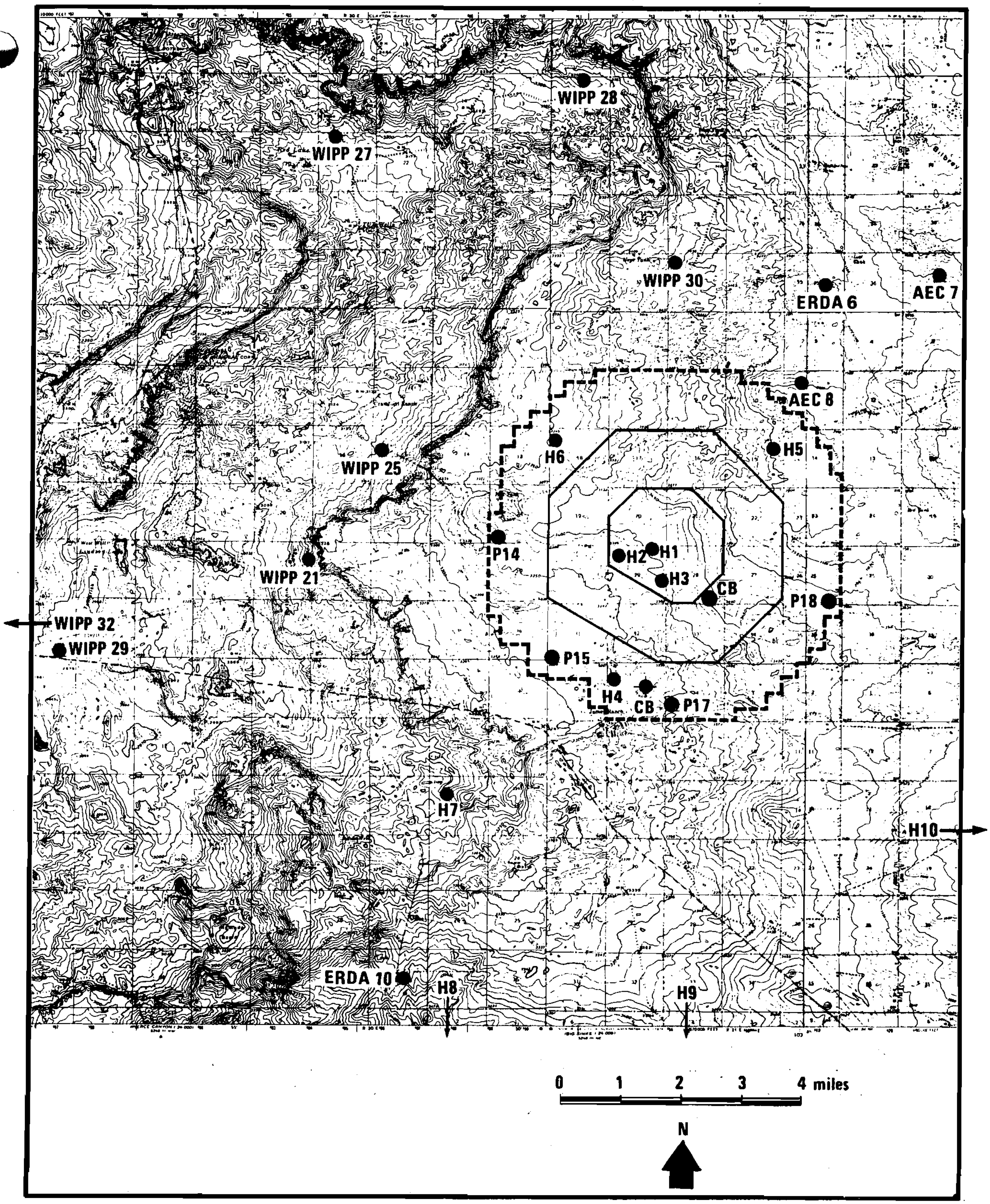


Figure J-6. Location of drill holes used for hydrologic testing.

easier to identify zones that might contain fluid and to prevent the plugging of the aquifer test zones, which may occur when standard drilling fluids are used.

Detailed strategies for drilling and testing

The hydrologic complexes have been drilled and tested following generalized criteria. To date complexes 2 and 4 through 10 (each complex consisting of three holes) have been completed. The H-2 complex is described below as an example of the strategy that was used.

The H-2 complex consists of three holes spaced as shown in Figure J-7. Hole 2a penetrates the Magenta aquifer, hole 2b the Culebra aquifer, and hole 2c the Rustler-Salado contact (Figure J-8). This three-hole configuration makes possible four types of study: independent open-hole testing of the Magenta and Culebra aquifers and the Rustler-Salado contact without interference from the other zones, convenient monitoring of the three formations without the use of downhole hardware such as packers, pump tests of low-yield formations in closely spaced holes, and tracer-injection tests. Each hole was drilled to within 10 feet of its intended depth, casing was set and cemented, and then the hole was cored to total depth.

Investigations usually began with the geophysical logging of the open borehole to obtain information on changes in rock strata, formational characteristics, potential zones of water yield, and borehole-diameter changes. These

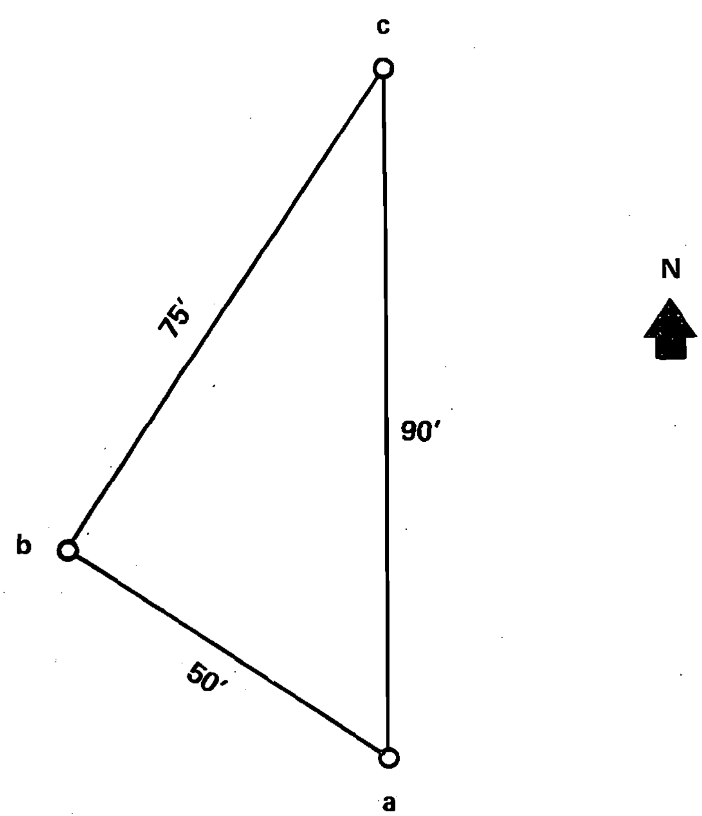


Figure J-7. Plan view showing the configuration of the H-2 three-hole array.

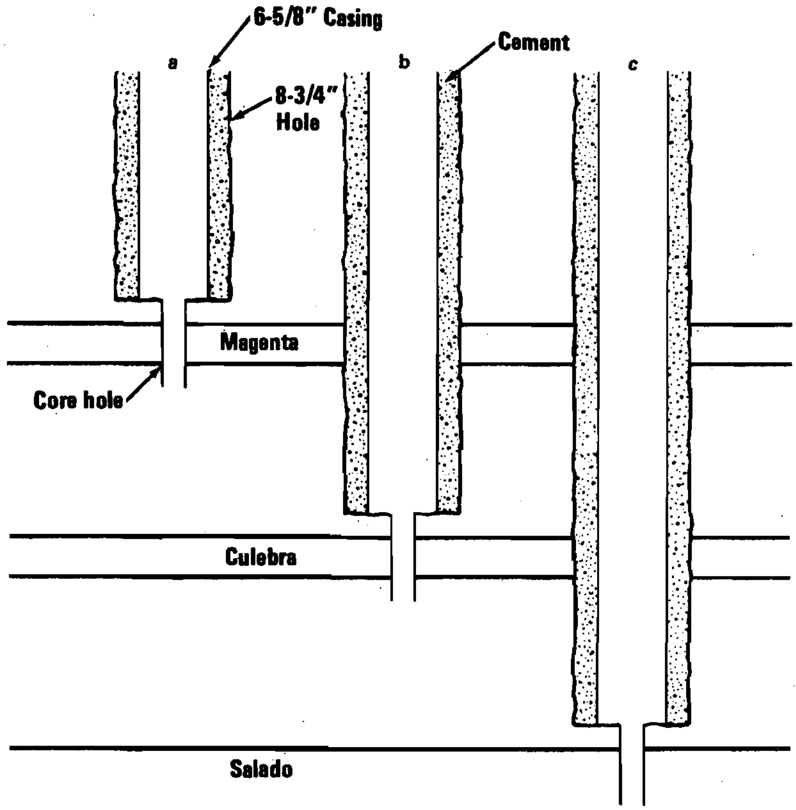


Figure J-8. Configuration of completed H-2 holes.

parameters aided in the selection of borehole intervals to be tested in detail and provided useful information on hole conditions needed in the selection of packer seats. The following logs were run in the deepest of the three-hole array, H-2c: natural gamma and density, caliper, compensated density, compensated neutron gamma ray, dual-induction laterolog, microlaterolog, temperature, acoustic, and 16-inch electric. All holes were surveyed for lateral deviation with a Sperry-Sun directional survey.

After logging, the proposed test zone was isolated by an inflatable packer or packers, and a preliminary drill-stem test (DST) was conducted. The DST is designed to provide a representative sample of formational fluid, undisturbed formation pressure, and estimates of formational permeability. Standard oil-field DSTs were run with slight modifications applied to measuring formation pressures.

Hydrologic tests at the site--whether DSTs, open-hole tests, or cased-hole tests--generally consisted of bailing a known volume of fluid from the borehole. Hydraulic parameters such as hydraulic conductivity, storage, transmissivity, and potentiometric head could be determined by the analysis of observed fluid recovery.

Radioactive-tracer tests are conducted in some hydrologic test holes after they have been cased and perforated at selected intervals. The objective of these tests is to check the quality of cement bonding between the casing and the borehole wall and to provide estimates of the vertical distribution of permeability across the test interval.

Water samples were obtained by bailing only after measurements of conductivity, temperature, and density had indicated that representative formation water was being retrieved.

Rationale for establishing hydrologic complexes

Discussions between WIPP hydrologists and mathematical modelers revealed special data requirements for hydrologic data collection. The general philosophy of hydrologic data collection for the WIPP is outlined in a report (Lambert and Mercer, 1977) that establishes a set of procedures for the collection of data describing the hydrogeologic system of the Rustler Formation at a certain point. The goal of the data collection is to determine a distribution of data values that can establish practical bounds on the spatial nonuniformity of hydrologic parameters and on the variations in experimental results.

Like tests in other hydrologic test holes, these tests are intended to add to the bank of data describing the potentiometric surface, the hydraulic conductivity, and the water quality within the Magenta and the Culebra aquifers of the Rustler Formation and the zone of contact between the Rustler and the Salado. A closely spaced system of holes is required for multihole testing of particular water-bearing, yet low-yielding, zones. Close spacing provides an opportunity for two-hole testing in a finite amount of time, even with the expected low water velocities in the Rustler Formation (Mercer and Orr, 1977).

The locations of hydrologic complexes were based on the need for the following information:

1. Hydraulic definition near the center of the site and at its boundaries (local hydrology)

2. Hydraulic definition outside the boundary of the site (regional hydrology)

3. Location of salt-dissolution fronts and dissolution rates along the western edge of the site

4. Data between already existing holes drilled for other purposes

5. Location of hydraulic boundaries proper for mathematical modeling

6. Location of recharge and discharge areas

7. Verification of assumed directions of groundwater flow

J.1.3 Meteorology

The primary source of meteorological data is the site meteorological station, which has been operating since mid-1976. The three locations of the station are shown in Figure J-9. Specifically, the latest location, 26 miles east of Carlsbad in Section 21, T 22 S, R 31 E, is at elevation 1050 meters, latitude 32 degrees 22.48 minutes north, and longitude 103 degrees 47.24 minutes west.

Until May 1977 the meteorological monitoring system consisted of the following sensors:

- Average wind speed, 10 meters
- Wind direction, 10 meters
- Humidity, 10 meters
- Pressure, 1 meter
- Precipitation, 1 meter
- Ionizing radiation, 1 meter
- Sky radiation, 3 meters
- Temperature, 10 meters

These sensors were interfaced with signal conditioners; their output was recorded by a data logger and a strip-chart recorder. The data logger sequentially sampled data at about three channels per second and displayed output voltages on paper tape. Appropriate calibrations were made to convert this information to engineering units. Computer programs were written to convert and store the data. Peak wind speed was obtained by visually scanning the wind-speed strip chart and finding the maximum wind speed during the hour preceding the report hour.

From November 1977 through March 1980 the meteorological system provided data as described in Table J-2. The on-site meteorological system was designed to comply with most of the criteria in NRC Regulatory Guide 1.23. In September 1978 the 30-meter instruments were raised to 40 meters to insure compliance with this regulatory guide.

The data are managed and processed with a system of two PDP 11/03 minicomputers, each capable of managing 40 channels of information. Recording is made directly on a nine-track incremental magnetic tape. The wind speed and wind direction continue to be recorded on a strip chart for a backup record.

The sensors in the present system are supplied by the Climatronics Corporation. An exception is the rain gauge, which is supplied by Texas Electronics. The sensors are described in Table J-3.

In addition to the above sensors, four solar and terrestrial radiation sensors have been added to the system at a height of 3 meters. Of two pyranometers, one measures the direct component of sunlight and the diffuse, short-wave component of the skylight; the other measures the reflected short-wave component from the surface. Of two pyrgeometers, one measures the long-wave skylight components from the downward emission of atmospheric gases; the other measures the upward emission and reflection by natural surfaces and atmospheric gases.

The pyranometer (Eppley Model PSP) has the following specifications:

Sensitivity	9 mV/(W/m^2)
Impedance	650 ohms
Temperature dependence	$\pm$1% over -20 to +40^{o}C
Linearity	$\pm$0.5% from 0 to 1800 W/m^2
Mechanical vibration	Tested to 20g

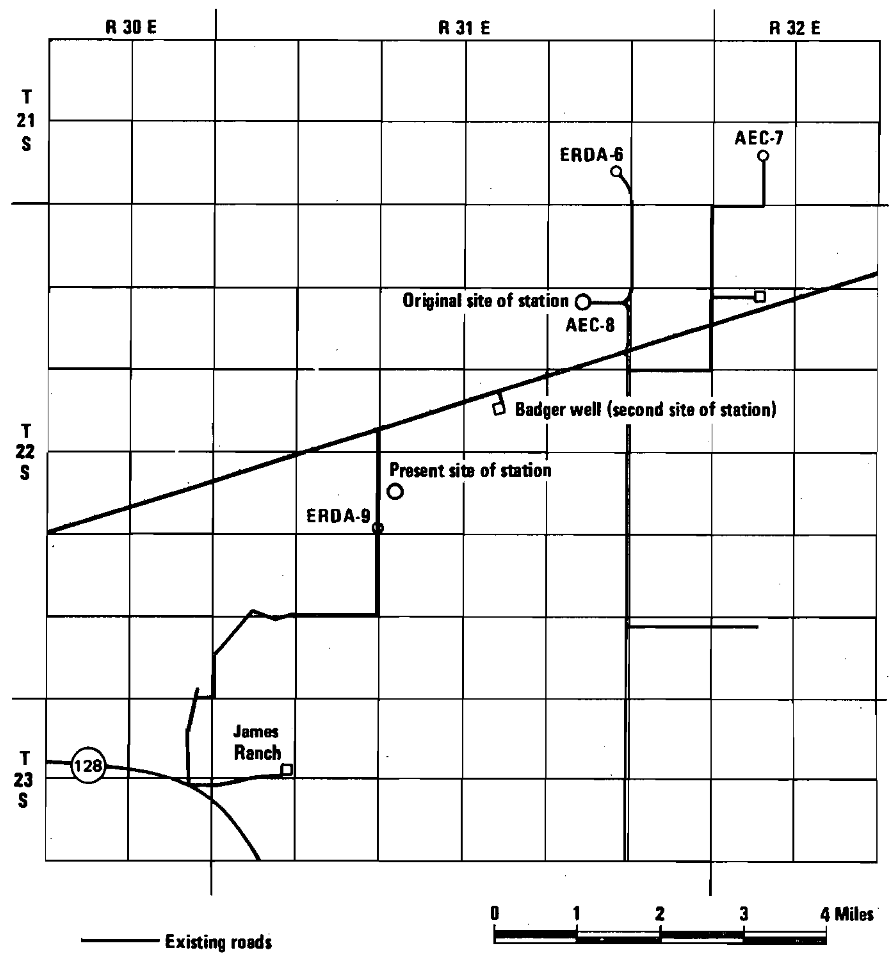


Figure J-9. Location of the meteorology and air-quality-monitoring station.

The pyrgeometer is an Eppley Model PIR; it has the following specifications:

Sensitivity	3 mV/(W/m^2)
Impedance	700 ohms
Temperature dependence	$\pm$2% over -20 to +40°C
Linearity	$\pm$1% from 0 to 700 W/m^2
Mechanical vibration	Tested to 20g

Maintenance and calibration of all the sensors are performed on a formal, periodic basis.

Additional sources of surface meteorological data used in the site meteorological analysis are the Carlsbad-airport, Hobbs, and Roswell stations that report to the National Climatic Center. Upper-air data have come from the Albuquerque, El Paso, Midland-Odessa, and Lubbock stations that report to the National Climatic Center.

Table J-2. Summary of Meteorological Measurements

Parameter	Height (meters)	Sampling interval	Recording interval	Units
Pressure	3	1 hour	1 hour	mb
Precipitation	1	1 hour	1 hour	cm
Dew point	3	1 hour	1 hour	°C
Temperature	3, 10, 30[a]	15 sec	15 sec	°C
Wind speed	3, 10, 30[a]	0.1 sec[b]	15 sec	m/sec
Wind direction	3, 10, 30[a]	0.1 sec	15 sec	degrees clockwise from north
Temperature difference	10-3, 30-3, 30-10	15 sec	15 sec	°C

[a]This height was raised to 40 m in September 1978.

[b]For each of the three levels of wind data, the 10-per-second samples are processed to produce 15-second values of mean component values (east-west, north-south), standard deviation of each component, coefficient of correlation between the two components, standard deviations of downwind and crosswind components, and downwind and crosswind components of turbulence intensity.

J.1.4 Air Quality

Air-quality measurements have been made at the meteorological station, which has been at three locations since data collection began in early 1976 (Figure J-9). From January to June 1976 the measurements were made at the AEC-8 drilling pad. The location was changed in June 1976 to the site of the old Badger well in Section 15, R 31 E, T 22 S, and in May 1977 to the most recent location in Section 21. Air-quality measurements were suspended in October 1979.

The air-quality data collected at the site and the methods of collection have been documented by Brewer and Metcalf (1977). Air-quality samples are analyzed for total suspended particulates, sulfur dioxide, nitrogen dioxide, hydrogen sulfide, carbon monoxide, and ozone. The program as operated before November 1977 is described below.

Total-suspended-particulate samples were taken with a high-volume air sampler that originally had its collector head attached to the instrument trailer tower 4 feet above the trailer roof. The samples were collected on glass fiber or on Whatman 41 4-inch-diameter filters. Samples were collected for 24 hours at a constant sampling rate of 18.5 ft^3/min. The sampling rate was maintained by flow controllers. Each sample was analyzed for the concentration of sodium, potassium, calcium, magnesium, silicon, iron, aluminum, chloride, and sulfate. These elements and species were selected because they are effluents released by the nearby potash-refining plants. The water-soluble metals, sulfate, and chloride were extracted from the filter by heating in an aqueous solution for 2 hours. Sulfates and chlorides were analyzed by turbidimetric and colorimetric methods, respectively. After extraction, the filters were dissolved in concentrated nitric acid, and the elements were analyzed by atomic-absorption spectrophotometry.

Table J-3. Specifications on Meteorological Sensors Used

	WIND SPEED
Threshold	0.33 m/sec
Distance constant	1.5 meters
Accuracy	0.1 m/sec or ±1%, whichever greater
Range	0.3 to 50 m/sec
Linearity	±0.1% of full scale
Stability	±0.1% of full scale
Survivability	Gusts to 45 m/sec, sustained to 33 m/sec
	WIND DIRECTION
Threshold	0.33 m/sec
Distance constant	1.5 meters
Accuracy	±2.5 degrees
Damping ratio	0.4 degree at 10-degree angle of attack
Range	0 to 540 degrees
Linearity	±0.1% of full scale
Stability	±0.1% of full scale
Survivability	Gusts to 45 m/sec, sustained to 33 m/sec
	TEMPERATURE
Range	-30 to +50°C
Accuracy	±0.25°C
Linearity	±0.2°C
	DEW POINT
Range	-40 to +42°C
Accuracy	±0.5°C
Response time	1°C/min
	TEMPERATURE DIFFERENTIAL
Accuracy	0.1°C
Range	-2 to + 10°C
	STATION PRESSURE
Range	850 to 975 mb
Linearity	±0.3%
Sensitivity	0.2%
	RAIN GAUGE
Type	Tipping bucket
Measurement	0.01-inch water per tip
Signal out	Momentary switch closure

Air samples for particle-size determination and mineralogical analysis were taken for periods of 5 to 7 days once a month. A Sierra Cascade impactor with five stages was used. The impactor was originally located on the trailer roof, about 12 feet above the ground.

Sulfur dioxide, hydrogen sulfide, and nitrogen dioxide were determined by wet-chemistry techniques. The sampling frequency was once a week on a random-day basis. The wet-chemistry sampler was located about 3 feet above the roof of the meteorological trailer. The sampling rate was 200 ml/min in high-efficiency bubblers. The sulfur dioxide and nitrogen dioxide samples were analyzed colorimetrically; the hydrogen sulfide samples were titrated. The methods used were standardized through the use of samples of known concentrations.

Carbon monoxide was detected with a continuous nondispersive infrared analyzer. An average concentration for each 24 hours was calculated. The monitor was calibrated weekly by means of a carbon monoxide-in-nitrogen gas standard. The monitor sampling inlet was inside the housing of the Sierra Cascade impactor.

Ozone was measured continuously with an automated ultraviolet-absorption detection technique. An average concentration for each 24 hours was calculated. The ozone monitor was calibrated weekly by electronic methods.

After November 1977, changes were made to the original system for air-quality monitoring. The system was automated to reduce recording by personnel. Of primary importance was the introduction of a redundant system of PDP 11/03 minicomputers to manage data input from the sampling devices. The concentrations of all monitored species are monitored by the minicomputers. The data are averaged and recorded every 15 seconds. The species continuously monitored are ozone, oxides of nitrogen, carbon monoxide, total hydrocarbons, sulfur dioxide, and hydrogen sulfide.

Changes in pollutant-detection techniques after November 1977 included new methods for sulfur dioxide and hydrogen sulfide, which were then measured with pulsed-ultraviolet-fluorescence detectors; total hydrocarbons, which were then measured with a flame-ionization detector; and oxides of nitrogen, which were then measured by a chemiluminescence technique. Total-particulate samples were analyzed for lead for about 6 months. This analysis was in addition to the other elements measured before November 1977. No lead was detected in any of the samples during this 6-month interval, and the analysis was therefore discontinued. All elements are analyzed by atomic-absorption spectrometry.

The location of some of the sampling equipment was also changed. The Sierra Cascade impactor was relocated 12 feet above the ground on a sampling platform. The high-volume sampler and the wet-chemistry sampler inlet, a chemical sampler now used as a backup system, are also on the platform at heights of 10 and 8 feet, respectively. The preoperational program samplers will remain at these levels.

J.1.5 Ecology

From 1975 through 1977, the New Mexico Environmental Institute (NMEI) carried out environmental baseline studies for the DOE in the area of the WIPP site. Their results are published in two progress reports (Wolfe et al., 1977a, 1977b).

During 1977, the biological team was reorganized. Baseline studies were continued and in some cases augmented. The area within a 5-mile radius of the center of the WIPP site was designated the Terrestrial Ecology Study Area. Semipermanent transects, unfenced plots, and exclosures have been established in connection with these studies. Some will be retained as permanent sites for ecological monitoring during and after the operational period. Field and laboratory methods are detailed in the annual report for fiscal year 1978 (Best and Neuhauser, 1979).

All major habitats within the study area have been and are being sampled seasonally for plants, mammals, birds, reptiles, amphibians, terrestrial invertebrates, and aquatic species. In addition, microbial flora, soils, and nutrient cycling have been and are being studied.

Soil studies

The objectives of the soil studies are (1) to confirm and refine the physical and chemical descriptions of the major soils series in the study area; (2) to study soil-water-plant relationships; and (3) to characterize biologically mediated chemical transformations in the soil. These activities are being carried out in close cooperation with the vegetation mapping work because plant community composition is often strongly influenced by soil characteristics.

Microbial processes in terrestrial and aquatic communities are being studied to determine primary productivity and to assess what impact these processes may have on radionuclide mobilization or demobilization. Furthermore, soil crusts of cyanobacteria and lichens have been described at the site; they cover large areas of soil and are thought to contribute significantly to soil stabilization. The affects of climatic variation on these crusts and the rate of colonization of freshly bared surfaces are of interest because the magnitude of wind and water erosion at the site may be influenced by changes in the soil crust.

Botanical studies

The objectives of botanical studies are (1) to obtain as complete a species list as possible, with special attention to possible rare, threatened, or endangered species; and (2) to gather density and distribution data in order to construct a vegetation map and to determine primary productivity. The reproductive and vegetative phenophases of dominant species are also being determined. These data can be correlated with soil data, as noted above, and with data on consumers (amphibians, reptiles, birds, and mammals) to provide a picture of trophic relationships at the site. Annual and seasonal variations due to changes in rainfall and other climatic factors are recorded. These variations, which directly affect many populations of primary consumers, are often extreme in this semiarid region. Baseline data covering several years will, however, provide a reliable estimate of the magnitude of natural variation.

The succession of plant communities that occurs in disturbed areas and the impact of grazing pressure on existing plant communities are also being studied because WIPP construction must inevitably cause at least localized disturbances that will alter the structure of plant communities as defined by the baseline data. The objective of these studies is to obtain data that will make it possible to predict the kind and the magnitude of changes induced by such disturbances.

Terrestrial invertebrate studies

In addition to providing an inventory list of invertebrates in the study area, the studies focus on the role of soil arthropods, especially termites, in the cycling of soil nutrients and detritus. In addition to density and distribution data, feeding rates and estimates of the quantities and types of material transported and consumed are being made; the effects of termites on soil movement and redistribution are also being measured. Aside from their crucial role in nutrient cycling in this ecosystem, the termites may affect the distribution of radionuclides deposited on soil and plant surfaces.

Terrestrial vertebrate studies

The species composition and density distribution of terrestrial vertebrates within the study area are being studied, as are the feeding habits, population dynamics, and reproductive phenology of selected species. These studies include amphibians, reptiles, birds, and mammals. Significant annual changes in densities are correlated with plant density and weather data. Special attention is given to the possible presence of rare, threatened, or endangered species.

Aquatic studies

The objective of the aquatic studies is to establish baseline levels for parameters of significance at the aquatic study sites. These include physical-chemical water-quality data, density, and population dynamics data for flora and fauna at major trophic levels. Study sites are located at stock tanks within the terrestrial study area, nearby playas, Laguna Grande de la Sal, and several stations along the Pecos River. The possible presence of rare, threatened, or endangered species is given special attention.

Radioecological monitoring

As a result of the above studies, indicator organisms will be selected for long-term monitoring. Factors involved in the selection process will include trophic level, sensitivity to other ecological stresses, and difficulty and expense of monitoring. Organisms at high trophic levels should be included to detect biomagnification. However, several otherwise suitable species--for example, hawks--are rare and/or protected by law. Thus, the selection process must consider such factors as well as strictly technical considerations. Final development of a monitoring program cannot take place until all baseline data are analyzed.

J.1.6 Radiation Monitoring

A radiation-monitoring program has been established at the WIPP site to assess the level of natural background radiation in the area and its variations with time. This program will continue at its present level until about 2 years prior to the expected beginning of plant operation. At that time, the program will be increased in scope to be consistent with the requirements of ERDA Manual Chapter 0513--the current DOE regulations for preoperational environmental monitoring.

When the current environmental sampling program was instituted, no site-specific meteorological data were available to use in choosing sampling locations, nor had a potential site been selected for the WIPP surface facilities. Therefore, several sites were selected that would be accessible and would provide information on the variability of the radiation background within the boundaries of the site. With the meteorological data now available, the selection of future sampling locations can be based on EPA guidelines for nuclear power plants (EPA ORD/SID 72-2), taking into account local terrain, population distribution, and meteorological conditions.

The preoperational program is characterized below, although it cannot be described in detail until the WIPP is nearer to operation. The construction of the WIPP will have no effect on the radiological levels of the environment except that the accumulation of mined-salt piles, which contain naturally occurring potassium-40, radon-220, and radon-222, may increase the site background levels slightly. More detail will be added when the full program begins 2 years before the expected commencement of operation. Instrument detection limits and sensitivities will be selected to insure that radiation levels well below standards can be detected. In addition, a strict quality-assurance program will be followed. Procedures will be written and standardized for each type of analysis. Accuracy and standardization will be maintained by routine quality-control procedures. The quality-assurance program will also insure samples of sufficient size to provide accurate measurements.

Air particulates

Air-particulate samples have been taken at the site meteorological station (Figure J-10). Samples were taken three times a week for 24 hours by a high-volume air sampler (18.5 ft^3/min) with Whatman-41 filter media. Gross beta concentrations are measured by a beta proportional counter. If the beta activity exceeds 0.06 pCi/m^3, a gamma scan may also be taken.

For the preoperational monitoring program a network of air samplers will be established at and in the vicinity of the WIPP site. Sampling sites will be determined based on population distribution, meteorological conditions, and other factors to insure that both maximum and representative conditions can be detected. Gross alpha and gross beta counting will be performed on the filter media, and analyses of the collected particulates will be performed.

If the results of the initial counting indicate that higher than normal concentrations are present, additional analyses will be performed to determine the source and type of nuclides in the samples.

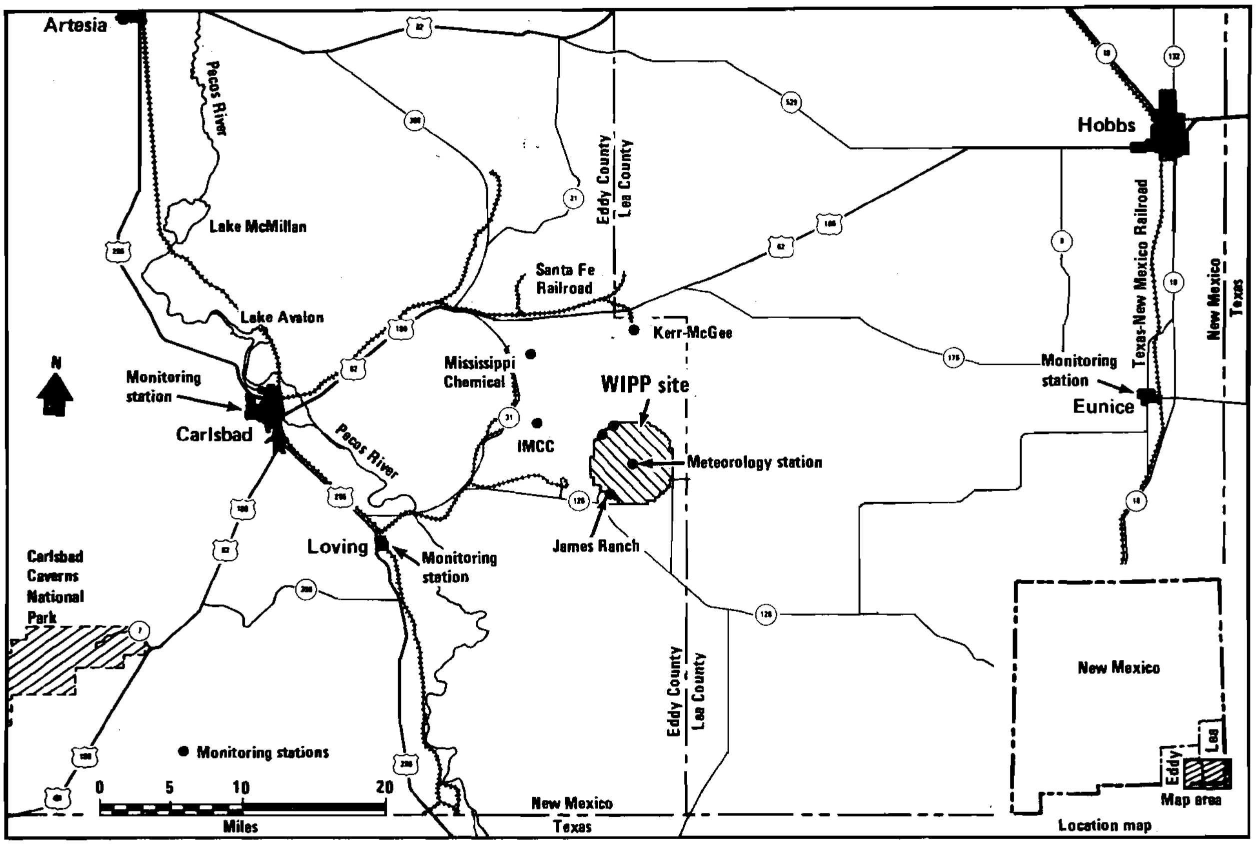


Figure J-10. Proposed air-particulate-monitoring stations.

Soil samples

Radionuclides in soil can be determined by laboratory analyses of soil samples taken at several locations in the vicinity of the WIPP site or by field gamma spectroscopy at selected locations. Gamma-emitting radionuclides could be determined by either technique, but the presence of plutonium would have to be inferred from the measurement of americium-241 if the in-situ technique is used. Initial soil profile samples would be necessary to determine the vertical distribution of any radionuclides present.

Direct gamma radiation

Levels of direct gamma radiation currently are being measured at the site. This program will be continued on a limited basis until 2 years before operation. The present program uses one Reuter-Stokes pressurized ionization chamber at the meteorological station. The radiation level is measured continuously and averaged on a weekly basis. Gamma-radiation measurements are also made at seven different locations (Figure J-11) by thermoluminescent dosimeters (TLDs). At each location, five TLD-100 chips are placed approximately 1 meter above the ground; these are exchanged and evaluated quarterly.

Two years before operation begins, the preoperational monitoring program will be increased in scope to include TLD stations at several additional sites in the vicinity of the WIPP site.

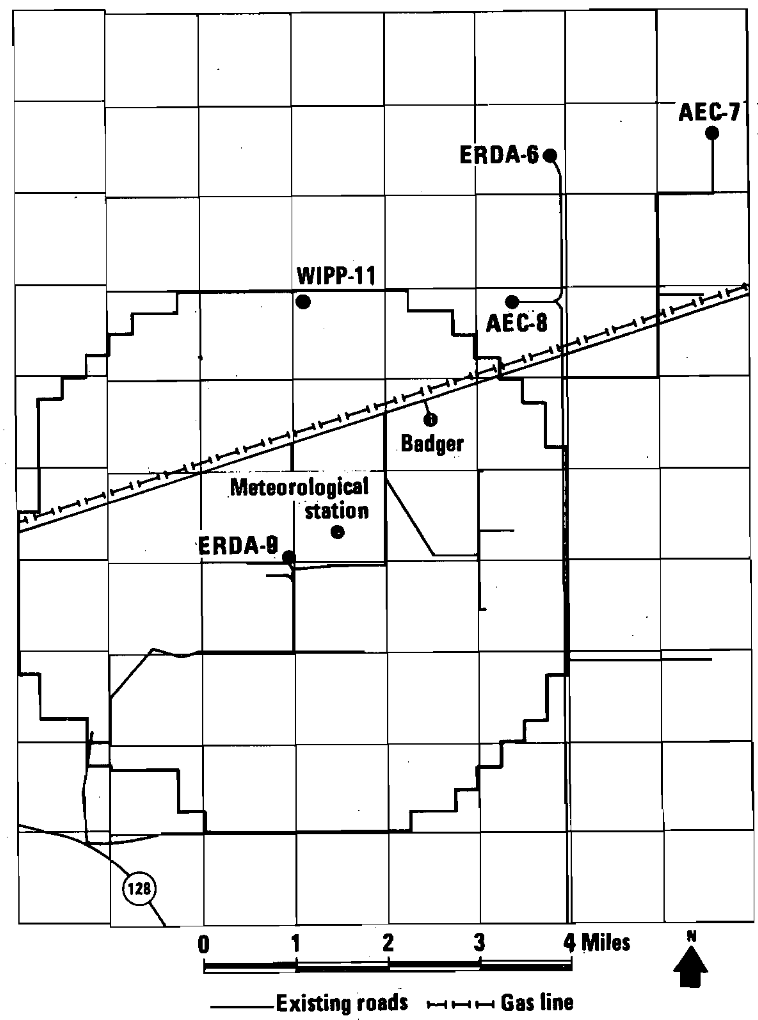


Figure J-11. Locations of thermoluminescent dosimeters in the site area. An additional thermoluminescent dosimeter will be located in Carlsbad.

Water sampling

One of the most important aspects of the radiological monitoring program will be to monitor groundwater at available sampling locations (Figure J-12). Considerable attention will be given to groundwater monitoring, since groundwater is a potential pathway for radionuclide transport. Sampling locations at the site will be established and sampling begun 2 years before operation. All sites will be monitored quarterly for gross alpha and gross beta concentrations. Isotopes present in the water will be identified by the analysis of gamma-ray spectra.

Beginning 2 years before the start of operations, surface-water samples from the Pecos River will be taken on a routine schedule and possibly after periods of rainfall. Surface-water samples will be evaluated by gamma-spectrum isotope analyses.

No well whose water is used for human consumption exists within 5 miles of the site. Public drinking water supplies in Carlsbad, Loving, and Malaga are presently being monitored annually by the EPA as a result of the Gnome project in 1961. That monitoring program is discussed elsewhere in this appendix.

Sediment, benthic organisms, aquatic plants, fish, and shellfish

No sampling of benthic organisms, aquatic plants, fish, or shellfish is planned because the nearest surface water, excluding water tanks, an impoundment, and salt lakes, is 14 miles away from the site at its closest point. However, to account for the extremely remote possibility of radionuclide buildup on sediments over long periods of time, baseline radiation levels in sediments of the Pecos River will be determined; these will be compared with data obtained after operation commences. Such samples will be taken along with surface-water samples and will be subjected to gamma-spectrum isotope analyses.

Milk

No milk sampling is planned since the nearest dairy farm is more than 40 miles away. No commercial feed crops are grown within 10 miles of the site.

Fruits and vegetables

No food crops for public consumption are grown within 10 miles of the site. Therefore, there are no plans to sample food crops except for green leafy vegetables and representative fruits from any private garden plot that may come to exist within 5 miles of the site. Sampling will be performed at each harvest. The edible portions of these fruits and vegetables will be subjected to a gamma-spectrum isotope analysis. The green leafy vegetables will also be analyzed for tritium. The sampling of existing private garden plots will start 2 years before operation begins.

Meat and poultry

At least one sample each of meat, poultry, and eggs from fowl, if any, feeding on land within 10 miles of the site in the prevailing downwind direction will be collected annually. One of the major game species, the mourning dove, will be collected in season. One sample of beef from cattle grazing within 10 miles of the site in the prevailing downwind direction will be taken annually, if available. This sampling will commence 2 years before the WIPP begins operating. Edible portions will be analyzed for gamma-emitting radioisotopes and the predominant actinides expected to be present in the waste emplaced in the WIPP.

J.2 PROPOSED OPERATIONAL MONITORING PROGRAMS

The preoperational monitoring programs described in this appendix will form the basis of the operational monitoring programs. The operational programs, however, will profit from the experience and the techniques developed during the preoperational phase.

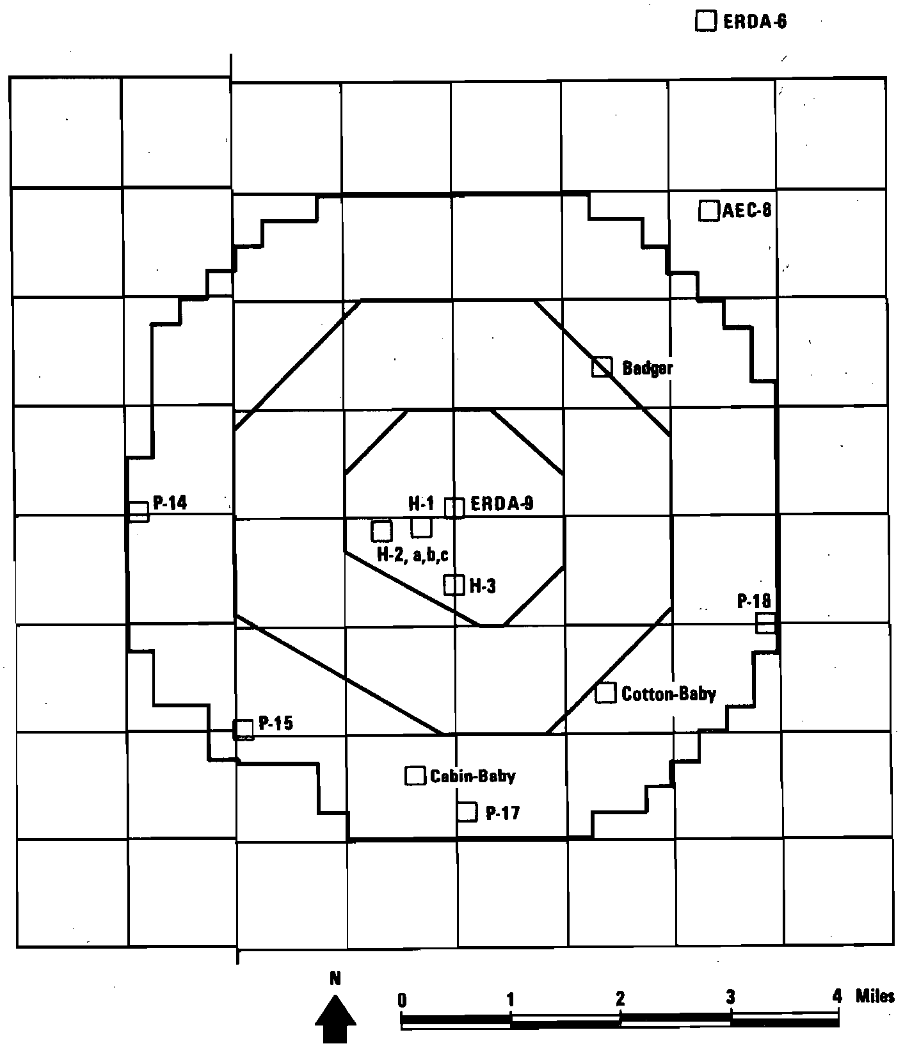


Figure J-12. Groundwater-sampling locations.

J.2.1 Geology

During the construction and routine operation of the WIPP, several monitoring programs will be conducted to insure that no unacceptable geologic conditions are encountered or caused by development of the facility.

Underground monitoring

As shafts are sunk and drifts are mined into the salt, geologic mapping of stratigraphic units and structural features will be conducted regularly. Before mining drifts, horizontal pilot holes will be cored along the drift paths and the rock examined to provide information on physical properties. When suitable, radar sounding will be used to probe in advance of mining for pockets of brine or gas.

Deformation gauges will be installed at important locations in the shaft pillar region and in major haulage-and-access drifts. These gauges will be monitored regularly and compared with expected deformations calculated by rock-mechanics computer codes. The shafts will be regularly inspected to detect any unusual movement of the shaft walls.

Bulk salt samples obtained from the waste-storage and experiment rooms will be analyzed to determine the chemical makeup, brine content, mechanical properties, and thermal properties. This sampling will establish whether the medium has been adequately described from earlier, more limited, samples. If the deviations in properties are significant, new calculations will be performed to describe the repository behavior.

Surface measurements of geologic parameters

Continuous monitoring of seismic activity will be conducted by seismometers located near the surface buildings but remote enough to avoid microseisms produced by human activities. This station will monitor regional and local natural seismicity and microseisms that may develop from subsidence; it will document the ground motions imposed on surface facilities.

Surface level-line stations that have been and will be installed over the site will be resurveyed regularly, perhaps every 1 to 5 years, to detail the movement of the surface in response to thermal loading and room collapse. The results will be compared with calculated results to monitor room collapse after individual rooms or sections of the WIPP have been closed.

J.2.2 Hydrology

The hydrologic program described in this appendix is expected to extend well beyond the operational lifetime of the WIPP. Long-term proposals include the installation of water-level recorders in all monitored wells. The continuous output from the recorders will be correlated with barometric data from the local weather station to eliminate atmospheric influences in water-level fluctuations.

The surface hydrology of the region will be defined in terms of the major components that contribute to surface flows and water quality. Water balances in critical areas of interest or local watersheds will be investigated to establish the scope of aquifer recharge and to predict hydrologic changes. Measurement programs for spring flows, potash effluent, and other surface runoff will be carried out.

It is expected that groundwater sampling for long-term monitoring will be performed on an annual basis. However, after mining for the WIPP has started, sampling will be quarterly until conditions stabilize. The increased frequency of measurement will permit early detection of changes in groundwater systems from mining and construction activities.

J.2.3 Meteorology

The operational monitoring program will follow the preoperational program very closely. The measurements taken during the preoperational phase will continue to be taken at a permanently established monitoring station. The increased amounts of data will be used to better characterize the meteorological conditions at the site.

J.2.4 Air Quality

The operational air-quality monitoring program is expected to be identical with the preoperational program. The program will remain flexible, however, to meet the requirements of new sampling regulations and guidelines, either State or Federal. The program, in all cases, will be adequate to establish whether or not State and Federal air-quality standards are being met.

J.2.5 Ecology

The operational ecological monitoring program, building on the foundation established through preoperational ecological monitoring, will document the ecological effects of construction and operation. The proposed monitoring plan will be flexible to permit modifications. Initial experience may suggest such modifications as changes in instrumentation, addition or deletion of parameters, adjustments in the number and location of sampling stations, or alterations in the frequency of observations and the number of replications.

Sampling methods and strategy will follow those presented in the preoperational biological monitoring program, unless there is substantial reason to modify them. However, operational monitoring will focus primarily on indicator organisms and selected abiotic parameters. Biological data will be collected near meteorological and radiation-monitoring stations (when possible) to facilitate correlation with data collected at these stations. Samples will be collected during each season at biologically significant times (as determined through preoperational monitoring). When unusual trends are observed, sampling will be intensified to elucidate the cause. Unusual trends will not necessarily be attributable to the WIPP because biota respond dramatically to fluctuations in rainfall and resource availability.

Information generated by the operational (and preoperational) monitoring program will be published by the principal investigators in recognized professional journals and presented at appropriate meetings and symposia. In addition, all work will be reviewed by an independent committee of scientists from appropriate fields. These practices will insure that data are being collected and interpreted according to the most up-to-date professional standards.

J.2.6 Radiation Monitoring

The radiation-monitoring program provides data on measurable levels of radioactivity in effluents and the environment. This monitoring is done to assist in evaluating the relationships between the radioactivity released in effluents and the resultant radiation doses received by people beyond the boundaries of the site through credible pathways of exposure.

The off-site environmental radiation monitoring program, coupled with on-site effluent monitoring, performs the following functions:

1. It identifies measurable changes in off-site radiation levels or quantities of biologically significant radionuclides.

2. It provides a means of determining whether off-site radiation exposures are maintained as low as reasonably achievable and are within applicable limits.

3. It provides a means of evaluating the impact of WIPP operations on the environment.

Both the on-site and off-site effluent and environmental monitoring programs are discussed below.

Effluent monitoring

The gaseous-exhaust systems provide potential pathways for the release of airborne radionuclides. The effluent monitoring system located at each release point will consist of measuring devices that sample airborne particulate radioactivity.

Samplers will be installed at the release points to collect the particulate activity from a representative fraction of the total volume of air being discharged at the release point. The samplers will consist of a probe into the air stream, a filter holder, and a vacuum supply. The sampling probe will be designed in accordance with ANSI N13.1-1969. The sampling flow rate and probe will be designed so that the particle velocity in the effluent stream will be the same as the particle velocity in the sample probe. This will eliminate particle-size biases in the sampler. A sample flow-rate controller will maintain constant sample flow as the filter collects dust. This will increase the pressure drop across the filter and tend to reduce sample flow.

Other design features to be incorporated to improve sampling efficiency include the following:

1. Electrically grounding the probe to minimize electrostatic deposition

2. Designing the interior finish and general arrangement of the probe to minimize turbulent deposition

3. Locating the filter holder as close to the probe as possible to minimize particle fallout in the transport line

4. Insulating and, if necessary, electrically heating the lines between the probe and the filter holder to eliminate condensation

5. Providing a flush line to allow periodic cleaning of the probe and the transport line if necessary

The filter holder will be designed to prevent leakage of ambient air into the filter holder and to support the filter paper under the design pressure of the vacuum supply. Furthermore, the holder will be designed so that particulate matter is uniformly deposited on the filter paper to avoid inefficiencies in sample counting.

The samplers will provide a record of the total airborne particulate radioactivity discharged. In order to provide the lowest minimum detectable concentration at the discharge point, the sampling periods will be as long as possible so that the largest practical volume of air is sampled.

Both alpha and beta-gamma continuous air monitors will be located at the release points. These instruments will sample air from the release point through a probe similar to that designed for the filter sampler. The sample flow will be split so that half of the air being sampled is directed to each of the instruments.

The sensitivity of the beta instrument will be such that a concentration of 1×10^{-12} microcurie of strontium-90 and yttrium-90 per cubic centimeter produces a response of about 11 counts per minute after 4 hours at a sampling flow of 60 liters per minute. Alpha instrument sensitivity will be such that the release-point maximum permissible plutonium-239 concentration (2×10^{-12} microcurie per cubic centimeter) can be detected in 4 hours at a sampling flow rate of 60 liters per minute. The instruments will be designed to meet the requirements of ANSI N13.10-1974. The radionuclide inventory of the WIPP will be such that there will be no need to monitor continuously for either iodine or noble gases.

The effluent-monitoring systems will be designed to withstand the effects of a design-basis earthquake and supplied with emergency power to allow monitoring in the event of a power failure.

Environmental radiation monitoring

After the WIPP begins operating, a program for monitoring environmental radiation levels will be operated continuously in order to verify projected or expected radioactivity concentrations and related public exposures in accordance with ERDA Manual Chapter 0513. When operations begin, the operational monitoring program is expected to be essentially identical with the preoperational monitoring program. Initially, at least, the same media will be sampled, the same sampling locations will be monitored, and the same types of analyses will be made. However, the operational program will be flexible; it will be continually reevaluated and modified if needed. A strict quality-control program will be followed to insure the accuracy of samples and measurements. If any additional radioactivity is detected beyond the levels expected from preoperational monitoring results, an immediate program of evaluation will be undertaken to discover and eliminate the cause.

Equipment sensitivities

The equipment used for measurement during operation will meet or exceed the sensitivities required to detect radiation levels below the limits described in 10 CFR 20, Appendix B. State-of-the-art equipment and instruments will continually be evaluated for incorporation into the monitoring program.

Data reporting

Annual reports will summarize the environmental-sample monitoring. These reports will provide applicable data in the format required by ERDA Manual Chapter 0513. They will include the results of environmental activities and assessments of observed environmental impacts.

J.3 POSTOPERATIONAL MONITORING PROGRAMS

The basic purpose of geologic disposal is to isolate wastes from the biosphere so that surveillance will not be needed after the repository is closed. Indeed, the WIPP will not be closed up at all if there is any serious concern regarding the post-decommissioning risk.

For a limited time after the WIPP is decommissioned, monitoring will continue. This monitoring will, for the most part, be a continuation of the operational monitoring program. The rationale for the postoperational monitoring program is presented in this section.

The objective of postoperational monitoring is to give timely warning of radionuclide releases or of events or processes that may precede the release of radionuclides to the environment. This goal will require measures to assure people in the future that no gross underestimate of risks has been made. It is expected that this can be accomplished by periodic, rather than continuous, observations and that the monitoring program would not be complex.

Three kinds of post-decommissioning monitoring appear to be appropriate: geologic, hydrologic, and radiologic. Possible measurements are outlined in Table J-4. Much of the operational monitoring program is designed to detect impacts associated with the operation of the WIPP. Portions of the operational monitoring program, like measurements of effluents and meteorological parameters, will no longer be appropriate.

Geologic monitoring is primarily concerned with detecting variations in geologic parameters that may reveal a release of radioactivity, whether the variations are caused by natural geologic events or by the presence of the repository. The fundamental measurement will be periodic resurveys of the surface to observe the depth and areal extent of subsidence associated with closure of the subsurface cavities. In addition, a periodic surface geologic reconnaissance will be conducted for fractures and other phenomena indicative of subsurface movement. Borehole monitoring would not be undertaken because holes located close enough to the waste to measure geologic movement and subsurface temperatures would at the same time breach the natural integrity of the strata over or near the waste.

The postoperational radiation-monitoring program will include measurements of activity levels in biological indicator species. The sampling program will give direct assurance that some unanticipated event has not bypassed the natural and man-made barriers against release of radioactivity and that radionuclides have not been missed in the radiobiological monitoring of downgradient groundwater. Useful indicator species will be designated before decommissioning. At the surface above the disposal area, such sampling might be

Table J-4. Outline of the Post-Decommissioning Monitoring Program

Measurement	Location	Frequency	Objective
	HYDROLOGIC MONITORING		
Borehole measurement and sampling			
Gross alpha activity Gross beta activity Chemistry	Holes down-gradient at a distance of 2 miles or more	5-10 years	To detect migration of radionuclides out of disposal area
Head measurements			To detect any change in hydrology
	GEOLOGIC MONITORING		
Resurvey of surface topography	Level lines across surface of site	5-10 years	To detect and measure subsidence and/or uplift
	RADIOLOGICAL MONITORING		
Sampling of indicator species	At and near site	5-10 years	To detect releases directly
Sampling of water, indicator species	At groundwater discharge points	5-10 years	To detect releases directly

of grasses and game birds. At the groundwater discharge points in lower Nash Draw and along the Pecos River, such sampling might be of water and periphyton.

Hydrologic monitoring will continue almost undiminished from the operational phase because groundwater is the most likely pathway for radionuclide transport in the long term. The basic hydrologic monitoring will consist of periodic sampling and radiobiological analysis of water from open boreholes downgradient from the disposal area. There are at present five hydrologic holes in control zone IV that could be used for this purpose (holes P-14, P-15, P-17, P-18, and H-4), and it may be necessary to drill more holes to eliminate the possibility that a plume of released radionuclides might pass between monitoring holes without being observed. The hydrologic test holes in control zone II and all upgradient test holes will be plugged. The latter will not be needed, and to leave the former open would be to leave a potential connection between aquifers and Salado salt.

J.4 RELATED ENVIRONMENTAL PROGRAMS BY OTHERS

J.4.1 Bureau of Land Management

In 1974, the Bureau of Land Management (BLM) began preparation of a preliminary regional environmental assessment record (EAR) (BLM, 1976a) in order to fulfill responsibilities outlined in the National Environmental Policy Act of 1969. The compilation of an EAR was the major step toward the resumption of potash leasing and prospecting in the Carlsbad area. The preliminary document was published in October 1975, and the Executive Summary and Supplement (BLM, 1976a and b) was completed in 1976. Public-reference copies of this document are available in the city libraries of Carlsbad, Hobbs, and Albuquerque, as well as at the BLM offices in Santa Fe and Albuquerque.

J.4.2 New Mexico Environmental Improvement Division

The New Mexico Environmental Improvement Agency (now Division) performed an air-quality assessment of the potash-mining activities in the general area of the WIPP site. The assessment was undertaken after apparent violations of the State and Federal air-quality standards were mentioned in the environmental assessment record of the BLM. The assessment analyzes the impact of the potash industry on the air; the analysis used computer-modeling techniques to predict average air-particulate levels in the vicinity of the local potash mines.

The Air Quality Division of the NMEID monitors air quality throughout the State and provides data on the concentrations of total suspended particulates, sulfur dioxide, carbon monoxide, and ozone. The information recently gathered in the vicinity of the site is in the Municipal Building in Carlsbad. Only total suspended particulates are measured at the site. Other sites of interest are at Artesia, Hobbs, and Lovington; data are available on microfiche on a semiannual basis.

J.4.3 U.S. Geological Survey

The U.S. Geological Survey (USGS) has had major involvement in characterizing the hydrology and geology of the area surrounding the site. The involvement was further intensified when the DOE (and its predecessors, ERDA and AEC) and BLM requested detailed studies in the area. The AEC needed site characterization for Project Gnome in 1961; the USGS performed a detailed hydrologic and geologic study of the Gnome site during the period between 1958 and 1961. The BLM needed assistance in preparing the preliminary environmental analysis record and requested input from the USGS. Also, the State of New Mexico has received assistance in the preparation of hydrologic reports for many parts of the State, including the site. On a routine monitoring basis, the USGS issues an annual generic water-data report. The report describes water resources in the State of New Mexico (USGS, 1977). The detailed data include discharge rates of streams and water levels of selected wells in the site area. Some chemical analyses of selected water samples are also documented in the same report. Furthermore, the USGS performs environmental analyses for proposed oil and gas operations. Through this process, an assessment of environmental impacts would be made before any further development of Federal mineral resources would be allowed.

J.4.4 Environmental Protection Agency, Las Vegas, Nevada

The Environmental Protection Agency (EPA) has performed environmental monitoring surveys in the vicinity of the site as a result of Project Gnome. Except at the Nevada Test Site, the EPA monitors wells, springs, and spring-fed surface-water sources at sites where underground nuclear detonations have taken place; the monitoring looks for the migration of radionuclides resulting from the movement of groundwater. Consequently, a number of wells in the vicinity of the Gnome site are monitored annually by the EPA. In addition to the water monitoring, the EPA has monitored radionuclide concentrations in plant and animal tissues collected at the Gnome site.

J.4.5 Potash Industry

Some detailed environmental monitoring of the potash industry before 1976 resulted from the preliminary environmental assessment record. Although the monitoring included soil and well-water sampling, the potash mines in the Carlsbad area do not generally have extensive environmental monitoring programs. Present levels of monitoring are beginning to increase as a result of interaction with the NMEID. The most extensive monitoring programs include the collection of meteorological data and high-volume air sampling for total suspended particulates; such programs are conducted at two of the seven potash mines in the vicinity of the WIPP site. As State guidelines for high-volume sampling are formulated, similar programs can be expected at other mines.

J.4.6 National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration provides a Climatological Data Publication, which is published by the National Climatic Center (NCC). It is a compendium of reports from selected weather stations throughout the United States, and it includes such data as temperature, daily precipitation, wind speed, humidity, and sky cover. More detailed data are available through the NCC for selected sites. This information is available to the general public through a monthly subscription service. However, meteorological data specific to the WIPP site are not available from the NCC.

J.4.7 New Mexico Department of Game and Fish

A study being conducted by the New Mexico Department of Game and Fish will provide information related to the WIPP biological monitoring program. This study monitors conditions and trends of range lands grazed by livestock and wildlife in four southern New Mexico counties (including Eddy County).

J.4.8 Ongoing Regional Ecological Studies

In addition to the comprehensive ecological studies being carried out by the WIPP project, several ecological investigations are being carried out in the region by governmental agencies and university researchers.

The Roswell District of the BLM is completing an extensive preliminary draft environmental statement (PDES) on proposed livestock-grazing practices on public lands in southeastern New Mexico, east of the Pecos River. In addition, the BLM is sponsoring a groundwater study related to potash mining in the Region (A. Gebel, personal communication, August 25, 1978). The primary questions to be answered by the BLM study are the following:

1. Is fresh water in the Carlsbad potash area in danger of contamination from current or expanded potash-mining activity?

2. Is the brackishness of the Pecos River below Malaga Bend in whole or in part attributable to mining activities?

3. Is the amount of leakage from brine-disposal ponds significant when compared to the tremendous volumes of naturally occurring brines?

The hydrology investigation also includes an evaluation of phreatophytes and wetland vegetation as water-quality indicators and a botanical evaluation of Nash Draw (Geohydrology Associates, 1978).

The Bureau of Reclamation at Amarillo, Texas, is continuing to update the project history of the Malaga Bend Division-McMillan Delta Project. The Malaga Bend Division was an experimental salinity-alleviation project intended to improve the water quality in the Pecos River by lowering the head of the brine aquifer at Malaga Bend and thus diverting the brine. In 1976 active monitoring on the project was discontinued.

The Bureau of Reclamation at Amarillo is also currently preparing a supplement to its final environmental impact statement on the Brantley Dam project, which is located on the Pecos River approximately 12 miles northwest of Carlsbad. Fishery studies have been conducted by the State of New Mexico to determine the fish species present in the area and to develop possible mitigation measures to protect the rare fish in Major Johnson Springs.

Reynolds Electrical & Engineering Co., Inc., has been conducting a radiological survey for the DOE Nevada Operations Office at the Gnome site. Project Gnome was the first scientific experiment in the Plowshare Program in December 1961. Portions of the 1-square-mile site were contaminated during mine-back operations and postshot activities. The survey involves monitoring radiation levels and includes decontamination and decommissioning of the site (D. D. Jackson, DOE, personal communication, September 26, 1978).

Various projects are being carried out in the site area by university researchers. For example, graduate students at Eastern New Mexico University have been studying the fish fauna in the Black River, an endemic subspecies of white-tailed deer at the Mescalero Sands in northern Eddy County, and pocket mice in eastern Eddy County (A. L. Gennaro and J. E. Sublette, Eastern New Mexico University, personal communication, September 21, 1978).

The study being conducted by the New Mexico Department of Game and Fish, which will provide information of use to the WIPP biological monitoring program, was discussed earlier.

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Appendix K

METHODS USED IN LONG-TERM SAFETY ANALYSES

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Appendix K

METHODS USED IN LONG-TERM SAFETY ANALYSES

K.1 HYDROLOGIC TRANSPORT

K.1.1 Introduction

The numerical model used for hydrologic-transport calculations was developed by Intera Environmental Consultants, Inc., for the Nuclear Regulatory Commission (Dillon et al., 1977). It is a modified version of a deep-well-disposal model developed for the U.S. Geological Survey (INTERCOMP, 1976). The model is three-dimensional and uses finite-difference methods to solve a set of partial differential equations describing fluid flow, energy, salinity, and radionuclide concentration in a porous medium. The basic equations are coupled by two properties of the fluid: density and viscosity.

Three basic coupled equations describe the conservation of total liquid mass, the conservation of energy, and the conservation of the mass of a single solute in the fluid. In addition, there are coupled equations describing the conservation of mass for each of the radioactive constituents dissolved in the fluid; these equations are coupled by terms that account for radioactive decay and the production of daughter radionuclides from decaying parent radionuclides.

This set of equations predicts the concentrations of radioactive constituents and of the specified inert components. It also predicts the temperature and pressure patterns that result from the flow and discharge of liquid waste. The aquifer fluid properties are permitted to be functions of the concentration and temperature of liquid chemical waste.

The basic physical assumptions contained in the model equations are as follows:

1. Flow is three-dimensional, transient, and laminar.

2. Fluid density can be a function of the pressure, temperature, and concentration of the inert component. Fluid viscosity can be a function of temperature and concentration.

3. Injected wastes can mix with the in-place fluids.

4. Aquifer properties vary with position; i.e., porosity, permeability, thickness, and elevation can be specified for each numerical grid block in the model.

5. Hydrodynamic dispersion is a function of fluid velocity.

6. Radioactive constituents are present in trace quantities only; that is, fluid properties are independent of the concentrations of these contaminants.

7. Chemical reactions among the radioactive trace constituents and chemical species on the porous rock surfaces go to equilibrium instantaneously.

8. The energy equation can be described as "enthalpy in - enthalpy out = change in the internal energy of the system." This is rigorous except for kinetic energy and potential energy, which have been neglected.

9. Boundary conditions allow for natural water movement in the aquifer, heat losses to adjacent formations, and the location of injection, production, and observation points anywhere within the system.

A more technical description of the model equations is provided in the next subsection.

K.1.2 Reservoir Model Equations

Let x, y, z be a Cartesian coordinate system and let Z(x,y,z) be the height of a point above a horizontal reference plane. The basic equation describing single-phase flow in a porous medium combines the continuity equation

$$\nabla \cdot \rho \underline{u} + q' = -\frac{\partial}{\partial t}(\phi\rho) \qquad \text{(K-1)}$$

and Darcy's law in three dimensions,

$$\underline{u} = -\frac{k}{\mu}(\nabla p - \rho g \nabla Z) \qquad \text{(K-2)}$$

(Symbols are defined in Table K-1.) The basic flow equation is then

$$\nabla \cdot \frac{\rho k}{\mu}(\nabla p - \rho g \nabla Z) - q' = \frac{\partial}{\partial t}(\phi\rho) \qquad \text{(K-3)}$$

The energy balance defined as (enthalpy in - enthalpy out = change in internal energy) is described by the energy equation

$$\nabla \cdot \left[\frac{\rho H k}{\mu}(\nabla p - \rho g \nabla Z)\right] + \nabla \cdot \underline{\underline{E}}_H \cdot \nabla T - q'_L - q'H - q'_H$$

$$= \frac{\partial}{\partial t}[\phi \rho U + (1 - \phi)(\rho C_p)_R T] \qquad \text{(K-4)}$$

The five terms on the left-hand side of Equation K-4 describe net energy convection, conduction, heat loss to surrounding strata, enthalpy accompanying a fluid source, and energy not accompanying a fluid source. A material balance for the solute produces the solute-concentration equation.

$$\nabla \cdot \left[\rho \hat{C} \frac{k}{\mu} (\nabla p - \rho g \nabla Z) \right] + \nabla \cdot \rho \underline{\underline{E}}_c \cdot \nabla \hat{C} - q' \hat{C} = \frac{\partial}{\partial t} (\rho \phi \hat{C}) \qquad \text{(K-5)}$$

The three terms on the left-hand side of Equation K-5 represent net convection, dispersion, and production of the solute. A similar material balance for N radioactive components results in N component equations. For component i,

$$\nabla \cdot \left[\rho C_i \frac{k}{\mu} (\nabla p - \rho g \nabla Z) \right] + \nabla \cdot \rho \underline{\underline{E}}_c \cdot \nabla C_i - q_i'$$

$$+ \sum_{j=1}^{N} k_{ij} K_j \rho \phi C_j - \sum_{k=1}^{N} k_{ki} K_i \rho \phi C_i = \frac{\partial}{\partial t} (\phi \rho K_i C_i) \qquad \text{(K-6)}$$

where

$$k_{ki} K_i \rho \phi C_i = k_{ki} \rho \phi C_i + k_{ki} \rho_s (1 - \phi) C_{si} \qquad \text{(K-7)}$$

The two summation terms describe the generation of component i from the decay of other radionuclides and the decay of component i to other radionuclides. Implicit in Equation K-6 is the approximation

$$\frac{\partial}{\partial t} (\phi \rho K_i C_i) \approx \frac{\partial}{\partial t} (\phi \rho C_i) + \frac{\partial}{\partial t} [(1 - \phi) \rho_s C_s] \qquad \text{(K-8)}$$

The equilibrium adsorption constant is defined as follows:

$$K_i = 1 + \frac{\rho_B (K_d)_i}{\phi} \qquad \text{(K-9)}$$

where $(K_d)_i$ is the distribution coefficient for compound i.

The system of Equations K-3, K-4, K-5, and K-6--along with the fluid-property dependence on pressure, temperature, and concentration--describes the reservoir flow due to the discharge of wastes into an aquifer. This nonlinear system of partial differential equations must be solved numerically by high-speed digital computers. Equations K-3, K-4, and K-5 are coupled through fluid-property dependence. Since it is assumed that the radioactive components are present in trace quantities only and the fluid properties are independent of these concentrations, Equation K-6 is uncoupled from the other equations.

These equations are solved by dividing the region of interest into three-dimensional grid blocks and constructing finite-difference approximations to all partial derivatives in this grid. The resulting set of finite-difference equations have numerical solutions that closely approximate the analytic solutions of Equations K-3, K-4, K-5, and K-6 in certain simplified (one-dimensional) geometries. The finite-difference equations in three dimensions are as follows:

Basic flow equation

$$\Delta[T_w(\Delta p - \rho g \Delta Z)] - q = \frac{V}{\Delta t}\delta(\phi\rho) \tag{K-10}$$

Energy equation

$$\Delta[T_w H(\Delta p - \rho g \Delta Z)] + \Delta(T_H \Delta T) - q_L - qH - q_H$$

$$= \frac{V}{\Delta t}\delta[\phi\rho U + (1 - \phi)(\rho C_p)_R T] \tag{K-11}$$

Solute equation

$$\Delta[T_w \hat{C}(\Delta p - \rho g \Delta Z)] + \Delta(T_c \Delta \hat{C}) - \hat{C}q = \frac{V}{\Delta t}\delta(\rho\phi\hat{C}) \tag{K-12}$$

Trace-component equation

$$\Delta[T_w C_i(\Delta p - \rho g \Delta Z)] + \Delta(T_c \Delta C_i) - q_i + V\rho \sum k_{ij} K_j C_j$$

$$- V\rho K_i C_i \sum k_{ik} = \frac{VK_i\rho}{\Delta t}\delta C_i \tag{K-13}$$

The difference operators in space are defined by

$$\Delta(T_w \Delta p) = \Delta_x(T_w \Delta_x p) + \Delta_y(T_w \Delta_y p) + \Delta_z(T_w \Delta_z p) \tag{K-14}$$

with

$$\Delta_x(T_w \Delta_x p) = T_{w,i+1/2,j,k}\left(p^{n+1}_{i+1,j,k} - p^{n+1}_{i,j,k}\right)$$

$$- T_{w,i-1/2,j,k}\left(p^{n+1}_{i,j,k} - p^{n+1}_{i-1,j,k}\right) \tag{K-15}$$

The symbol δ denotes variation over a single time step; for any quantity χ,

$$\delta\chi = \chi^{n+1} - \chi^{n} \tag{K-16}$$

The terms

$$T_w = \frac{kA\rho}{\mu \ell} \tag{K-17}$$

$$T_H = \frac{E_H A}{\ell} \tag{K-18}$$

$$T_c = \rho \frac{E_c A}{\ell} \tag{K-19}$$

have been introduced for notational convenience; since all of them are position-dependent, a further expansion is illustrated as

$$T_{w,i+1/2,j,k} = \frac{2\Delta y_j \Delta z_k}{\left(\frac{\Delta x}{k_x}\right)_i + \left(\frac{\Delta x}{k_x}\right)_{i+1}} \left(\frac{\rho}{\mu}\right)_{i+1/2,j,k} \tag{K-20}$$

For radial geometry, the term

$$\frac{2\Delta y_j \Delta z_k}{\Delta x_i + \Delta x_{i+1}}$$

becomes $2\pi\Delta z_k / \ln(r_{i+1}/r_i)$. The volume term is written as $\pi\Delta r_i^2 \Delta z_k$.

Two terms, the constituent-dispersion tensor $\underline{\underline{E}}_C$ and the effective heat-conductivity tensor $\underline{\underline{E}}_H$ need additional description. In the present model both depend on hydrodynamic dispersivity, which is a function of local fluid velocity. For an isotropic porous medium there can be no more than two independent dispersivity factors; this requirement insures that the dispersion tensor is invariant under coordinate transformations. These two dispersivities are longitudinal, in the direction of flow, and transverse, perpendicular to flow. Generally, both are functions of the magnitude of the flow velocity:

$$D_l = \alpha_l |\underline{u}|$$

and

$$D_t = \alpha_t |\underline{u}|$$

When the velocity vector is divided into components along three coordinate axes, nine components of both the dispersivity and the conductivity tensors occur.

More general expressions for the dispersivity and the conductivity tensors can be written in terms of molecular properties and hydrodynamic dispersivity:

$$\underline{\underline{E}}_C \equiv \phi\ \underline{\underline{\alpha u}}/\phi + D_m$$

and (K-21)

$$\underline{\underline{E}}_H \equiv \phi\ \underline{\underline{\alpha u}}/\phi(\rho C_p)_w + K_m$$

where the dispersivity coefficient α is a vector quantity. The apparent conductivity due to hydrodynamic dispersion in the porous medium has been taken as the product of the dispersivity and velocity multiplied by fluid volumetric heat capacity. The ordinary molecular heat conductivity of fluid plus rock, K_m, has been treated as an additive constant. The concept expressed in Equations K-21 is that the microscopic heterogeneity in convective flow creates the same dispersive effect in temperature that it creates in the concentration of constituents.

Table K-1. Nomenclature

A	Area perpendicular to flow--either $\Delta x\Delta y$, $\Delta x\Delta z$, or $\Delta y\Delta z$
C	Concentration, mass fraction
$\hat{C}$	Concentration of solute, salinity
C_p	Specific heat (at constant pressure)
C_s	Concentration of radioactive component on rock
D	Diffusion coefficient
E	Dispersion coefficient
$\underline{\underline{E}}_C$	Constituent-dispersion tensor
$\underline{\underline{E}}_H$	Effective heat-conductivity tensor (including hydrodynamic dispersion)
g	Acceleration due to gravity
H	Enthalpy
k	Permeability
k_{ij}	Rate of decay of component j to component i
K	Thermal conductivity
K_d	Distribution coefficient
K_i	Equilibrium adsorption constant defined in Equation K-9
ℓ	Distance between grid-block centers
p	Pressure
q	Mass source per grid block
q'	Mass source per unit of porous-medium volume
q_H	Energy stored without fluid input per grid block
q_H'	Energy stored without fluid input per unit of porous-medium volume
q_L	Rate of heat loss per grid block
q_L'	Rate of heat loss per unit of porous-medium volume
r	Radial space coordinate
t	Time
T	Temperature

Table K-1. Nomenclature (continued)

T_H, T_W, T_C	Transmissibility of energy, flow, and contaminant; defined by Equations K-17, K-18, K-19
u	Superficial (Darcy) fluid velocity in the porous rock
U	Internal energy
V	Grid-block volume
x,y,z	Cartesian space coordinates
Z	Elevation above reference plane
<u>Subscripts</u>	
av	Average over depth increment
R	Rock
S	Solid material (always rock)
i,j,k	Indices labeling radioactive components or, in Equations K-15 and K-20, indices labeling grid blocks
w	Liquid
l,t	Longitudinal and transverse, respectively
m	Molecular properties in porous media
<u>Superscripts</u>	
n	Time level n
<u>Greek</u>	
α	Dispersivity coefficient
ϕ	Porosity
ρ_B	Bulk density = $(1 - \phi)\rho_S$
ρ_S	Density of rock
ρ	Density of fluid
μ	Viscosity (kinematic)
Δt	Time increment
$\Delta x, \Delta y, \Delta z$	Grid-block dimensions

K.2 APPLICATION OF THE TRANSPORT MODEL TO THE WIPP SITE

This section describes in detail applications of the hydrologic-transport model described in Section K.1 to the modeling of phenomena at the WIPP site for the long-term safety assessment.

The modeling of hydrologic-transport phenomena has involved a three-step approach: data interpretation and regional hydrologic modeling, the calculation of waste-release rates for the various scenarios, and the calculation of the transport of radionuclides assumed in each of the scenarios. These three parts of the modeling effort are discussed in this section under separate headings.

K.2.1 Data Interpretation and Regional Hydrologic Modeling

The objectives of this part of the modeling effort are as follows:

1. To check consistency or lack of it between various sets of hydrologic data.
2. To calculate the extent of communication (vertical permeabilities) between various hydrologic units.
3. To delineate heterogeneities existing within each geologic formation. Heterogeneity here refers to the spatial variation of permeability values.
4. To calculate potentials and/or hydraulic conductivities in areas where data are lacking.
5. To calculate boundary conditions for local scenario and nuclide-transport modeling.

The calculational procedure is straightforward. Permeability values determined by laboratory or well tests are used as initial values in the calculations. Permeability distributions are adjusted until the calculated potentials are in satisfactory agreement with a consistent set of measured potential values.

The hydrologic data used in this work were obtained primarily from a report by Mercer and Orr (1977), who reviewed and summarized all data existing through February 1977. After the report by Mercer and Orr was issued, the U.S. Geological Survey (USGS) conducted well tests in the Los Medanos area; some data from a draft USGS report to Sandia National Laboratories were used to check consistency and obtain permeabilities immediately above the WIPP site. Other sources of data were Griswold (1977), Rai and Mason (1977), Lambert (1978), and Lambert and Mercer (1977); laboratory-measured distribution coefficients in unpublished form were also used.

A map of the modeled region is shown in Figure K-1, and a geologic cross section of the Los Medanos area looking toward the northwest is presented in Figure K-2. The Santa Rosa Sandstone is a moderately permeable formation

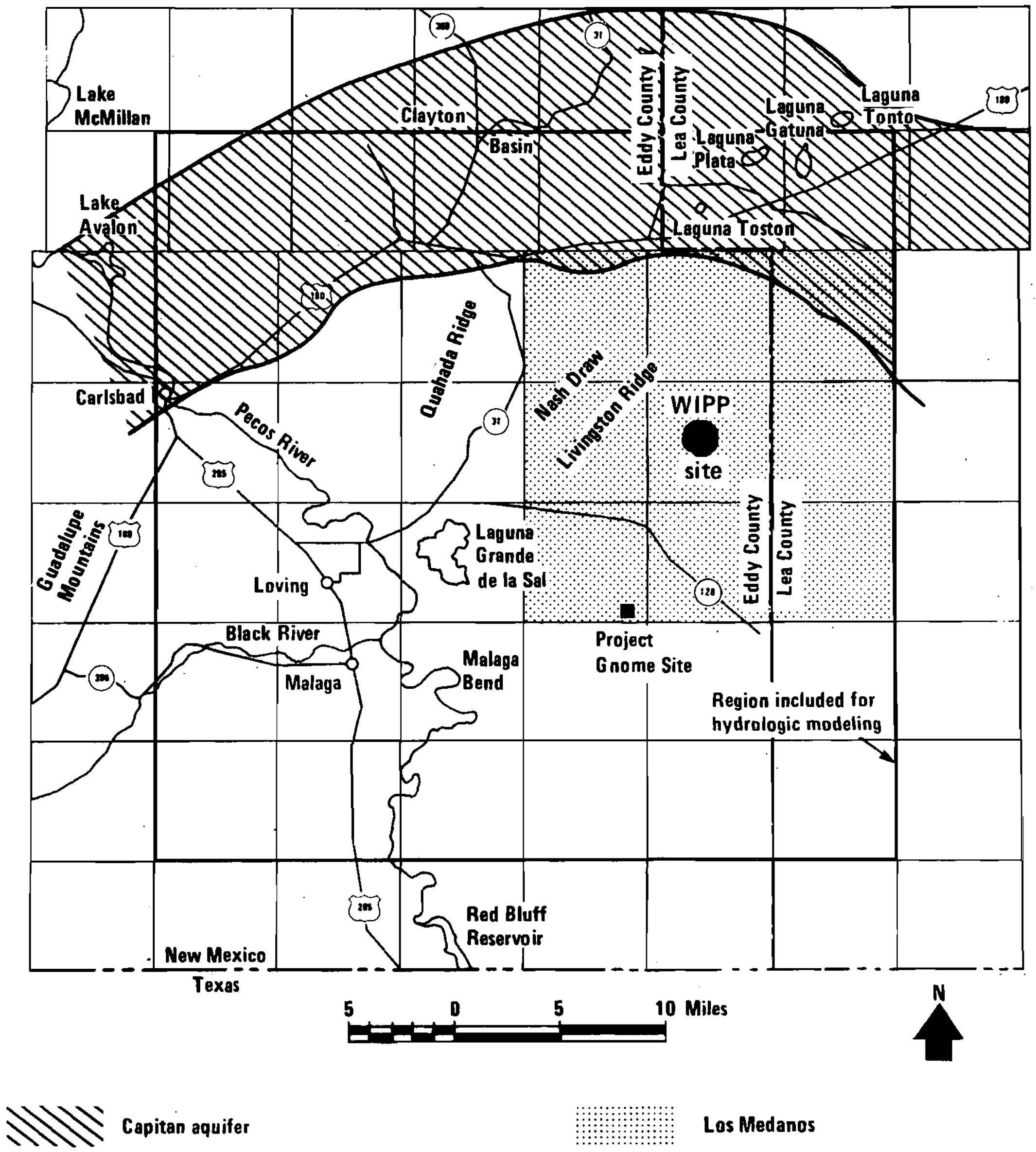

Figure K-1. Hydrologic modeling region.

containing relatively fresh water. However, the low permeability of the Dewey Lake Red Beds prevents significant seepage of water from the Santa Rosa Sandstone to the Rustler Formation. Two thin aquifers, the Magenta and the Culebra, are contained in the Rustler Formation, which is predominantly composed of impervious anhydrites, polyhalites, and gypsum. The WIPP will be in the Salado Formation. The Castile Formation, composed of very pure halite and anhydrite, contains no water-bearing strata. Beneath it lies the Delaware Mountain Group, approximately 3000 feet thick, which contains aquifers.

The Santa Rosa Sandstone does not extend beyond the WIPP to the west, and the intermediate Dewey Lake Red Beds are essentially confining beds. Therefore, for the purpose of regional hydrologic modeling, the upper surface of the Rustler was assumed impermeable and the Santa Rosa Sandstone was not included in the calculations.

Within the hydrologic region modeled in this study, the Rustler Formation aquifers (Culebra and Magenta) apparently do not communicate hydrologically with any of the aquifers below the Salado Formation or with the shallow-dissolution zone. The Magenta and the Culebra are modeled as one aquifer, the Rustler aquifer, with a total thickness equal to the combined thicknesses of the two actual aquifers. The regional flow in the Rustler aquifer is generally to the southwest. As can be seen from Figure K-3, discharge from the Rustler is into the Pecos River at Malaga Bend, about 15 miles from the WIPP site, and possibly at points south of Malaga Bend. (The reader who is unfamiliar with the conventions of groundwater hydrology can easily deduce the flow pattern from sets of hydraulic-potential curves, such as the ones in Figures K-3 and K-4, by drawing a set of nonintersecting curved lines that are everywhere orthogonal to the potential curves; the direction of flow is then along these curved lines, proceeding from the highest values of potential to the lowest values.)

More recent data obtained by the U.S. Geological Survey and presented by Mercer and Orr (1978) suggest that flow immediately above the repository in the Culebra is toward the southeast. However, combining the map in Figure K-3 with the recent data shows that the flow toward the southeast is only local; on a larger scale the flow in the Rustler Formation is toward the Pecos River.

Potentials in the Delaware Mountain Group (Figure K-4, solid lines) show that flow there is essentially toward the northeast. The Delaware Mountain aquifers communicate with the Capitan aquifer, though the degree of communication will vary considerably at different locations. In the regional modeling, the Capitan aquifer was combined with the aquifers of the Delaware Mountain Group.

Finally, the existence of a shallow-dissolution zone along the Rustler-Salado interface in Nash Draw is known. This feature is roughly 50 feet

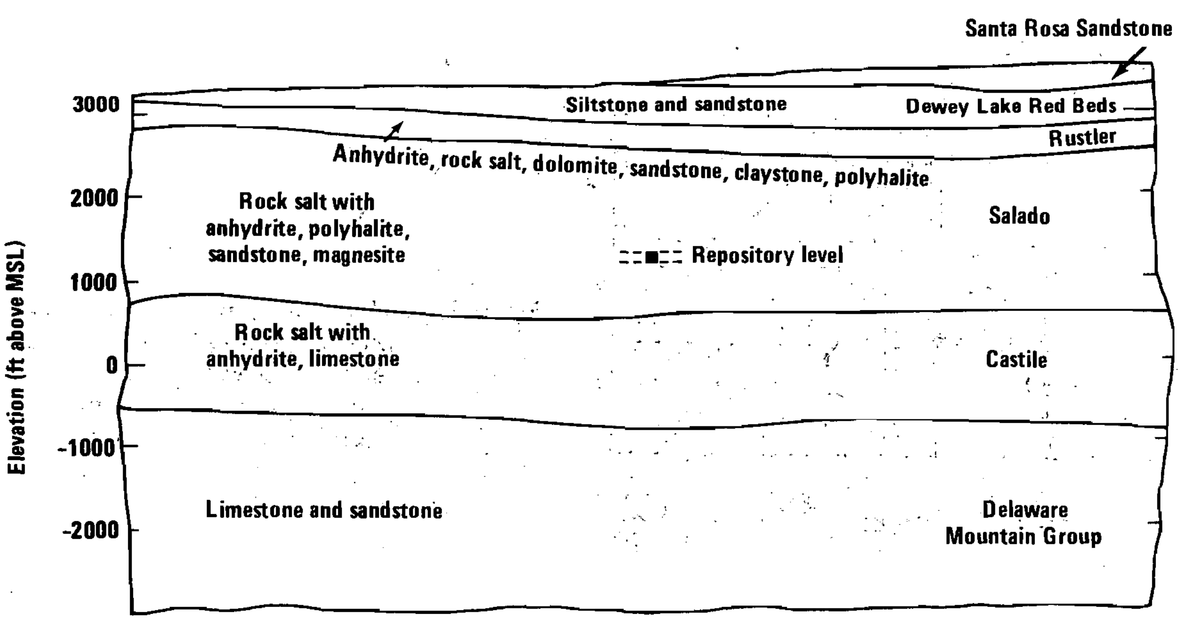

Figure K-2. Geologic section of the Los Medanos area.

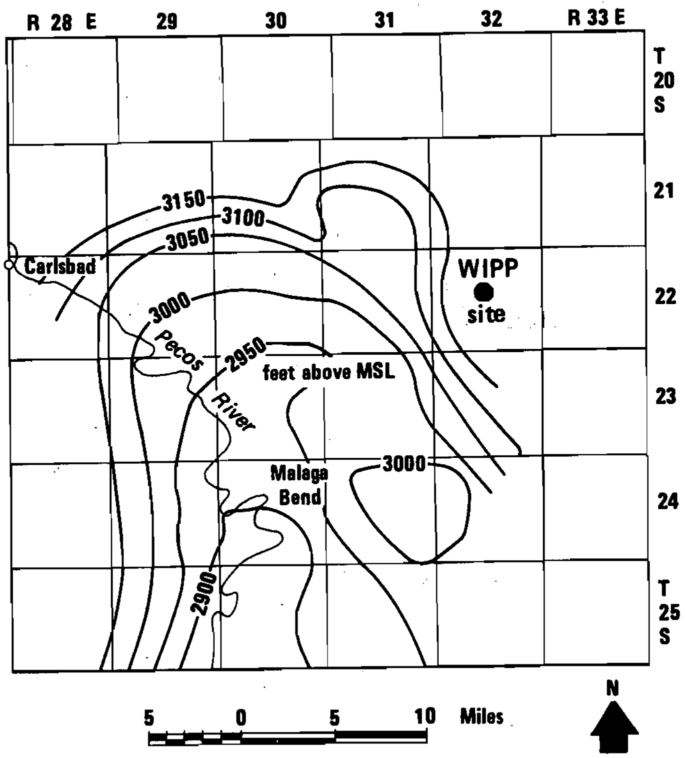

Figure K-3. Hydraulic potentials (feet above MSL) measured in the Rustler Formation.

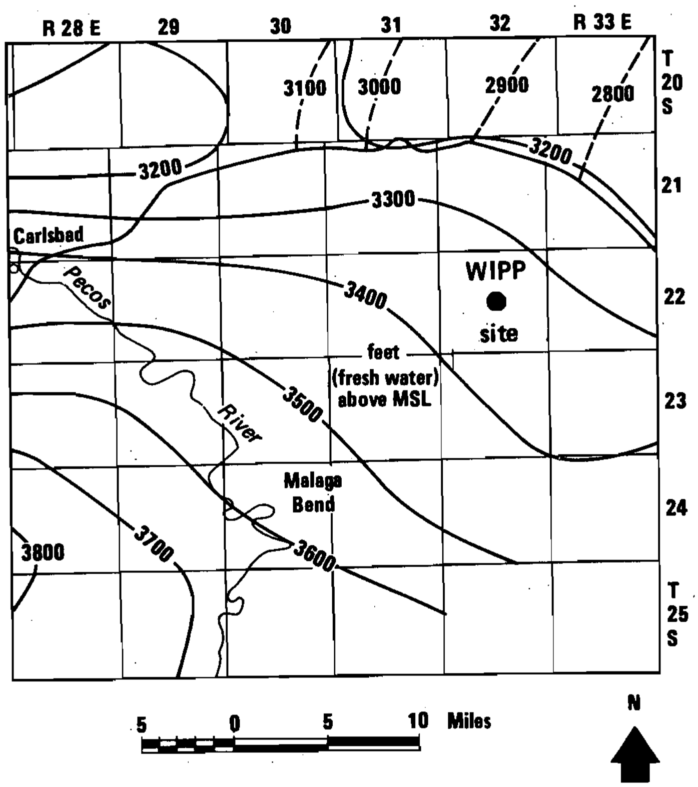

Figure K-4. Hydraulic potentials (feet above MSL) measured in the Capitan aquifer (broken lines) and in the Delaware Mountain Group (solid lines).

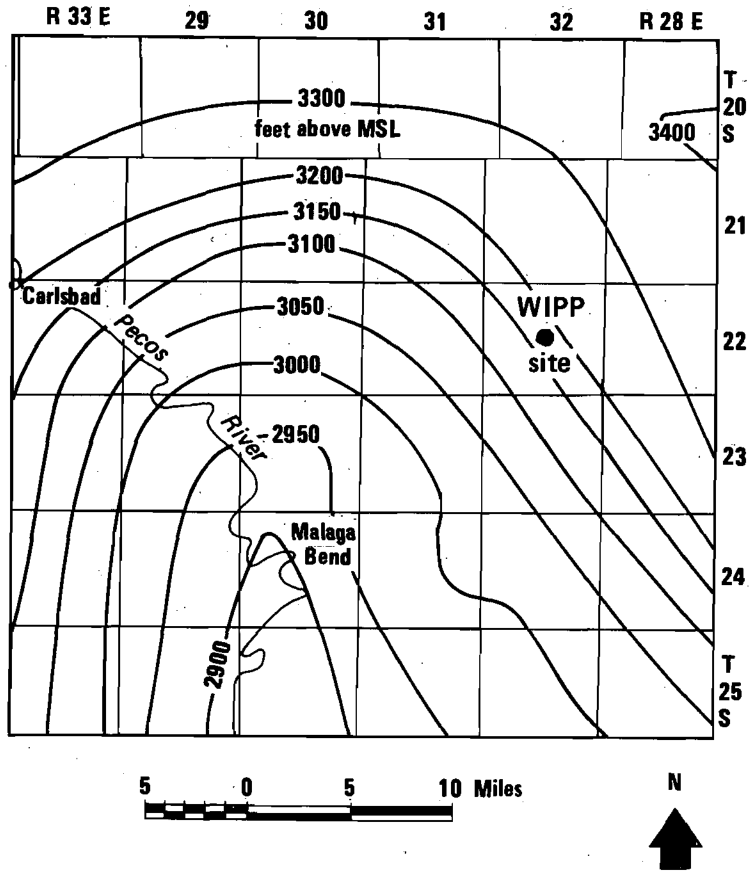

Figure K-5. Calculated hydraulic potentials (feet above MSL) for the Rustler Formation.

thick, 30 miles long, and 2 to 10 miles wide. Its nearest edge is several miles west of the repository.

The Rustler Formation, the shallow-dissolution zone, the Delaware Mountain Group, and the Capitan reef were modeled to obtain a match with the observed potentials. Modeling of intervening anhydrite and salt layers showed that the anhydrite and salt had to be essentially impermeable; an upper limit to the vertical hydraulic conductivity in these formations was calculated to be 10^{-6} ft/day. It was difficult to simultaneously match potentials in different layers with a higher value. Calculated potentials in the Rustler and the Delaware Mountain Group are shown in Figures K-5 and K-6. The match of measured and calculated potentials in the Rustler (Figures K-3 and K-5, respectively) is especially reasonable for this analysis, in which only the potentials between the site and Malaga Bend determine the flow path. The match of the potentials in the Delaware Mountain Group (Figures K-4 and K-6) is adequate; these, however, are of little importance to the transport of radionuclides from the repository.

A set of calculated hydraulic conductivities in various layers is shown in Figures K-7 to K-10. It is important to note that these conductivity

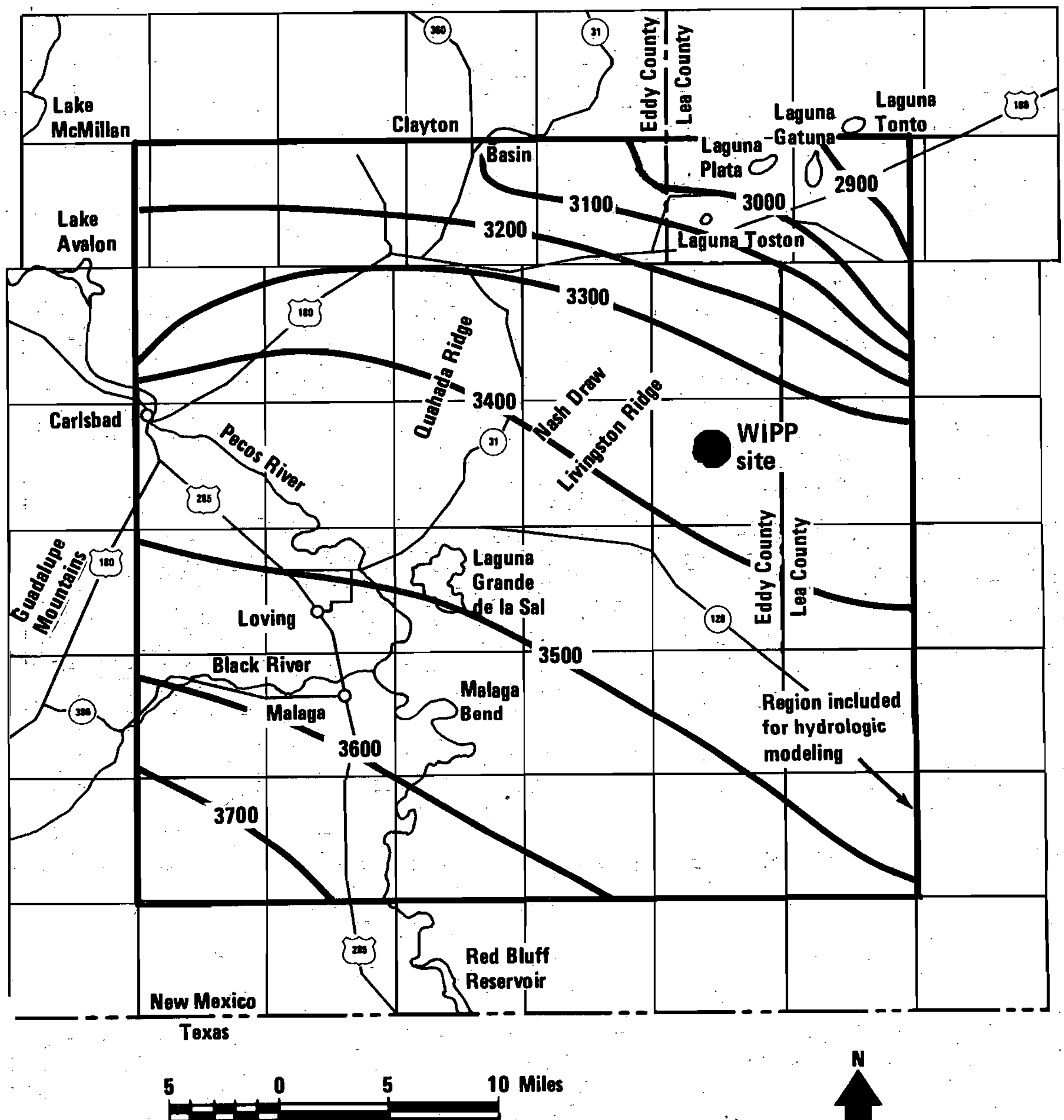

Figure K-6. Calculated hydraulic potentials (feet above MSL) for the Delaware Mountain Group.

values are not unique. Any set of conductivity values scaled up or down by a constant factor will produce exactly the same results; the velocities and flow rates will differ by the same factor. Therefore, it is necessary to "calibrate" with one or more conductivity values obtained from well tests. Based on the available data, two values of the conductivity in the Rustler aquifers can be used to describe upper and lower bounds. The lower-bound conductivities are lower by a factor of 20 than the values shown in Figure K-7.

Calculated natural water velocities in the Rustler aquifers ranged from 0.075 to 15 ft/yr, and in the Delaware Mountain Group aquifer the velocities

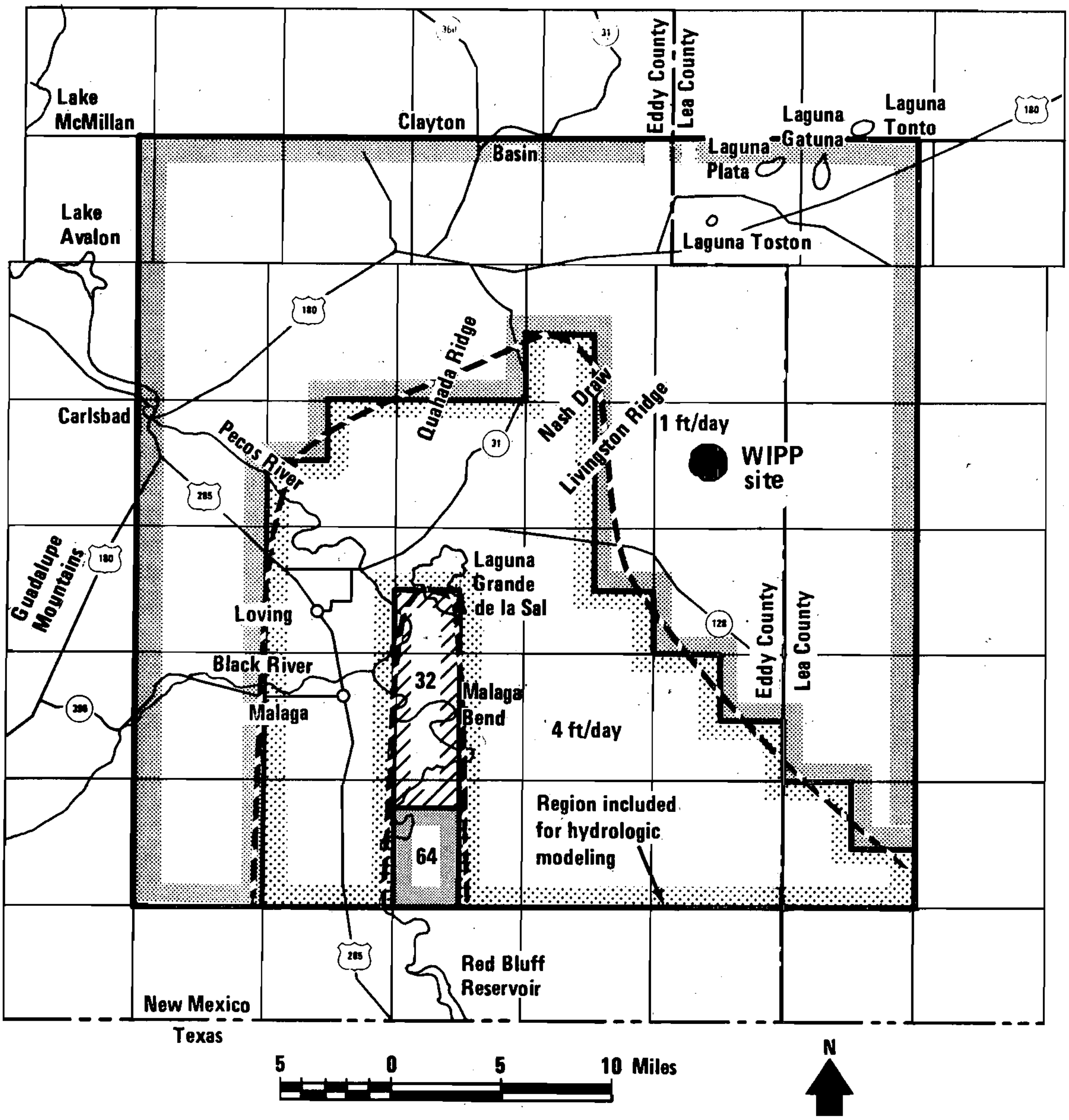

Figure K-7. Hydraulic conductivities in the Rustler aquifers.

are less than 0.1 ft/yr. A direct travel path to the shallow-dissolution zone for any waste released from the repository would have to be either through salt or along the Salado-Rustler interface; water velocities along these paths are essentially zero at the site. A path to the Capitan aquifer would have to be through the Delaware Mountain Group aquifer. Consequently, the time needed for the waste to travel from the repository to either the shallow-dissolution zone or the Capitan aquifer would be very long and of little concern.

The Rustler aquifers are of primary importance in the WIPP safety analysis for two reasons: the travel times to the biosphere are shorter there than in the Delaware Mountain Group, and the greater hydraulic potentials in the Delaware Mountain Group provide a driving force for upward water flow into the Rustler. A degree of uncertainty is nevertheless associated with the hydrologic data for

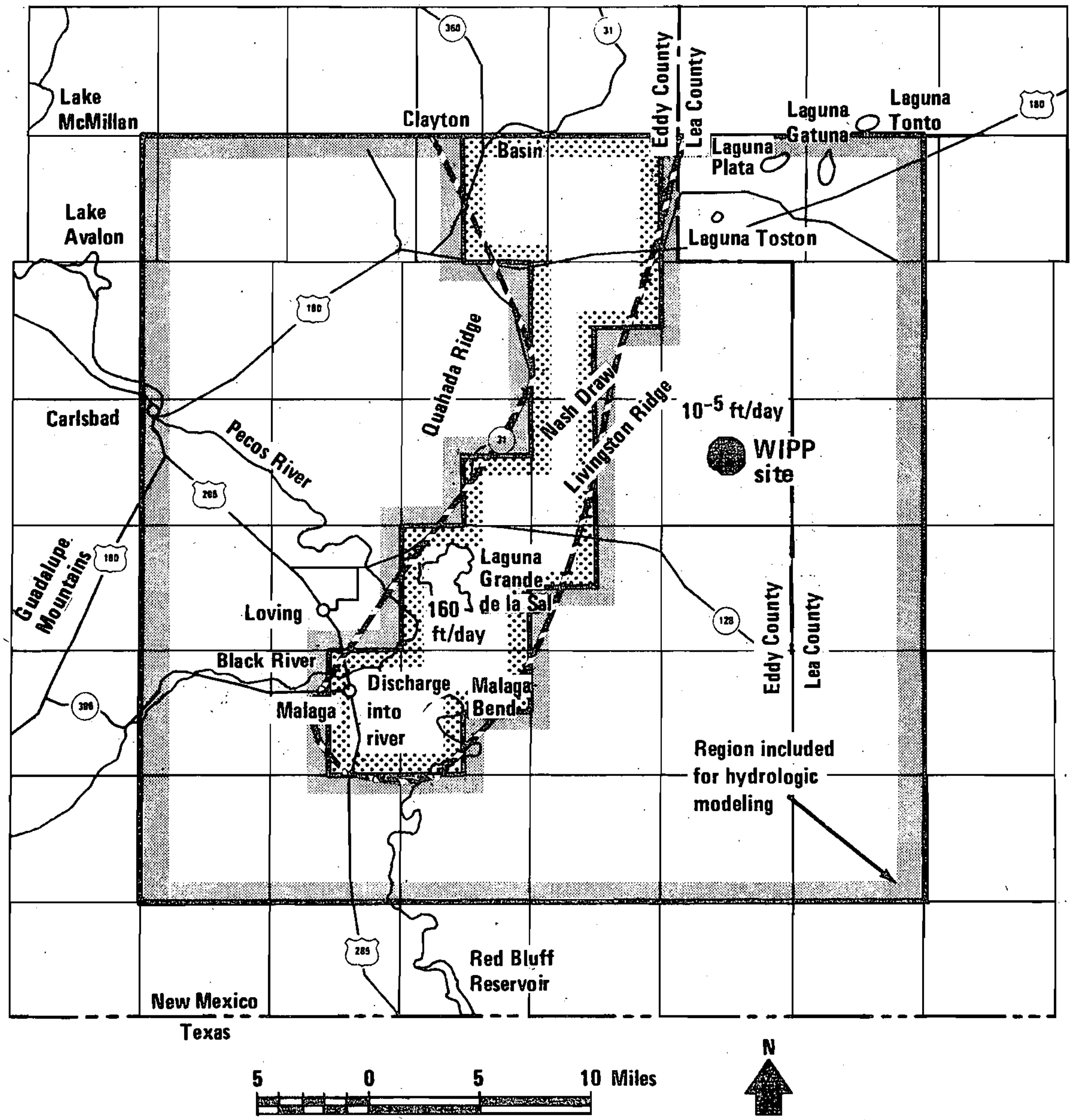

Figure K-8. Hydraulic conductivities in the shallow-dissolution zone.

the Rustler, as was mentioned above. Uncertainty in the hydraulic conductivity induces uncertainty in predicted transport rates. A preliminary analysis (Tang and Pinder, 1977) shows that

1. Changes in groundwater velocity, within the range used here, generated relatively little change in the mass concentrations at long times.

2. Increases in groundwater velocity together with increases in dispersivity cause earlier arrivals at points where concentrations are being

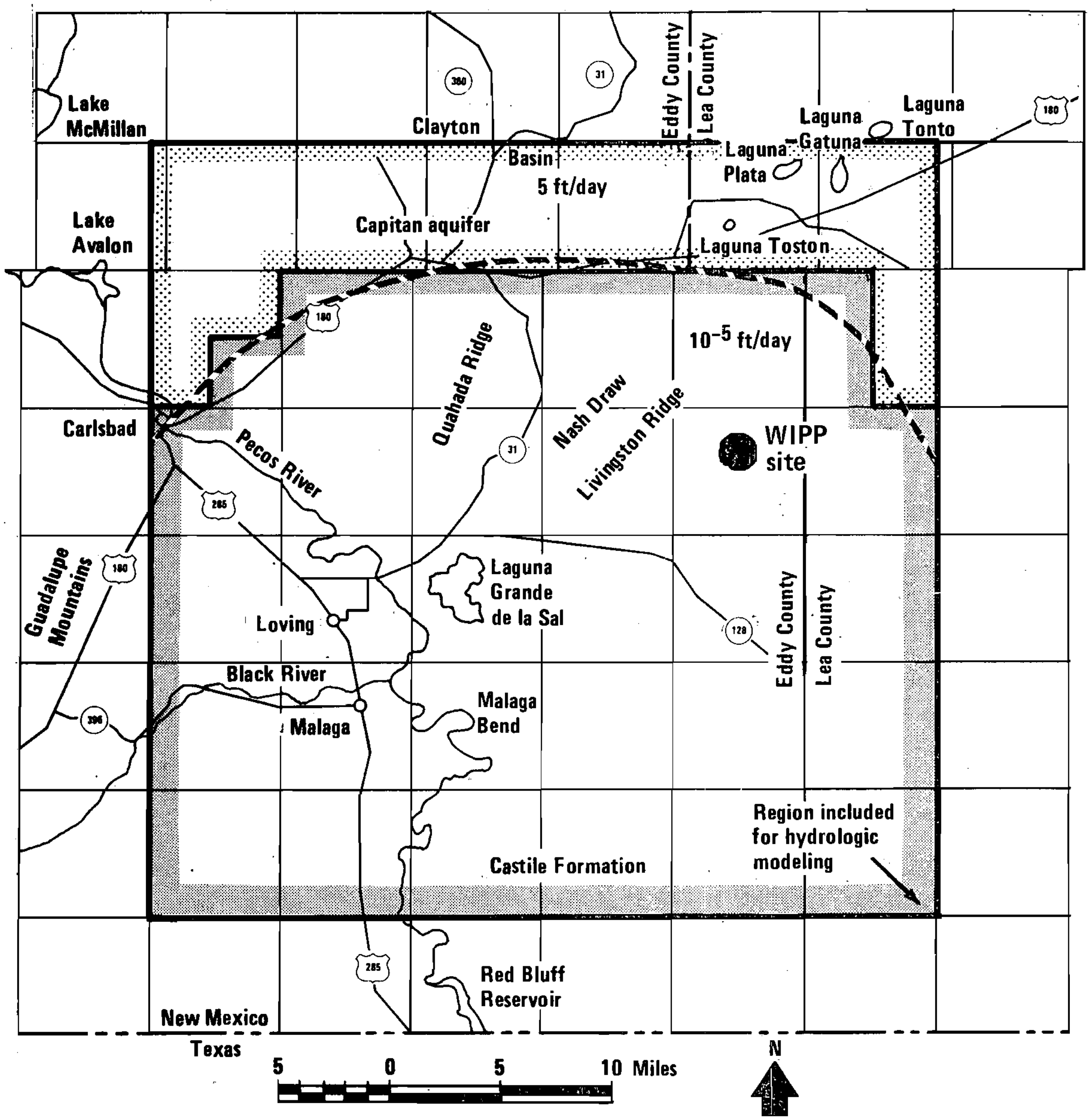

Figure K-9. Hydraulic conductivities in the Capitan aquifer and the Castile Formation.

determined. Therefore, calculations that take dispersion into account may predict earlier arrival times than those reported here, although the differences would not be great.

3. To a high degree of confidence, in each scenario the actual geosphere transport must lie within the results predicted by calculations with the two transmissivities.

4. The use of the higher transmissivity value gives conservative results.

The present analysis accounts for uncertainty by using conservative, upper-bound values in all safety-assessment calculations.

Table K-2. Summary of Hydrologic Data

Property	Formation	Reported value	Reference	Value used in this work
Thickness, ft	Rustler	210	Griswold, 1977	210
	Rustler--Culebra	20	Griswold, 1977	
	Rustler--Magenta	20		40 (total)
	Shallow-dissolution zone	50	Mercer and Orr, 1977	50
	Salado	1600	Griswold, 1977	2000
	Capitan aquifer	1600	Mercer and Orr, 1977	
	Castile	1000 to 1500	Griswold, 1977	1000
	Delaware Mountain Group	3000	Mercer and Orr, 1977	3000
Hydraulic transmissivity, ft^2/day	Rustler	0 to 500	Griswold, 1977	Not used
	Rustler--Culebra	10^{-4} to 140	Mercer and Orr, 1978	2 to 1280 (total)
	Rustler--Magenta	1 to 40	Mercer and Orr, 1978	
	Shallow-dissolution zone	8000	Mercer and Orr, 1977	8000
	Delaware Mountain Group	50	Mercer and Orr, 1977	1 to 200
Hydraulic conductivity, ft/day	Capitan aquifer	1 to 25, average	Mercer and Orr, 1977	5
	Salado, Castile, and Rustler anhydrite	4×10^{-6} to 2×10^{-5}	Lambert and Mercer, 1977	10^{-5}
Porosity	Rustler	0.1	Mercer and Orr, 1977	0.1
	Shallow-dissolution zone			0.2
	Capitan aquifer			0.15
	Delaware Mountain Group	0.1565	Mercer and Orr, 1977	0.16
	Salado, Castile, and Rustler anhydrite			0.005

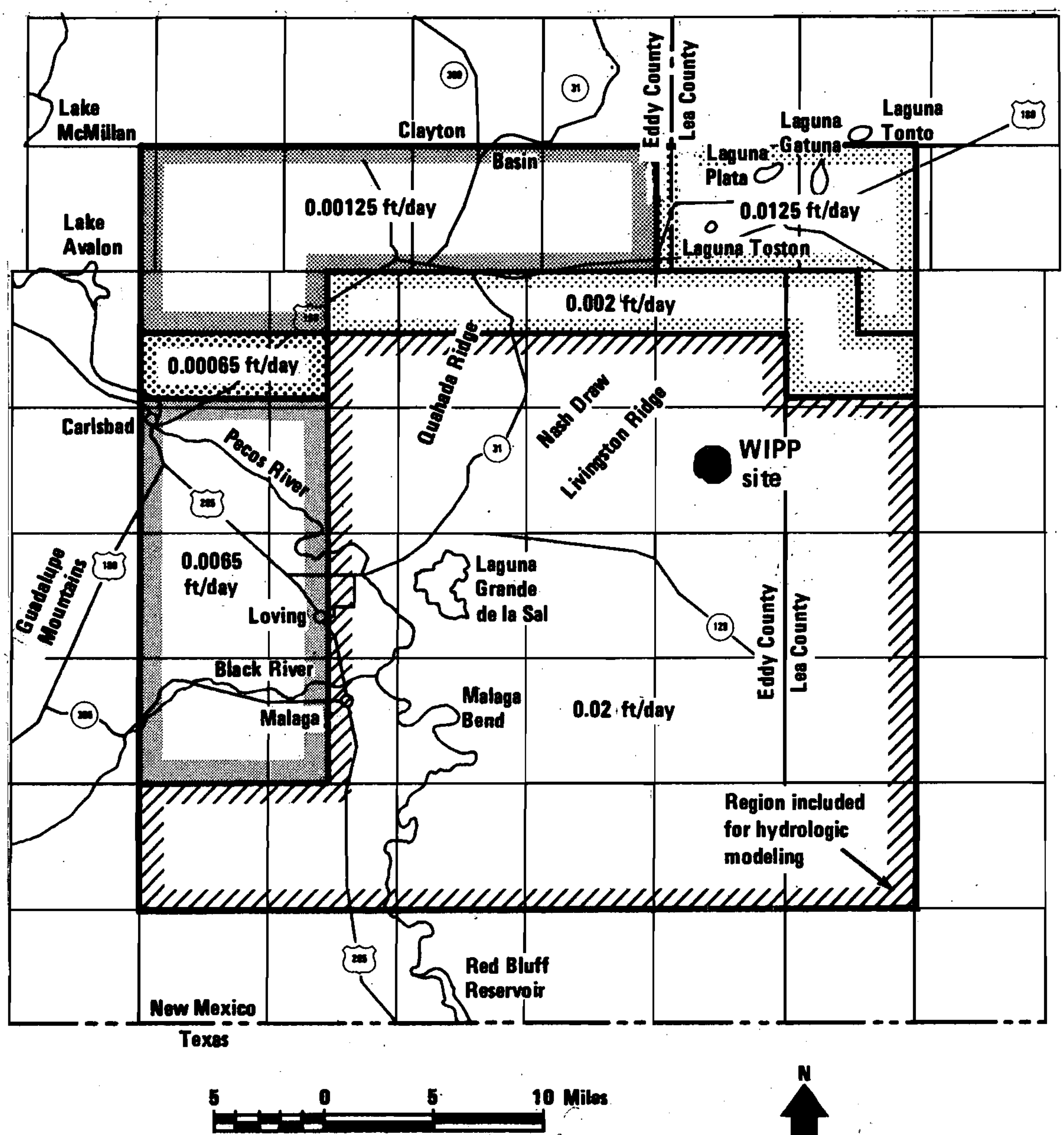

Figure K-10. Hydraulic conductivities in the Delaware Mountain Group.

A summary of available hydrologic data and the values used in this work are given in Table K-2. As can be seen from the table, the values used are reasonably conservative; that is, they are upper bounds on conductivity and permeability. They are, however, consistent with the measured data.

The total thickness of the upper aquifer was taken to be 40 feet, although the effective hydraulic thickness may actually be much smaller. The larger value of 40 feet was used because the calculated communication flow through the repository is then conservatively calculated on the high side.

A summary of reported water-quality data is given in Table K-3 along with the values of distribution coefficients used in this work. Ideally, the

Table K-3. Summary of Geochemical Data

Formation	Water quality: Reported value (mg/l)	Reference	Value used in this work
Rustler	3,350-35,600 TDS[a]	Lambert, 1978	Not used
Rustler--Culebra	23,720-118,290 TDS 17,900-89,200 NaCl	Mercer and Orr, 1978	8,000 TDS
Rustler--Magenta	10,350-20,680 TDS 6,800-24,300 NaCl	Mercer and Orr, 1978	
Delaware Mountain Group	296,400 TDS	Lambert, 1978	230,000 TDS

Distribution coefficients in the Rustler aquifer[b]

Element	Distribution coefficient (ml/g)
Americium	1460
Neptunium	350
Uranium	10
Thorium	2190
Plutonium	2100
Radium	25

[a]TDS = total dissolved solids.
[b]See text for the sources of the distribution coefficients.

geochemical data required for complete modeling would consist of water quality, the distribution coefficient for each radionuclide, nuclide solubilities in the Rustler water, and waste leach rates. For a real repository the rates at which radionuclides could enter the water would be limited by the solubility of the waste and by the rate at which the nuclides could be leached from the waste. This analysis took no advantage of these reductions; the waste-dissolution rate was assumed to be the same as the rate at which the salt formation is dissolved. A number of distribution coefficients have been measured at Sandia National Laboratories (Dosch and Lynch, 1978) for the WIPP-site rock material. Site-specific adsorption data were, however, not available for some radionuclides included in the modeling here. The distribution coefficients for these nuclides were estimated from the ratios of distribution coefficients for similar elements, measured at Sandia National Laboratories in WIPP-site rock and at the Pacific Northwest Laboratory (Rai and Mason, 1977) in desert soil.

K.2.2 Modeling of Liquid-Breach Scenarios

Four of the scenarios selected for analysis in this study involve the movement of water, salt, and waste products through a connection developed between the repository and one or more aquifers. To distinguish them from the direct-access scenarios (Section K.3), the term "liquid-breach scenario" is used. The reasons for choosing the four scenarios out of the many possible liquid-breach scenarios are outlined in Section 9.7.1.2; the discussion in this subsection centers on the modeling processes necessary for the four scenarios that were chosen.

Given a hydraulic communication between an aquifer and the waste repository, there are three mechanisms that can transfer waste from the repository to the aquifer:

1. Forced convection--fluid flow along a pressure or potential gradient.
2. Natural convection--fluid flow along a density gradient.
3. Molecular diffusion--transport along a concentration gradient.

Each of the four scenarios selected for analysis postulates a hydraulic connection. Because the driving mechanism is largely determined by the properties of the connection, detailed modeling of this small set of scenarios predicts the consequences of many scenarios. Of the four liquid-breach scenarios, three specify forced convection and one specifies molecular diffusion. None of them specify natural convection, which is expected to produce much weaker effects in the absence of a significant heat load in the repository.

Two types of scenario involving forced convection were modeled:

1. A hydrologic communication exists (or develops) between the Rustler aquifer and aquifers of the Delaware Mountain Group. The communication could be a wellbore or some natural feature. Water flows up or down the feature, depending on the relative hydraulic potentials or pressures in the two aquifers.

2. A hydrologic communication exists (or develops) between the Rustler aquifer and the repository through two wellbores (or perhaps natural channels). This situation is also known as a U-tube communication. Water flows down through one leg of the U-tube, through the repository, and up the other leg.

In each type of forced-convection scenario, the rate of waste release is assumed to be proportional to the rate of water flow through the repository.

A parametric study (Intera Environmental Consultants, personal communication, September 1979) has shown that, for both types of forced-convection scenario, the critical variables controlling water flow are the pressure or the potential difference between the inlet and the outlet of the communication, and the hydraulic conductance of the communication. Hydraulic conductance is the reciprocal of hydraulic resistance; it is defined as kA/L, where k is the hydraulic conductivity (feet per day), A is the cross-sectional area available for flow, and L is the effective length of the flow medium.

There are, however, limits to the control exercised by the hydraulic conductance of the communication. This fact is illustrated in Figure K-11, which shows the water-flow rate as a function of the hydraulic conductance of a communication between the upper and the lower aquifer. The figure applies to forced convection between two aquifers, the first type of scenario mentioned

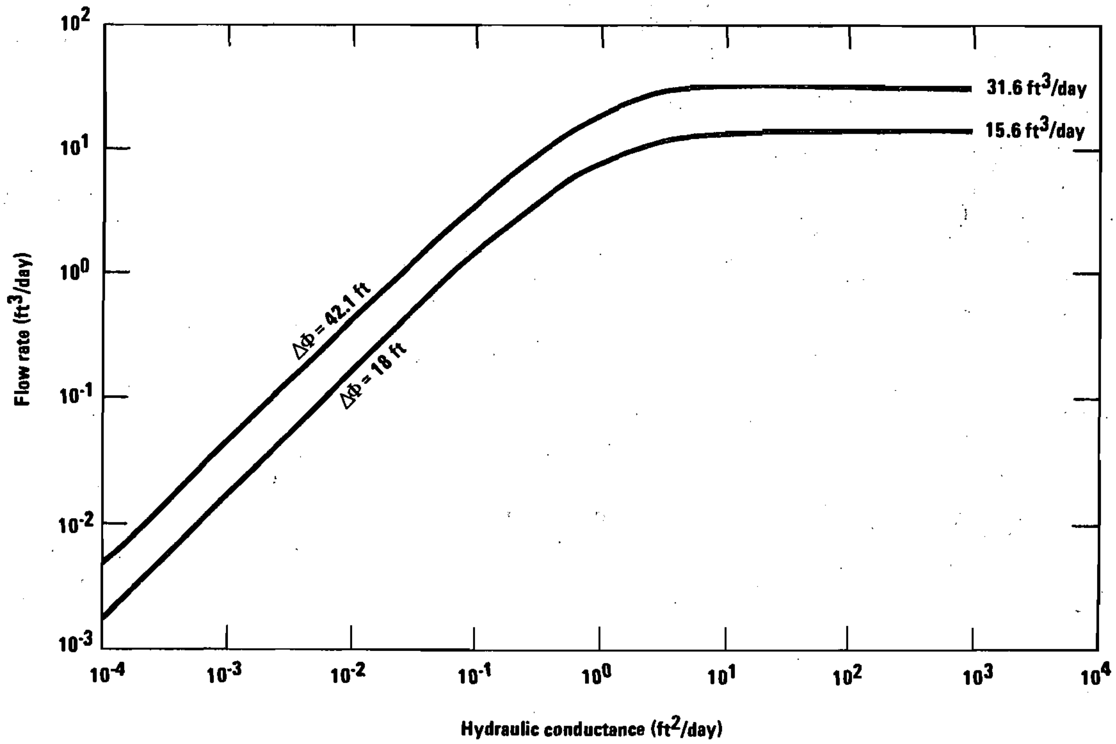

Figure K-11. Flow rate as a function of hydraulic conductance for two values of pressure-head difference: two-aquifer communication.

above. Two values of natural (undisturbed) pressure-head difference are shown. It is seen that the flow rate is proportional to the hydraulic conductance only for a limited range of values of that parameter; if the conductance is higher than about 1 ft^2/day, the flow rate asymptotically becomes a constant. This effect can be explained by noting that large flow rates are limited by the natural pressure-head difference and combined resistance of the two aquifers involved; in other words, the ultimate controlling parameter is the amount of fluid that can be supplied by the aquifers for flow through the repository. Similar studies were conducted for the case of a single-aquifer communication, the second type of scenario mentioned above. The qualitative behavior of the flow-rate versus conductance curves was identical with the behavior of the curves shown in Figure K-11; but in the former case the asymptotic limit is determined by natural pressure-head differences in, and the conductivity of, the single aquifer to which the U-tube is connected.

The functional dependence of flow rate on hydraulic conductance exhibited by the parametric studies can be used to support a claim made earlier: the small set of forced-convection scenarios modeled in the present study are capable of predicting the consequences of a wider class of events. If the flow rate is large enough, the nature, size, and origin of the assumed communication (i.e., whether it is a wellbore, a breccia pipe, or a conducting fault) do not really matter in determining the consequences of a waste-release scenario. The upper-limit values of conductance used in the scenarios of the text (Section 9.7.1) are judged to be sufficiently near the appropriate asymptotic limiting values so that these scenarios could cover a wide class of events leading to the release of waste.

Parametric studies for the liquid-breach scenario based on molecular diffusion are presented directly in the results for that scenario given in Section 9.7.1.4 of the text. The limiting parameters for molecular diffusion are the area of the communication (which cannot be larger than the area of the repository) and, implicitly, the rate at which the Rustler aquifers can supply water to carry away waste products that have diffused upward from the breached repository. It is assumed that waste products diffuse as rapidly as salt does through the stagnant water in the communication.

In the modeling of liquid-breach scenarios, potentials, waste-dissolution rates, and fluid-flow rates are based on hydrologic steady states. This assumption is reasonable because the time required to reach the steady state is small in comparison with the total waste-dissolution times. Furthermore, all fluid coming out of the repository into an aquifer is assumed to be saturated brine, with a total-dissolved-solids concentration of 410,000 ppm by weight. Fluid enters the repository at the total-dissolved-solids concentration listed in Table K-3. The salt formation and waste material are assumed to disssolve uniformly and at the same rate, bringing the total-dissolved-solids concentration up to the indicated saturated-brine concentration. For modeling convenience, both the contact-handled and the remotely handled wastes are assumed to be uniformly distributed throughout the volumes of their disposal areas at the time the scenario begins; specifications for the disposal areas are given in the text (Section 9.7.1).

K.2.3 Modeling of Radionuclide Transport

The transport of waste radionuclides away from the repository through the action of flowing groundwater is modeled in essentially four steps:

1. The determination of the flow lines (direction and speed) in the Rustler aquifer over the repository, under the disturbed conditions postulated in the scenario.

2. The determination of the rate of waste discharge into the Rustler aquifer, under the disturbed conditions postulated in the scenario.

3. The integration of the radionuclide-transport equations along a set of the flow lines determined in step 1, using the waste-discharge rate determined in step 2 as a source term. The integration is carried along each flow line until the line reaches a discharge point. (In all scenarios, discharge points were on the Pecos River.)

4. The determination of the total rate of discharge for each radionuclide into the Pecos River as a function of time. This step is performed by summing the integrated contributions from each of the flow lines of step 1 that reach the river.

In this study, steps 1 and 2 were performed in parallel by applying the three-dimensional regional hydrologic model on a limited but finely zoned grid centered on the repository. Hydrologic parameters for grid blocks were assigned to reflect the initial disturbed conditions for each liquid-breach scenario. Potentials and flows at the boundaries of the limited region were set according to the undisturbed potentials and flows determined by the large-scale regional modeling. It is believed that the size of the limited grid was large enough to insure that such boundary conditions were appropriate.

Step 3 was performed by numerically integrating one-dimensional versions of the coupled set of radionuclide-transport equations (Equations K-6 of Section K.1.2) along selected flow lines, taking into account changes in the hydrologic parameters (hydraulic conductivity mainly) in the regional grid blocks crossed by the flow lines. The one-dimensional transport equations do not account for hydraulic dispersion transverse to the flow lines and generally lead to overestimates of the peak concentrations of the trace constituent at a fixed time and position along the flow line. However, a good estimate of the net discharge to the Pecos is obtained by integrating the one-dimensional flux at the terminus of each flow line over the projected area of the envelope of flow lines at the discharge point. This is the procedure indicated in step 4 above.

In all transport calculations performed for this study, it was assumed that the events of the scenarios began either 1000 years (scenarios 1 through 3) or 50,000 years (scenario 4) after the repository is sealed. The calculations were carried out for the important isotopes of actinides listed in Table K-3. Shorter-lived fission products, present in modest amounts in the remotely handled TRU waste, contribute little activity to the inventory 1000 years after emplacement. Since nearly all of the considered actinides are long-lived isotopes, the nuclide inventory changes slowly during the unfolding of the scenario.

These 1000-year-event calculations are believed to be conservative predictions of direct consequences of events that could begin after many thousands of years. Although there would be a diminished radionuclide inventory in scenarios beginning later than 1000 years after burial, the consequences of such scenarios would not be radically different from the consequences of the ones considered; the only effect would be a displacement of the peak discharge rate at Malaga Bend to a later point in time. As stated in the text, the time at which maximum consequences are realized is not considered valuable information for this safety assessment, owing to the lack of a consensus on the times after which the waste products could be considered safe.

K.3 DIRECT-ACCESS SCENARIOS

The direct-access scenarios for the WIPP arise from the assumption that at some future time people will be motivated to drill into or mine in the unguarded and unmarked site. Specifically, these scenarios consider the consequences of drilling at the site in the course of exploring for mineral resources and the more serious consequences of solution mining for salt at the site. With one exception, the methods used to analyze these scenarios are straightforward and are described in Section 9.7.1 of the text along with results of the analyses. The exception is the method used to calculate the transport in air and the airborne concentrations of radionuclides suspended from a drilling-mud pit. Details of this method are given below.

K.3.1 Method for Calculating Radionuclide Transport in Air

It is assumed that a drill hole penetrates either the disposal area for remotely handled TRU waste or the disposal area for contact-handled TRU waste. In the process, waste materials are intercepted by the drill bit and radionuclides are uniformly mixed with the drilling mud. The contaminated mud is brought to the surface and directed to a mud pit, where it is left to dry uncovered and undisturbed. Thereafter wind erodes the surface, transporting contaminants downwind.

Drilling mud is pure clay (usually bentonite) with additives to adjust its density and pH. The surface of the mud pit is likely to dry to a crusted bricklike consistency, which would not present much opportunity for wind erosion. However, it is assumed that sand particles from the surrounding plain will scour the surface of the mud pit, and the material thus loosened will be resuspended to the same degree as material from the rest of the plain.

Provided the area of the mud pit is small (less than 100 square meters), the suspended material transported to distances greater than, say, 100 meters from the pit may be assumed to come from a point source. The Reactor Safety Study uses a squared Gaussian plume model for air concentration downwind (NRC, 1975, Appendix VI, p. 4-1, and Appendix A). The expression is

$$\chi = \frac{2Q}{3\sigma_y \sqrt{2\pi}\,\sigma_z u}$$

where

χ = ground-level air concentration (Ci/m^3)

Q = source strength (Ci/sec)

$3\sigma_y$ = lateral width of the assumed uniform distribution (m)

σ_z = vertical standard deviation (m)

u = average wind speed (m/sec)

The quantity Q can be expressed as the upward flux of suspended particles multiplied by the area of the source (Healy, 1977). The resuspension rate, in reciprocal units of sec^{-1}, multiplied by the surface concentration gives the value of the upward flux. The resuspension rate measured for desert soil at the Nevada Test Site is 10^{-13} sec^{-1} and varies as the cube of the wind speed (Healy, 1977). Thus the transport of suspended material is described by the equation

$$\chi_1 = \frac{2\rho d_0 A K \Omega_i (10^4)}{\sqrt{2\pi}\, 3\sigma_y \sigma_z u}$$

where

Ω_i = concentration of isotope i in the drilling mud (Ci/g)

ρ = density of the drilling mud (assumed to be 2 g/cm^3)

d_0 = depth from which material is available for resuspension (assumed to be 1 cm)

K = resuspension rate (sec^{-1}); $K = 10^{-13}(u/u_0)^3$; u_0 is assumed to be 1 m/sec

A = area of the mud pit (m^2)

10^4 = factor for converting from square meters to square centimeters

The expressions for σ_y and σ_z for slightly unstable to neutral conditions typical of the desert southwest (Pasquill stability category C) are

$$\sigma_y = 0.11d(1 + 10^{-4}d)^{-\frac{1}{2}}$$

$$\sigma_z = 0.08d(1 + 2 \times 10^{-4}d)^{-\frac{1}{2}}$$

where d is the downwind transport distance expressed in meters. The mud-pit areas assumed are 720 square feet (66.9 square meters) for a 10-inch drill hole and 144 square feet (13.4 square meters) for a 3-inch drill hole. To allow for the finite size of these pits, a virtual point source is created upwind of the pond such that $3\sigma_y = A^{\frac{1}{2}}$ at the leeward side of the pond. Thus for the 10- and 3-inch drill holes the virtual point source is taken to be 24.8 and 11.1 meters, respectively, upwind of the leeward side. Using these values, a short table giving χ_i as a function of Ω_i and distance can be constructed. (All downwind transport distances d' given below are measured from the middle of the pond.)

d' (m)	χ_i (Ci/m^3) 10-inch drill hole	χ_i (Ci/m^3) 3-inch drill hole
100	$3.58 \times 10^{-9}\Omega_i$	$8.73 \times 10^{-10}\Omega_i$
500	$2.04 \times 10^{-10}\Omega_i$	$4.25 \times 10^{-11}\Omega_i$
1000	$5.67 \times 10^{-11}\Omega_i$	$1.16 \times 10^{-11}\Omega_i$

The subsequent surface deposition of suspended radionuclides is also required for the analyses. It is assumed that dry deposition is the dominant mechanism. The dry-deposition flux is the product of the deposition velocity and the air concentration near the ground (Ci/m^2-sec = $V_d \chi$). The deposition velocity V_d is taken to be 0.01 m/sec, which corresponds to a particle about 1 micron in diameter. The particle-size distribution of the suspended material can be related to the particle-size distribution of the surface source. Healy (1977) indicates that for clays the aerodynamic mean activity diameter of these particles is 1 micron or less. Thus 1 micron is taken to be the nominal value for the suspended and transported material.

K.3.2 Uncertainties in the Calculation

Air concentrations and surface depositions previously described as applying to the direct-access scenario have been obtained using generally conservative assumptions and parameters. However, it is worthwhile to understand how uncertainties in these assumptions and parameters may affect the results.

Radionuclide distribution in the drilling mud. If radionuclides are uniformly distributed in the drilling mud, their concentration and hence the resulting dose will vary inversely with the total mass of the mud. However, to the extent that the heavy elements settle to the bottom of the pond, they will not be resuspended in significant quantities even if the mass of the mud is greatly reduced.

Resuspension factor. The dried drilling mud (clay) is most likely to have a bricklike consistency that, if left in an undisturbed state, is not liable to produce as much suspendable material as the surface at the Nevada Test Site, where small and large particles are more intimately but more loosely mixed. This tendency is likely to persist even if the surface is mechanically disturbed after drying, provided the thickness of the mud is on the order of feet.

Atmospheric stability. Values cited above are for slightly unstable atmospheric conditions. Under very stable conditions, air concentrations downwind of the source would increase by more than a factor of 10. Under very unstable conditions, they would decrease by about a factor of 5. However, the exposures being estimated are long-term exposures, and for this purpose median stability conditions are in order.

Wind direction. In directions other than the usual downwind direction, concentrations and hence exposures will be smaller than those estimated.

Particle deposition. The assumption used in the transport and deposition calculation above holds that the dust cloud is not depleted by surface deposition as it travels downwind. In fact, material is continuously lost from the cloud; thus all downwind concentrations are overestimated, roughly by a factor of 2.

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Appendix L

AN OUTLINE OF THE INPUT-OUTPUT MODEL AND THE METHODS USED IN PROJECTING SOCIOECONOMIC IMPACTS

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Appendix L

AN OUTLINE OF THE INPUT-OUTPUT MODEL AND THE METHODS USED IN PROJECTING SOCIOECONOMIC IMPACTS

L.1 INPUT-OUTPUT MODEL

A static model in the form of a regional input-output model was constructed for Eddy and Lea Counties, New Mexico. The original derivation of the input-output model is described in a paper published in the Proceedings of the 1975 Conference of the Association of University Business and Economic Research; that paper is attached to this appendix as an annex. The procedure described in that document was, in general, followed in building the regional input-output model.

Since the publication of that document, better information on the agricultural sector in New Mexico has become available, and its credibility is believed to be such that the variation experienced in the original model has been decreased. Regardless of the accuracy of the agricultural information, the effect of the construction and operation of the WIPP on the agricultural sector is believed to be less than 1% in terms of employment and income. Therefore, the agricultural sector and the reliability of agricultural information exert little effect on the overall modeling process.

This model has been used to assess the economic impacts of the following projects for the following agencies: the San Juan power plant (units 1, 3, and 4) for the Public Service Company of New Mexico; the Gallup-Navajo Indian Water Supply Project for the Bureau of Reclamation; a proposed nuclear power plant at Cementon, New York, for Harbridge House, Inc., an agent for the Power Authority of the State of New York; two sites for nuclear or fossil-fuel power plants for Harbridge House, Inc., an agent for the New York State Electric & Gas Corporation; four coal-development scenarios in northwest New Mexico for Harbridge House, Inc., an agent for the Bureau of Land Management; and the proposed New Mexico Generating Station for the Public Service Company of New Mexico. It has also been used to study general economic impacts (an ongoing process) for the Bureau of Business and Economic Research, University of New Mexico.

During or about the same time this study was being conducted, the model was used for analyzing the economic impacts of a proposed coal-fired power plant for Burns and McDonnell, an agent for the Plains Electric Cooperative; industrial linkages in Cecil County, Maryland, for Harbridge House, Inc., an agent for the Cecil County Development Agency; and the economic impacts of decreased grazing allocations in the Roswell, New Mexico, Grazing District for Harbridge House, Inc., an agent for the Bureau of Land Management. Thus, the model has been used extensively and is accepted as a tool for determining the economic impacts of proposed new facilities and developments.

L.1.1 Base Model

The regional model adjusts a national model by means of location quotients and aggregating techniques. The national, or base, model contains 407 economic categories, or subsectors of the economy, 389 of which represent the private economy and 18 of which represent other activities, including the public sector. The 389 private subsectors were used in the model; the government impact was computed from four of the public subsectors supplemented by a final demand pattern from the business-service subsector.

The base model is an updated version of the 1967 National Input-Output Model constructed by the Department of Commerce, Bureau of Economic Analysis. Two important changes in the 1967 version have been made. First, the mining sectors have been expanded to 44 subsectors. Second, the Lawrence Berkeley Laboratory has mathematically updated the 1967 version to a 1972 version by using data from the 1972 Census of Business.

As already mentioned, the detailed modeling process and technical procedures are discussed in the annex. However, several important aspects of this particular model for Eddy and Lea Counties should be noted. First, detailed information on employment, by category, was determined from information supplied by the New Mexico Employment Security Department (NMESD), formerly the Employment Security Commission. From this information, detailed location quotients for manufacturing were determined at the four-digit SIC code level, and this added credibility and accuracy to the modeling process.

Second, because of the makeup of retail and wholesale subsectors in Eddy and Lea Counties, a detailed analysis of the types of outlets present in the area was conducted. Basic information from the 1972 Census of Business was used with updated information from the employment files for this analysis.

Finally, once the location quotients had been determined, 1972 Census data and various other State and local data sources were used to identify the output per employee for subsectors whose location quotients were computed through employment statistics. A total-output figure was derived for these subsectors. In turn, the total-ouput figures were used to aggregate the 389 subsectors in the base model into 37 private-business subsectors and one governmental subsector for the regional model.

Subsectors for WIPP aboveground construction (1980, 1981, 1982, 1983, and 1984), WIPP management and design, WIPP belowground construction (1980, 1981, 1982, 1983, and 1984), and WIPP operation--aboveground operation, remote handling and security, and belowground operation--were derived from data supplied by Sandia National Laboratories, Bechtel, Inc., and the Westinghouse Electric Corporation. There are a total of 52 subsectors in the model for Eddy and Lea Counties and two additional subsectors to account for labor compensation.

L.1.2 Household Compensation for Labor and Personal Consumption in the Area

The average percentages of cost going to labor from the technical production process (direct coefficients) were determined from the 1972 national input-output model. Personal-consumption figures were adjusted by weighting the location quotients of each of the 37 private-business subsectors and the government subsector in the regional model. An additional personal-consumption column adjusted for reduced local purchases was incorporated into the model to allow for lower local consumption by construction workers who commute weekly. The labor coefficients for the 14 WIPP subsectors were derived from data supplied by Sandia, Bechtel, and Westinghouse. For the five WIPP aboveground-construction subsectors and the five WIPP belowground-construction subsectors, labor coefficients for construction workers who commute and those who reside in the two-county area were assigned by using comparable factors from the Construction Worker Profile.

The direct coefficients obtained by determining location quotients and the aggregation process are listed in Table L-1. The aggregated direct, indirect, and induced coefficients are given in Table L-2.

L.2 OUTPUT MULTIPLIER

The volume of activity generated in the private sector by a $1 exogenous increase in a subsector can be determined through the input-output process. For example, for WIPP aboveground construction in 1982, subsector 40, we find the column sum of 1.67062 in Table L-2. Thus, $1.67 in total activity will result in the region from a $1 exogenous increase in WIPP aboveground-construction (1982) activity; that is, an additional $0.67 of indirect activity, including payments to labor, will be generated in Eddy and Lea Counties.

It should be noted at this point that the output multiplier is not of primary concern in determining the overall impact of new developments in the area. The employment and income multipliers are believed to be of greater importance, and they may vary significantly from the 1.67 output multiplier.

L.3 EMPLOYMENT MULTIPLIERS

To determine the employment multipliers for WIPP-related development, three basic calculations must be performed. First, wages for the area under consideration must be determined in constant dollars--in this case 1979 dollars. Second, the change in the total annual output for an exemplary year must be calculated in constant 1979 dollars. Third, the actual number of dollars spent directly for labor must be computed.

Once the annual labor costs for each subsector have been determined, the average labor unit cost is divided into each gross amount to find the actual number of jobs supported in that specific subsector by an exogenous increase in the specific activity being investigated, such as WIPP aboveground construction, belowground construction, or aboveground operation.

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients

Industry Selling		Industry purchasing 1	2	3	4	5	6	7	8	
Livestock and livestock products	1	0.30891	0.02889	0.09777	0.01457	0.14889	0.00151	0.00000	0.00000	1
Cotton	2	0.00000	0.01636	0.00000	0.00000	0.00000	0.00095	0.00000	0.00000	2
Grains and seeds	3	0.26662	0.00000	0.02988	0.00000	0.00000	0.00772	0.00000	0.00000	3
Fruits and vegetables	4	0.00049	0.00000	0.00000	0.00378	0.00000	0.00090	0.00000	0.00000	4
Forestry and fishery products	5	0.00000	0.00000	0.00000	0.00000	0.07198	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00263	0.10165	0.01289	0.05881	0.02604	0.00000	0.00000	0.00000	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00009	0.00020	0.00008	0.00000	0.00000	0.00836	0.00000	7
Crude petroleum	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00250	8
Natural gas and liquid petroleum	9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
Stone, gravel, and sand	10	0.00001	0.00137	0.00184	0.00094	0.00000	0.00000	0.00000	0.00000	10
Potash mining	11	0.00000	0.00071	0.00120	0.00056	0.00000	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00387	0.01065	0.00935	0.00702	0.00000	0.00000	0.00222	0.02719	15
Food products	16	0.02322	0.00000	0.00000	0.00000	0.01580	0.00003	0.00000	0.00000	16
Fabrics and apparel	17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	17
Wood and lumber products	18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
Printing	19	0.00001	0.00003	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000	19
Chemical products	20	0.00079	0.00507	0.00659	0.00247	0.00056	0.00000	0.02144	0.00319	20
Plastics and petroleum products	21	0.00328	0.03672	0.03285	0.01250	0.03032	0.00012	0.00205	0.00426	21
Glass and stone products	22	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00008	24
Machinery	25	0.00008	0.00024	0.00011	0.00010	0.00000	0.00000	0.01063	0.00008	25
Electrical products	26	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	26
Transportation and warehousing	27	0.01356	0.01047	0.01312	0.00868	0.00522	0.00065	0.00984	0.00139	27
Communications	28	0.00146	0.00296	0.00184	0.00133	0.00000	0.00000	0.00282	0.00078	28
Electrical utility	29	0.00186	0.00738	0.00161	0.00281	0.00021	0.00003	0.01118	0.01071	29
Gas utility	30	0.00002	0.00000	0.00000	0.00000	0.00028	0.00003	0.00239	0.00159	30
Water and sewer	31	0.00018	0.00832	0.00720	0.00770	0.00000	0.00000	0.00000	0.00050	31
Wholesale trade	32	0.01542	0.03706	0.02949	0.02561	0.02824	0.00047	0.00958	0.00409	32
Retail trade	33	0.01004	0.02745	0.02302	0.01103	0.00893	0.00023	0.00119	0.00382	33
Finance, insurance, and real estate	34	0.00868	0.07375	0.04181	0.02078	0.01685	0.00107	0.00815	0.09158	34
Lodging and personal and repair services	35	0.00330	0.00862	0.00442	0.00377	0.00575	0.00002	0.00051	0.00216	35
Businesses and miscellaneous services	36	0.00139	0.02915	0.02602	0.01550	0.00005	0.00000	0.00816	0.01375	36
Medical and nonprofit	37	0.00051	0.00056	0.00085	0.00040	0.00000	0.00000	0.00121	0.00028	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.00007	0.00014	0.00010	0.00012	0.00032	0.00000	0.00154	0.00037	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.04276	0.07285	0.07285	0.07285	0.20020	0.35031	0.32507	0.11930	54
Column sums		0.70916	0.48049	0.41450	0.27144	0.55967	0.36404	0.42633	0.28762	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 9	10	11	12	13	14	15	16	
Livestock and livestock products	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07348	1
Cotton	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.10494	2
Grains and seeds	3	0.00000	0.00000	0.00000	0.00031	0.00013	0.00018	0.00000	0.02323	3
Fruits and vegetables	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00155	4
Forestry and fishery products	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00000	0.00000	0.00000	0.00139	0.00077	0.00285	0.00047	0.00000	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005	7
Crude petroleum	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	8
Natural gas and liquid petroleum	9	0.14584	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
Stone, gravel, and sand	10	0.00000	0.00446	0.00000	0.00201	0.00271	0.02103	0.00657	0.00012	10
Potash mining	11	0.00000	0.00048	0.01395	0.00000	0.00000	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.03218	0.00796	0.00205	0.00025	0.00036	0.00034	0.00015	0.00244	15
Food products	16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02480	16
Fabrics and apparel	17	0.00000	0.00000	0.00000	0.00098	0.00003	0.00061	0.00010	0.00019	17
Wood and lumber products	18	0.00000	0.00000	0.00000	0.03789	0.01187	0.00210	0.00382	0.00000	18
Printing	19	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00131	19
Chemical products	20	0.00803	0.00646	0.01969	0.00049	0.00191	0.00263	0.00032	0.00106	20
Plastics and petroleum products	21	0.00441	0.01289	0.00574	0.00601	0.00944	0.02759	0.00749	0.00317	21
Glass and stone products	22	0.00000	0.05511	0.00000	0.02664	0.03524	0.02147	0.00287	0.00000	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00003	0.00000	0.00000	0.00196	0.00309	0.00187	0.00047	0.00000	24
Machinery	25	0.00011	0.00509	0.01535	0.00038	0.00058	0.00051	0.00024	0.00000	25
Electrical products	26	0.00000	0.00000	0.00000	0.00020	0.00029	0.00023	0.00007	0.00000	26
Transportation and warehousing	27	0.00167	0.01329	0.00977	0.02637	0.02787	0.04716	0.02166	0.02313	27
Communications	28	0.00093	0.00020	0.00259	0.00316	0.00471	0.00431	0.00211	0.00465	28
Electrical utility	29	0.00574	0.02649	0.02001	0.00055	0.00084	0.00077	0.00037	0.00600	29
Gas utility	30	0.01419	0.00291	0.02469	0.00012	0.00017	0.00015	0.00007	0.00187	30
Water and sewer	31	0.00105	0.00281	0.00000	0.00029	0.00044	0.00036	0.00017	0.00040	31
Wholesale trade	32	0.00923	0.03455	0.00250	0.05106	0.04953	0.04327	0.03911	0.02976	32
Retail trade	33	0.00448	0.01193	0.00138	0.08578	0.04874	0.03914	0.06360	0.00185	33
Finance, insurance, and real estate	34	0.10845	0.03037	0.00694	0.00697	0.01026	0.00916	0.00484	0.00709	34
Lodging and personal and repair services	35	0.00255	0.01085	0.00064	0.00488	0.00730	0.00801	0.00354	0.00341	35
Businesses and miscellaneous services	36	0.01627	0.03144	0.00860	0.05413	0.07157	0.04270	0.01936	0.00810	36
Medical and nonprofit	37	0.00033	0.00009	0.00119	0.00078	0.00115	0.00106	0.00052	0.00060	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.00043	0.00022	0.00115	0.00046	0.00068	0.00070	0.00031	0.00092	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.11930	0.32507	0.27808	0.32535	0.32535	0.32535	0.49419	0.14492	54
Column sums		0.47521	0.58268	0.41431	0.63840	0.61502	0.60383	0.67271	0.46901	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 17	18	19	20	21	22	23	24	
Livestock and livestock products	1	0.00568	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
Cotton	2	0.03292	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
Grains and seeds	3	0.00000	0.00000	0.00000	0.00006	0.00000	0.00000	0.00000	0.00000	3
Fruits and vegetables	4	0.00000	0.00000	0.00000	0.00114	0.00000	0.00000	0.00000	0.00000	4
Forestry and fishery products	5	0.01529	0.00000	0.00000	0.00374	0.00000	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00000	0.00124	0.00004	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.00000	0.00000	0.00000	0.00000	0.45740	0.00000	0.00000	0.00000	8
Natural gas and liquid petroleum	9	0.00000	0.00000	0.00000	0.00231	0.02337	0.00000	0.00000	0.00000	9
Stone, gravel, and sand	10	0.00000	0.00000	0.00000	0.00038	0.00000	0.06606	0.00000	0.00008	10
Potash mining	11	0.00000	0.00000	0.00000	0.00755	0.00000	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00131	0.00294	0.00311	0.00431	0.01019	0.00289	0.00000	0.00224	15
Food products	16	0.00001	0.00000	0.00000	0.00088	0.00000	0.00000	0.00000	0.00000	16
Fabrics and apparel	17	0.10091	0.00080	0.00143	0.00021	0.00007	0.00047	0.00000	0.00075	17
Wood and lumber products	18	0.00000	0.00791	0.00000	0.00000	0.00000	0.00000	0.00000	0.00065	18
Printing	19	0.00001	0.00004	0.01586	0.00004	0.00000	0.00008	0.00000	0.00000	19
Chemical products	20	0.00080	0.00274	0.01263	0.05002	0.00578	0.00123	0.00000	0.00071	20
Plastics and petroleum products	21	0.00093	0.00272	0.00236	0.05459	0.05487	0.00919	0.00000	0.00410	21
Glass and stone products	22	0.00000	0.00034	0.00000	0.00000	0.00001	0.02440	0.00000	0.00018	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00000	0.00000	0.00000	0.00005	0.00001	0.00000	0.00000	0.00141	24
Machinery	25	0.00000	0.00191	0.00000	0.00002	0.00001	0.00308	0.00000	0.02363	25
Electrical products	26	0.00000	0.00001	0.00002	0.00002	0.00000	0.00000	0.00000	0.00001	26
Transportation and warehousing	27	0.00945	0.02748	0.01179	0.02047	0.02876	0.12118	0.00000	0.01518	27
Communications	28	0.00319	0.00406	0.01098	0.00326	0.00067	0.00573	0.00000	0.00490	28
Electrical utility	29	0.00687	0.00674	0.00499	0.01371	0.00569	0.00645	0.00000	0.00639	29
Gas utility	30	0.00048	0.00134	0.00096	0.01014	0.01029	0.00399	0.00000	0.00339	30
Water and sewer	31	0.00049	0.00000	0.00062	0.00235	0.00188	0.00008	0.00000	0.00008	31
Wholesale trade	32	0.02700	0.04642	0.01965	0.01909	0.00657	0.02680	0.00000	0.02364	32
Retail trade	33	0.00261	0.00177	0.00510	0.00247	0.00045	0.00175	0.00000	0.00844	33
Finance, insurance, and real estate	34	0.01053	0.01530	0.01723	0.01438	0.01657	0.01788	0.00000	0.01264	34
Lodging and personal and repair services	35	0.00102	0.00163	0.00339	0.00129	0.00048	0.00418	0.00000	0.00103	35
Businesses and miscellaneous services	36	0.00681	0.00877	0.02700	0.01384	0.00968	0.01648	0.00000	0.00885	36
Medical and nonprofit	37	0.00043	0.00049	0.00156	0.00056	0.00015	0.00078	0.00000	0.00055	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.00180	0.00103	0.00664	0.00076	0.00050	0.00080	0.00000	0.00067	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.29852	0.28617	0.23671	0.38320	0.10374	0.31907	0.31473	0.30851	54
Column sums		0.52704	0.42061	0.38203	0.61209	0.73718	0.63258	0.31473	0.42805	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 25	26	27	28	29	30	31	32	
Livestock and livestock products	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
Cotton	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
Grains and seeds	3	0.00000	0.00000	0.00133	0.00000	0.00000	0.00000	0.00000	0.00000	3
Fruits and vegetables	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	4
Forestry and fishery products	5	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00117	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00004	0.00000	0.00000	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.00000	0.00000	0.00065	0.00000	0.00059	0.02381	0.00000	0.00001	8
Natural gas and liquid petroleum	9	0.00000	0.00000	0.00405	0.00000	0.00361	0.14625	0.00000	0.00004	9
Stone, gravel, and sand	10	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00002	10
Potash mining	11	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00168	0.00245	0.02048	0.01411	0.02801	0.01443	0.06484	0.00095	15
Food products	16	0.00000	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00327	16
Fabrics and apparel	17	0.00070	0.00088	0.00036	0.00012	0.00022	0.00009	0.00031	0.00093	17
Wood and lumber products	18	0.03302	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00035	18
Printing	19	0.00000	0.00235	0.00037	0.00016	0.00001	0.00000	0.00001	0.00064	19
Chemical products	20	0.00029	0.00000	0.00015	0.00001	0.00086	0.00000	0.00154	0.00072	20
Plastics and petroleum products	21	0.00562	0.00735	0.02989	0.00193	0.01204	0.00076	0.00334	0.00877	21
Glass and stone products	22	0.00000	0.00002	0.00001	0.00000	0.00000	0.00000	0.00000	0.00048	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	24
Machinery	25	0.01938	0.00000	0.00017	0.00000	0.00000	0.00000	0.00000	0.00044	25
Electrical products	26	0.00081	0.01076	0.00000	0.00000	0.00000	0.00000	0.00000	0.00006	26
Transportation and warehousing	27	0.01890	0.01110	0.08829	0.00146	0.02086	0.00020	0.00232	0.01572	27
Communications	28	0.00339	0.00726	0.00861	0.01282	0.00250	0.00210	0.00443	0.01173	28
Electrical utility	29	0.00541	0.00596	0.01622	0.00553	0.07355	0.00260	0.02800	0.00382	29
Gas utility	30	0.00134	0.00193	0.00338	0.00110	0.03353	0.36157	0.01650	0.00046	30
Water and sewer	31	0.00047	0.00013	0.00114	0.00125	0.00097	0.00065	0.00091	0.00168	31
Wholesale trade	32	0.04501	0.02005	0.02379	0.00304	0.00623	0.00063	0.00463	0.01558	32
Retail trade	33	0.00664	0.00762	0.01069	0.00492	0.00168	0.00156	0.00329	0.01564	33
Finance, insurance, and real estate	34	0.01276	0.01924	0.01853	0.01229	0.00464	0.00549	0.01416	0.02239	34
Lodging and personal and repair services	35	0.00082	0.00193	0.02424	0.06180	0.00203	0.00034	0.00783	0.01772	35
Businesses and miscellaneous services	36	0.00679	0.01306	0.00894	0.00983	0.00417	0.00455	0.00751	0.02311	36
Medical and nonprofit	37	0.00045	0.00127	0.00052	0.00059	0.00027	0.00025	0.00051	0.00099	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.00060	0.00187	0.00308	0.00254	0.00267	0.01382	0.57360	0.00282	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.36951	0.33341	0.40647	0.39097	0.13980	0.13980	0.13980	0.42500	54
Column sums		0.53363	0.44863	0.67151	0.52446	0.33824	0.71889	0.87351	0.57453	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 33	34	35	36	37	38	39	40	
Livestock and livestock products	1	0.00000	0.00034	0.00109	0.00000	0.00003	0.00000	0.00000	0.00000	1
Cotton	2	0.00000	0.00006	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	2
Grains and seeds	3	0.00000	0.00067	0.00337	0.00000	0.00000	0.00006	0.00006	0.00006	3
Fruits and vegetables	4	0.00000	0.00003	0.00001	0.00000	0.00002	0.00000	0.00000	0.00000	4
Forestry and fishery products	5	0.00000	0.00001	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00000	0.00028	0.00020	0.00000	0.00000	0.00032	0.00032	0.00032	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.00000	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	8
Natural gas and liquid petroleum	9	0.00000	0.00037	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
Stone, gravel, and sand	10	0.00000	0.00004	0.00001	0.00000	0.00000	0.00744	0.00744	0.00744	10
Potash mining	11	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00280	0.01757	0.00743	0.00494	0.00900	0.00000	0.00000	0.00000	15
Food products	16	0.00017	0.00012	0.00000	0.00000	0.00032	0.00000	0.00000	0.00000	16
Fabrics and apparel	17	0.00005	0.00010	0.00148	0.00000	0.00018	0.00000	0.00000	0.00000	17
Wood and lumber products	18	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
Printing	19	0.00049	0.00299	0.00009	0.00051	0.00300	0.00000	0.00000	0.00000	19
Chemical products	20	0.00005	0.00013	0.00030	0.00090	0.00017	0.00000	0.00000	0.00000	20
Plastics and petroleum products	21	0.00540	0.00357	0.00838	0.00430	0.00884	0.00047	0.00047	0.00047	21
Glass and stone products	22	0.00001	0.00002	0.00004	0.00001	0.00000	0.00000	0.00000	0.00000	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00000	0.00000	0.00000	0.00001	0.00000	0.00136	0.00136	0.00136	24
Machinery	25	0.00005	0.00011	0.00387	0.00238	0.00000	0.00011	0.00011	0.00011	25
Electrical products	26	0.00000	0.00000	0.00009	0.00009	0.00084	0.00000	0.00000	0.00000	26
Transportation and warehousing	27	0.00172	0.00350	0.00487	0.00803	0.00349	0.00431	0.00431	0.00431	27
Communications	28	0.00559	0.01517	0.00644	0.01478	0.01308	0.00439	0.00439	0.00439	28
Electrical utility	29	0.01428	0.00966	0.01214	0.00214	0.01781	0.00094	0.00094	0.00094	29
Gas utility	30	0.00314	0.00194	0.00265	0.00262	0.00352	0.00000	0.00000	0.00000	30
Water and sewer	31	0.00225	0.00393	0.00340	0.00118	0.00646	0.00000	0.00000	0.00000	31
Wholesale trade	32	0.00573	0.00635	0.02391	0.01323	0.02089	0.06613	0.06613	0.06613	32
Retail trade	33	0.00383	0.00913	0.01504	0.01652	0.01888	0.00000	0.00000	0.00000	33
Finance, insurance, and real estate	34	0.03464	0.08665	0.03929	0.03435	0.06246	0.00830	0.00830	0.00830	34
Lodging and personal and repair services	35	0.00793	0.00453	0.03926	0.01584	0.02056	0.00211	0.00211	0.00211	35
Businesses and miscellaneous services	36	0.00795	0.05356	0.01151	0.05497	0.02381	0.00000	0.00000	0.00000	36
Medical and nonprofit	37	0.00082	0.00689	0.00191	0.00221	0.00340	0.00008	0.00008	0.00008	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.01696	0.02965	0.00350	0.01293	0.01238	0.00000	0.00000	0.00000	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.02612	0.01410	0.03087	53
Households/PC local	54	0.42500	0.36153	0.34761	0.42166	0.51489	0.16734	0.09038	0.19783	54
Column sums		0.53885	0.61897	0.53788	0.61362	0.74405	0.28948	0.20050	0.32472	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 41	42	43	44	45	46	47	48	
Livestock and livestock products	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1
Cotton	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2
Grains and seeds	3	0.00006	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	3
Fruits and vegetables	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	4
Forestry and fishery products	5	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5
Agricultural services	6	0.00032	0.00032	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	8
Natural gas and liquid petroleum	9	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	9
Stone, gravel, and sand	10	0.00744	0.00744	0.00000	0.00268	0.00268	0.00268	0.00268	0.00268	10
Potash mining	11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00000	0.00000	0.00494	0.00000	0.00000	0.00000	0.00000	0.00000	15
Food products	16	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	16
Fabrics and apparel	17	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	17
Wood and lumber products	18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18
Printing	19	0.00000	0.00000	0.00051	0.00000	0.00000	0.00000	0.00000	0.00000	19
Chemical products	20	0.00000	0.00000	0.00090	0.00000	0.00000	0.00000	0.00000	0.00000	20
Plastics and petroleum products	21	0.00047	0.00047	0.00430	0.00000	0.00000	0.00000	0.00000	0.00000	21
Glass and stone products	22	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00136	0.00136	0.00001	0.00051	0.00051	0.00051	0.00051	0.00051	24
Machinery	25	0.00011	0.00011	0.00238	0.00141	0.00141	0.00141	0.00141	0.00141	25
Electrical products	26	0.00000	0.00000	0.00009	0.00000	0.00000	0.00000	0.00000	0.00000	26
Transportation and warehousing	27	0.00431	0.00431	0.00803	0.00401	0.00401	0.00401	0.00401	0.00401	27
Communications	28	0.00439	0.00439	0.01478	0.00067	0.00067	0.00067	0.00067	0.00067	28
Electrical utility	29	0.00094	0.00094	0.00214	0.00882	0.00882	0.00882	0.00882	0.00882	29
Gas utility	30	0.00000	0.00000	0.00262	0.00000	0.00000	0.00000	0.00000	0.00000	30
Water and sewer	31	0.00000	0.00000	0.00118	0.00000	0.00000	0.00000	0.00000	0.00000	31
Wholesale trade	32	0.06613	0.06613	0.01323	0.07448	0.07448	0.07448	0.07448	0.07448	32
Retail trade	33	0.00000	0.00000	0.01652	0.00000	0.00000	0.00000	0.00000	0.00000	33
Finance, insurance, and real estate	34	0.00830	0.00830	0.31435	0.00347	0.00347	0.00347	0.00347	0.00347	34
Lodging and personal and repair services	35	0.00211	0.00211	0.01584	0.00236	0.00236	0.00236	0.00236	0.00236	35
Businesses and miscellaneous services	36	0.00000	0.00000	0.05497	0.00000	0.00000	0.00000	0.00000	0.00000	36
Medical and nonprofit	37	0.00008	0.00008	0.00221	0.00011	0.00011	0.00011	0.00011	0.00011	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	52
Households/PC weekly	53	0.04351	0.03817	0.00000	0.04873	0.05452	0.05462	0.05265	0.04802	53
Households/PC local	54	0.27879	0.24445	0.53737	0.27294	0.30537	0.30590	0.29485	0.26896	54
Column sums		0.41832	0.37864	0.71638	0.42019	0.45841	0.45904	0.44602	0.41550	

Table L-1. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct Coefficients (Continued)

Industry Selling		Industry Purchasing 49	50	51	52	53	54		Row Sums
Livestock and livestock products	1	0.00000	0.00000	0.00000	0.00000	0.00024	0.00095	1	0.68235
Cotton	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2	0.15525
Grains and seeds	3	0.00000	0.00133	0.00000	0.00001	0.00010	0.00041	3	0.33565
Fruits and vegetables	4	0.00000	0.00000	0.00000	0.00000	0.00020	0.00078	4	0.00889
Forestry and fishery products	5	0.00000	0.00002	0.00000	0.00000	0.00021	0.00083	5	0.09210
Agricultural services	6	0.00000	0.00000	0.00000	0.00001	0.00007	0.00026	6	0.21110
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00004	0.00000	0.00000	0.00000	0.00000	7	0.01016
Crude petroleum	8	0.00000	0.00065	0.00000	0.00001	0.00000	0.00000	8	0.48568
Natural gas and liquid petroleum	9	0.00000	0.00405	0.00000	0.00006	0.00000	0.00000	9	0.32996
Stone, gravel, and sand	10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	10	0.15828
Potash mining	11	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	11	0.02447
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12	0.00000
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13	0.00000
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14	0.00000
Construction maintenance	15	0.00494	0.02048	0.00205	0.02145	0.00000	0.00000	15	0.37554
Food products	16	0.00000	0.00005	0.00000	0.00000	0.00417	0.01668	16	0.08958
Fabrics and apparel	17	0.00000	0.00036	0.00000	0.00004	0.00001	0.00003	17	0.11240
Wood and lumber products	18	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	18	0.09763
Printing	19	0.00051	0.00037	0.00000	0.00014	0.00072	0.00287	19	0.03316
Chemical products	20	0.00090	0.00015	0.00000	0.00149	0.00013	0.00053	20	0.16379
Plastics and petroleum products	21	0.00430	0.02989	0.00000	0.00406	0.00047	0.01901	21	0.49214
Glass and stone products	22	0.00001	0.00001	0.00000	0.00002	0.00000	0.00001	22	0.16691
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23	0.00000
Fabricated metal products	24	0.00001	0.00000	0.00000	0.00001	0.00000	0.00000	24	0.01841
Machinery	25	0.00238	0.00017	0.01535	0.00337	0.00012	0.00048	25	0.12043
Electrical products	26	0.00009	0.00000	0.00000	0.00006	0.00000	0.00000	26	0.01375
Transportation and warehousing	27	0.00803	0.08829	0.00977	0.01274	0.00395	0.01578	27	0.83680
Communications	28	0.01478	0.00861	0.00259	0.01371	0.00280	0.01119	28	0.26830
Electrical utility	29	0.00214	0.01622	0.04470	0.00445	0.00354	0.01416	29	0.48067
Gas utility	30	0.00262	0.00338	0.00000	0.00377	0.00207	0.00828	30	0.53547
Water and sewer	31	0.00118	0.00114	0.00000	0.00119	0.00085	0.00340	31	0.06831
Wholesale trade	32	0.01323	0.02379	0.00250	0.01423	0.01102	0.04406	32	1.59229
Retail trade	33	0.01652	0.01069	0.00138	0.00674	0.03834	0.15335	33	0.72415
Finance, insurance, and real estate	34	0.03435	0.01853	0.00694	0.03167	0.01140	0.04561	34	1.16017
Lodging and personal and repair services	35	0.01584	0.02424	0.00064	0.01177	0.01291	0.05163	35	0.44278
Businesses and miscellaneous services	36	0.05497	0.00894	0.00000	0.01345	0.00179	0.00714	36	0.80892
Medical and nonprofit	37	0.00221	0.00052	0.00119	0.00188	0.00238	0.00953	37	0.05452
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38	0.00000
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39	0.00000
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40	0.00000
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41	0.00000
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42	0.00000
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43	0.00000
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44	0.00000
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45	0.00000
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46	0.00000
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47	0.00000
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48	0.00000
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49	0.00000
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50	0.00000
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51	0.00000
Government	52	0.00000	0.00000	0.00000	0.03548	0.02100	0.08500	52	0.83762
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53	0.41131
Households/PC local	54	0.57448	0.56290	0.54173	0.45300	0.00000	0.00000	54	15.35617
Column sums		0.75349	0.82482	0.62884	0.63481	0.11849	0.49198		

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients

Industry Selling		Industry Purchasing 1	2	3	4	5	6	7	8	
Livestock and livestock products	1	1.51090	0.04604	0.15328	0.02313	0.24603	0.00534	0.00194	0.00110	1
Cotton	2	0.00433	1.01744	0.00089	0.00050	0.00327	0.00184	0.00090	0.00050	2
Grains and seeds	3	0.41657	0.01399	1.07351	0.00712	0.06893	0.00995	0.00110	0.00069	3
Fruits and vegetables	4	0.00102	0.00038	0.00031	1.00402	0.00051	0.00127	0.00042	0.00022	4
Forestry and fishery products	5	0.00024	0.00030	0.00026	0.00019	1.07792	0.00041	0.00053	0.00025	5
Agricultural services	6	0.01001	0.10394	0.01452	0.05937	0.03017	1.00057	0.00034	0.00022	6
Miscellaneous metallic and nonmetallic minerals	7	0.00009	0.00011	0.00023	0.00009	0.00002	0.00000	1.00846	0.00001	7
Crude petroleum	8	0.01322	0.02325	0.02150	0.00923	0.02268	0.00558	0.00774	1.00833	8
Natural gas and liquid petroleum	9	0.00206	0.00297	0.00260	0.00147	0.00298	0.00178	0.00301	0.00194	9
Stone, gravel, and sand	10	0.00091	0.00157	0.00212	0.00105	0.00020	0.00005	0.00007	0.00023	10
Potash mining	11	0.00055	0.00080	0.00137	0.00061	0.00010	0.00002	0.00018	0.00003	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.01447	0.01803	0.01623	0.01079	0.00665	0.00343	0.00699	0.03197	15
Food products	16	0.04040	0.00657	0.00814	0.00411	0.03027	0.00810	0.00840	0.00453	16
Fabrics and apparel	17	0.00015	0.00017	0.00014	0.00010	0.00017	0.00011	0.00016	0.00010	17
Wood and lumber products	18	0.00010	0.00012	0.00010	0.00007	0.00007	0.00004	0.00042	0.00015	18
Printing	19	0.00108	0.00141	0.00111	0.00081	0.00148	0.00153	0.00165	0.00120	19
Chemical products	20	0.00477	0.00643	0.00835	0.00313	0.00217	0.00061	0.02340	0.00380	20
Plastics and petroleum products	21	0.02844	0.05023	0.04648	0.01986	0.04896	0.01173	0.01613	0.01224	21
Glass and stone products	22	0.00013	0.00018	0.00020	0.00012	0.00007	0.00003	0.00005	0.00012	22
Primary metal products	23	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00001	0.00086	0.00001	0.00001	0.00002	0.00000	0.00001	0.00010	24
Machinery	25	0.00061	0.00002	0.00064	0.00046	0.00057	0.00053	0.01154	0.00049	25
Electrical products	26	0.00001	0.02361	0.00002	0.00001	0.00002	0.00001	0.00003	0.00001	26
Transportation and warehousing	27	0.03758	0.01150	0.02700	0.01647	0.02285	0.01141	0.02348	0.00956	27
Communications	28	0.00934	0.01802	0.00898	0.00617	0.00853	0.00766	0.01163	0.00736	28
Electrical utility	29	0.01161	0.00781	0.01038	0.00888	0.01108	0.00989	0.02340	0.01873	29
Gas utility	30	0.00589	0.01079	0.00638	0.00457	0.00847	0.00784	0.01326	0.00828	30
Water and sewer	31	0.00496	0.05887	0.00955	0.00904	0.00280	0.00225	0.00246	0.00225	31
Wholesale trade	32	0.05286	0.08122	0.05080	0.03878	0.05948	0.02457	0.03643	0.02022	32
Retail trade	33	0.06697	0.11283	0.06936	0.04510	0.07780	0.07313	0.07814	0.04827	33
Finance, insurance, and real estate	34	0.05689	0.03111	0.07563	0.04115	0.05798	0.03306	0.04404	0.12074	34
Lodging and personal and repair services	35	0.02492	0.04582	0.02352	0.01783	0.03298	0.02759	0.03039	0.01928	35
Businesses and miscellaneous services	36	0.02349	0.00473	0.04065	0.02363	0.01368	0.00872	0.01922	0.02643	36
Medical and nonprofit	37	0.00402	0.00000	0.00374	0.00285	0.00467	0.00488	0.00646	0.00384	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.02872	0.03973	0.03253	0.02583	0.04067	0.04454	0.04891	0.02978	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.24680	0.30595	0.25042	0.19910	0.39272	0.45748	0.47816	0.25761	54
Column sums		2.62411	2.04678	1.96093	1.58565	2.27698	1.76597	1.90946	1.64059	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing 9	10	11	12	13	14	15	16	
Livestock and livestock products	1	0.00144	0.00234	0.00174	0.00255	0.00248	0.00246	0.00302	0.12352	1
Cotton	2	0.00064	0.00109	0.00081	0.00121	0.00115	0.00115	0.00143	0.11033	2
Grains and seeds	3	0.00090	0.00141	0.00100	0.00182	0.00162	0.00169	0.00176	0.05911	3
Fruits and vegetables	4	0.00029	0.00047	0.00037	0.00050	0.00049	0.00049	0.00061	0.00193	4
Forestry and fishery products	5	0.00034	0.00055	0.00047	0.00058	0.00056	0.00056	0.00068	0.00030	5
Agricultural services	6	0.00030	0.00045	0.00030	0.00189	0.00125	0.00331	0.00103	0.01259	6
Miscellaneous metallic and nonmetallic minerals	7	0.00002	0.00001	0.00003	0.00001	0.00001	0.00001	0.00001	0.00008	7
Crude petroleum	8	0.00811	0.01468	0.00990	0.01160	0.01313	0.02214	0.01335	0.00938	8
Natural gas and liquid petroleum	9	1.17713	0.00426	0.00916	0.00313	0.00323	0.00387	0.00348	0.00247	9
Stone, gravel, and sand	10	0.00032	1.00839	0.00007	0.00391	0.00522	0.02274	0.00689	0.00047	10
Potash mining	11	0.00008	0.00055	1.01431	0.00002	0.00003	0.00005	0.00002	0.00017	11
Residential construction	12	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	14
Construction maintenance	15	0.04434	0.01570	0.00762	0.00720	0.00743	0.00808	1.00715	0.00922	15
Food products	16	0.00589	0.01007	0.00751	0.01085	0.01065	0.01043	0.01321	1.03388	16
Fabrics and apparel	17	0.00014	0.00027	0.00015	0.00139	0.00031	0.00095	0.00037	0.00037	17
Wood and lumber products	18	0.00021	0.00030	0.00059	0.03830	0.01209	0.00224	0.00395	0.00007	18
Printing	19	0.00159	0.00209	0.00148	0.00223	0.00220	0.00214	0.00262	0.00254	19
Chemical products	20	0.01050	0.00788	0.02170	0.00162	0.00308	0.00403	0.00143	0.00282	20
Plastics and petroleum products	21	0.01588	0.03098	0.01890	0.02455	0.02802	0.04750	0.02830	0.01987	21
Glass and stone products	22	0.00017	0.05705	0.00005	0.02762	0.03650	0.02337	0.00341	0.00009	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00006	0.00001	0.00001	0.00197	0.00310	0.00188	0.00048	0.00001	24
Machinery	25	0.00068	0.00628	0.01642	0.00156	0.00182	0.00167	0.00130	0.00053	25
Electrical products	26	0.00002	0.00003	0.00003	0.00023	0.00032	0.00026	0.00010	0.00002	26
Transportation and warehousing	27	0.01275	0.03849	0.02270	0.05020	0.05228	0.07166	0.04317	0.03909	27
Communications	28	0.00996	0.01234	0.01066	0.01654	0.01802	0.01692	0.01634	0.01229	28
Electrical utility	29	0.01685	0.04348	0.03226	0.01718	0.01685	0.01719	0.01875	0.01617	29
Gas utility	30	0.03337	0.01743	0.04859	0.01230	0.01224	0.01231	0.01389	0.00958	30
Water and sewer	31	0.00358	0.00602	0.00226	0.00376	0.00383	0.00374	0.00411	0.00358	31
Wholesale trade	32	0.03213	0.06957	0.02708	0.08919	0.08641	0.07947	0.08083	0.05706	32
Retail trade	33	0.06323	0.10556	0.07059	0.18599	0.14757	0.13595	0.18448	0.05893	33
Finance, insurance, and real estate	34	0.16625	0.07980	0.04067	0.06006	0.06247	0.06105	0.06298	0.04640	34
Lodging and personal and repair services	35	0.02541	0.04856	0.02751	0.04626	0.04833	0.04827	0.05147	0.02661	35
Businesses and miscellaneous services	36	0.03654	0.04972	0.01914	0.07343	0.09163	0.06142	0.03756	0.02324	36
Medical and nonprofit	37	0.00508	0.00669	0.00594	0.00776	0.00806	0.00776	0.00876	0.00438	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.03963	0.06004	0.04429	0.06363	0.06263	0.06095	0.07548	0.03393	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.33318	0.56905	0.42858	0.60984	0.59955	0.58792	0.74892	0.30990	54
Column sums		2.04698	2.27161	1.89298	2.38085	2.34460	2.32560	2.44131	2.03090	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing 17	18	19	20	21	22	23	24	
Livestock and livestock products	1	0.01735	0.00186	0.00164	0.00359	0.00142	0.00250	0.00161	0.00191	1
Cotton	2	0.03825	0.00090	0.00080	0.00128	0.00065	0.00117	0.00076	0.00092	2
Grains and seeds	3	0.00543	0.00110	0.00096	0.00185	0.00089	0.00163	0.00090	0.00111	3
Fruits and vegetables	4	0.00042	0.00037	0.00034	0.00171	0.00029	0.00050	0.00033	0.00039	4
Forestry and fishery products	5	0.01878	0.00044	0.00044	0.00481	0.00034	0.00057	0.00037	0.00044	5
Agricultural services	6	0.00474	0.00037	0.00031	0.00065	0.00028	0.00046	0.00027	0.00035	6
Miscellaneous metallic and nonmetallic minerals	7	0.00001	0.00001	0.00002	0.00133	0.00006	0.00001	0.00000	0.00000	7
Crude petroleum	8	0.00794	0.00764	0.00674	0.03651	0.49197	0.01495	0.00474	0.00828	8
Natural gas and liquid petroleum	9	0.00245	0.00260	0.00223	0.01051	0.03421	0.00502	0.00155	0.00315	9
Stone, gravel, and sand	10	0.00012	0.00009	0.00007	0.00052	0.00023	0.06838	0.00003	0.00016	10
Potash mining	11	0.00005	0.00003	0.00011	0.00808	0.00007	0.00006	0.00001	0.00001	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00688	0.00793	0.00777	0.01292	0.03091	0.01268	0.00287	0.00708	15
Food products	16	0.00948	0.00805	0.00649	0.01184	0.00597	0.01070	0.00709	0.00828	16
Fabrics and apparel	17	1.11241	0.00109	0.00176	0.00045	0.00022	0.00081	0.00010	0.00101	17
Wood and lumber products	18	0.00007	1.00811	0.00007	0.00010	0.00015	0.00022	0.00003	0.00152	18
Printing	19	0.00177	0.00167	1.01754	0.00221	0.00140	0.00230	0.00136	0.00166	19
Chemical products	20	0.00186	0.00355	0.01409	1.05419	0.00887	0.00276	0.00047	0.00141	20
Plastics and petroleum products	21	0.01672	0.01600	0.01416	0.07794	1.07140	0.03134	0.00994	0.01724	21
Glass and stone products	22	0.00007	0.00043	0.00006	0.00011	0.00013	1.02896	0.00003	0.00025	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	23
Fabricated metal products	24	0.00001	0.00001	0.00001	0.00006	0.00007	0.00001	0.00000	1.00142	24
Machinery	25	0.00066	0.00258	0.00061	0.00097	0.00057	0.00445	0.00047	0.02475	25
Electrical products	26	0.00002	0.00003	0.00004	0.00005	0.00002	0.00003	0.00001	0.00005	26
Transportation and warehousing	27	0.02509	0.04246	0.02383	0.04131	0.04417	0.15385	0.00928	0.02917	27
Communications	28	0.01316	0.01316	0.01936	0.01518	0.00909	0.01879	0.00673	0.01392	28
Electrical utility	29	0.02016	0.01832	0.01519	0.03091	0.02165	0.02568	0.00869	0.01811	29
Gas utility	30	0.01022	0.01077	0.00932	0.03013	0.02642	0.01917	0.00689	0.01421	30
Water and sewer	31	0.00347	0.00241	0.00280	0.00579	0.00437	0.00364	0.00192	0.00253	31
Wholesale trade	32	0.05970	0.07267	0.04255	0.05487	0.03035	0.06691	0.02103	0.05073	32
Retail trade	33	0.08485	0.07546	0.06942	0.10223	0.05998	0.10247	0.06455	0.08448	33
Finance, insurance, and real estate	34	0.05319	0.05122	0.04991	0.06656	0.09850	0.07117	0.02776	0.04912	34
Lodging and personal and repair services	35	0.03333	0.03134	0.02968	0.04050	0.02450	0.04715	0.02441	0.03106	35
Businesses and miscellaneous services	36	0.02081	0.02072	0.03904	0.03070	0.03077	0.03610	0.00734	0.02036	36
Medical and nonprofit	37	0.00603	0.00556	0.00608	0.00744	0.00457	0.00768	0.00432	0.00576	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.05222	0.04633	0.04722	0.06385	0.03859	0.06236	0.03950	0.04763	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.49854	0.45192	0.39293	0.61410	0.33882	0.60640	0.40704	0.46956	54
Column sums		2.12624	1.90719	1.82400	2.33523	2.38191	2.41090	1.66242	1.91802	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing 25	26	27	28	29	30	31	32	
Livestock and livestock products	1	0.00232	0.00203	0.00304	0.00248	0.00111	0.00170	0.00277	0.00303	1
Cotton	2	0.00112	0.00098	0.00131	0.00111	0.00053	0.00080	0.00129	0.00160	2
Grains and seeds	3	0.00135	0.00117	0.00325	0.00159	0.00067	0.00099	0.00165	0.00177	3
Fruits and vegetables	4	0.00047	0.00041	0.00056	0.00048	0.00022	0.00035	0.00056	0.00053	4
Forestry and fishery products	5	0.00053	0.00047	0.00065	0.00053	0.00026	0.00039	0.00063	0.00060	5
Agricultural services	6	0.00045	0.00037	0.00054	0.00042	0.00021	0.00032	0.00053	0.00168	6
Miscellaneous metallic and nonmetallic minerals	7	0.00001	0.00000	0.00006	0.00000	0.00000	0.00001	0.00001	0.00001	7
Crude petroleum	8	0.01032	0.01003	0.02553	0.00837	0.01224	0.04419	0.01266	0.01249	8
Natural gas and liquid petroleum	9	0.00308	0.00293	0.01031	0.00284	0.01605	0.27118	0.00860	0.00323	9
Stone, gravel, and sand	10	0.00008	0.00007	0.00023	0.00015	0.00025	0.00027	0.00061	0.00012	10
Potash mining	11	0.00001	0.00001	0.00002	0.00001	0.00003	0.00003	0.00003	0.00002	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00745	0.00762	0.03048	0.01997	0.03500	0.03746	0.08606	0.00768	15
Food products	16	0.01014	0.00876	0.01204	0.01021	0.00478	0.00733	0.01188	0.01456	16
Fabrics and apparel	17	0.00104	0.00115	0.00071	0.00040	0.00037	0.00028	0.00062	0.00126	17
Wood and lumber products	18	0.03403	0.00007	0.00018	0.00012	0.00016	0.00018	0.00045	0.00045	18
Printing	19	0.00202	0.00419	0.00282	0.00220	0.00097	0.00157	0.00252	0.00292	19
Chemical products	20	0.00121	0.00074	0.00143	0.00079	0.00159	0.00301	0.00359	0.00168	20
Plastics and petroleum products	21	0.02176	0.02115	0.05300	0.01754	0.02201	0.01405	0.02520	0.02647	21
Glass and stone products	22	0.00009	0.00008	0.00016	0.00010	0.00014	0.00015	0.00034	0.00056	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00003	0.00001	0.00002	0.00001	0.00002	0.00003	0.00005	0.00002	24
Machinery	25	1.02056	0.00066	0.00119	0.00100	0.00039	0.00068	0.00301	0.00137	25
Electrical products	26	0.00086	1.01089	0.00003	0.00003	0.00001	0.00002	0.00007	0.00009	26
Transportation and warehousing	27	0.38686	0.02503	1.11581	0.01637	0.03271	0.01249	0.03041	0.03355	27
Communications	28	0.01451	0.01691	0.02248	1.02385	0.00824	0.01220	0.02594	0.02412	28
Electrical utility	29	0.01963	0.01821	0.03560	0.01996	1.08655	0.01655	0.04938	0.01948	29
Gas utility	30	0.01281	0.01242	0.01976	0.01262	0.06233	1.58053	0.04357	0.01268	30
Water and sewer	31	0.00345	0.00274	0.00494	0.00440	0.00256	0.00362	1.00528	0.00508	31
Wholesale trade	32	0.07915	0.04771	0.06482	0.03620	0.02363	0.02800	0.05375	1.05116	32
Retail trade	33	0.09930	0.08823	0.12321	0.10029	0.04809	0.07356	0.12172	0.11892	33
Finance, insurance, and real estate	34	0.05733	0.05846	0.07615	0.05806	0.02929	0.07663	0.08804	0.07305	34
Lodging and personal and repair services	35	0.03749	0.03383	0.07072	0.10101	0.02020	0.02806	0.05894	0.05936	35
Businesses and miscellaneous services	36	0.02096	0.02572	0.02736	0.02375	0.01254	0.02464	0.03459	0.03938	36
Medical and nonprofit	37	0.00680	0.00686	0.00820	0.00712	0.00337	0.00541	0.00932	0.00816	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.05780	0.05196	0.07246	0.06157	0.03168	0.06621	0.66433	0.06802	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	53
Households/PC local	54	0.57183	0.49829	0.68086	0.58435	0.27216	0.41856	0.67710	0.63849	54
Column sums		2.13683	1.96017	2.46992	2.11990	1.73037	2.73144	2.02550	2.23361	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing 33	34	35	36	37	38	39	40	
Livestock and livestock products	1	0.00251	0.00323	0.00454	0.00272	0.00338	0.00119	0.00078	0.00135	1
Cotton	2	0.00118	0.00128	0.00114	0.00126	0.00156	0.00056	0.00037	0.00064	2
Grains and seeds	3	0.00146	0.00241	0.00555	0.00162	0.00199	0.00075	0.00052	0.00084	3
Fruits and vegetables	4	0.00050	0.00054	0.00047	0.00055	0.00068	0.00023	0.00015	0.00027	4
Forestry and fishery products	5	0.00056	0.00059	0.00054	0.00061	0.00074	0.00026	0.00017	0.00030	5
Agricultural services	6	0.00043	0.00077	0.00070	0.00048	0.00060	0.00060	0.00053	0.00062	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.01037	0.01012	0.01159	0.01071	0.01468	0.00401	0.00283	0.00448	8
Natural gas and liquid petroleum	9	0.00373	0.00398	0.00356	0.00371	0.00487	0.00123	0.00084	0.00139	9
Stone, gravel, and sand	10	0.00009	0.00025	0.00014	0.00011	0.00016	0.00753	0.00752	0.00754	10
Potash mining	11	0.00001	0.00003	0.00002	0.00002	0.00002	0.00001	0.00001	0.00001	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00957	0.02649	0.01434	0.01231	0.01877	0.00274	0.00201	0.00303	15
Food products	16	0.01092	0.01117	0.00990	0.01167	0.01440	0.00519	0.00339	0.00590	16
Fabrics and apparel	17	0.00025	0.00032	0.00190	0.00023	0.00049	0.00015	0.00013	0.00016	17
Wood and lumber products	18	0.00008	0.00017	0.00024	0.00018	0.00014	0.00006	0.00005	0.00006	18
Printing	19	0.00270	0.00553	0.00216	0.00294	0.00602	0.00104	0.00069	0.00117	19
Chemical products	20	0.00092	0.00115	0.00119	0.00191	0.00140	0.00046	0.00034	0.00051	20
Plastics and petroleum products	21	0.02166	0.02104	0.02439	0.02241	0.03079	0.00844	0.00597	0.00942	21
Glass and stone products	22	0.00007	0.00014	0.00013	0.00010	0.00012	0.00048	0.00047	0.00048	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00001	0.00002	0.00001	0.00002	0.00001	0.00137	0.00136	0.00137	24
Machinery	25	0.00091	0.00119	0.00486	0.00350	0.00120	0.00057	0.00045	0.00062	25
Electrical products	26	0.00002	0.00004	0.00012	0.00012	0.00089	0.00001	0.00001	0.00001	26
Transportation and warehousing	27	0.01744	0.02115	0.02051	0.02601	0.02490	0.01283	0.01047	0.01376	27
Communications	28	0.01726	0.02945	0.01786	0.02849	0.02931	0.01032	0.00861	0.01100	28
Electrical utility	29	0.02966	0.02630	0.02715	0.01837	0.03877	0.00799	0.00578	0.00886	29
Gas utility	30	0.01683	0.01568	0.01539	0.01658	0.02145	0.00517	0.00342	0.00586	30
Water and sewer	31	0.00547	0.00763	0.00661	0.00481	0.01089	0.00157	0.00108	0.00176	31
Wholesale trade	32	0.03917	0.04298	0.05636	0.05078	0.06582	0.08269	0.07735	0.08481	32
Retail trade	33	1.10289	0.11349	0.10672	0.12510	0.14936	0.04668	0.03028	0.05318	33
Finance, insurance, and real estate	34	0.08293	0.14469	0.08719	0.08937	0.12952	0.03119	0.02414	0.03398	34
Lodging and personal and repair services	35	0.04664	0.04656	1.07664	0.05986	0.07271	0.02127	0.01507	0.02372	35
Businesses and miscellaneous services	36	0.02301	0.07614	0.02748	0.07449	0.04643	0.00801	0.00614	0.00874	36
Medical and nonprofit	37	0.00775	0.01460	0.00841	0.00986	1.01268	0.00328	0.00218	0.00371	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	40
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.08058	0.09927	0.06277	0.08188	0.09844	0.02844	0.01841	0.03241	52
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	0.00000	0.02612	0.01410	0.03087	53
Households/PC local	54	0.61520	0.63006	0.55908	0.66581	0.80134	0.27800	0.17761	0.31778	54
Column sums		2.15278	2.35848	2.15966	2.32859	2.60450	1.60043	1.42324	1.67062	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing								
		41	42	43	44	45	46	47	48	
Livestock and livestock products	1	0.00178	0.00160	0.00328	0.00174	0.00192	0.00192	0.00186	0.00172	1
Cotton	2	0.00084	0.00076	0.00152	0.00083	0.00091	0.00092	0.00089	0.00082	2
Grains and seeds	3	0.00108	0.00098	0.00193	0.00100	0.00110	0.00110	0.00106	0.00099	3
Fruits and vegetables	4	0.00036	0.00032	0.00066	0.00035	0.00039	0.00039	0.00037	0.00035	4
Forestry and fishery products	5	0.00039	0.00035	0.00074	0.00039	0.00043	0.00043	0.00042	0.00038	5
Agricultural services	6	0.00069	0.00066	0.00057	0.00038	0.00041	0.00041	0.00040	0.00037	6
Miscellaneous metallic and nonmetallic minerals	7	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	7
Crude petroleum	8	0.00572	0.00519	0.01230	0.00546	0.00595	0.00596	0.00579	0.00539	8
Natural gas and liquid petroleum	9	0.00180	0.00162	0.00422	0.00186	0.00203	0.00203	0.00197	0.00184	9
Stone, gravel, and sand	10	0.00754	0.00754	0.00011	0.00274	0.00275	0.00275	0.00275	0.00274	10
Potash mining	11	0.00001	0.00001	0.00002	0.00001	0.00001	0.00001	0.00001	0.00001	11
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14
Construction maintenance	15	0.00380	0.00347	0.01298	0.00380	0.00411	0.00411	0.00401	0.00376	15
Food products	16	0.00780	0.00700	0.01412	0.00772	0.00848	0.00849	0.00823	0.00762	16
Fabrics and apparel	17	0.00019	0.00018	0.00026	0.00020	0.00021	0.00021	0.00020	0.00020	17
Wood and lumber products	18	0.00007	0.00007	0.00019	0.00012	0.00012	0.00012	0.00012	0.00012	18
Printing	19	0.00153	0.00138	0.00341	0.00150	0.00165	0.00165	0.00160	0.00148	19
Chemical products	20	0.00063	0.00058	0.00205	0.00060	0.00065	0.00065	0.00063	0.00059	20
Plastics and petroleum products	21	0.01202	0.01092	0.02576	0.01143	0.01247	0.01249	0.01213	0.01130	21
Glass and stone products	22	0.00049	0.00049	0.00010	0.00022	0.00023	0.00023	0.00023	0.00022	22
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23
Fabricated metal products	24	0.00137	0.00137	0.00002	0.00051	0.00052	0.00052	0.00052	0.00051	24
Machinery	25	0.00075	0.00069	0.00362	0.00202	0.00207	0.00207	0.00205	0.00201	25
Electrical products	26	0.00002	0.00002	0.00013	0.00002	0.00002	0.00002	0.00002	0.00002	26
Transportation and warehousing	27	0.01624	0.01519	0.02900	0.01597	0.01697	0.01698	0.01664	0.01585	27
Communications	28	0.01279	0.01203	0.03060	0.00895	0.00968	0.00969	0.00944	0.00886	28
Electrical utility	29	0.01118	0.01020	0.02129	0.01937	0.02030	0.02032	0.02000	0.01925	29
Gas utility	30	0.00770	0.00692	0.01887	0.00798	0.00872	0.00874	0.00848	0.00789	30
Water and sewer	31	0.00227	0.00206	0.00545	0.00223	0.00243	0.00244	0.00237	0.00220	31
Wholesale trade	32	0.09043	0.08804	0.05781	0.09844	0.10071	0.10075	0.09997	0.09817	32
Retail trade	33	0.07043	0.06311	0.14726	0.06944	0.07638	0.07650	0.07413	0.06858	33
Finance, insurance, and real estate	34	0.04140	0.03825	0.09844	0.03568	0.03867	0.03872	0.03770	0.03532	34
Lodging and personal and repair services	35	0.03025	0.02748	0.06809	0.02997	0.03259	0.03264	0.03174	0.02964	35
Businesses and miscellaneous services	36	0.01071	0.00987	0.07678	0.01032	0.01111	0.01113	0.01086	0.01023	36
Medical and nonprofit	37	0.00487	0.00438	0.01133	0.00480	0.00527	0.00528	0.00512	0.00475	37
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40
WIPP surface construction, 1983	41	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41
WIPP surface construction, 1984	42	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42
WIPP construction management and design	43	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	44
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	45
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	46
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	47
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	48
WIPP general surface operations	49	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49
WIPP security and remote handling	50	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	50
WIPP underground operations	51	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	51
Government	52	0.04296	0.03849	0.08208	0.04221	0.04646	0.04653	0.04508	0.04169	52
Households/PC weekly	53	0.04351	0.03817	0.00000	0.04873	0.05452	0.05462	0.05265	0.04802	53
Households/PC local	54	0.42339	0.37860	0.80638	0.41573	0.45809	0.45878	0.44435	0.41053	54
Column sums		1.85702	1.77799	2.54136	1.85273	1.92831	1.92956	1.90380	1.84345	

Table L-2. Input-Output Tables, Lea and Eddy Counties, November 1979: Direct, Indirect, and Induced Coefficients (Continued)

Industry Selling		Industry Purchasing 49	50	51	52	53	54		Row Sums
Livestock and livestock products	1	0.00347	0.00383	0.00295	0.00286	0.00128	0.00513	1	2.23268
Cotton	2	0.00161	0.00169	0.00139	0.00133	0.00060	0.00242	2	1.22548
Grains and seeds	3	0.00204	0.00369	0.00168	0.00170	0.00071	0.00287	3	1.72453
Fruits and vegetables	4	0.00070	0.00072	0.00060	0.00058	0.00027	0.00106	4	1.03169
Forestry and fishery products	5	0.00078	0.00083	0.00067	0.00064	0.00029	0.00117	5	1.12606
Agricultural services	6	0.00060	0.00067	0.00050	0.00052	0.00022	0.00085	6	1.26417
Miscellaneous metallic and nonmetallic minerals	7	0.00001	0.00005	0.00000	0.00001	0.00000	0.00001	7	1.01085
Crude petroleum	8	0.01286	0.02785	0.00930	0.01115	0.00165	0.01505	8	2.12687
Natural gas and liquid petroleum	9	0.00440	0.01108	0.00360	0.00426	0.00108	0.00492	9	1.67548
Stone, gravel, and sand	10	0.00012	0.00025	0.00008	0.00022	0.00002	0.00010	10	1.17864
Potash mining	11	0.00002	0.00002	0.00001	0.00002	0.00000	0.00002	11	1.02776
Residential construction	12	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	12	1.00000
Nonresidential construction	13	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	13	1.00000
All other construction	14	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	14	1.00000
Construction maintenance	15	0.01332	0.03182	0.00929	0.02940	0.00214	0.00913	15	1.76049
Food products	16	0.01496	0.01552	0.01290	0.01230	0.00561	0.02254	16	1.58688
Fabrics and apparel	17	0.00028	0.00075	0.00022	0.00028	0.00008	0.00031	17	1.13592
Wood and lumber products	18	0.00020	0.00020	0.00060	0.00028	0.00003	0.00011	18	1.10804
Printing	19	0.00357	0.00348	0.00251	0.00265	0.00107	0.00431	19	1.13032
Chemical products	20	0.00210	0.00165	0.00093	0.00257	0.00033	0.00149	20	1.23028
Plastics and petroleum products	21	0.02693	0.05786	0.01934	0.02321	0.00331	0.03158	21	2.31894
Glass and stone products	22	0.00010	0.00017	0.00007	0.00016	0.00002	0.00009	22	1.18561
Primary metal products	23	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	23	1.00000
Fabricated metal products	24	0.00002	0.00002	0.00001	0.00003	0.00000	0.00001	24	1.01902
Machinery	25	0.00367	0.00140	0.01652	0.00451	0.00037	0.00149	25	1.16641
Electrical products	26	0.00013	0.00003	0.00003	0.00009	0.00001	0.00003	26	1.01516
Transportation and warehousing	27	0.03010	0.12032	0.02934	0.03238	0.00718	0.02950	27	2.71340
Communications	28	0.03139	0.02574	0.01542	0.02761	0.00531	0.02140	28	1.82307
Electrical utility	29	0.02231	0.03985	0.06459	0.02151	0.00680	0.02760	29	2.20222
Gas utility	30	0.01968	0.02312	0.01530	0.01904	0.00536	0.02189	30	2.38613
Water and sewer	31	0.00567	0.00588	0.00363	0.00492	0.00150	0.00609	31	1.22293
Wholesale trade	32	0.06029	0.07511	0.04246	0.05407	0.01657	0.06683	32	4.19660
Retail trade	33	0.15487	0.15491	0.11948	0.12146	0.05099	0.20510	33	6.08939
Finance, insurance, and real estate	34	0.10171	0.08967	0.05945	0.08775	0.02161	0.08821	34	4.54199
Lodging and personal and repair services	35	0.07097	0.08268	0.04586	0.05737	0.01927	0.07756	35	3.20018
Businesses and miscellaneous services	36	0.07765	0.03091	0.01466	0.03161	0.00570	0.02334	36	2.61442
Medical and nonprofit	37	0.01184	0.01032	0.00916	0.00983	0.00341	0.01374	37	1.35884
WIPP surface construction, 1980	38	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	38	1.00000
WIPP surface construction, 1981	39	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	39	1.00000
WIPP surface construction, 1982	40	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	40	1.00000
WIPP surface construction, 1983	41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	41	1.00000
WIPP surface construction, 1984	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	42	1.00000
WIPP construction management and design	43	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	43	1.00000
WIPP underground construction, 1980	44	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	44	1.00000
WIPP underground construction, 1981	45	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	45	1.00000
WIPP underground construction, 1982	46	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	46	1.00000
WIPP underground construction, 1983	47	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	47	1.00000
WIPP underground construction, 1984	48	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	48	1.00000
WIPP general surface operations	49	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	49	1.00000
WIPP security and remote handling	50	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	50	1.00000
WIPP underground operations	51	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	51	1.00000
Government	52	0.08674	0.08868	0.07244	1.10787	0.03094	0.12551	52	4.60289
Households/PC weekly	53	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	53	1.41131
Households/PC local	54	0.85437	0.88099	0.73940	0.70171	0.07172	1.29330	54	27.27817
Column sums		2.61947	2.79177	2.31439	2.37592	1.26546	2.10475		

L.3.1 Wages

First, the level of wages must be determined. The average annual wages and labor costs for each of the 37 private subsectors and the government subsector (State, local, and Federal) are listed in Table L-3.

Average employee costs for all of the 38 subsectors in the input-output model were computed from information obtained from the New Mexico Employment Security Department. Since complete 1979 data were not available, the 1978 average wages for the area were derived from the quarterly report Covered Employment and Wages and the increase in wages from 1978 to 1979 was estimated for each sector.

Expected fringe benefits were then added to the wages for each subsector. The fringe benefits were computed in several ways. Information on fringe benefits was obtained from several companies in the construction, petroleum, and mining industries. For subsectors that are not dominated by large companies, averages reflecting minimum fringe benefits at various salary levels were used. Thus, the labor cost per employee is the estimated annual wages paid in 1979 plus the expected fringe-benefit percentage. Table L-3 gives the annual wages, fringe-benefit percentage, and estimated annual labor cost for the 38 economic subsectors. The annual wages for the government subsector were derived from Bureau of Economic Analysis data.

L.3.2 Calculating Indirect Job Impact

Given below is a sample calculation that illustrates the procedure used to estimate the number of new indirect jobs created by the WIPP in the two-county area.

The first step is to determine the annual flow of dollars through the economy from an increase in activity in a specific economic subsector. The example used here is aboveground construction and the year is 1983. It is estimated that the new dollars brought to the area by aboveground construction in 1983 will be $53.113 million. This direct construction impact is then multiplied by the coefficients given in Table L-2 (the inverted input-output table listing the direct, indirect, and induced effects) for the activity of interest (column 41: aboveground construction--1983).

The process for determining the impact on indirectly affected economic subsectors is illustrated in the following equations:

$$I_{ij} \times AIMP_{1983} = \$IMP_{ij}$$

(0.01279 x $53,113,200 = $679,318)

where

I_{ij} = coefficient from Table L-2 for row i and column entry j; i = 1,...,52 and j = 1,...,52. Example uses i = 28 (communications subsector) and j = 41, (aboveground construction in 1983); $I_{28,41}$ = 0.01279.

$AIMP_{1983}$ = aboveground-construction impact for 1983 (e.g., $53,113,200).

Table L-3. Estimated Annual Wages and Labor Costs per Employee in Eddy and Lea Counties, 1979[a]

Subsector	Estimated 1979 annual wages[b]	Estimated fringe benefits[c] (%)	Estimated annual labor costs per employee, 1979[d]
1. Livestock and livestock products	$ 9,320	10.0	$10,252
2. Cotton	7,585	10.0	8,343
3. Grains and seeds	7,585	10.0	8,343
4. Fruits and vegetables	7,585	10.0	8,343
5. Forestry and fishery products	9,298	16.0	10,786
6. Agricultural services	9,298	16.0	10,786
7. Miscellaneous metals and other minerals	17,321	28.0	22,171
8. Crude petroleum	16,567	28.0	21,206
9. Natural gas and liquid petroleum	16,567	28.0	21,206
10. Stone, gravel, and sand	17,321	28.0	22,171
11. Potash mining	17,321	28.0	22,171
12. Residential construction	10,545	20.0	12,654
13. Nonresidential construction	12,808	25.0	16,010
14. All other construction	11,573	25.0	14,466
15. Construction maintenance	11,052	15.0	12,710
16. Food products	10,181	16.0	11,810
17. Fabrics and apparel	7,818	17.0	9,147
18. Wood and lumber products	11,097	16.0	12,873
19. Printing	9,989	16.0	11,587
20. Chemical products	18,618	15.0	21,411
21. Plastics and petroleum products	21,227	15.0	24,411
22. Glass and stone products	12,666	16.0	14,693
23. Primary metal products	(e)	(e)	(e)
24. Fabricated metal products	12,323	16.0	14,295
25. Machinery	13,177	16.0	15,285
26. Electrical products	10,399	16.0	12,063
27. Transportation and warehousing	12,850	16.0	14,906
28. Communications	10,917	16.0	12,664
29. Electrical utility	18,821	15.0	21,644
30. Gas utility	18,821	15.0	21,644
31. Water and sewer	10,536	16.0	12,222
32. Wholesale trade	13,946	16.0	16,177
33. Retail trade	7,751	17.0	9,069
34. Finance, insurance, and real estate	11,068	16.0	12,839
35. Lodging and personal and repair services	6,541	17.0	7,653

Table L-3. Estimated Annual Wages and Labor Costs per Employee Employee in Eddy and Lea Counties, 1979[a] (continued)

	Subsector	Estimated 1979 annual wages[b]	Estimated fringe benefits[c] (%)	Estimated annual labor costs per employee, 1979[d]
36.	Businesses and miscellaneous services	11,142	16.0	12,925
37.	Medical and nonprofit	9,049	16.0	10,497
52.	Government	12,944	16.0	15,015

[a]These wages and labor costs are for jobs supported in indirectly affected subsectors. Jobs created by (directly associated with) the construction and operation of the WIPP project have annual wages that are not included in the listed figures.

[b]Derived from Covered Employment and Wages, Quarterly Report, New Mexico Employment Security, 1978. Wages were estimated for 1979 by using an adjustment factor specific to major sectors.

[c]Determined from interviews with private companies and unions. Minimum applicable percentage applies to most secondary and tertiary subsectors.

[d]Per employee costs are representative of the annual wage and not necessarily of a 40-hour average week.

[e]No activity in this subsector in the two-county area.

$\$IMP_{ij}$ = dollar indirect impact in subsector i from an exogenous increase in subsector j; that is, impact on the communications subsector from an increase in aboveground-construction activity.

From this calculation it is apparent that the model estimates that the increase in the communications subsector during 1983 will be about $680,000.

The next step is to determine the amount of money in the communications subsector that will be expended for labor (i.e., labor costs). The following equation illustrates this:

$$\$IMP_{ij} \times LC_{54i} = \$LC_{ji}$$

$$(\$679{,}318 \times 0.39097 = \$265{,}593)$$

where

LC_{54i} = coefficient for labor costs in subsector i from Table L-1; i = 1,...,52 (e.g., $LC_{54,28}$ = 0.39097 represents the coefficient for labor cost in subsector i = 28, communications).

$\$LC_{ji}$ = dollars flowing to labor cost in subsector i from an increase in activity in subsector j (i.e., total labor cost in communications (i = 28) as an indirect result of an increase in aboveground construction (j = 41) of $53,113,200 in 1983).

After determining that just more than $265,000 will flow into labor costs during 1983 through the communications subsector from increased aboveground-construction activity, the remaining step is to determine how many jobs this $265,000 will support during 1983. This is accomplished by the following mathematical operation:

$\$LC_{ji} \div \text{annual } ULC_i = \text{indirect job}_{ji}$

($265,593 ÷ $12,664 = 21.0)

where

Annual ULC_i = annual average per-unit labor cost in subsector i (e.g., in subsector i = 28, communications, annual ULC_i = $12,664).

Indirect Job_{ji} = number of jobs in subsector i supported by new activity in subsector j (e.g., i = 41, aboveground construction, $53,113,200, supports 21.0 jobs in i = 28, communications).

This example shows that the resulting impact on jobs in this subsector--communications--will be 21.0 jobs for 1983. Obviously the number of jobs supported indirectly by the WIPP project will vary from year to year. Tables L-4 through L-10 list the indirect effects of the WIPP for each year from 1980 through 1986 and for an average operations year thereafter. These tables list the estimated dollar volume flow into the 38 indirectly affected subsectors of the two-county economy (37 private and 1 government) and the number of jobs indirectly created in each one of these subsectors.

Tables L-11 and L-12 list the indirect employment impacts by <u>major</u> sector (including government) and give the employment multiplier for each year. Table L-13 gives the total number of direct, private indirect, and government jobs supported by the WIPP project for the years 1980 through 1986 before the plant becomes fully operational.

Table L-4. Indirect Impact of the WIPP Project in 1980: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	0.2	0.0	2.0	0.0	11.2	0.0
2. Cotton	0.1	0.0	0.9	0.0	5.3	0.0
3. Grains and seeds	0.1	0.0	1.2	0.0	6.4	0.1
4. Fruits and vegetables	0.0	0.0	0.4	0.0	2.2	0.0
5. Forestry and fishery products	0.0	0.0	0.4	0.0	2.5	0.0
6. Agricultural services	0.1	0.0	0.3	0.0	2.4	0.1
7. Miscellaneous metals and other minerals	0.0	0.0	0.0	0.0	0.0	0.0
8. Crude petroleum	0.7	0.0	7.5	0.0	34.9	0.2
9. Natural gas and liquid petroleum	0.2	0.0	2.6	0.0	11.9	0.1
10. Stone, gravel, and sand	1.3	0.0	0.1	0.0	17.5	0.3
11. Potash mining	0.0	0.0	0.0	0.0	0.1	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	0.5	0.0	7.9	0.3	24.3	0.9
16. Food products	0.9	0.0	8.6	0.1	49.3	0.6
17. Fabrics and apparel	0.0	0.0	0.2	0.0	1.3	0.0
18. Wood and lumber products	0.0	0.0	0.2	0.0	0.8	0.0
19. Printing	0.2	0.0	2.1	0.0	9.6	0.2
20. Chemical products	0.1	0.0	1.2	0.0	3.8	0.1
21. Plastics and petroleum products	1.5	0.0	15.7	0.1	73.1	0.3
22. Glass and stone products	0.1	0.0	0.1	0.0	1.4	0.0
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	0.2	0.0	0.0	0.0	3.3	0.1
25. Machinery	0.1	0.0	2.2	0.1	12.9	0.3
26. Electrical products	0.0	0.0	0.1	0.0	0.1	0.0
27. Transportation and warehousing	2.3	0.1	17.6	0.5	102.1	2.8
28. Communications	1.8	0.1	18.6	0.6	57.3	1.8
29. Electrical utility	1.4	0.0	12.9	0.1	123.9	0.8
30. Gas utility	0.9	0.0	11.5	0.1	51.1	0.3
31. Water and sewer	0.3	0.0	3.3	0.0	14.2	0.2
32. Wholesale trade	14.8	0.4	35.1	0.9	629.6	16.5

Table L-4. Indirect Impact of the WIPP Project in 1980: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations: Estimated volume[a]	Surface operations: Jobs supported	Management and design: Estimated volume[a]	Management and design: Jobs supported	Underground operations: Estimated volume[a]	Underground operations: Jobs supported
33. Retail trade	8.3	0.4	89.5	4.2	444.1	20.8
34. Finance, insurance, and real estate	5.6	0.2	59.8	1.7	228.2	6.4
35. Lodging and personal and repair services	3.8	0.2	41.4	1.9	191.6	8.7
36. Businesses and miscellaneous services	1.4	0.0	46.7	1.5	66.0	2.2
37. Medical and nonprofit	0.6	0.0	6.9	0.3	30.7	1.5
Total indirect impact	47.9	1	396.8	13	2213.1	65

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-5. Indirect Impact of the WIPP Project in 1981: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	15.7	0.1	13.7	0.1	31.6	0.1
2. Cotton	7.4	0.1	6.4	0.1	15.1	0.1
3. Grains and seeds	10.5	0.1	8.1	0.1	18.1	0.2
4. Fruits and vegetables	3.0	0.0	2.8	0.0	6.4	0.1
5. Forestry and fishery products	3.4	0.1	3.1	0.1	7.1	0.1
6. Agricultural services	10.7	0.3	2.4	0.1	6.7	0.2
7. Miscellaneous metals and other minerals	0.0	0.0	0.0	0.0	0.1	0.0
8. Crude petroleum	57.2	0.3	51.3	0.3	98.1	0.6
9. Natural gas and liquid petroleum	17.0	0.1	17.6	0.1	33.4	0.2
10. Stone, gravel, and sand	151.9	2.2	0.5	0.0	45.3	0.7
11. Potash mining	0.2	0.0	0.1	0.0	0.2	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	40.6	1.6	54.2	2.1	67.7	2.6
16. Food products	68.4	0.8	58.9	0.7	139.7	1.7
17. Fabrics and apparel	2.6	0.1	1.1	0.0	3.4	0.1
18. Wood and lumber products	1.0	0.0	0.8	0.0	2.0	0.0
19. Printing	14.0	0.3	14.2	0.3	27.2	0.6
20. Chemical products	6.9	0.1	8.6	0.2	10.7	0.2
21. Plastics and petroleum products	120.6	0.5	107.5	0.5	205.4	0.9
22. Glass and stone products	9.6	0.2	0.4	0.0	3.7	0.1
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	27.5	0.6	0.1	0.0	8.5	0.2
25. Machinery	9.2	0.2	15.1	0.4	34.1	0.8
26. Electrical products	0.2	0.0	0.5	0.0	0.3	0.0
27. Transportation and warehousing	211.5	5.8	121.0	3.3	279.5	7.6
28. Communications	173.8	5.4	127.7	3.9	159.4	4.9
29. Electrical utility	116.8	0.8	88.8	0.6	334.5	2.2
30. Gas utility	69.1	0.4	78.7	0.5	143.7	0.9
31. Water and sewer	21.8	0.2	22.7	0.3	40.1	0.5
32. Wholesale trade	1561.7	41.0	241.3	6.3	1659.2	43.6

Table L-5. Indirect Impact of the WIPP Project in 1981: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	611.4	28.7	614.6	28.8	1258.5	59.0
34. Finance, insurance, and real estate	487.4	13.7	410.8	11.6	637.1	17.9
35. Lodging and personal and repair services	304.2	13.8	284.2	12.9	537.0	24.4
36. Businesses and miscellaneous services	124.0	4.0	320.5	10.5	183.1	6.0
37. Medical and nonprofit	44.0	2.2	47.3	2.3	86.8	4.3
Total and indirect impact	4303.2	124	2725.0	86	6083.4	181

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-6. Indirect Impact of the WIPP Project in 1982: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	75.8	0.3	32.9	0.1	69.3	0.3
2. Cotton	35.9	0.3	15.3	0.1	33.1	0.3
3. Grains and seeds	47.3	0.4	19.3	0.2	39.6	0.3
4. Fruits and vegetables	15.0	0.1	6.6	0.1	14.0	0.1
5. Forestry and fishery products	16.7	0.3	7.4	0.1	15.5	0.3
6. Agricultural services	35.0	1.1	5.7	0.2	14.7	0.5
7. Miscellaneous metals and other minerals	0.1	0.0	0.1	0.0	0.1	0.0
8. Crude petroleum	251.8	1.4	123.4	0.7	215.1	1.2
9. Natural gas and liquid petroleum	78.0	0.4	42.3	0.2	73.3	0.4
10. Stone, gravel, and sand	423.9	6.2	1.2	0.0	99.2	1.5
11. Potash mining	0.6	0.0	0.2	0.0	0.3	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	170.4	6.6	130.2	5.1	148.4	5.8
16. Food products	332.1	4.1	141.6	1.7	306.5	3.8
17. Fabrics and apparel	9.2	0.3	2.6	0.1	7.5	0.2
18. Wood and lumber products	3.6	0.1	1.9	0.0	4.4	0.1
19. Printing	65.9	1.3	34.2	0.7	59.6	1.2
20. Chemical products	28.5	0.5	20.5	0.4	23.5	0.4
21. Plastics and petroleum products	529.9	2.3	258.3	1.1	450.7	1.9
22. Glass and stone products	27.2	0.6	1.0	0.0	8.2	0.2
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	76.8	1.7	0.2	0.0	18.6	0.4
25. Machinery	34.9	0.8	36.3	0.9	74.8	1.8
26. Electrical products	0.8	0.0	1.3	0.0	0.7	0.0
27. Transportation and warehousing	774.3	21.1	290.8	7.9	612.9	16.7
28. Communications	618.5	19.1	306.8	9.5	349.7	10.8
29. Electrical utility	498.6	3.2	213.4	1.4	733.3	4.7
30. Gas utility	329.9	2.1	189.2	1.2	315.3	2.0
31. Water and sewer	99.1	1.1	54.6	0.6	87.9	1.0
32. Wholesale trade	4770.6	125.3	579.7	15.2	3636.2	95.5

Table L-6. Indirect Impact of the WIPP Project in 1982: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	2,991.3	140.2	1476.6	69.2	2,761.0	129.4
34. Finance, insurance, and real estate	1,911.5	53.8	987.1	27.8	1,397.5	39.4
35. Lodging and personal and repair services	1,334.5	60.6	682.8	31.0	1,178.0	53.5
36. Business and miscellaneous services	491.9	16.0	769.9	25.1	401.6	13.1
37. Medical and nonprofit	208.9	10.2	113.6	5.6	190.4	9.3
Total and indirect impact	16,288.4	482	6547.1	206	13,340.9	396

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-7. Indirect Impact of the WIPP Project in 1983: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	94.5	0.4	57.2	0.2	23.4	0.1
2. Cotton	44.7	0.4	26.6	0.2	11.2	0.1
3. Grains and seeds	57.5	0.5	33.7	0.3	13.4	0.1
4. Fruits and vegetables	18.9	0.2	11.5	0.1	4.7	0.0
5. Forestry and fishery products	21.0	0.4	12.8	0.2	5.2	0.1
6. Agricultural services	36.9	1.2	10.0	0.3	5.0	0.2
7. Miscellaneous metals and other minerals	0.2	0.0	0.1	0.0	0.0	0.0
8. Crude petroleum	303.6	1.7	214.8	1.2	72.8	0.4
9. Natural gas and liquid petroleum	95.6	0.5	73.7	0.4	24.8	0.1
10. Stone, gravel, and sand	400.7	5.9	2.0	0.0	34.5	0.5
11. Potash mining	0.6	0.0	0.4	0.0	0.1	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	201.6	7.8	226.6	8.8	50.4	2.0
16. Food products	414.3	5.1	246.5	3.0	103.5	1.3
17. Fabrics and apparel	10.1	0.3	4.6	0.2	2.6	0.1
18. Wood and lumber products	3.9	0.1	3.4	0.1	1.5	0.0
19. Printing	81.5	1.7	59.5	1.2	20.1	0.4
20. Chemical products	33.5	0.6	35.8	0.6	8.0	0.1
21. Plastics and petroleum products	638.4	2.7	449.8	1.9	152.5	0.6
22. Glass and stone products	26.1	0.6	1.8	0.0	2.8	0.1
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	72.6	1.6	0.4	0.0	6.5	0.1
25. Machinery	39.6	1.0	63.1	1.5	25.8	0.6
26. Electrical products	0.9	0.0	2.2	0.1	0.2	0.0
27. Transportation and warehousing	862.7	23.5	506.4	13.8	209.2	5.7
28. Communications	679.6	21.0	534.3	16.5	118.7	3.7
29. Electrical utility	594.0	3.8	371.6	2.4	251.4	1.6
30. Gas utility	409.2	2.6	329.4	2.1	106.7	0.7
31. Water and sewer	120.7	1.4	95.1	1.1	29.7	0.3
32. Wholesale trade	4,802.9	126.2	1,009.4	26.5	1256.8	33.0

Table L-7. Indirect Impact of the WIPP Project in 1983: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	3,740.6	175.3	2,571.2	120.5	931.9	43.7
34. Finance, insurance, and real estate	2,198.7	61.9	1,718.7	48.4	473.9	13.3
35. Lodging and personal and repair services	1,606.5	73.0	1,188.8	54.0	399.0	18.1
36. Businesses and miscellaneous services	568.6	18.5	1,340.6	43.7	136.5	4.5
37. Medical and nonprofit	258.6	12.7	197.7	9.7	64.3	3.2
Total and indirect impact	18,438.5	553	11,399.9	359	4547.2	135

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-8. Indirect Impact of the WIPP Project in 1984: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	13.9	0.1	40.5	0.2	1.6	0.0
2. Cotton	6.6	0.1	18.8	0.2	0.8	0.0
3. Grains and seeds	8.5	0.1	23.8	0.2	0.9	0.0
4. Fruits and vegetables	2.8	0.0	8.2	0.1	0.3	0.0
5. Forestry and fishery products	3.1	0.1	9.1	0.2	0.4	0.0
6. Agricultural services	5.8	0.2	7.1	0.2	0.4	0.0
7. Miscellaneous metals and other minerals	0.0	0.0	0.1	0.0	0.0	0.0
8. Crude petroleum	45.1	0.3	151.8	0.9	5.1	0.0
9. Natural gas and liquid petroleum	14.1	0.1	52.1	0.3	1.8	0.0
10. Stone, gravel, and sand	65.5	1.0	1.4	0.0	2.6	0.0
11. Potash mining	0.1	0.0	0.3	0.0	0.0	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	30.1	1.2	160.2	6.2	3.6	0.1
16. Food products	60.8	0.7	174.3	2.1	7.3	0.1
17. Fabrics and apparel	1.5	0.1	3.3	0.1	0.2	0.0
18. Wood and lumber products	0.6	0.0	2.4	0.1	0.1	0.0
19. Printing	12.0	0.2	42.1	0.9	1.4	0.0
20. Chemical products	5.0	0.1	25.3	0.5	0.6	0.0
21. Plastics and petroleum products	94.8	0.4	318.0	1.4	10.8	0.0
22. Glass and stone products	4.2	0.1	1.2	0.0	0.2	0.0
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	11.9	0.3	0.2	0.0	0.5	0.0
25. Machinery	6.0	0.1	44.6	1.1	1.9	0.0
26. Electrical products	0.1	0.0	1.6	0.0	0.0	0.0
27. Transportation and warehousing	131.9	3.6	357.9	9.8	15.1	0.4
28. Communications	104.5	3.2	377.7	11.7	8.5	0.3
29. Electrical utility	88.6	0.6	262.7	1.7	18.4	0.1
30. Gas utility	60.1	0.4	232.9	1.5	7.5	0.0
31. Water and sewer	17.9	0.2	67.2	0.8	2.1	0.0
32. Wholesale trade	764.7	20.1	713.5	18.7	93.7	2.5

Table L-8. Indirect Impact of the WIPP Project in 1984: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	548.1	25.7	1817.4	85.2	65.5	3.1
34. Finance, insurance, and real estate	332.2	9.4	1214.8	34.2	33.7	0.9
35. Lodging and personal and repair services	238.7	10.8	840.3	38.2	28.3	1.3
36. Businesses and miscellaneous services	85.8	2.8	947.6	30.9	9.8	0.3
37. Medical and nonprofit	38.0	1.9	139.8	6.9	4.5	0.2
Total and indirect impact	2803.0	84	8057.8	254	327.6	10

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-9. Indirect Impact of the WIPP Project in 1985 and 1986: Dollar Volume and Jobs Supported by Subsector

Subsector	Management and design, 1985		Management and design, 1986	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	49.2	0.2	68.7	0.3
2. Cotton	22.9	0.2	31.9	0.3
3. Grains and seeds	29.0	0.3	40.5	0.4
4. Fruits and vegetables	9.9	0.1	13.9	0.1
5. Forestry and fishery products	11.0	0.2	15.4	0.3
6. Agricultural services	8.6	0.3	12.0	0.4
7. Miscellaneous metals and other minerals	0.1	0.0	0.1	0.0
8. Crude petroleum	184.8	1.0	258.0	1.5
9. Natural gas and liquid petroleum	63.4	0.4	88.5	0.5
10. Stone, gravel, and sand	1.7	0.0	2.4	0.0
11. Potash mining	0.3	0.0	0.4	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0
15. Construction maintenance	194.9	7.6	272.2	10.6
16. Food products	212.1	2.6	296.1	3.6
17. Fabrics and apparel	4.0	0.1	5.5	0.2
18. Wood and lumber products	2.9	0.1	4.0	0.1
19. Printing	51.2	1.0	71.5	1.5
20. Chemical products	30.8	0.0	43.0	0.8
21. Plastics and petroleum products	386.9	1.6	540.3	2.3
22. Glass and stone products	1.5	0.0	2.1	0.0
23. Primary metal products	0.0	0.0	0.0	0.0
24. Fabricated metal products	0.3	0.0	0.4	0.0
25. Machinery	54.3	1.3	75.8	1.8
26. Electrical products	1.9	0.1	2.7	0.1
27. Transportation and warehousing	435.6	11.9	608.2	16.6
28. Communications	459.6	14.2	641.7	19.8
29. Electrical utility	319.7	2.1	446.4	2.9
30. Gas utility	283.4	1.8	395.7	2.6
31. Water and sewer	81.8	0.9	114.2	1.3
32. Wholesale trade	868.2	22.8	1,212.3	31.8

Table L-9. Indirect Impact of the WIPP Project in 1985 and 1986: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Management and design, 1985		Management and design, 1986	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	2211.6	103.6	3,088.0	144.7
34. Finance, insurance, and real estate	1478.3	41.6	2,064.2	58.1
35. Lodging and personal and repair services	1022.6	46.4	1,427.8	64.9
36. Businesses and miscellaneous services	1153.1	37.6	1,610.1	52.5
37. Medical and nonprofit	170.1	8.3	237.5	11.6
Total and indirect impact	9805.6	309	13,691.7	437

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.
[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-10. Indirect Impact of the WIPP Project, Average Year 1987 and Thereafter: Dollar Volume and Jobs Supported by Subsector

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
1. Livestock and livestock products	47.3	0.2	9.0	0.0	22.0	0.1
2. Cotton	22.0	0.2	4.0	0.0	10.4	0.1
3. Grains and seeds	27.8	0.2	8.6	0.1	12.5	0.1
4. Fruits and vegetables	9.6	0.1	1.7	0.0	4.5	0.0
5. Forestry and fishery products	10.6	0.2	2.0	0.0	5.0	0.1
6. Agricultural services	8.2	0.3	1.6	0.1	3.7	0.1
7. Miscellaneous metals and other minerals	0.1	0.0	0.1	0.0	0.0	0.0
8. Crude petroleum	175.5	1.0	65.3	0.4	69.4	0.4
9. Natural gas and liquid petroleum	60.1	0.3	26.0	0.1	26.8	0.2
10. Stone, gravel, and sand	1.6	0.0	0.6	0.0	0.6	0.0
11. Potash mining	0.3	0.0	0.0	0.0	0.1	0.0
12. Residential construction[b]	0.0	0.0	0.0	0.0	0.0	0.0
13. Nonresidential construction	0.0	0.0	0.0	0.0	0.0	0.0
14. All other construction	0.0	0.0	0.0	0.0	0.0	0.0
15. Construction maintenance	181.7	7.1	74.6	2.9	69.3	2.7
16. Food products	204.1	2.5	36.4	0.4	96.3	1.2
17. Fabrics and apparel	3.8	0.1	1.8	0.1	1.6	0.1
18. Wood and lumber products	2.7	0.1	0.5	0.0	4.5	0.1
19. Printing	48.7	1.0	8.2	0.2	18.7	0.4
20. Chemical products	28.7	0.5	3.9	0.1	7.0	0.1
21. Plastics and petroleum products	367.5	1.6	135.7	0.6	144.3	0.6
22. Glass and stone products	1.4	0.0	0.4	0.0	0.5	0.0
23. Primary metal products	0.0	0.0	0.0	0.0	0.0	0.0
24. Fabricated metal products	0.3	0.0	0.0	0.0	0.1	0.0
25. Machinery	50.1	1.2	3.3	0.1	123.3	3.0
26. Electrical products	1.7	0.0	0.1	0.0	0.3	0.0
27. Transportation and warehousing	410.7	11.2	282.1	7.7	218.9	6.0
28. Communications	428.4	13.2	60.4	1.9	115.1	3.6
29. Electrical utility	304.4	2.0	93.4	0.6	481.9	3.1
30. Gas utility	268.5	1.7	54.2	0.4	114.1	0.7
31. Water and sewer	77.4	0.9	13.8	0.2	27.1	0.3
32. Wholesale trade	822.6	21.6	176.1	4.6	316.8	8.3

Table L-10. Indirect Impact of the WIPP Project Average Year, 1987 and Thereafter: Dollar Volume and Jobs Supported by Subsector (continued)

Subsector	Surface operations		Management and design		Underground operations	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
33. Retail trade	2133.0	99.0	363.3	17.0	891.4	41.8
34. Finance, insurance, and real estate	1387.7	39.1	210.3	5.9	443.5	12.5
35. Lodging and personal and repair services	968.3	44.0	193.9	8.8	342.2	15.5
36. Businesses and miscellaneous services	1059.4	34.6	72.5	2.4	109.4	3.6
37. Medical and nonprofit	161.5	7.9	24.2	1.2	68.3	3.4
Total and indirect impact	9255.6	292	1927.8	56	3749.5	108

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]Thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate subsector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impacts of the construction-subsector portions cycled through the fire, insurance, and real estate subsector are not available.

Table L-11. Indirect Impact of the WIPP Project, 1980-1983: Dollar Volume and Jobs Supported by Major Sector

Major sector	Total 1980		Total 1981		Total 1982		Total 1983	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
Agriculture	35.9	0.3	171.8	1.8	499.2	5.2	488.3	5.0
Mining	76.8	0.6	472.9	4.4	1,309.6	12.0	1,223.9	10.9
Construction[b]	32.7	1.2	162.5	6.3	449.0	17.5	478.6	18.6
Manufacturing	189.0	2.0	902.3	9.6	2,561.3	26.8	2,511.3	25.7
Transportation, communication, and utilities	419.2	7.2	1,989.3	37.3	5,474.4	102.6	5,218.9	100.3
Trade	1221.3	43.3	5,946.7	207.4	16,215.4	574.8	14,312.8	525.2
Finance, insurance, and real estate	293.6	8.3	1,535.3	43.2	4,296.0	121.0	4,391.3	123.6
Services	389.1	16.3	1,931.0	80.3	5,371.5	224.5	5,760.7	237.3
Subtotal (private sector)	2657.6	79.2	13,111.8	390.3	36,176.4	1084.4	34,385.8	1,046.6
Government	324.9	9.8	1,479.7	44.6	4,325.6	130.5	4,281.7	129.1
Total	2982.5	89.0	14,591.5	434.9	40,502.0	1214.9	38,677.3	1175.7
Employment multiplier (additive)	1.44	1.54			1.32			1.24

Source: Larry Adcock and Associates, 1978.

Note: Detail may not equal total due to rounding.

[a]In thousands of 1979 dollars.

[b]A portion of the constructon impact is assigned to the finance, insurance, and real estate sector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impact of the construction-sector portion cycled through the finance, insurance, and real estate sector is not available.

Table L-12. Indirect Impact of the WIPP Project, 1984-1987 and Thereafter: Dollar Volume and Jobs Supported by Major Sector

Major sector	Total 1984		Total 1985		Total 1986		Total 1987 and each year thereafter	
	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported	Estimated volume[a]	Jobs supported
Agriculture	$ 152.3	1.5	$ 130.7	1.2	$ 182.4	1.7	$ 210.4	1.9
Mining	340.0	2.6	250.3	1.4	349.5	2.0	426.5	2.5
Construction[b]	193.9	7.5	194.9	7.6	272.2	10.6	325.6	12.7
Manufacturing	832.9	8.3	745.8	7.4	1,041.4	10.4	1,295.5	14.0
Transportation, communication, and utilities	1,753.0	34.3	1,580.0	30.9	2,206.2	43.1	2,950.3	53.4
Trade	4,002.8	155.2	3,079.8	126.5	4,300.4	176.6	4,683.4	192.4
Finance, insurance, and real estate	1,580.7	44.5	1,478.3	41.6	2,064.2	58.1	2,041.5	57.5
Services	2,332.8	93.1	2,345.8	92.4	3,275.4	129.0	2,999.7	121.4
Subtotal (private sector)	11,188.4	347.1	9,805.6	309.0	13,691.7	431.5	14,932.9	455.8
Government	1,387.1	41.9	1,232.7	37.2	1,721.2	51.9	1,931.8	58.3
Total	12,575.5	389.0	11,038.3	346.2	15,412.9	483.4	16,864.7	514.1
Employment multiplier (additive)	1.31		1.29		1.16		1.17	

Source: Larry Adcock and Associates, 1979.

Note: Detail may not equal total due to rounding.

[a]In thousands of 1979 dollars.

[b]A portion of the construction impact is assigned to the finance, insurance, and real estate sector because of the procedures followed in building the national model by the Bureau of Economic Analysis, Department of Commerce. The exact impact of the construction-sector portion cycled through the finance, insurance, and real estate sector is not available.

Table L-13. Jobs Created or Supported by the Construction and the Operation of the WIPP Project, 1980-1987 and Thereafter

Activity	1980	1981	1982	1983	1984	1985	1986	1987	After 1987
Surface construction									
Direct jobs	1	68	415	551	79	--	--	--	--
Private indirect jobs	2	124	482	553	84	--	--	--	--
Government Jobs	1	11	55	69	10	--	--	--	--
Total jobs	3	203	952	1173	173	--	--	--	--
Annual new jobs	3	200	749	221	(1000)	(173)	--	--	--
Management and design									
Direct jobs	5	52	152	281	208	269	417	--	--
Private indirect jobs	13	86	206	359	254	309	432	--	--
Government Jobs	1	10	25	43	31	37	52	--	--
Total jobs	19	148	383	684	493	615	901	--	--
Annual new jobs	19	129	235	301	(191)	122	286	(901)	--
Underground construction									
Direct jobs	56	162	355	119	9	--	--	--	--
Private indirect jobs	66	181	396	135	10	--	--	--	--
Government Jobs	8	23	51	17	1	--	--	--	--
Total jobs	130	366	802	271	20	--	--	--	--
Annual new jobs	130	236	436	(531)	(251)	(20)	--	--	--
Surface operations (general)									
Direct jobs	--	--	--	0	(a)	(a)	(a)	256	256
Private indirect jobs	--	--	--	0	(a)	(a)	(a)	292	292
Government Jobs	--	--	--	0	(a)	(a)	(a)	36	36
Total jobs	--	--	--	0	(a)	(a)	(a)	584	584
Annual new jobs	--	--	--	0	(a)	(a)	(a)	584	--
Operations: remote storage and security									
Direct jobs	--	--	--	0	(a)	(a)	(a)	44	44
Private indirect jobs	--	--	--	0	(a)	(a)	(a)	56	56
Government Jobs	--	--	--	0	(a)	(a)	(a)	6	6
Total jobs	--	--	--	0	(a)	(a)	(a)	106	106
Annual new jobs	--	--	--	0	(a)	(a)	(a)	106	--
Underground operations									
Direct jobs	--	--	--	0	(a)	(a)	(a)	140	140
Private indirect jobs	--	--	--	0	(a)	(a)	(a)	108	108
Government Jobs	--	--	--	0	(a)	(a)	(a)	16	16
Total jobs	--	--	--	0	(a)	(a)	(a)	264	264
Annual new jobs	--	--	--	0	(a)	(a)	(a)	264	--
Total all activities									
Direct jobs	62	282	922	951	296	269	417	440	440
Private indirect jobs	81	391	1084	1047	348	309	432	456	456
Government Jobs	10	44	131	129	42	37	52	58	58
Total jobs	152	717	2137	2128	686	615	901	954	954
Annual new jobs	152	565	4274	(9)	(1442)	(71)	286	53	--

Note: Detail may not equal total due to rounding.
[a]The years 1984-1986 are transition years, and some jobs listed as management and design will continue into operation positions.

L.4 POPULATION

L.4.1 Factors Affecting Population

Three critical economic parameters must be analyzed in order to determine the overall impact generated by an exogenous increase in a specific activity within a region: employment increases, increases in the flow of dollars, including personal income, and population changes. The order in which these specific categories are computed is important to the methods demonstrated in this appendix.

Changes in employment and increases in dollar flows can be derived directly from the results of the input-output model. Population migration, however, is dependent on the increase in employment derived from the input-output model. While the derivation of employment depends on assumptions concerning certain coefficients and factors drawn from previous studies, increases in population may be significantly influenced by changes in activity in other areas of the economy that cannot be predicted with reasonable accuracy. Specific conditions of uncertainty involve mining, which supports much of the economic activity in the two-county area.

Recent examples of fluctuation in economic activity that make it difficult to determine exact population-migration figures are evident. Between 1960 and 1970 both Eddy and Lea Counties lost population principally because of decreased levels of activity in mining. During the 10-year period, the population of Eddy County decreased by 19%, and the population loss in Lea County was just more than 7%. Before this decreasing trend was recognized, in the middle and early 1960s, population projections by the Bureau of Business and Economic Research (BBER), the official State population-projecting agency, were relatively high, indicating that professional demographic researchers felt that the area would continue to grow. Later population projections by the Federal Government and the BBER indicated somewhat lower levels of population growth. Since 1970, and particularly since the energy crisis, both counties have maintained high levels of growth. Growth in Eddy County is correlated with the end of potash "dumping" on the U.S. market by Canadian firms. In Lea County higher levels of oil and gas exploration and continued production have increased the population.

While the current outlook--particularly during the last 5 or 6 years--has been one of high expectations in terms of population growth in the near future, population growth is influenced by a number of outside factors. For example, high prices and limited supplies of petroleum have indirectly created growth in Lea County and in the City of Hobbs. Should these conditions change, the degree of growth in the area could also change. The potash industry of Eddy County (the major basic industry) now supplies between 80% and 90% of all potash sold in U.S. markets. Should the demand for potash decrease, the mining sector in Eddy County would be significantly affected.

Personal interviews with industrial development executives for Hobbs and Carlsbad indicate that a determined effort is under way to diversify the economy of both counties in order to stabilize their economic bases. Because of the high level of activity in the extractive industries, the availability of labor for certain occupations in Eddy and Lea Counties may require the in-migration of a number of laborers into the area. However, recent developments while this study was being conducted indicate that there is a reasonable labor supply for many of the needed occupations in the area.

Employment-application records from the NMESD were examined to determine the availability of labor for various occupations. From this examination the percentage of workers needed for occupations directly connected with the construction and operation of the WIPP was determined. Economic activity within an area can change rather rapidly. As the level of economic activity changes, available labor in certain occupations also changes. Migration to work on a large construction project or to operate a facility like the WIPP depends on many factors. These include the recruitment procedure for employees, the availability of labor within an area, the construction-company subcontracting practices, and the availability of community facilities.

Many of the major factors affecting in-migration can be recognized, but dealing with them in a quantitative manner is difficult. Researchers tend to rely on previous studies conducted to determine the degree of migration and/or specific analogous case studies of construction projects. Possibly one of the best studies in recent years is the Construction Worker Profile, completed for the Old West Regional Commission (OWRC) in early 1976. A large number of the migration factors contained in this appendix have been drawn from that document. However, there is very little information that can be used in estimating the number of people who will move into the area to fill jobs in secondary and tertiary sectors (i.e., spinoff jobs from the construction and operation of the WIPP). These facts should be recognized while reading this appendix.

L.4.2 Population Impact Calculations

The impact on population of WIPP construction and operation was calculated from the results of the employment portion of the model. The calculations for each year are too extensive to give here. However, sample calculations and formulas are given below to illustrate the procedure used in determining the annual population impact. For illustrative purposes only, the year 1981, the second year of construction, and the year 1987, the first full year of operation, have been used in the sample calculations.

The calculation of population impact consists of three major steps. The first step calculates the number of people who are expected to move into the area because of WIPP construction. The formulas are as follows:

$AGC_{1981} \times MigCON_A = AGCJM_{1981}$

$(68 \times 0.539 = 37)$

$BGC_{1981} \times MigCON_B = BGCJM_{1981}$

$(162 \times 0.606 = 98)$

$MDE_{1981} \times MigCON_N = MDEJM_{1981}$

(52 x 0.498 = 26)

$AGCJM_{1981} + BGCJM_{1981} = CJM_{1981}$

(37 + 98 = 135)

$MDEJM_{1981} = MOWH_{1981}$

(26 = 26)

$CJM_{1981} \times HCWF = MCWH_{1981}$

(139 x 0.985 = 133)

$MCWH_{1981} \times CWHSZ = MCP_{1981}$

(133 x 2.28 = 303)

$MOWH_{1981} \times OWHSZ_{1981} = MOP_{1981}$

(26 x 2.75 = 72)

$MCP_{1981} + MOP_{1981} = MDP_{1981}$

(303 + 72 = 375)

where

AGC_{1981} = the total number of WIPP-associated aboveground-construction jobs in 1981.

BGC_{1981} = the total number of WIPP-associated belowground-construction jobs in 1981.

MDE_{1981} = the total number of WIPP-associated management and design jobs in 1981.

$MigCON_A$ = the proportion of total aboveground-construction jobs expected to be filled by newcomers to the area. The factor 0.539 was derived from Construction Worker Profile figures for the Four Corners Region in 1975 (Arizona, Colorado, New Mexico, and Utah).

$MigCON_B$ = the proportion of total belowground-construction jobs expected to be filled by newcomers to the area. The factor 0.606 was determined by matching needed occupations and skill levels to present availability (first quarter of 1977 and third quarter of 1978 and 1979) of labor.

$MigCON_N$ = the proportion of total nonconstruction jobs expected to be filled by newcomers to the area. The factor 0.498 is the weighted average of the final operational migration factors.

JM_{1981} = the total number of jobs expected to be filled by newcomers to the area; AGCJM = aboveground-construction JM; BGCJM = belowground-construction JM; MDE = management-and-design JM; CJM = construction JM.

HCWF = the factor that accounts for more than one construction worker per household (0.985).

$MCWH_{1981}$ = the number of newcomer construction-worker households expected in the area in 1981.

$MOWH_{1981}$ = the number of newcomer management-and-design worker households in 1981.

CWHSZ = the average size of newcomer construction-worker households (2.28--Construction Worker Profile).

$OWHSZ_{1981}$ = the average size of newcomer nonconstruction-worker households in 1981 (see pages L-54 and L-55).

MCP_{1981} = the expected number of individuals in-migrating directly for WIPP-construction jobs in 1981.

MOP_{1981} = the expected number of individuals in-migrating directly for management-and-design jobs at the WIPP in 1981.

MDP_{1981} = the expected number of individuals in-migrating directly for jobs at the WIPP in 1981.

The sources of data are extremely important in computing the population in-migrating to take new jobs in the construction and operation of the WIPP. The average number of employees by year for construction or operation was derived from data supplied by the Bechtel Corporation (October 23, 1979) and the Westinghouse Electric Corporation (November 1978). The proportion of new jobs expected to be filled by newcomers to the area is derived from the Construction Worker Profile. That OWRC study involved 14 large construction projects (six projects in the Four Corners Region) and showed that the percentage of local workers varied from a high of more than 79% to a low of 3.3% for all projects and a high of 79% to a low of 32% for the six projects in the Southwest (Arizona, Colorado, New Mexico, and Utah). The average percentage of local workers employed on the southwestern projects was 46.1%, indicating that 53.9% of the construction workers were not residents of the area before the construction activity (Four Corners Region only). A review of job applications in the computer files of the NMESD supports this distribution. Thus, approximately 54% of the construction workers for these six projects had migrated to the area for construction work. This percentage has been used to compute the number of aboveground jobs that would be filled by individuals not in the area before the construction began.

As construction workers move into the area to fill these positions, they bring with them other members of their households. Certain of these members--the older children and spouse--may take up jobs in the area of the construction site. The OWRC study indicates that about 1.5% of the new households contain two construction workers. This means that 985 households will supply

1000 construction workers to the project, on the average. Thus, the number of needed households has been decreased by 1.5% to account for the two-construction-worker households. This factor of 0.985 is identified in the formula above as HCWF. The final formula above yields the total number of individuals in-migrating to take new construction jobs. This number is computed by taking the average household size and multiplying it by the needed number of households to fill construction positions. In this case the average household size of 2.28 is the average household size determined from the OWRC study of all 14 construction projects in the West and Southwest. (For the explanation of the nonconstruction employment in-migration, see the section below on operation-associated in-migration.)

After the population in-migration due directly to construction has been calculated, the change due to operation must be computed. This is determined in the same way and is given by the following formulas:

(Note: The example year is 1987 because the full operational impact does not occur before 1987.)

$$OAG_{1987} \times MigOPP_{AG} = OAGJM_{1987}$$

$$(256 \times 0.498 = 127)$$

$$OBG_{1987} \times MigOPP_{BG} = OBGJM_{1987}$$

$$(140 \times 0.498 = 70)$$

$$OST_{1987} \times MigOPP_{OST} = OSTJM_{1987}$$

$$(44 \times 0.498 = 22)$$

$$OAGJM_{1987} + OBGJM_{1987} + OCNJM_{1987} = OJM_{1987}$$

$$(127 + 70 + 22 = 219)$$

$$OJM_{1987} = MOWH_{1987}$$

$$(219 = 219)$$

$$MOWH_{1987} \times AVHSZ_{1987} = MOP_{1987}$$

$$(219 \times 2.71 = 594 \quad 600)$$

where

OAG_{1987} = the total number of WIPP-associated aboveground-operation jobs in 1987.

OBG_{1987} = the total number of WIPP-associated belowground-operation jobs in 1987.

OST_{1987} = the total number of WIPP-associated disposal-operation jobs in 1987.

$MigOPP_{AG}$ = the proportion of total aboveground-operation jobs expected to be filled by newcomers to the area. The factor 0.498 was determined from occupation and skill-level data supplied by Sandia National Laboratories, a review of available occupations and skills in the two-county area, and information supplied by the Westinghouse Electric Corporation.

$MigOPP_{BG}$ = the proportion of total belowground-operation jobs to be filled by newcomers to the area. The factor 0.498 is the same factor that was used in the general projections for aboveground operation.

$MigOPP_{OST}$ = the proportion of total disposal-operation jobs to be filled by newcomers to the area. The factor 0.498 is the same as the factor used for other operation jobs.

JM_{1987} = the number of total operational jobs expected to be filled by newcomers to the area; OAGJM = aboveground-operation JM, OBGJM = belowground-operation JM, OSTJM = remote handling and security JM, OJM = total.

$MOWH_{1987}$ = the number of newcomer operational-worker households in 1987.

$AVHSZ_{1987}$ = the average size of household for the in-migrating operational workers.

MOP_{1987} = the population in-migrating directly to take operational jobs at the WIPP.

Again, sources of information for the formulas above are extremely important. The direct operational employment is determined from information supplied by Westinghouse. The proportion of operational jobs to be filled by newcomers to the area is determined to be 0.498. Literature searches indicate no directly applicable research projects that would give the average number of operational jobs filled by newcomers to the area. In order to determine this factor, NMESD job-application records, currently available occupational skill levels, and the occupations and skill levels needed for the operation phase were reviewed. In addition, information on the activities of operating contractors was obtained from the Westinghouse Electric Corporation.

Data on the average sizes of newcomer households were drawn directly from Bureau of the Census publications on projected household sizes and family sizes. The figures used within the calculations represent Series I population figures and Series D household sizes. These are the high-range household sizes of the 12 projections listed by the Bureau of the Census in Current Population Reports, Series P-25, No. 805, May 1979.

The last quantity needed to determine the overall population impact is the number of people taking jobs generated indirectly by the construction and operation of the WIPP. These population changes are computed much like the preceding calculations, with one major exception. Construction workers and operational workers who have moved into the area bring with them other household members. Some of these household members take up employment in other areas of the economy. These people must be accounted for in determining the overall in-migration of people to the area. Thus, the following formulas differ somewhat from the preceding calculations:

$IDE_{1981} \times MigID = IDJM_{1981}$

$(435 \times 0.50 = 218)$

$IDJM_{1981} - ADCE_{1981} - ADOE_{1981} = \text{Net } IDJM_{1981}$

$(218 - 26 - 8 = 184)$

$\text{Net } IDJM_{1981} \times HWF = MIDWH_{1981}$

$(184 \times 0.769 = 141)$

$MIDWH_{1981} \times AVHSZ_{1981} = MIDP_{1981}$

$(141 \times 2.75 = 388)$

where

IDE_{1981} = the number of new indirect jobs (private and government) supported by the construction or operation of the WIPP (example year is 1981).

MigID = the proportion of indirect jobs to be filled by newcomers to the area (0.50).

$IDJM_{1981}$ = the number of indirect jobs in 1981 to be filled by newcomers to the area.

$ADCE_{1981}$ = the expected number of indirect jobs in 1981 filled by members of households moving into the area to take new construction jobs (0.195 x MCWH).

$ADOE_{1981}$ = the number of indirect jobs filled by members of households moving into the area in 1981 to take new management-and-design jobs (0.30 x MOWH).

Net $IDJM_{1981}$ = the net number of jobs in 1981 to be filled by newcomers moving into the area to take jobs created indirectly by the construction or operation of the WIPP.

HWF = the factor that accounts for more than one worker per household in in-migrating households (0.769).

$MIDWH_{1981}$ = the number of newcomer households attracted to the area in 1981 primarily by jobs indirectly created by the construction or operation of the WIPP.

$AVHSZ_{1981}$ = the average household size in 1981 of persons moving into the area for jobs indirectly created by the construction or operation of the WIPP.

$MIDP_{1981}$ = the population moving into the area in 1981 for jobs indirectly created by the construction or operation of the WIPP.

From the above formulas, it is apparent that several new characteristics have entered the calculations of population impacts. The quantity IDE is determined from calculations explained in the employment section of this appendix. It is a direct result of the input-output modeling process. The quantity MigID is a subjective number based on an evaluation of the area in terms of labor availability and the skill levels needed for indirect new jobs. In this case, the factor is 0.5, which indicates that half of the new jobs created in indirectly affected sectors will be filled by newcomers to the area.

As workers move into the area to work in construction or operation, they bring with them households that contain members who also become part of the labor force and are available to fill newly created positions in the area under impact. The quantity ADCE accounts for these additional workers brought by construction-worker households. The OWRC Construction Worker Profile indicates that between 19 and 29 additional workers for each 100 newcomer construction-worker households will take jobs in indirectly affected sectors. In this study, a factor of 0.195 was used to determine the number of additional workers in each household in-migrating directly for construction work.

The term ADCE accounts for the number of new workers brought by households in-migrating directly for operation jobs. The Construction Worker Profile indicates that this number is substantially larger than the factor for the construction-worker households. Between 30 and 31 additional workers will be brought in for each 100 households moving in to take direct operation jobs. A factor of 30% was used in this appendix to account for those additional workers. It is also apparent that the households moving in to work in sectors indirectly affected by construction and operation may contain more than one worker per household. Again, this number is approximately 30 to 31 additional workers for 100 new households. Thus, for 100 households, just about 130 workers would be available for positions in indirectly affected sectors. In order to account for these multiple-worker households, a factor of 1/1.3 = 0.769 was used to decrease the number of needed households moving into the area.

Finally, the actual size of the households moving into the area was calculated from Bureau of the Census data on projected household and family sizes (specifically Population Series I and Household Series C).

The final step in determining the population impact of WIPP construction and operation is to add the three quantities that determine population change: the change caused directly by construction, the change caused directly by operation, and the change caused indirectly by construction and operation.

Because the economy may be somewhat slow to react to new jobs, population changes are assumed to lag in the indirectly affected sectors. In order to account for this lag in the model, it is assumed that only half the expected in-migration will occur within the first year of impact. The remaining individuals are assumed to in-migrate during the next year. This assumption allows for a 6-month to 1-year lag in the spinoff effects of construction and operation.

It should be noted that the assumption allowing for a 6-month to 1-year lag in filling indirect jobs with newcomers does not necessarily affect the time at which the impact on the economy is calculated to occur. The impact on the economy is incurred when local purchases or payments to direct labor are made; therefore, the support for the jobs to be filled by the newcomers occurs before the jobs are actually filled. This means, for example, that persons who receive income from the construction of the WIPP do not wait to spend their income until population-serving businesses increase their employment. For the economic entities that are indirectly affected by WIPP construction and operation, there will be a period of time in which new economic activity creates support for new jobs, but those jobs have not yet been filled. This means that the productivity of employees will have to increase above the average until employers recognize the need for new employees and hire them. Therefore, there is no discrepancy between calculating the impact of the WIPP and assuming that the economy does not instantaneously react in terms of new employees in sectors that are indirectly affected.

The total in-migrating population for a given year is determined by adding the population attracted by construction, the population attracted by operation, and the population attracted by new activity in indirectly affected economic sectors. The formula that is used is as follows:

$$MCP_{1981} + MOP_{1981} + 0.5\ MIDP_{1981} + 0.5\ MIDP_{1981-1} = MP_{1981}$$

$$(303 + 72 + 194 + 39 = 608 \simeq 600)$$

where

MCP_{1981} = population in-migrating directly for construction jobs.

MOP_{1981} = population in-migrating directly for management-and-design (or operational) jobs.

$MIDP_{1981}$ = population in-migrating for jobs supported indirectly by construction and operation.

MP_{1981} = total in-migrating population for 1981 (= 608 $\simeq$ 600).

$MIDP_{1981-1}$ = population in-migrating for jobs supported indirectly by construction and management and design (or operational) jobs in 1980.

A final word of caution is needed. The sample calculations for 1981 above are for impacts during the second year of construction. The annual number of people moving into the area in following years is not necessarily the same. Calculations must also be made for each succeeding year.

As the construction phase of the WIPP ends and the full operational phase begins (1987), the job situation will change drastically. From the end of 1984 through 1986 a transitional period between construction and operation will cause significant changes in the population. These population changes--that is, negative changes, or outflows--are computed like the preceding example. However, other studies, such as the Construction Worker Profile, indicate that individuals do not leave immediately. This lag has been taken into account in determining the impacts occurring during the transitional phase of the project. The final results of all of the calculations appear in Table L-14.

The population-impact predictions have been made for two different population-distribution scenarios. The first scenario assumes that 99% of the direct impact and 90% of the indirect impact will go to Eddy County, with only 1% of the direct impact and 10% of the indirect impact going to Lea County. The second scenario assumes that 42% of the combined impact will occur in Lea County and 58% of the combined impact will occur in Eddy County.

The two different scenarios resulted from interviews with six large potash-mining operations in the area. Carlsbad is the center of potash-mining activity, and more than 95% of the present potash miners live in Eddy County. However, one company recruits mainly in the Hobbs area, and as a result 42% of its employees live in Lea County.

The construction and operation of the WIPP will be similar to a combination of construction, mining, and warehousing operations and hence similar to the potash-mining activities in the area. Thus, the first scenario assumes that the major impact will be felt in Eddy County, including about 88% in Carlsbad. It was assumed that the contractors would recruit employees from the Carlsbad area for WIPP construction and operation.

Subsequent discussions suggested the possibility that the construction and operation contractors might recruit from the Hobbs area, with the major impact being felt in Lea County and the City of Hobbs. To account for this possibility, a second scenario was developed, as outlined above.

It should also be noted that population predictions for the cities listed include only the population within the incorporated limits and do not include the fringe areas. In Hobbs and Carlsbad, these fringe areas contain from 3000 to 5000 additional people.

Table L-14. Baseline Population Estimates and Projections (without WIPP Project)

Year	Eddy County	Carlsbad	Carlsbad School District	Loving	Loving School District	Lea County	Hobbs	Hobbs School District
1970	41,119	21,297	25,961	1,192	1,350	49,554	26,025	29,858
1975	42,900	N/A	N/A	N/A	N/A	51,600	N/A	N/A
1976	45,300	25,500	29,300	N/A	N/A	53,100	29,600	33,400
1977	46,200	26,600	30,400	1,488	1,650	55,100	30,550	34,500
1978	47,300	27,900	31,600	1,550	1,700	56,300	31,650	35,650
1979	48,200	28,600	32,400	1,600	1,750	57,500	32,600	36,650
1980	49,300	29,500	33,300	1,650	1,800	58,700	33,450	37,550
1981	50,200	30,200	34,100	1,650	1,800	60,000	34,400	38,550
1982	51,600	31,300	35,300	1,700	1,850	61,200	35,250	39,450
1983	52,000	31,600	35,700	1,700	1,850	62,500	36,200	40,450
1984	52,900	32,300	36,400	1,750	1,900	63,800	37,150	41,450
1985	53,800	32,800	37,000	1,800	1,950	65,200	38,150	42,500
1986	55,100	33,600	37,900	1,800	1,950	66,500	38,900	43,350
1987	56,400	34,400	38,800	1,850	2,000	67,700	39,600	44,150
1988	57,800	35,300	39,800	1,900	2,050	68,800	40,250	44,850
1989	59,200	36,100	40,700	1,950	2,100	69,900	40,900	45,600
1990	60,600	37,000	41,700	2,000	2,150	70,900	41,500	46,250
1995	64,300	39,200	44,200	2,100	2,250	75,100	43,950	49,000
2000	68,300	41,700	47,000	2,250	2,450	79,000	46,200	51,500

Source: 1970 data from 1970 Census of Population. All other data collected for this report by Larry Adcock and Associates, 1979.

N/A = Not available.

L.5 PERSONAL INCOME

L.5.1 General

The change in total annual personal income in the two-county area is determined from the direct wages paid during the construction and operation of the WIPP, allowing for a certain amount of fringe benefits. The indirect total personal income generated is computed by determining what proportion of labor costs will enter the total personal-income stream from the total number of dollars allocated to labor costs.

In addition to wages, dividends, interest, and rents account for a portion of the total personal income. That portion has been estimated from unpublished regional data for the two-county area provided by the Bureau of Economic Analysis to the Bureau of Business and Economic Research at the University of New Mexico (Tables L-15 and L-16).

From Tables L-15 and L-16 it is apparent that the total labor and proprietors' income in 1977 (the latest year available) amounted to some $526.3 million in the two-county area. Interest, dividends, and rents accounted for $72.3 million (13.7%) in additional income. Further calculations indicate a variation of approximately 4% from this figure, depending on which year of the last few years is examined. The actual figure used for this study was 14%.

The other major factor considered in calculating the total annual personal income is transfer payments. As shown by the data from the Bureau of Economic Analysis, the flow of transfer payments to the area is positive. However, during the construction of the WIPP, the impact of transfer payments on the total-personal-income stream is assumed to be negative because more Social Security payments will flow out than flow in from these jobs created and supported by the construction phase. During the operational phase, however, the impact of transfer payments on the total-personal-income stream may be either negative or positive. In the early years of operation it should be positive; however, as individuals retire from jobs or positions created by the operation of the WIPP, the transfer payments will return. Therefore, it is assumed that transfer payments are neutral during the operation of the WIPP.

L.5.2 Explanation and Values

Table L-17 summarizes some of the information presented in this section. Details appear in the text below.

During the construction period (mid-1980 through mid-1984) and for the period before full operation (mid-1984 through 1986), it is expected that a total of just over $93 million will flow directly into wages and salaries from the construction of the plant and associated management-and-design employment. In addition, there will be almost $46 million in wages and salaries in businesses indirectly affected by construction.

Personal income from interest, dividends, and rent is expected to total an estimated $20 million during the 6.5-year period. A total of about $140.5 million is expected to be derived both directly and indirectly in the private

Table L-15. Personal Income in Eddy County by Major Source, 1972-1977 (thousands of dollars)

Item	1972[a]	1973[a]	1974[a]	1975[b]	1976[b]	1977[b]
TOTAL LABOR AND PROPRIETORS' INCOME BY PLACE OF WORK[c]						
By type						
Wage and salary disbursements	85,032	91,736	103,723	132,147	148,472	168,934
Other labor income	6,294	7,229	8,999	12,082	14,360	17,385
Proprietors' income[d]	16,270	19,194	21,864	18,827	23,839	26,427
Farm	5,258	9,482	7,227	5,701	6,883	6,752
Nonfarm[d]	11,012	9,712	14,637	13,126	16,956	19,675
By industry						
Farm	6,975	11,392	9,041	7,732	9,103	9,121
Nonfarm	100,621	106,769	125,545	155,324	177,568	203,625
Private	86,225	91,476	109,280	136,552	155,724	179,886
Agricultural services, forestry, fishing, and other[e]	426	425	486	553	524	587
Mining	33,166	32,344	41,966	50,315	57,698	68,140
Construction	5,744	6,771	7,631	13,926	15,736	17,159
Manufacturing	5,844	6,655	8,430	11,765	14,964	16,879
Nondurable goods	4,459	5,041	6,547	9,705	11,425	13,012
Durable goods	1,385	1,614	1,883	2,060	3,539	3,867
Transportation and public utilities	7,355	8,860	9,812	11,336	13,607	16,054
Wholesale trade	3,522	4,012	4,959	7,656	7,136	8,330
Retail trade	12,370	13,227	15,300	16,666	18,613	21,368
Finance, insurance, and real estate	3,295	3,397	3,616	4,274	5,316	6,156
Services	14,503	15,785	17,080	20,061	22,130	25,213
Government and government enterprises	14,396	15,293	16,265	18,772	21,844	23,739
Federal, civilian	2,447	2,583	2,794	3,162	3,803	4,009
Federal, military	478	526	531	540	579	592
State and local	11,471	12,184	12,940	15,070	17,462	19,138
DERIVATION OF PERSONAL INCOME BY PLACE OF RESIDENCE						
Total labor and proprietors' income by place of work	107,596	118,161	134,586	163,056	186,671	212,746
Less: personal contributions for social insurance by place of work	5,085	6,102	7,194	8,948	10,027	11,338
Net labor and proprietors' income by place of work	102,511	112,059	127,392	154,108	176,644	201,408
Plus: residence adjustment	201	218	425	-62	-208	-192
Net labor and proprietors' income by place of residence	102,712	112,277	127,817	154,046	176,436	201,216
Plus: dividends, interest, and rents[f]	20,098	22,278	26,687	31,728	34,838	39,023
Plus: transfer payments	18,529	21,646	25,236	29,529	33,919	36,536
Personal income by place of residence	141,339	156,201	179,740	215,303	245,193	276,775
Per capita personal income (dollars)	3,442	3,781	4,332	5,018	5,415	6,089
Total population (thousands)	41.1	41.3	41.5	42.9	45.3	45.5

Source: Regional Economics Information System, Bureau of Economic Analysis.

[a]Estimates based on 1967 SIC.
[b]Estimates based on 1972 SIC.
[c]Consists of wage and salary disbursements, other labor income, and proprietors' income.
Primary source for private nonfarm wages: ES-202 covered wages, New Mexico Employment Security Commission.
[d]Includes the capital consumption adjustment for nonfarm proprietors.
[e]Includes wage and salaries of U.S. residents working for international organizations.
[f]Includes the capital consumption adjustment for rental income of persons.

Table L-16. Personal Income in Lea County by Major Source, 1972-1977 (thousands of dollars)

Item	1972[a]	1973[a]	1974[a]	1975[b]	1976[b]	1977[b]
TOTAL LABOR AND PROPRIETORS' INCOME BY PLACE OF WORK[c]						
By type						
Wage and salary disbursements	121,107	133,089	163,925	190,942	207,111	236,570
Other labor income	10,982	12,343	16,397	20,650	23,585	28,379
Proprietors' income[d]	21,399	24,521	37,549	31,241	42,417	48,604
Farm	7,993	13,766	13,746	12,818	12,430	13,779
Nonfarm[d]	13,406	10,755	23,803	18,423	29,987	34,825
By industry						
Farm	9,579	15,673	15,689	14,991	14,805	16,312
Nonfarm	143,909	154,280	202,182	227,842	258,308	297,241
Private	127,968	137,470	184,385	207,165	234,457	271,081
Agricultural services, forestry, fishing, and other[e]	635	694	(D)	(D)	692	804
Mining	42,573	46,162	74,419	79,026	93,976	112,645
Construction	8,287	8,498	13,051	14,417	14,724	16,645
Manufacturing	7,545	8,284	10,021	12,609	13,070	16,539
Nondurable goods	5,172	6,127	7,775	9,562	11,329	13,229
Durable goods	2,373	2,157	2,246	3,047	2,741	3,310
Transportation and public utilities	22,591	23,952	27,343	32,506	36,330	39,662
Wholesale trade	9,162	9,972	12,329	15,502	17,642	20,483
Retail trade	15,846	16,810	18,842	21,100	23,541	26,650
Finance, insurance, and real estate	4,838	5,296	(D)	(D)	8,173	9,812
Services	16,491	17,802	22,090	24,728	25,309	27,841
Government and government enterprises	15,941	16,810	17,797	20,677	23,851	26,160
Federal, civilian	1,294	1,428	1,575	1,827	2,043	2,258
Federal, military	494	534	537	564	599	643
State and local	14,153	14,848	15,685	18,286	21,209	23,259
DERIVATION OF PERSONAL INCOME BY PLACE OF RESIDENCE						
Total labor and proprietors' income by place of work	153,488	169,953	217,871	242,833	273,113	313,553
Less: personal contributions for social insurance by Place of work	7,050	8,651	11,376	12,850	14,226	16,146
Net labor and proprietors' income by place of work	146,438	161,302	206,495	229,983	258,887	297,407
Plus: residence adjustment	807	-114	-1,689	-986	-924	-896
Net labor and proprietors' income by place of residence	147,245	161,188	204,806	228,997	257,963	296,511
Plus: dividends, interest, and rent[f]	18,505	19,678	23,907	28,132	29,909	33,269
Plus: transfer payments	15,440	18,055	20,878	25,018	28,468	30,674
Personal income by place of residence	181,190	198,921	249,591	282,147	316,340	360,454
Per-capita personal income (dollars)	3,643	4,028	5,014	5,464	5,954	6,811
Total population (thousands)	49.7	49.4	49.8	51.6	53.1	52.9

Source: Regional Economics Information System, Bureau of Economic Analysis.

[a]Estimates based on 1967 SIC.
[b]Esimates based on 1972 SIC.
[c]Consists of wage and salary disbursements, other labor income, and proprietors' income. primary source for private Nonfarm wages: ES-202 Covered Wages, New Mexico Employment Security Commission.
[d]Includes the capital consumption adjustment for nonfarm proprietors.
[e]Includes wage and salaries of U.S. residents working for international organizations. Includes the capital consumption adjustment for rental income of persons.
[f]Not shown to avoid disclosure of confidential infomation, data are included in totals.

Table L-17. Personal Income From The WIPP (Millions of 1979 Dollars)

Income type	Construction[a] 1980	1981	1982	1983	1984	1985	1986	Total before full operation	Operation each year-- 1987 and after
Direct wages and salaries	2.2	9.3	28.1	27.8	8.4	7.3	10.1	93.2	11.9
Indirect wages and salaries	1.0	4.9	13.7	13.0	4.2	3.7	5.2	45.7	5.5
Interest, dividends, and rents	0.5	2.1	6.1	6.0	1.9	1.6	2.2	20.4	2.5
Total private-sector income	3.7	16.3	47.9	46.8	14.5	12.6	17.5	159.3	19.9
Public-sector income	0.1	0.6	1.8	1.8	0.6	0.5	0.7	6.1	0.8
Net transfer payments	(0.2)	(0.9)	(2.6)	(2.6)	(0.8)	(0.3)	(0.5)	(7.9)	(b)
Net personal income	3.6	16.0	47.1	46.0	14.3	12.7	17.8	157.5	20.7

SOURCE: Larry Adcock and Associates, 1979.

[a]The figures for the construction period 1980 through 1986 include management and design activity.

[b]Transfer payments during the operational phase are assumed to be neutral over time.

sector. In the public sector, about $6 million in personal income will come from the increased activity in the area from additional State and local government and the indirect Federal-agency employment required for support. Thus, the total personal income added to the area during the construction phase of the WIPP project is expected to be $165 million from the beginning of construction until full operation at the beginning of 1987. However, net loss from transfer payments (generally Social Security payments) will decrease this total to just less than $158 million.

The personal income to be derived from the operation of the WIPP project will be significantly different from that derived in the construction phase. The amount of money flowing directly into the local economy during a normal year of operation will be approximately $16.9 million. Although this amount may vary with expenditure patterns in the operation of the plant, this appendix uses a constant figure of $16.9 million. This figure is significantly different from the total direct expenditures of $40 to 42 million annually during the peak years of the construction period.

The estimated $16.9 million annual flow directly associated with the operation of the plant with local procurement and labor will mean that (1) approximately $11.9 million will be realized in personal income by persons connected directly with the plant; (2) wages and salaries derived from indirectly affected businesses in the area will amount to almost $5.5 million; (3) government expenditures required by additional activity and flowing into personal income will total about $0.8 million per year; (4) new dividends, interest, and rents will create approximately $2.5 million in personal income; and (5) during the first years of operation, net transfer payments will be negative, but later they will have a net positive effect. Because of this balancing effect, transfer payments for an average year have been considered neutral. The net result, therefore, will be an annual increase in total personal income of approximately $20.7 million.

L.6 HOUSING, LAND USE, AND COMMUNITY SERVICES

L.6.1 Housing and Land Use

The demand for new housing depends on population and household size. The housing-demand projections developed for the impact analysis prepared in conjunction with this appendix are based on population projections discussed previously and household-size projections derived from several sources.

Household size for the baseline population is based on household-size projections in Bureau of the Census Publication P-25, No. 607, adjusted to 1970 household size in the impact area (derived from the 1970 Census of Housing). Thus, if the 1970 household size in the impact area is above the U.S. average in that year, the projected household size in the impact area will be adjusted upward from the projected U.S. average.

Household sizes for WIPP-induced population changes come from two basic sources. For construction workers and their families, household size is based on information in the Construction Worker Profile (Old West Regional Commission, Washington, D.C., 1975). For operation employees and for persons migrating for indirectly created jobs, household size depends on the likely place of origin of the individuals moving into the area. If there is no obvious or logical single place of origin, then the U.S. average household size (from Bureau of Census Publication P-25, No. 607) will be used. If it appears that most of the individuals will be likely to come from elsewhere in New Mexico, then U.S. household-size projections will be adjusted to account for past State differences from the U.S. average.

Once household sizes have been projected, the demand for housing units is determined by dividing the household size into the appropriate population component. For baseline population changes, the population component is essentially the entire population, with a small adjustment for the portion of the population not living in housing units. This latter group is generally a small fraction of the total population, comprised primarily of people living in nursing homes. The population components for project-related populations are derived by methods discussed earlier in this appendix.

The demand for occupied housing units provides the base for a second set of calculations that show the housing stock necessary to maintain a 3% vacancy rate. This is found simply by dividing the demand for occupied units by 0.97.

The amount of construction activity needed to meet the demand for housing at a 3% vacancy rate is then calculated. It is based on the present assessment of housing and vacancy-rate figures and projected housing requirements.

Finally, housing requirements are allocated to housing types (single family, multifamily, and mobile home) based on information in the Construction Worker Profile. Table L-18 shows the housing-type demands of three classes of population: newcomer construction workers, other newcomers, and long-time residents. Baseline populations are assumed to have the same housing-type demands as the long-time residents, while the preferences of newcomer construction workers are used to allocate housing types for construction newcomers attracted by the project. The in-migrants attracted by indirectly created jobs are assumed to have the same preferences as the other newcomers.

Table L-18. Housing-Type Demand

Type of unit	Newcomer construction workers	Other newcomers	Long-time residents
Single family	34	55	81
Multifamily	11	17	5
Mobile home and other	56	27	14
Totals[a]	101	99	100

Source: Old West Regional Commission, Construction Worker Profile, Washington, D.C., 1975, p. 103.

[a]Totals do not add to 100 because of rounding.

Methods used to calculate land requirements for projected population increases depend on the relative scale of population changes, both under baseline and impact conditions. For small relative changes in population (and therefore small changes in housing demand) the principal demand for land is for housing units and roads. In this case, land-use requirements are calculated on the basis of a relatively generous average lot size (e.g., one-quarter acre) per housing unit. The assumption is that relatively small increases in population will not require proportional increases in all municipal land-use categories. For example, a 5% population increase should not require a 5% increase in land requirements associated with such public facilities as city hall, police stations, and fire stations. In essence, it is assumed that there is some excess capacity in the land associated with such facilities.

For larger relative population increases, the basic assumption is that land requirements for virtually all types of land use will grow in proportion to the housing stock. In this situation, the total land occupied in the municipality is divided by the amount of housing to obtain the land required for each unit of housing.

Finally, it should be noted that for different purposes either of the methods above may be appropriate in determining land-use requirements. For example, the baseline population growth may be substantial, calling for the use of a large land-use figure for each housing unit, while the marginal change associated with the impact population is small, thus requiring only a small land-use figure. Conversely, there are instances in which baseline growth is expected to be small while the project impact is expected to be large, which indicates that a small baseline land-use figure and a large impact figure are appropriate.

L.6.2 Community Services and Facilities

Population increases in a community usually generate two types of impact on community services and facilities. First, in most cases there will be an increase in the demand for services, more or less in proportion to population or housing increases. For example, more people will require more water, generate more sewage, and need more medical assistance. As a result of the increased demand, personnel requirements and operating expenses will generally rise. (For a discussion of operating expenses, see Section L.7, Fiscal-Impact Analysis.)

The second type of impact is an overloading of some part of the system that has a fixed capacity. Generally, fixed capacity implies some type of capital facility, such as a school or a sewage-treatment plant, but it also includes water rights.

The analysis of impacts on community services and facilities therefore requires two basic steps. First, changes in the demand for variable parts of the system (e.g., personnel, cubic feet of natural gas) must be projected. Then, projected increases in demand must be compared with the existing capacity of those parts of the system that are not readily varied in small increments. In other words, an important part of the analysis is to determine whether one of the impacts of a proposed action is to require the construction of, for example, a new sewage-treatment plant.

Two basic methods are used to project the demand for services: the per-capita multiplier and the per-household multiplier (or its equivalent, the multiplier for each occupied housing unit). (For a discussion of the appropriate application and the advantages and disadvantages of these methods, see R. Burchell et al., The Fiscal Impact Handbook, Center for Urban Policy Research, New Brunswick, New Jersey, 1978.) Generally, the per-household multiplier is used to project demands for natural-gas, electricity, and telephone service, while the per-capita method is used to project the demands for water, sewage treatment, solid-waste disposal, fire and police protection, and medical services. With slight modifications, the per-capita multiplier is used to project traffic flows as well.

The multipliers used in each approach are based on recent actual per-capita or per-household figures in the impact area, with adjustments made where appropriate. Adjustments are made when national, regional, or local data indicate that recent per-capita or per-household levels may not remain unchanged over time. For example, in projecting water demand for New Mexico communities, per-capita use rates are changed over time in the same proportion as the changes projected by the New Mexico State Engineer in the "County Profile" series (New Mexico Interstate Stream Commission and New Mexico State Engineer Office, County Profile (various counties), Santa Fe, New Mexico, 1975).

Adjustments are also made if very recent changes in some key factor have caused historical per-capita or per-household use rates to be unreliable for future projections. For example, if a water-price increase has occurred in the past year, resulting in less than a full year's data at the new rate, per-capita use rates will be adjusted on the basis of water-demand price elasticity estimates. (For a discussion of water-demand price elasticity estimates, see G. Bonem et al., Water Demand and Supply in the Albuquerque Greater Urban Area, Bureau of Business and Economic Research, University of New Mexico, December 1977.)

Once demand for a service has been projected, it is compared with the service capacity of the fixed components of the system. This is generally a straightforward numerical comparison (e.g., acre-feet per year of water demand versus annual water rights). The areas in which demand exceeds existing capacity are identified, and the implications of the excess demand are noted.

For several reasons, the level of detail varies considerably in the analysis of each community-service category. First, an investigation of the existing service capacity may show that there is considerable excess capacity, more than needed to accommodate any potential change in demand from baseline or impact population changes. A similar situation exists when the impact area is small in relation to the service area, as often happens with natural-gas, electricity, and telephone service. In this case, even relatively large baseline or impact population changes in the impact area have little effect on the overall service area. In both situations (significant excess capacity and small impact area in relation to the service area) a detailed analysis is generally unwarranted.

At the other extreme, sometimes a proposed action may exert a large relative impact on the demand for a service. In this instance, every effort is made to determine in detail the extent of the impact. This often involves extensive interviews with the manager or other personnel of the agency or company providing the service.

Finally, baseline projections often use less-sophisticated techniques (e.g., unadjusted per-capita multipliers) than do impact projections. This is because baseline projections generally are intended to provide a background against which impacts are evaluated, and not to be a precise projection of service-level demands under baseline conditions. The key factor in the analysis of baseline projections is the effect on system capacity. If a new sewage-treatment plant or school is required under baseline conditions during the period under analysis, then the capital cost of the facility is not assigned to the proposed action whose impact is being studied. On the other hand, if capital facilities or water rights are adequate under baseline conditions but inadequate under impact conditions, the burden of reduced service levels or increased capital costs rests on the proposed action. A more detailed discussion of the treatment of costs is presented in Section L.7.

L.7 FISCAL-IMPACT ANALYSIS

L.7.1 Revenues

Projection techniques for county and municipal revenues are essentially the same. The first step is to collect data on past revenue levels. For New Mexico counties the source is generally the Department of Finance and Administration, New Mexico County Governments, Annual Report. For New Mexico municipalities the source is the equivalent annual report series, New Mexico Municipal Governments. During the period that follows the end of the fiscal year but precedes the publication of the annual reports, county and municipal governments are contacted to obtain reports for the most recent fiscal year.

Once data covering several years have been collected, a preliminary analysis is made. This involves putting each major revenue category (fund) in constant dollars, using the Gross National Product Price Index as a deflator, and examining the record for pronounced trends or major changes. If such trends or changes are found, they are considered in making projections. However, trends generally are gradual and are usually ignored. Major changes usually result from increases in revenues that are not expected to continue each year. These are generally revenues from bond sales or from special government transfers (e.g., drought relief). Such changes are noted and considered in subsequent stages of the projection process, as described below.

After the preliminary examination of the budget is completed, the revenues for the most recent fiscal year are separated into the categories shown in Table L-19. These categories present a clear picture of the type and source of revenues, a picture that is not evident when revenues are classified by fund, as they generally are in municipal or county budgets.

Table L-19. Revenue Categories and Projection Methods Used for New Mexico Municipalities and Counties[a]

Revenue Type	Municipal	County
OWN-SOURCE REVENUE		
Taxes		
Property	PH	PH
Franchise (M)	PC	
Occupation (M)	PC	
Oil and gas	NC/T	NC/T
Lodgers	PC	PC
Gross receipts	PC	PC
Charges and miscellaneous		
Licenses, permits, and fees	PC	PH
Charges for services	PC	PC
Fines and forfeits	PC	PC
Utilities (M)	PH	
Interest on investments	PC	PC
Payments in lieu of taxes	PC	PC
Miscellaneous	PC	PC
INTERGOVERNMENTAL TRANSFERS		
State		
Gasoline taxes	PC	PC
Auto-license distribution (M)	PC	
Cigarette taxes	PC	PC
Gross receipts taxes (M)	PC	
Motor vehicle (C)		PC
Fire allotment	PC	PC
Grants	PC	PC
Miscellaneous (C)		PC
Federal		
Revenue sharing and grants	PC	PC
Miscellaneous (C)		PC
Local (M)	PC	
Other[b]	PC	PC

Source: Adcock and Associates, 1979.

[a]Key: C, county revenue item only; M, municipal revenue item only; PH, projection on per-housing-unit basis; PC, projection on per-capita basis; NC, no change projected.

[b]Included in "other" are revenues not clearly assignable to specific sources.

Once revenues have been allocated to the proper categories, projections are made. The revenue-projection method is based on modifications of methods suggested in The Fiscal Impact Handbook. For baseline projections, most revenue items are projected on a per-capita basis. A smaller group are projected per housing unit, and occasionally a revenue item is projected to show no change.

For most revenue items the most recent actual annual per-capita or per-housing-unit level is taken as the most reliable guide to future levels. Although budgeted levels for the coming fiscal year are checked for major changes from past amounts, budgets are felt to be an unreliable basis for projections. For one thing, they are themselves projections, and their accuracy depends on the skill of the municipal or county officials making them. There is also a tendency for budgets to include a rather large "other" category with unspecified components. Finally, comparisons of past budgeted revenues with actual revenues show a rather large discrepancy between budgeted and actual amounts.

In choosing the most recent actual revenue levels as the guide to the future, several assumptions are made. First, it is assumed that tax rates will not change. While this is probably not a reliable assumption, the alternative is to project the behavior of elected officials, many of whom have not yet been elected, since it is these officeholders who set tax rates. The "no change" assumption seems the more conservative of the two alternatives.

A similar set of assumptions (that is, no change) applies to the level of charges for services, such as utility rates, and distribution formulas for State and Federal transfers. Again, it is not felt that these items will never change, but that predicting the direction and timing of such changes is less reliable than assuming no change.

In essence, the use of the most recent actual revenue level combined with the per-capita or per-housing-unit projection method indicates what revenue levels would be if current conditions continued into the future.

There are some exceptions to the use of the per-capita or per-housing-unit projection method. Some revenue sources are clearly independent of local population or household levels, because of the nature of the tax base or because of the distribution formula. For example, in some counties in New Mexico, oil and gas production (severance) taxes are an important revenue source. These taxes are based on the level of oil and gas production in these counties, a tax base that is not influenced by population or the housing stock.

Four alternatives are available for the projection of such a revenue source. First, an independent projection of the tax base may be used. However, such projections are frequently unavailable. A second possibility is to generate a projection of the base, a process that is usually too time-consuming (and expensive) for an impact analysis. The third approach is to rely on recent trends in the base--or in the tax revenue itself. This is often the best alternative, given the limits of time and budget, but there are situations in which it is not appropriate. For example, in the case of the oil and gas production taxes mentioned above, the recent history of the industry shows great fluctuations in this source of revenue in some counties. As a result, no statistically reliable recent trend can be isolated. This makes it necessary to use the fourth method, which is to assume no change in the total (as opposed to per-capita) level of this source of revenue. While this is the most conservative assumption under the circumstances, it leads to problems when projected revenues are compared with projected expenditures. More will be said about this problem after expenditure-projection methods are discussed below.

There are also exceptions to the use of the most recent actual revenue level for projections, even when per-capita or per-housing-unit projections are used. These exceptions are generally made for those nonrecurring revenue items mentioned above (bond proceeds and government transfers) that may have occurred in the most recent year. In the case of bond proceeds, it is generally assumed that no bond sales will occur unless a specific bond issue has been planned. For government transfers, the general rule is that the most recent year is used except for those programs that are obviously not recurring.

The same general methods are used to project revenues resulting from the impact of the proposed action. However, if the proposed action requires major capital expenditures that would not be required under baseline conditions, an attempt is made to project the magnitude and timing of bond revenues to finance the expenditures.

Table L-19 shows the specific projection methods used for municipalities and counties in New Mexico. In most instances the per-capita multiplier is used. There are three reasons for choosing this method. First, in many cases (e.g., gross receipts taxes) it is clearly the best available alternative.

In some cases it is used even though some other method is clearly better. An example of this is Taylor Grazing Act fees (a Federal transfer) going to the county. Since the base is independent of population, these fees would not be expected to rise in proportion to county population. However, the actual amount of revenue from this source is so small that making an independent projection or assuming no change would involve computational complexities not offset by a measurable improvement in the reliability of the overall revenue projection. Therefore, this source is included with other Federal transfers, and the entire subgroup is projected on a per-capita basis.

A third group of revenue items is projected on a per-capita basis even though population represents only one of the determining factors in the revenue level. This group includes gasoline-tax, cigarette-tax, and auto-license distributions from the State, all of which have distribution formulas in which population is only one factor. However, it can be shown that, if the other items in the distribution formula increase in proportion to population, then per-capita projection methods are appropriate. This condition is likely to be met fairly closely when comparing revenues under baseline and impact conditions. For example, in calculating gasoline-tax distributions the ratio of roads in the local jurisdiction to roads in the State is used along with population. If the number of miles of road in a local area (e.g., municipality) is higher under impact conditions than under baseline conditions in rough proportion to the relative population levels under the two conditions, then the per-capita share of gasoline-tax distributions will be the same under both conditions. Thus, the use of the per-capita projection method may somewhat bias the baseline revenue projections, but will be relatively accurate in comparing baseline and impact conditions.

Revenue items projected on the basis of housing units include utility fees, property taxes, and fees (e.g., building permits), since these are more closely related to the number of housing units than to population.

The only item projected to show no change in the total revenue level in the two examples shown is the oil and gas tax category for the county.

L.7.2 Expenditures

As with revenues, the projection methods used for county and municipal expenditures are essentially the same. The process begins with the acquisition of data from the same sources as those for revenues. Spending for several years is then converted to constant dollars by using the Gross National Product Price Index. Municipal expenditures are allocated by fund, while county expenditures are allocated by service function (e.g., public works, public safety), as dictated by the format of the original data.

Once the data are in constant dollars, they are examined for major trends and nonrecurring items, which are noted and accounted for in the projection process.

After a preliminary analysis of the data, the projections are made. The methods used are a combination of the per-capita multiplier and the case study method, as set forth in The Fiscal Impact Handbook. Basically, this involves projecting future expenditures on the basis of the most recent actual per-capita levels, except that nonrecurring capital-spending items are excluded.

The projections made in the analysis of demands for community services and facilities provide the basis for the capital-spending forecasts. If these projections indicate excess capacity for a particular capital facility for the period under analysis, only recurring capital expenditures are included in the service function. On the other hand, if a capital facility is projected to become inadequate in the future, estimates of expansion costs are included in the forecasts. Recurring capital spending is based on statewide, county, or municipal averages, derived from Department of Finance and Administration annual reports. Capital-facility costs are derived from various sources generally in the building industry; they are expressed in terms of annual debt service.

The same general methods apply to baseline and impact projections. In both cases the approach is to isolate the factors that will result in deviations from recent per-capita spending levels and to incorporate those changes into spending projections.

L.7.3 Net Fiscal Impacts

The underlying philosophy used to make baseline projections of revenues and expenditures is somewhat different from that used to make impact projections, although the methods used in each case are similar. Baseline projections are used to judge impacts. As a result, less detail goes into the baseline projections. For example, for counties, all spending is projected to grow in proportion to population under baseline conditions, while some revenue items may not be projected to grow. This can result in a projected deficit for a county. However, the proper interpretation of this result is not that the county is necessarily facing fiscal difficulties, but rather that, if spending grows in proportion to population, some revenue sources will have to increase by more than the projected amount. As an alternative, spending (and service) levels may be reduced from current per-capita levels.

No matter what fiscal adjustments may be made under baseline conditions, the baseline projections are intended to indicate orders of magnitude for spending and revenues during the period under analysis.

On the other hand, fiscal-impact projections are intended to show, with as much accuracy as possible, given historical data and information obtained in interviews with local officials, the actual likely fiscal effect of the proposed action. Every effort is made to include in the analysis only the fiscal impacts induced by the proposed action. Thus, a projected fiscal deficit or surplus associated with the proposed action should be interpreted as such. Not only is greater detail incorporated into impact projections, but generally these projections can be made with greater reliability than can baseline projections. For example, projecting oil and gas tax revenues causes problems under baseline conditions, but since oil and gas production generally is not expected to be affected by the proposed project, no change in these revenues is attributable to the project, regardless of what happens to oil and gas taxes.

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ANNEX

A NON-SURVEY TECHNIQUE FOR CONSTRUCTING A DIRECT REQUIREMENTS REGIONAL INPUT-OUTPUT TABLE

by

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In an article entitled "An Appraisal of Non-Survey Techniques for Estimating Regional Input-Output Models," David G. McMenamin and Joseph Haring state that:

> "Non-survey or minimum-survey methods for constructing regional input-output tables are attractive to model builders because of the relatively small cost involved as compared with full survey models." (9)

McMenamin and Haring go on to state that many of the non-survey techniques have not been highly successful in the past, but recently accuracy seems to have improved by the use of newly developed techniques. Indeed, the full survey method of building input-output tables is costly. While records are rather poor, it is estimated that the 1960 New Mexico table cost approximately $100,000 to construct and work was accomplished over a three-year period. Recent estimates indicate that a new table for New Mexico of the full-survey type would probably cost well over $100,000.

Such costs for a full-survey table for relatively small states makes the non-survey technique desirable in terms of available resources. However, the level of accuracy of the non-survey technique table is still in question. Therefore, in this study, an in-depth examination of several aspects of the location quotient adjustment process for deriving a non-survey input-output table from national coefficients was undertaken. In performing the task, two basic questions were answered: (1) can the table be constructed with available data and available techniques? and (2) how does the table compare with a full-survey based table?

The results of this study could be extremely important not only to the research work being conducted at the University of New Mexico, but to the State in general. Since the 1960 New Mexico full-survey table was compiled, little updating has occurred (2, Appendix A). In early 1970 an examination was made of this original survey-based table to determine if a household sector could be added to the direct coefficients table given the information available from the national level. This was accomplished in 1971. Basically, this constitutes the updating of the original 1960 table.

It is apparent that since the economic sector mix and the level of sophistication of the economy has changed significantly since 1960, the value of the 1960 table for research work is questionable. In this study, a non-survey 1960 table was derived from available information and then compared to the full-survey table in order to determine the level of accuracy of the non-survey technique. Since the tests proved positive, the BBER used the technique to construct a non-survey 1972 table for the State.

METHOD

The basic method employed in this study centers around the use of location quotients for determining the adjustment to be made to the direct coefficients of the United States input-output table in order to produce a regional direct coefficient input-output table. The result is a non-survey input-output table of direct coefficients for the New Mexico economy of 1960. Consequently, the location quotients were those for the period 1960 while the national survey coefficients are from 1963. The method therefore makes the naive assumptions that the coefficients did not change between 1960 and 1963, and that on the average the techniques of production in New Mexico are similar to those in the United States, at least in the 1960-1963 period.

The objective of this paper is not to engage in a digression of the relative positive and negative aspects of the input-output technique itself, but it does seem in order to discuss the assumption that the techniques used in production are constant to a specific industry regardless of its geographic location or size. Basically, a survey-derived input-output table for a specific region should point out the various techniques used in production when that table is compared with a table compiled for any other region. We would expect some differences; for example, the use of labor as a quantity input to production would vary from region to region depending upon the alternative costs in the production of a product, recognizing the fact that the producer minimizes his cost and that the labor costs relative to the price of other inputs vary from region to region.

The non-survey technique employed in this study, however, cannot take the varying techniques of production under consideration because the process of adjustment does not account for them. In this way the non-survey table differs from the region-specific survey type model.

Although many other minor dissimilarities can be distinguished, one other major distinction in this method exists. This variation concerns an assumption that normally occurs, not in the building of the model but in its use. In employing an I-O model for deriving the impact of changes to a specific industry in terms of size or production levels, or for the addition or deletion of industries in an area, normally we make the assumption that a specific industry or firm buys input products from other firms in the area that appear to produce those needed products for the production of the buyer's products. In other words, under normal conditions, the input-output process is not refined to the degree needed to adjust for the absence of a specific product needed from the existing industry that appears to produce the input simply because the Standard Industrial Classification code listing encompasses that specific input.

In the building of a survey-type input-output model this assumption is not needed, since the inputs are traced to domestic producers in the existing economy or the input is designated as an import. However, in the non-survey technique of building the input-output model, an assumption is also made that if the industry exists in the area, the product is bought in the area, and thus it is available. The location quotient does nothing more than adjust the level of purchasing of that specific input. Therefore, under normal conditions, it may be assumed that the non-survey technique employed in this study could slightly overestimate the purchasing of the required input-product from existing industries in the area by another existing industry. This could possibly underestimate the importation of needed inputs by any one specific industry. On the other hand, since a firm is classified by the major product (or service) it produces, then some product identification is obscured through classification and the result is an underestimate of available products. The latter situation appears to be the lesser of the two-sided problem.

Turning to the specific method used in this study, the first matter to consider is that of the adjustment technique, specifically, the location-quotient derivation and its application to the U.S. table. Two types of location quotients were used in this study. The first is the traditional type, which is a comparison of the relative importance of an industry in a region with its relative importance in the Nation, by use of employment figures. Secondly, the output-location quotient accomplishes the same comparison; however, instead of employment, the dollar volume of output is used.

The following is a description of the location quotients employed.

LOCATION QUOTIENTS

Employment Location Quotient

In its simplest form the employment-location quotient is defined for the i^{th} industry as:

$$ELQ = \frac{e_i/e}{E_i/E}$$

where:

ELQ is defined as the Employment-Location Quotient;
e_i is the regional (New Mexico) employment in the i^{th} industry;
e is the total employment in the region (New Mexico);
E_i is the national (total) employment in the i^{th} industry;
E is the total national employment (13,14).

If the location quotient is equal to 1, we assume that the region is self-sufficient in that industry. That is, on the average, the region is producing its domestic needs specific to that industry. If the location quotient is less than 1, the region is probably not producing its domestic needs in relation to that industry, and therefore part of the industry-specific consumption of that region is necessarily imported. On the other hand, if the location quotient is more than one, we assume that the region is producing goods for export./ Several basic qualifications are necessary in order for the location quotient to be a realistic tool.

One necessary assumption is that the consumption patterns for each region are analogous to those of the nation as a whole, and that all production in the United States is consumed domestically. We can easily see that if the consumption is not 100 percent domestic, then a location quotient for any specific industry which is equal to unity does not necessarily mean that that industry is just self-sufficient. It may in fact be a net exporter.

Moreover, if national consumption of a specific product warrants importation of that product, a location quotient greater than unity may be needed for an industry to be self-sufficient in the production of that specific product. However, if we assume that the consumption patterns are fairly equal from region to region, and that imports and exports are small relative to total production, then the location quotient concept is intuitively a logical tool for the adjustment process.

Output-Location Quotients

Basically, those deficiencies and positive aspects of the employment-location quotient hold true for the output-location quotient. The output-location quotient is defined as:

$$XLQ = \frac{x_i/x}{X_i/X}$$

where:

- XLQ is defined as the dollar output-location quotient;
- x_i is the dollar output of the i^{th} industry in the region (New Mexico);
- x is the dollar output of all industry (Gross State Product) in the region (New Mexico);
- X_i is the dollar output nationally of the i^{th} industry;
- X is the total dollar output of all industry (Gross National Product) in the nation.

We should note at this point that the output-location quotient is a non-traditional location quotient. The use of the output-location quotient is necessary in this study simply because employment location quotients do not properly represent an adjustment factor for certain industries. This is true because of the incompleteness of data on employment in certain industries or the simple non-existence of certain types of data needed to make the employment-location quotient a workable tool for other industries (particularly agriculture).

Direct Coefficients

The objective of this study is to produce a table of direct coefficients for a region by adjusting the national technical direct coefficients from the 1963 national study. The U.S. study used in this research consists of 352 endogenous sectors plus 27 exogenous sectors including such things as household, inventory-evaluation adjustment, net inventory change and government expenditures in addition to net exports and imports (23).

Procedure for Adjustment

Theoretically, the use of location quotients to adjust the national input-output coefficients can be justified by the assumption that if an industry in an area is not of average size, then it cannot supply all of the needs of other industries in terms of product inputs. The adjustment procedure using location quotients assumes that the selling industries are able to supply a product to the buying industries in relation to their size. Their size in the study is determined by both the industry's employment and output.

The location quotients, having once been computed, are used as adjustment factors on a row-by-row basis to the national table. Any location quotient which is greater than 1 indicates in the most basic terms that that industry is an exporting industry. That is, since it produces more, or employs more people than the average industry employs for the domestic location in which it is set, then the excess product is exported and it becomes a net exporting industry. For those industries which had a location quotient greater than 1, we assumed that they continued to buy input products in a similar fashion to that of the average industry across the United States; therefore, any upward adjustment in the direct coefficients on the national table would indicate that that specific industry is selling more of a product, percentage-wise, to a region-specific industry than that industry can use. This assumption, of course, would be unrealistic. Therefore, all location quotients which were greater than 1 were set to a constant factor of unity. This situation means that the selling industry, with a location quotient of unity, provides no more or no less than the products needed as inputs to other industries.

Data Limitations and Location-Quotient Computation

In trying to gather data to compute the needed location quotients for 352 endogenous sectors, the obvious conclusion is that the finer the breakout of the sub-industries of any major industry, the more limited the data. For example, excellent wage- and salary-employment statistics are available for a complete year at the two-digit SIC code level for all manufacturing industries. However, when the industries are disaggregated to a basic four-digit SIC code level, then the data becomes harder to obtain. Those employment data which are available at the four-digit SIC code level are published only once a year for the first quarter of the year. Therefore, when computing the employment location quotients, use of year-round data at the four-digit SIC code level was impossible, and only first-quarter information was used.

This situation could lead to a problem: the first quarter may not be representative of the employment in the industry, since (1) the industry may expand or contract throughout the year and the level in the first quarter is not the average for the year and (2) many industries are beset with seasonal employment and the first quarter nationwide is normally the slowest quarter of the year. Therefore, employment in the first quarter in many cases would not be representative of the total year because of seasonal fluctuation.

To eliminate part of the problem of using first-quarter data, the 1960 first-quarter data could be averaged with the 1961 data to produce a figure which probably would be closer to the 1960 average than that produced by using the first-quarter data. However, since this procedure would involve averaging two quarters from the same time of the year, no adjustment would be made for seasonal fluctuation. The effort in making such an averaging adjustment appeared to be a fruitless task since in computation of the location quotients by both methods, very little difference occurs in the results. This fact can be accounted for because a region in most cases would experience the same fluctuations in employment for any specific industry that the nation would in the very short run. Therefore, it was decided that the use of first-quarter data for 1960 would be as relevant to the situation as the average of the first quarters of 1960 and 1961. The employment-location quotients were therefore applied to all of the manufacturing sectors.

While it would have been preferable to use employment-location quotients for all sectors defined in the national table, such a plan was not possible considering the limitations of the data. For example, very little information is available on employment in the agricultural sector for the sub-industry categories listed on the national table. A figure for employment in all agriculture, of course, is available (24). However, when trying to locate employment in dairy farms, or for poultry and egg production, or in meat animal and miscellaneous livestock products, or in cotton, etc., the task is highly difficult if not impossible. Furthermore, if figures can be located, there is no guarantee that those figures are inclusive of the total employment in that industry, since many of the production units in the agricultural industry are nothing more than "ma and pa" operations, with employment of the proprietor rarely counted in the employment statistics at the sub-industry level. Therefore, after careful examination of the problems involved in trying to use employment-location quotients for the agricultural sector, a decision was made to use a non-traditional location quotient which we have called an output-location quotient (as explained in the foregoing section of this paper).

AGGREGATION OF THE NATIONAL TABLE

While the objective of this study is to produce a nonsurvey input-output table, the overall result of the study can be said to include a comparison of the nonsurvey table with a survey data table for New Mexico of 1960. The 1960 New Mexico table contained 42 endogenous sectors (2). In order to make such a comparison, the 352 endogenous sectors in the national table must be aggregated to the 42 sector level. Note that 292 of the 352 sectors are specific to manufacturing basically at the four-digit SIC code level. Therefore, the manufacturing portion of the table makes up nearly 83 percent of the total sectors defined in the national table. While aggregation is necessary due to the objective of the study, it should also be desirable for any region which could be defined below the national level because a high probability exists that something less than the 292 defined manufacturing sectors exist in that region. This premise is particularly true in New Mexico with its small manufacturing sector that comprised approximately 7 percent of total wage and salary employment in 1960 (33).

The aggregation process could have been accomplished using several means. First, a simple averaging of the coefficients for each by adding together each of the national sectors into its respective New Mexico sector, and then dividing by the number of sectors included. Obviously, this is a naive approach. Secondly, the sectors could have been averaged by weighting them as to their employment, which was apparently done in previous research (Shaffer, etc.) using the location-quotient method (13, 14). However, a third method exists which appeared to be better. Estimated output for each of the identified national sectors was computed and these sectors were weighted by their output. Obviously, one of the effects of this method would be the same as using employment as a weight -- that is, to give the larger industries in the state more influence in the determination of the direct coefficients than the smaller industries when two or more industries of unequal size are aggregated together. However, the third method did something more than the aggregation by employment size was able to accomplish. The aggregation by volume of output accounted for varying levels of productivity which exist from industry to industry. For those industries which had been adjusted by output location quotients the output figures already existed for the aggregation process.

For other industries which had been adjusted by employment-location quotients, estimating output in 1960 was necessary. Luckily, output data for 1958 and 1963 existed from the various detailed Censuses of Manufacturing, Business, etc. for those industries which had been adjusted by employment-location quotients (26). Therefore, the procedure was to arrive at an estimated level of output per employee (productivity) using a weighted average for the two data years. That output per employee is applied to the number of employees to get an estimated total output for that industry or sub-industry in 1960. Where possible, the level of productivity was specific to that State. However, some sub-industries were so small that no information on a state level was given in the various censuses. Therefore, productivity at the regional or national level had to be used.

The question arose as to how productivity at the national level compares with productivity for the individual states. In order to determine whether or not national productivity would be valid measure of local productivity, a random sample of five industries was chosen and an analysis was completed with from 10 to 20 observations, by state. The results of this analysis showed that the variation in productivity was negligible in the five industries among the states tested. Therefore, based on this random selection of five industries, we concluded that national productivity was a valid alternative to statewide productivity when necessary for use in computing estimated output.

COMPARISON

In this portion of the study, a description of the comparison between the 1960 survey-based table and the 1960 non-survey table is given. This comparison was performed with 39 and not 42 columns. Three sectors from the survey-based 1960 New Mexico table had to be deleted as they were defined differently in the non-survey table. A comparison test was performed that was similar to the test described by Shaffer and Chu in their article on non-survey based input-output techniques (14).

To test the accuracy of the non-survey table, X^2 was computed for each column in the direct requirements table, taking as the true values the technical coefficients from the survey-based 1960 New Mexico Input-Output Table published by the UNM Bureau of Business Research. Two comparisons were made between the survey-based table and the direct requirements table with function weights: (1) a non-survey table aggregated without the use of location quotients to the 1960 survey-based table; and (2) a direct requirements table with both function weights and location quotients to the 1960 survey-based table. The null hypothesis was that the non-survey technique would yield direct requirements coefficients which were the same as those in the survey-based table. An evaluation was made of the results of the tests at the 95 percent level with 38 degrees of freedom. The results of the tests were as follows: for the direct requirements table without location quotients the χ^2 statistic in 22 of 39 columns was in the rejection interval,[1] indicating that function weights alone are not enough to produce reasonable accuracy. However, for the table with the location quotients, the χ^2 statistic was in the rejection interval in only 8 of the 39 columns. This figure indicates that the location-quotient method produces results that are reasonably close to the 1960 survey value.

CONCLUSION

In the introduction we stated that two questions were to be answered in this study: (1) can the table be constructed with available data and techniques? and (2) how does the table compare with a full survey-based table?

First, a non-survey based table obviously can be constructed in the manner by which it was accomplished in this project. The methodology in this study was considerably more time consuming and difficult than the location-quotients adjustment procedure described in the recent literature (9, 11, 13, 14). The procedure of adjusting coefficients previous to aggregation should be more accurate. Unfortunately, the study cannot attest to a difference in accuracy; however, obtaining data for the 352 endogenous sectors listed in the national input-output tables of 1963 and 1967 is more detailed and difficult than locating data for the more highly aggregated sectors, such as those appearing in the New Mexico and Washington state tables (1, 3, 4).

The advantage of the lower-cost non-survey technique is significant. Compared with a survey-based table, the total time involved in producing a non-survey based table is minimal. (A 1972 New Mexico non-survey table was produced in five weeks using this technique. The cost was less than $5,000).

The comparison of the location-quotient adjusted non-survey based table with the full survey table showed that some columns were significantly different. However, analysis of the columns which varied significantly in the two tables indicates that certain major sectors accounted for a large portion of that variation. For example, five of the six sub-sectors in agriculture showed significant variation, and one of the six sub-sectors of the mining industry varied significantly. Both of these major sectors were adjusted by output-location quotients and since the mining sector

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1 $\chi^2_{.05}$ with 38 d.f. was computed according to the formula:

$$\chi^2_\alpha = n\left(1 - \frac{2}{9n} + Z_\alpha \sqrt{\frac{2}{9n}}\right)^3 \text{ where } n = 38 \text{ and } Z_\alpha = 1.645.$$

(Z_α is the normal deviate at the 95 percent level.)
Thus $\chi^2_{.05} = 53.380$.

Column Number	Industry	χ^2 Value Without Location Quotient Adjustment	χ^2 Value With Location Quotient Adjustment
1	Meat Animals	1837.86908	1836.52435
2	Dairy Products	3.91990	1.98851
3	Feed Grains	121.61327	110.09386
4	Cotton	68.22235	63.40295
5	Other Farm Products	79.11645	66.52820
6	Agricultural Services	1500.84171	535.16665
7	Copper Mining	156.29900	18.90447
8	Non-ferrous Ores Mining	126.60604	11.98700
9	Crude Oil & Petroleum	19.60852	11.60208
10	New Construction, Other	569.80825	70.58260
11	Chemical Mining	9.83117	0.80598
12	Coal, Stone & Clay Mining & Quarrying	157.44106	15.11602
13	Meat Products, Processed	334.29984	54.75327
14	Dairy Products, Processed	64.18916	0.17410
15	Grain Mill & Baked Products	466.76550	8.19718
16	Miscellaneous Food Products	107.07334	3.11619
17	Lumber, Wood & Furniture	56.70250	9.85470
18	Printing & Publishing	1155.28348	11.25779
19	Chemicals, Plastics & Rubber	94.98391	11.31261
20	Petroleum Refining	29.28434	0.92766
21	Concrete & Stone Products	10.50268	2.07352
22	Electrical Equipment & Machinery	95.06541	0.28200
23	Fabricated Metal Products	613.84833	0.25926
24	Miscellaneous Manufacturing	153.26054	0.92913
25	Railroads	20.06416	3.00616
26	Other Transportation	7.69775	0.51413
27	Gas & Oil Pipelines	17.40511	15.08370
28	Communications	11.00637	6.57453
29	Electric & Water Utilities	39.57436	2.81252
30	Gas Utilities	3321.07094	3320.87176
31	Wholesale Trade	21.68048	4.12142
32	Retail Trade	4.84526	0.13118
33	Finance & Insurance	2.77826	0.67102
34	Real Estate	4.20676	1.98422
35	Hotels & Motels	3.75628	0.28428
36	Personal Services	69.65323	1.18209
37	Business Services	1.58041	0.22846
38	Auto Repair	340.81264	1.46602
39	Medical & Educational	28.18200	0.15089

fared well in the test there is no reason to believe that the output-location quotient adjustment accounted for the variation in agriculture. Therefore, concerning agriculture and mining, six of the twelve columns varied significantly between the two tables. These columns account for three quarters of the total columns which had χ^2 in the unacceptable range.

In manufacturing, only one column showed significant variation between the two tables. This column was meat packing (closely related to the agricultural sector). This χ^2 (54.75) could be said to be in a marginal range of acceptance. The gas-utilities column had the largest χ^2 of any of the columns. The variation in the gas-utilities column could be expected since the gas-utilities in New Mexico are different in activity compared with the national average. The New Mexico gas utilities are both producers and distributors and therefore the national coefficients should not and do not reflect this vertical integration.

Considering these results, we believe that the non-survey based technique used to build a 1960 table for New Mexico is an acceptable procedure and gives valid results in a majority of the columns. For those columns that have χ^2 significantly different from the survey-based 1960 table, most problems occur in the one sector (agriculture) for which data is very limited.

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Attachment A

TABLE 8.—TECHNICAL COEFFICIENTS: DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT, NEW MEXICO, 1960

[Each entry shows direct purchases by the sector at top, per dollar of its output, from sector at left.]

INDUSTRY PURCHASING

INDUSTRY SELLING

Industry selling		1 Meat animals	2 Dairy & poultry	3 Food grains & field crops	4 Cotton & cottonseed	5 Vegetables, fruits, et al.	6 Agricultural services	7 Copper	8 Uranium	9 Petroleum & natural gas	10 Oil & gas field services	11 Potash	12 Other mining	13 Meat packing	14 Processed dairy products
		Agriculture						Mining						Manufacturing	
Agriculture	Meat animals 1													.5650	
	Dairy & poultry 2		.0164							*	*	*	.0001	.0436	.3385
	Food grains & field crops 3	.1113	.3229	.0163	.0020	.0032								.0231	
	Cotton & cottonseed 4		.0046		.0025										
	Vegetables, fruits, et al. 5					.0038	*	*	*	*	.0002	*		*	*
	Agricultural services 6	.0070	.0099	.0590	.1681	.0296									
Mining	Copper 7							.0166							
	Uranium 8								.1926						
	Petroleum & natural gas 9									.0004					
	Oil & gas field services 10									.0702	.0592				
	Potash 11											.0369			
	Other mining 12							.0570	.0177			.0091	.0034		
Manufacturing	Meat packing 13						.0001	*	*	.0001	.0008	.0001	.0001	*	*
	Processed dairy products 14						*	*	*	*	.0004	.0001	.0001	*	.0587
	Grain mill & bakery products 15	.0445	.1396	.0010	.0006	.0010			*	*	.0001	*			
	Miscellaneous food products 16	.0017	.0059				*	*	*	*	.0002	*	*	.0005	*
	Lumber & Wood products 17	.0014	.0019	.0017	.0011	.0007		.0027	.0020			.0006			
	Printing & publishing 18						.0006	.0002	*		.0037	.0009	.0003	.0014	.0011
	Chemicals 19	.0009	.0019	.0015	.0027	.0018						.0008			.0003
	Petroleum refining 20	.0064	.0050	.0246	.0126	.0138	.0209	.0013	.0041	.0099	.0252	.0033	.0150	.0015	.0043
	Concrete & stone products 21	.0009	.0013	.0011	.0008	.0005						.0002			
	Machinery & Electrical equipment 22			.0005	.0004						.0013	.0005			
	Fabricated metal products 23										.0014	.0003			
	Miscellaneous manufacturing 24														
Transport & Utilities	Railroads 25	.0012					.0001	.0404	.0013	.0006	.0019	.0119	.0013	.0019	.0006
	Trucking & other transportation 26	.0035	.0054		.0346		.0001	.0004	.0039	.0011	.0190	.0029	.0031	.0010	.0020
	Gas & petroleum pipelines 27									.0005					
	Telephone & telegraph 28	.0025	.0038	.0034	.0043	.0030	.0050	.0011	.0014	.0024	.0058	.0028	.0054	.0021	.0029
	Electric light & power 29	.0036	.0036	.0036	.0036	.0036	.0164	.0024	.0046	.0022	.0001	.0246	.0116	.0028	.0150
	Gas utilities 30						.0315	.0196	.0097		.0018	.0180	.0016	.0030	.0068
Trade	Wholesale 31	.0144	.0298	.0083	.0052	.0060	.0064	.0115	.0243	.0308	.0487	.0177	.0403	.0052	.0047
	Gasoline service stations 32	.0061	.0048	.0233	.0119	.0130	.0198	*	.0003	.0002	.0021	.0003	.0005	.0015	.0041
	Eating & drinking places 33						.0004	.0002	.0003	.0005	.0059	.0009	.0009	.0004	.0003
	Other retail trade 34	.0432	.0896	.0248	.0155	.0180	.0291		.0003	.0010	.0007	*	.0001	.0002	.0005
FIRE	Finance & insurance 35	.0300	.0201	.0282	.0410	.0147	.0219	.0099	.0007	.0009	.0219	.0094	.0142	.0100	.0060
	Real estate 36	.0105	.0118	.0062	.0082	.0015	.0038	.0010	.0034	.0035	.0046	.0066	.0006	.0017	.0180
Services	Hotels & motels 37						.0004	.0002	.0002	.0004	.0010	.0009	.0008	.0003	.0003
	Personal services 38						.0006							.0019	.0027
	Business services 39					.0002	.0059	.0008	.0007	.0025	.0225	.0002	.0188	.0011	.0241
	Auto & other repair services 40	.0054	.0102	.0268	.0114	.0151	.0581	.0007	.0010		.0112	.0008	.0177	.0025	.0121
	Medical & professional 41						.0028							.0035	.0040
	Research & development 42							.0008	.0088	.0060	.0044	.0073	.0031		

Industry selling	15 Grain mill & bakery products	16 Miscellaneous food products	17 Lumber & Wood products	18 Printing & publishing	19 Chemicals	20 Petroleum refining	21 Concrete & stone products	22 Machinery & Electrical equipment	23 Fabricated metal products	24 Miscellaneous manufacturing	25 Railroads	26 Trucking & other transportation	27 Gas & petroleum pipelines	28 Telephone & telegraph
	Manufacturing										Transport & Utilities			
Meat animals 1												.0021		
Dairy & poultry 2	.0075	.0005				*						*	*	*
Food grains & field crops 3	.3211													
Cotton & cottonseed 4		.0544												
Vegetables, fruits, et al. 5	*	.0358	*	.0001	*	*	*	*	*	*		.0004	.0001	.0002
Agricultural services 6														
Copper 7														
Uranium 8														
Petroleum & natural gas 9					.1450	.2760								
Oil & gas field services 10														
Potash 11							.0109							
Other mining 12						.0052	.0170							
Meat packing 13	*	.0001	.0001	.0002	.0002	.0002	.0002	.0002	.0001	.0002	*	.0023	.0004	.0005
Processed dairy products 14	*	*	.0001	.0001	.0001	.0001	.0001	.0001	*	.0001		.0009	.0002	.0003
Grain mill & bakery products 15	.0159		*	*	*	*	*	*	*	*		.0003	.0001	.0001
Miscellaneous food products 16	*	.0101	*	.0001	.0001	.0001	.0001	.0001	*	.0001	.0097	.0138	.0001	.0002
Lumber & Wood products 17			.1777						.0011	.0006		.0029		
Printing & publishing 18	.0020	.0028	.0013	.0044	.0017	.0004	.0013	.0016	.0020	.0018	.0003	.0055	.0003	.0046
Chemicals 19					.0046				.0013					
Petroleum refining 20	.0039	.0060	.0023	.0021	.0023	.0380	.0035	.0027	.0005	.0036	.0383	.0132	.0012	.0009
Concrete & stone products 21							.1158				.0019		.0042	
Machinery & Electrical equipment 22	.0002		.0017				.0058	.0117	.0144	.0098				
Fabricated metal products 23							.0058	.0018	.0431	.0098				
Miscellaneous manufacturing 24										.0196				
Railroads 25	.0002	.0004	.0106	.0007	.0280	.0003	.0009	.0004	.0019	.0016	.0054	.0005	.0004	.0003
Trucking & other transportation 26	.0036	.0017	.0130	.0021	.0017	.0011	.0026	.0012	.0028	.0058		.0266	.0035	.0002
Gas & petroleum pipelines 27					.1584	.3047								
Telephone & telegraph 28	.0043	.0057	.0068	.0079	.0075	.0026	.0075	.0061	.0062	.0040	.0014	.0159	.0054	.0132
Electric light & power 29	.0046	.0255	.0111	.0065	.0147	.0060	.0056	.0043	.0056	.0034	.0008	.0051	.0038	.0062
Gas utilities 30	.0054	.0101	.0021	.0019	.0028	.0054	.0061	.0018	.0028	.0017	.0005	.0029		.0010
Wholesale 31	.0173	.0377	.0121	.0206	.0094	.0073	.0168	.0284	.0042	.0085	.0096	.0145	.0039	.0091
Gasoline service stations 32	.0037	.0056	.0022	.0020	.0022	.0020	.0050	.0025	.0006	.0034	*	.0162	.0011	.0008
Eating & drinking places 33	.0003	.0004	.0009	.0017	.0016	.0016	.0013	.0013	.0006	.0016	*	.0043	.0026	.0043
Other retail trade 34	.0006	.0015	.0032	.0016	.0016	.0007	.0055	.0057	.0005	.0012	.0020	.0038	.0027	.0027
Finance & insurance 35	.0115	.0177	.0138	.0227	.0203	.0048	.0112	.0092	.0022	.0136	.0002	.0153	.0194	.0018
Real estate 36	.0110	.0205	.0040	.0210	.0181	.0061	.0080	.0147	.0024	.0228	.0018	.0243	.0040	.0092
Hotels & motels 37	.0004	.0004	.0008	.0026	.0014	.0017	.0003	.0005	.0004	.0013	*	.0010	.0025	.0037
Personal services 38	.0019	.0012	.0004	.0069			.0016	.0016	.0010	.0002	.0004	.0038		.0002
Business services 39	.0140	.0128	.0240	.0152	.0051	.0074	.0070	.0062	.0079	.0136	.0045	.0258	.0061	.0071
Auto & other repair services 40	.0036	.0120	.0204	.0070	.0014		.0162	.0047	.0049	.0005	.0005	.0155		.0051
Medical & professional 41	.0019	.0056	.0075	.0063	.0111	.0111	.0099	.0100	.0026	.0055	.0142	.0045	.0079	.0081
Research & development 42														

Industry selling	29 Electric light & power	30 Gas utilities	31 Wholesale	32 Gasoline service stations	33 Eating & drinking places	34 Other retail trade	35 Finance & insurance	36 Real estate	37 Hotels & motels	38 Personal services	39 Business services	40 Auto & other repair services	41 Medical & professional	42 Research & development	
	Transport & Utilities		Trade				FIRE		Services					R & D	
Meat animals 1														*	1
Dairy & poultry 2			*	*	.0001	*	*	*		*	*		.0003		2
Food grains & field crops 3									.0010						3
Cotton & cottonseed 4															4
Vegetables, fruits, et al. 5	*		.0002	.0001	.0003	.0001	.0001	.0007	*	*	.0001	*	.0014		5
Agricultural services 6															6
Copper 7															7
Uranium 8															8
Petroleum & natural gas 9		.3611													9
Oil & gas field services 10															10
Potash 11															11
Other mining 12															12
Meat packing 13	*		.0006	.0004	.0011	.0005	.0005	.0003	.0001	.0002	.0003	.0001	.0004	*	13
Processed dairy products 14	*		.0003	.0002	.0007	.0003	.0002	.0002	.0001	.0001	.0002	.0001	.0028	*	14
Grain mill & bakery products 15			.0001	.0001	.0002	.0001	.0001	.0001	*	*	.0001	*	.0008	.0001	15
Miscellaneous food products 16	*		.0002	*	.0004	.0002	.0002	.0001	*	.0001	.0001	*	.0008		16
Lumber & Wood products 17		.0004									.0070			.0007	17
Printing & publishing 18	.0027		.0183	.0099	.0109	.0115	.0113	.0110	.0099	.0080	.0070	.0050	.0058	.0007	18
Chemicals 19	.0008	.0001									.0012			.0009	19
Petroleum refining 20	.0010	.0011		.0106	.0022	.0028	.0030	.0014	.0022	.0030	.0043	.0068	.0034	.0001	20
Concrete & stone products 21			.0009								.0045				21
Machinery & Electrical equipment 22		.0002		.0001		.0012		.0003		*	.0105		.0003	.0077	22
Fabricated metal products 23		.0001		.0001		.0012		.0002		*	.0105			.0066	23
Miscellaneous manufacturing 24	.0012		.0005		.0016	.0031				.0020				.0004	24
Railroads 25	.0007	.0015	.0103			*	*	*	*	.0013	.0012	*	.0002	.0010	25
Trucking & other transportation 26	.0009	.0021	.0111	.0077	.0003	*	.0006	.0002	.0001	.0021	.0056	.0004	.0011	.0008	26
Gas & petroleum pipelines 27		.0269													27
Telephone & telegraph 28	.0115	.0006	.0169	.0167	.0180	.0012	.0148	.0122	.0256	.0130	.0202	.0094	.0132	.0044	28
Electric light & power 29	.0533	.0025	.0042	.0082	.0194	.0096	.0034	.0035	.0410	.0152	.0031	.0068	.0082	.0017	29
Gas utilities 30	.1116		.0029	.0058	.0174	.0056	.0011	.0025	.0325	.0105	.0016	.0031	.0050	.0001	30
Wholesale 31	.0044	.0032	.0211	.0054	.0053	.0056	.0021	.0009	.0160	.0179	.0111	.0161	.0116	.0017	31
Gasoline service stations 32	.0009	.0011	.0059	.0100	.0021	.0026	.0028	.0013	.0021	.0028	.0028	.0065	.0032	.0004	32
Eating & drinking places 33	.0002		.0044	.0030	.0088	.0036	.0038	.0025	.0006	.0011	.0014	.0007	.0024	.0004	33
Other retail trade 34	.0002	.0002	.0044	.0018	.0027	.0071	.0028	.0049	.0051	.0043	.0064	.0050	.0037	.0002	34
Finance & insurance 35	.0383	.0013	.0090	.0245	.0327	.0202	.0251	.0269	.0104	.0122	.0120	.0200	.0114	.0007	35
Real estate 36	.0025	.0043	.0298	.0442	.0475	.0588	.0233	.0160	.0268	.0539	.0187	.0276	.0242	.0007	36
Hotels & motels 37	.0002		.0018	.0023	.0002	.0023	.0034	.0005	.0009	.0006	.0007	.0006	.0029	.0001	37
Personal services 38			.0017	.0010	.0277	.0032	.0001	.0010	.0463	.0139	.0006	.0013	.0120	.0120	38
Business services 39	.0012	.0011	.0056	.0148	.0125	.0157	.0193	.0118	.0112	.0081	.0413	.0120	.0127	.0010	39
Auto & other repair services 40		.0037	.0068	.0024		.0023	.0024	.0028	.0091	.0077	.0015	.0014	.0040	*	40
Medical & professional 41	.0042	.0050	.0101	.0120	.0105	.0115	.0204	.0074	.0134	.0147	.0087	.0052	.0486	.0032	41
Research & development 42														.0007	42

* Less than .00005.

Source: New Mexico Business, October 1965, "A Preview of the Input-Output Study", Arthur A. Blumenfeld et al, Bureau of Business Research, University of New Mexico.

With Location Quotient Adjustment

NEW MEXICO INPUT-OUTPUT MODEL, 1960
TECHNICAL COEFFICIENTS: DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT

INDUSTRY PURCHASING

INDUSTRY SELLING		1	2	3	4	40	41	42		**** ROW SUMS ****
MEAT ANIMALS	1	0.27096	0.00000	0.05196	0.0441	0.00000	0.00000	0.00000	1	0.94268
DAIRY PRODUC	2	0.00295	0.00000	0.01007	0.006	.00000	0.00000	0.00000	2	0.34722
FEED GRAINS	3	0.20623	0.23408	0.02256	0.00	00000	0.00010	0.00000	3	0.66950
COTTON	4	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	4	0.23377
OTHER FARM P	5	0.00355	0.00002	0.00000	0.00	0000	0.00379	0.00000	5	0.19605
AGRICULTURAL	6	0.00000	0.03689	0.02692	0.115	0000	0.00004	0.00000	6	0.21494
COPPER MININ	7	0.00000	0.00000	0.00000	0.000	0000	0.00000	0.00000	7	0.29950
NONFERROUS O	8	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	8	0.16612
CRUDE OIL &	9	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	9	0.67426
NEW CONSTRUC	10	0.00000	0.00000	0.00000	0.0000	.00000	0.00000	0.00000	10	0.00000
CHEMICAL MIN	11	0.00000	0.00000	0.00173	0.000	.00000	0.00000	0.00000	11	0.07378
COAL, STONE	12	0.00003	0.00014	0.00261	0.001	00000	0.00806	0.00000	12	0.13382
MEAT PRODUCT	13	0.00000	0.00000	0.00000	0.00	00000	0.00000	0.00000	13	0.06155
DAIRY PRODUC	14	0.00000	0.00000	0.00000	0.00	00000	0.00000	0.00000	14	0.12100
GRAIN MILL &	15	0.05223	0.16519	0.00000	0.00	00000	0.00000	0.00000	15	0.34171
MISC. FOOD P	16	0.00613	0.00648	0.00000	0.00	00000	0.00001	0.00000	16	0.06534
LUMBER, WOOD	17	0.00000	0.00000	0.00000	0.00	.00000	0.02505	0.00000	17	0.26494
PRINTING & P	18	0.00001	0.00001	0.00001	0.00	.00080	0.00000	0.00385	18	0.02796
CHEMICALS, P	19	0.00121	0.00116	0.01625	0.01	.00008	0.00220	0.00022	19	0.17898
PETROLEUM RE	20	0.00379	0.00635	0.03222	0.020	.00375	0.01244	0.00462	20	0.39807
CONCRETE & S	21	0.00000	0.00000	0.00008	0.0000	00000	0.06121	0.00000	21	0.26486
ELECTRICAL &	22	0.00007	0.00009	0.00049	0.0003	00006	0.00056	0.00002	22	0.11071
FABRICATED M	23	0.00000	0.00001	0.00002	0.0000	0000	0.02206	0.00000	23	0.06663
MISC. MANUFA	24	0.00044	0.00025	0.00032	0.0003	000	0.00093	0.00000	24	0.09434
RAILROADS	25	0.00495	0.00716	0.00545	0.003	036	0.01320	0.00055	25	0.29136
OTHER TRANSP	26	0.01225	0.02493	0.00489	0.003	049	0.01913	0.00070	26	0.40760
GAS & OIL PI	27	0.00010	0.00017	0.00086	0.000	0006	0.00014	0.00009	27	0.04018
COMMUNICATIO	28	0.00161	0.00269	0.00311	0.002	01182	0.00272	0.01021	28	0.26010
ELECTRIC & W	29	0.00240	0.00471	0.00458	0.0082	.01233	0.00229	0.03280	29	0.43888
GAS UTILITIE	30	0.00000	0.00089	0.00000	0.0000	.00296	0.00040	0.00300	30	0.51581
WHOLESALE TR	31	0.01563	0.01606	0.01339	0.0097	00480	0.02921	0.00508	31	0.58733
RETAIL TRADE	32	0.00718	0.01308	0.01322	0.013	01906	0.03863	0.00786	32	0.32881
FINANCE & IN	33	0.00332	0.00385	0.00664	0.009	00438	0.00362	0.00286	33	0.37696
REAL ESTATE	34	0.01030	0.01234	0.08643	0.12	5412	0.00475	0.10525	34	1.43631
HOTELS & MOT	35	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00000	35	0.00432
PERSONAL SER	36	0.00000	0.00000	0.00000	0.00	0000	0.00000	0.00204	36	0.19501
BUSINESS SER	37	0.00566	0.00050	0.03871	0.02	01606	0.00694	0.01607	37	0.53671
AUTO REPAIR	38	0.00273	0.00355	0.00591	0.00	00659	0.00363	0.00803	38	0.18152
MEDICAL & ED	39	0.00181	0.00408	0.00000	0.000	.00000	0.00000	0.00491	39	0.02043
MISC. PROFES	40	0.00129	0.00145	0.00156	0.0017	.06982	0.04089	0.01416	40	0.33638
NEW CONSTRUC	41	0.00666	0.00933	0.01467	0.0141	00046	0.00026	0.04110	41	0.55663
NONPROFIT OR	42	0.00027	0.00503	0.00038	0.000	00074	0.00085	0.00067	42	0.04476
*** COLUMN SUMS ***		0.62377	0.56049	0.36507	0.426	0874	0.30309	0.26408		

Complete tables will be furnished upon request to the Bureau of Business and Economic Research, University of New Mexico, Albuquerque, NM 87131.

Attachment B-2

Without Location Quotient Adjustment

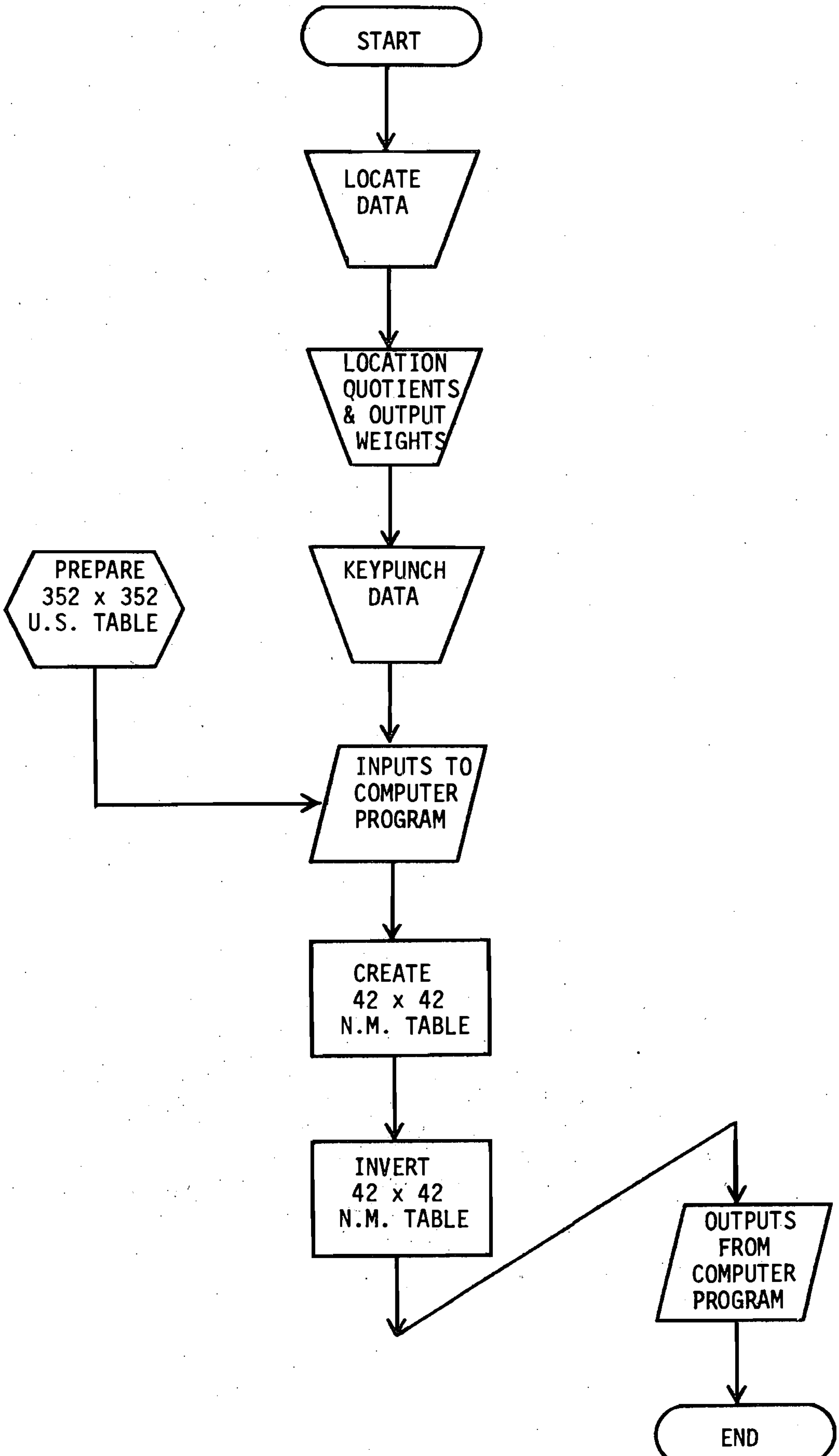
NEW MEXICO INPUT-OUTPUT MODEL, 1960
TECHNICAL COEFFICIENTS; DIRECT REQUIREMENTS PER DOLLAR OF OUTPUT

INDUSTRY PURCHASING

INDUSTRY SELLING		1	2	3	4	40	41	42	****	ROW SUMS ****
MEAT ANIMALS	1	0.27096	0.00000	0.05196	0.0441	0.00000	0.00000	0.00000	1	0.94268
DAIRY PRODUC	2	0.00521	0.00000	0.01934	0.0124	.00000	0.00000	0.00000	2	0.69955
FEED GRAINS	3	0.28783	0.32670	0.03148	0.000	.00000	0.00015	0.00000	3	0.93440
COTTON	4	0.00000	0.00000	0.00000	0.006	00000	0.00000	0.00000	4	0.23377
OTHER FARM P	5	0.00425	0.00003	0.00000	0.00	00000	0.00382	0.00000	5	0.27395
AGRICULTURAL	6	0.00000	0.03689	0.02692	0.11	00000	0.00004	0.00000	6	0.21494
COPPER MININ	7	0.00000	0.00000	0.00000	0.00	00000	0.00000	0.00000	7	0.30597
NONFERROUS O	8	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00000	8	0.16612
CRUDE OIL &	9	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00000	9	0.67426
NEW CONSTRUC	10	0.00000	0.00000	0.00000	0.0000	00000	0.00000	0.00000	10	0.00000
CHEMICAL MIN	11	0.00000	0.00000	0.00173	0.0009	.00000	0.00000	0.00000	11	0.07378
COAL, STONE	12	0.00004	0.00051	0.00395	0.0026	.00000	0.01222	0.00000	12	0.26821
MEAT PRODUCT	13	0.00000	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	13	0.15089
DAIRY PRODUC	14	0.00000	0.00000	0.00000	0.0000	0.00000	0.00000	0.00000	14	0.18967
GRAIN MILL &	15	0.05816	0.18486	0.00000	0.000	0.00000	0.00000	0.00000	15	0.47391
MISC. FOOD P	16	0.01635	0.02272	0.00000	0.000	0.00000	0.00036	0.00000	16	0.43149
LUMBER, WOOD	17	0.00011	0.00116	0.00012	0.000	0.00082	0.05798	0.00035	17	1.01735
PRINTING & P	18	0.00016	0.00022	0.00028	0.00	.00837	0.00003	0.01948	18	0.21111
CHEMICALS, P	19	0.00434	0.00599	0.06076	0.06	.00010	0.01131	0.00069	19	0.89618
PETROLEUM RE	20	0.00511	0.00858	0.04352	0.02	00506	0.02149	0.00623	20	0.54868
CONCRETE & S	21	0.00014	0.00130	0.00139	0.0	00023	0.13758	0.00000	21	1.07423
ELECTRICAL &	22	0.00081	0.00090	0.01399	0.00	0057	0.04247	0.00059	22	1.23212
FABRICATED M	23	0.00022	0.00375	0.00180	0.000	0005	0.10477	0.00000	23	0.48542
MISC. MANUFA	24	0.00235	0.00284	0.00727	0.004	0107	0.01086	0.00312	24	0.59791
RAILROADS	25	0.00495	0.00716	0.00545	0.003	0036	0.01320	0.00055	25	0.29136
OTHER TRANSP	26	0.01398	0.02553	0.00676	0.0053	0064	0.02065	0.00095	26	0.58462
GAS & OIL PI	27	0.00010	0.00017	0.00086	0.0005	0006	0.00014	0.00009	27	0.04018
COMMUNICATIO	28	0.00161	0.00269	0.00311	0.0027	01182	0.00272	0.01021	28	0.26010
ELECTRIC & W	29	0.00243	0.00475	0.00830	0.00974	.01434	0.00269	0.03411	29	0.48629
GAS UTILITIE	30	0.00000	0.00089	0.00000	0.00000	.00295	0.00040	0.00300	30	0.51581
WHOLESALE TR	31	0.02229	0.02291	0.01910	0.01390	.00685	0.04165	0.00724	31	0.83761
RETAIL TRADE	32	0.00718	0.01308	0.01322	0.0135	.01906	0.03863	0.00786	32	0.32881
FINANCE & IN	33	0.00561	0.00671	0.01204	0.0152	.00682	0.00651	0.00634	33	0.57405
REAL ESTATE	34	0.01030	0.01234	0.08643	0.1241	.05412	0.00475	0.10525	34	1.43631
HOTELS & MOT	35	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00000	35	0.00432
PERSONAL SER	36	0.00000	0.00000	0.00000	0.000	00000	0.00000	0.00241	36	0.19902
BUSINESS SER	37	0.00571	0.00050	0.03871	0.021	1801	0.00783	0.01760	37	0.75762
AUTO REPAIR	38	0.00273	0.00355	0.00591	0.005	0659	0.00363	0.00803	38	0.18152
MEDICAL & ED	39	0.00371	0.00639	0.00000	0.000	0000	0.00000	0.00746	39	0.03568
MISC. PROFES	40	0.00129	0.00145	0.00156	0.001	06982	0.04089	0.01416	40	0.33638
NEW CONSTRUC	41	0.00666	0.00933	0.01467	0.014	.00046	0.00026	0.04110	41	0.55663
NONPROFIT OR	42	0.00028	0.00522	0.00040	0.0006	.00075	0.00088	0.00069	42	0.04641
*** COLUMN SUMS ***		0.74399	0.72111	0.48092	0.5168	0.22892	0.58791	0.29752		

Complete tables will be furnished upon request to the Bureau of Business and Economic Research, University of New Mexico, Albuquerque, NM 87131.

FLOW CHART FOR CREATING A NON-SURVEY REGIONAL INPUT-OUTPUT MODEL



Appendix M

SOCIOECONOMIC EFFECTS OF PLANT CONSTRUCTION AND OPERATION: SUPPORTING DATA

CONTENTS

Table M-1. Population Estimates and Projections: WIPP Scenario I[a]

Year	Eddy County (99%, 90%)[b]	Carlsbad (88%, 80%)[b]	Carlsbad School District (93%, 85%)[b]	Loving (6%, 3%)[b]	Loving School District (6%, 3%)[b]	Lea County (1%, 10%)[b]
1970	41,119	21,297	25,498	1,192	1,350	49,554
1975	42,900	NA	NA	1,400	NA	51,600
1976	45,300	25,500	29,300	1,450	1,600	53,100
1977	46,200	26,600	30,400	1,500	1,650	55,100
1978	47,300	27,900	31,600	1,550	1,700	56,300
1979	48,200	28,600	32,400	1,600	1,750	57,500
1980	49,425	29,600	33,410	1,660	1,810	58,710
1981[c]	50,780	30,710	34,640	1,680	1,830	60,030
1982	53,430	32,930	37,020	1,790	1,940	61,280
1983	54,120	33,480	37,690	1,800	1,950	62,620
1984	53,880	33,170	37,320	1,790	1,940	63,870
1985	54,430	33,360	37,590	1,830	1,980	65,230
1986	55,950	34,360	38,700	1,840	1,990	66,540
1987	57,340	35,230	39,680	1,900	2,050	67,740
1988	58,750	36,140	40,690	1,950	2,100	68,850
1989	60,150	36,940	41,590	2,000	2,150	69,950
1990	61,550	37,840	42,590	2,050	2,200	70,950
1995[d]	65,250	40,040	45,090	2,150	2,300	75,150
2000	69,250	42,540	47,890	2,300	2,500	79,050
2010	73,150	44,940	50,590	2,450	2,600	88,150

[a]In scenario I, the direct impact of the WIPP (construction and operation) is assumed to be distributed as follows: Carlsbad, 88%; Loving, 6%; rest of Eddy County, 5%; Lea County, 1%. The indirect impact is distributed as follows: Carlsbad, 80%; Loving, 3%; rest of Eddy County, 7%; Lea County, 10%. Data computed by Larry Adcock and Associates; NA = not available.

[b]The percentages given in parentheses are the direct and indirect population migration, respectively, resulting from the WIPP. Percentages may vary because of rounding.

[c]Construction of the WIPP assumed to begin in 1980. All impacts assumed to be static after 1987.

[d]Projections for years beyond 1995 assume continued activity in the oil and gas industry at a stable but constant level. Present production levels measured against proved oil and gas reserves and recovery rates indicate that activity could decrease before 1990. However, secondary and tertiary (oil only) recovery procedures could prolong activity beyond the year 2010.

Table M-2. Population Estimates and Projections: WIPP Scenario II[a]

Year	Eddy County (58%)[b]	Carlsbad (54%)[b]	Remainder of Eddy County (4%)[b]	Lea County (42%)[b]	Hobbs (36%)[b]	Remainder of Lea County (6%)[b]	Hobbs School District (39%)[b]
1970	41,119	21,297	19,822	49,554	26,025	23,529	29,858
1975	42,900	NA	NA	51,600	NA	NA	33,300
1976	45,300	25,500	19,800	53,100	29,600	23,500	35,600
1977	46,200	26,600	19,600	55,100	30,550	24,550	36,900
1978	47,300	27,900	19,400	56,300	31,650	24,650	37,400
1979	48,200	28,600	19,600	57,500	32,600	24,900	37,950
1980	49,370	29,560	19,800	58,750	33,490	25,260	37,600
1981[c]	50,550	30,530	20,020	60,250	34,620	25,630	38,790
1982	52,710	32,330	20,380	62,000	35,940	26,060	39,200
1983	53,300	32,810	20,490	63,440	37,000	26,440	41,320
1984	53,510	32,870	20,640	64,240	37,530	26,710	41,860
1985	54,180	33,160	21,010	65,480	38,390	27,090	42,760
1986	55,620	34,080	21,540	66,870	39,220	27,650	43,700
1987	56,970	34,930	22,040	68,110	39,950	28,160	44,530
1988	58,380	35,840	22,540	69,220	40,610	28,610	45,240
1989	59,780	36,640	23,140	70,320	41,260	29,060	45,960
1990[d]	61,180	37,540	23,640	71,320	41,860	29,460	46,640
1995	64,880	39,740	25,140	75,520	44,310	31,210	49,390
2000	68,880	41,240	26,640	79,420	46,560	32,860	51,890
2010	72,780	44,640	28,140	88,520	51,910	36,610	57,840

[a]In scenario II, the distribution of direct and indirect impacts is assumed to be as follows: Carlsbad, 54%; rest of Eddy County, 4%; Hobbs, 36%; rest of Lea County, 6%. NA = not available.

[b]The percentages given in parentheses are the gross population migration resulting from the WIPP project. Percentages may vary because of rounding.

[c]Construction of the WIPP assumed to begin in 1980. All impacts assumed to be static after 1987.

[d]Projections for years beyond 1995 assume continued activity in the oil and gas industry at a stable but constant level. Present production levels measured against proved oil and gas reserves and recovery rates indicate that activity could decrease before 1990. However, secondary and tertiary (oil only) recovery procedures could prolong activity beyond the year 2010.

Table M-3. 1980 Resident Population Within 50 Miles of the WIPP Site (Maximum Impact--Scenarios I and II)

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	35	25	175	25	260
NNE	0	0	25	5	55	5,690	5,775
NE	0	0	0	25	75	8,785	8,885
ENE	0	0	10	70	205	34,100	34,385
E	0	0	5	15	3,290	160	3,470
ESE	0	0	5	10	3,080	270	3,365
SE	0	0	5	20	20	30	75
SSE	0	0	0	25	10	40	75
S	0	0	5	15	50	15	85
SSW	6	0	5	30	95	15	150
SW	0	5	55	30	10	40	140
WSW	0	0	1,810	200	50	65	2,125
W	0	0	70	32,660	40	30	32,800
WNW	0	10	5	190	55	40	300
NW	0	0	30	20	65	12,260	12,375
NNW	0	0	15	5	220	10	250
Radius total	6	15	2,080	33,345	7,495	61,575	104,515
Cumulative total	6	21	2,100	35,445	42,940	104,515	

Note: See Tables M-1 and M-2 for a description of the distribution of direct and indirect impacts associated with scenarios I and II.

Population allocations into the various geographic sectors have been based on the maximum impact of both scenarios I and II. This procedure leads to some double counting in a few areas, but increases the population count by a maximum of only 0.3% (approximately 400 people) in the overall area.

Table M-4. 1990 Resident Population Within 50 Miles of the WIPP Site (Maximum Impact--Scenarios I and II)

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	160	20	230
NNE	0	0	20	5	50	6,640	6,715
NE	0	0	0	20	65	10,860	10,945
ENE	0	0	10	65	185	42,625	42,885
E	0	0	5	15	3,840	140	4,000
ESE	0	0	5	10	3,595	255	3,865
SE	0	0	5	15	20	25	65
SSE	0	0	0	25	10	40	75
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	50	15	10	40	120
WSW	0	0	2,245	175	50	65	2,535
W	0	0	65	41,145	40	35	41,285
WNW	0	10	5	185	50	45	295
NW	0	0	30	20	60	15,975	16,085
NNW	0	0	15	5	235	10	265
Radius total	6	15	2,495	41,765	8,515	76,805	129,600
Cumulative total	6	21	2,515	44,280	52,795	129,600	

Note: See Tables M-1 and M-2 for a description of the distribution of direct and indirect impacts associated with scenarios I and II.

Population allocations into the various geographic sectors have been based on the maximum impact of both scenarios I and II. This procedure leads to some double counting in a few areas, but increases the population count by a maximum of only 0.3% (approximately 400 people) in the overall area.

Table M-5. 2000 Resident Population Within 50 Miles of the WIPP Site (Maximum Impact--Scenarios I and II)

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	150	20	220
NNE	0	0	20	5	45	7,385	7,455
NE	0	0	0	20	60	12,070	12,150
ENE	0	0	10	60	175	47,335	47,580
E	0	0	5	15	4,080	135	4,235
ESE	0	0	5	10	3,890	240	4,145
SE	0	0	5	15	15	25	60
SSE	0	0	5	20	10	35	70
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	60	15	10	50	140
WSW	0	0	2,545	195	50	70	2,860
W	0	0	75	46,225	40	35	46,375
WNW	0	10	5	205	60	50	330
NW	0	0	30	20	70	14,915	15,035
NNW	0	0	15	5	260	5	285
Radius total	6	15	2,820	46,875	9,060	82,400	141,175
Cumulative total	6	21	2,840	49,715	58,775	141,175	

Note: See Tables M-1 and M-2 for a description of the distribution of direct and indirect impacts associated with scenarios I and II.

Population allocations into the various geographic sectors have been based on the maximum impact of both scenarios I and II. This procedure leads to some double counting in a few areas, but increases the population count by a maximum of only 0.3% (approximately 400 people) in the overall area.

Table M-6. 2010 Resident Population Within 50 Miles of the WIPP Site (Maximum Impact--Scenarios I and II)

Sector	Miles from site						Total
	0-5	5-10	10-20	20-30	30-40	40-50	
N	0	0	30	20	160	20	230
NNE	0	0	25	5	50	8,300	8,380
NE	0	0	0	25	70	13,500	13,595
ENE	0	0	10	70	195	52,850	53,125
E	0	0	5	15	4,605	135	4,760
ESE	0	0	5	10	4,335	240	4,590
SE	0	0	5	20	20	25	70
SSE	0	0	0	20	10	35	65
S	0	0	5	15	45	15	80
SSW	6	0	5	30	100	15	155
SW	0	5	65	15	10	50	145
WSW	0	0	2,645	205	55	75	2,980
W	0	0	80	49,465	40	35	49,620
WNW	0	10	5	230	65	55	365
NW	0	0	30	20	75	15,770	15,895
NNW	0	0	15	5	275	5	300
Radius total	6	15	2,930	50,170	10,110	91,125	154,355
Cumulative total	6	21	2,950	53,120	63,230	154,355	

Note: See Tables M-1 and M-2 for a description of the distribution of direct and indirect impacts associated with scenarios I and II.

Population allocations into the various geographic sectors have been based on the maximum impact of both scenarios I and II. This procedure leads to some double counting in a few areas, but increases the population count by a maximum of only 0.3% (approximately 400 people) in the overall area.

Table M-7. Carlsbad Municipal Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	690	710	730	740	760	770	790	810	830
Charges and miscellaneous	3,300	3,410	3,500	3,560	3,640	3,720	3,810	3,900	4,000
Intergovernmental transfers									
State	2,960	3,050	3,120	3,170	3,230	3,290	3,370	3,450	3,540
Federal	1,040	1,070	1,100	1,110	1,130	1,160	1,180	1,210	1,240
Other	3,430	3,540	3,620	3,670	3,740	3,820	3,910	4,010	4,100
TOTAL	11,420	11,780	12,060	12,260	12,500	12,760	13,060	13,390	13,720
EXPENDITURES (thousands of 1979 dollars)									
General government	1,190	1,230	1,260	1,280	1,300	1,330	1,360	1,390	1,430
Public safety	1,530	1,580	1,610	1,640	1,670	1,700	1,740	1,790	1,830
Public works	7,890	4,140	4,250	4,330	4,430	4,520	4,630	4,750	4,860
Health and welfare	60	60	60	60	60	70	70	70	70
Recreation and culture	760	780	800	810	830	850	870	890	910
Debt service	760	810	810	810	900	800	620	620	620
TOTAL	12,210	8,610	8,800	8,940	9,190	9,270	9,290	9,510	9,730

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-8. Carlsbad Municipal Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
					REVENUES (thousands of 1979 dollars)				
Own source									
Taxes	6	22	39	34	20	16	18	19	20
Charges and miscellaneous	38	130	211	162	81	74	90	94	95
Intergovernmental transfers									
State	30	106	174	136	71	65	79	83	83
Federal	5	18	29	23	12	11	13	14	14
Other	20	70	114	90	46	43	52	54	55
TOTAL	99	346	567	445	231	209	251	265	266
					EXPENDITURES (thousands of 1979 dollars)				
General government	12	43	70	55	28	26	32	33	34
Public safety	16	55	90	71	37	34	41	43	43
Public works	47	161	262	200	99	90	109	115	116
Health and welfare	1	2	4	3	1	1	2	2	2
Recreation and culture	8	27	45	35	18	17	20	21	21
TOTAL	83	288	470	363	184	169	204	214	216

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-9. Loving Municipal Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
				REVENUES (thousands of 1979 dollars)					
Own source									
Taxes	18	18	19	19	20	20	20	21	21
Charges and miscellaneous	162	165	168	170	176	178	181	186	191
Intergovernmental transfers									
State	46	46	47	48	49	50	51	52	53
Federal	18	18	18	19	19	19	20	20	21
Local	63	64	65	66	68	69	70	72	74
TOTAL	307	312	317	322	332	337	342	351	360
				EXPENDITURES (thousands of 1979 dollars)					
General government	35	36	36	37	38	38	39	40	41
Public safety	77	78	79	80	82	84	85	87	89
Public works	165	169	172	175	180	183	186	191	196
Health and welfare	6	6	6	6	6	6	6	7	7
Recreation and culture	11	11	11	11	11	12	12	12	12
Debt service	20	21	22	23	24	25	26	28	29
TOTAL	314	320	326	332	342	348	354	364	375

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-10. Loving Municipal Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	(b)	1	1	1	(b)	(b)	1	1	1
Charges and miscellaneous	3	8	13	9	4	5	5	6	6
Intergovernmental transfers									
State	1	2	3	2	1	1	1	1	1
Federal	(b)	1	1	1	(b)	(b)	(b)	1	1
Local	1	1	1	1	1	1	1	1	1
TOTAL	5	12	19	14	7	7	8	9	9
EXPENDITURES (thousands of 1979 dollars)									
General government	1	1	2	2	1	1	1	1	1
Public safety	2	3	4	3	2	2	2	2	2
Public works	3	9	14	10	5	5	6	6	6
Health and welfare	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Recreation and culture	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Debt service	(b)	(b)	(b)	1	1	1	1	1	2
TOTAL	6	14	22	16	9	9	10	12	12

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]Less than $500.

Table M-11. Eddy County Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
	REVENUES (thousands of 1979 dollars)								
Own source									
Taxes	2,380	2,420	2,440	2,460	2,490	2,510	2,540	2,570	2,600
Charges and miscellaneous	1,780	1,820	1,850	1,880	1,910	1,950	2,000	2,040	2,090
Intergovernmental transfers									
State	610	620	630	640	650	660	680	700	710
Federal	870	890	910	920	940	960	980	1,000	1,030
TOTAL	5,640	5,750	5,840	5,900	5,980	6,080	6,190	6,310	6,440
	EXPENDITURES (thousands of 1979 dollars)								
General government	1,380	1,410	1,440	1,460	1,480	1,510	1,550	1,590	1,620
Public safety	780	790	810	820	830	850	870	890	910
Public works	1,820	1,860	1,890	1,920	1,950	1,990	2,040	2,090	2,140
Health and welfare	380	390	400	400	410	420	430	440	450
Recreation and culture	100	110	110	110	110	110	120	120	120
TOTAL	4,460	4,570	4,650	4,700	4,780	4,880	5,000	5,120	5,250

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-12. Eddy County Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	4	20	40	44	28	18	19	21	22
Charges and miscellaneous	6	20	32	25	13	12	14	15	15
Intergovernmental transfers									
State	4	15	24	19	10	9	11	11	12
Federal	6	20	33	26	13	12	15	16	16
TOTAL	20	74	129	113	64	51	59	64	64
EXPENDITURES (thousands of 1979 dollars)									
General government	10	33	55	43	22	20	25	26	26
Public safety	5	19	31	24	12	12	14	15	15
Public works	12	44	72	57	29	27	33	34	34
Health and welfare	3	9	15	12	6	6	7	7	7
Recreation and culture	1	2	4	3	2	2	2	2	2
TOTAL	31	108	177	139	72	66	80	84	85

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-13. Hobbs Municipal Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	1,110	1,140	1,180	1,210	1,250	1,280	1,310	1,330	1,350
Charges and miscellaneous	4,070	4,190	4,310	4,440	4,560	4,680	4,760	4,840	4,890
Intergovernmental transfers									
State	5,190	5,330	5,470	5,610	5,760	5,900	6,010	6,110	6,170
Federal	1,220	1,250	1,280	1,320	1,350	1,380	1,410	1,430	1,440
TOTAL[b]	11,590	11,920	12,240	12,580	12,930	13,240	13,490	13,720	13,860
EXPENDITURES (thousands of 1979 dollars)									
General government	1,810	1,860	1,910	1,960	2,010	2,060	2,100	2,140	2,160
Public safety	2,320	2,380	2,450	2,510	2,580	2,640	2,690	2,740	2,760
Public works	3,580	3,690	3,800	3,920	4,040	4,140	4,220	4,290	4,330
Health and welfare	600	610	630	640	660	680	690	700	710
Recreation and culture	710	730	750	770	790	810	820	840	840
Debt service	670	670	670	670	670	670	670	670	650
TOTAL[b]	9,690	9,950	10,200	10,470	10,750	10,990	11,180	11,360	11,450

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]Total includes approximately $4000 in transfers not classified as State or Federal.

Table M-14. Hobbs Municipal Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	3	13	23	21	12	9	11	12	12
Charges and miscellaneous	17	60	97	75	38	35	42	44	44
Intergovernmental transfers									
State	20	69	114	90	47	43	51	54	55
Federal	4	15	24	19	10	9	11	12	12
TOTAL	45	157	259	206	108	96	115	122	122
EXPENDITURES (thousands of 1979 dollars)									
General government	7	24	40	32	16	15	18	19	19
Public safety	9	31	51	40	21	19	23	24	24
Public works	16	55	89	69	34	31	37	39	40
Health and welfare	2	8	13	10	5	5	6	6	6
Recreation and culture	3	9	16	12	6	6	7	7	7
TOTAL	37	128	209	163	84	76	91	96	97

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-15. Lea County Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
	REVENUES (thousands of 1979 dollars)								
Own source									
Taxes	3,260	3,440	3,620	3,810	4,010	4,230	4,450	4,680	4,920
Charges and miscellaneous	1,340	1,380	1,400	1,430	1,460	1,500	1,520	1,550	1,570
Intergovernmental transfers									
State	560	580	590	600	610	630	640	650	660
Federal	1,070	1,090	1,110	1,140	1,160	1,180	1,210	1,230	1,250
TOTAL	6,240	6,480	6,730	6,980	7,250	7,530	7,820	8,110	8,400
	EXPENDITURES (thousands of 1979 dollars)								
General government	1,410	1,440	1,470	1,500	1,530	1,560	1,590	1,620	1,650
Public safety	730	750	760	780	800	810	830	840	860
Public works	2,060	2,110	2,150	2,200	2,240	2,290	2,340	2,380	2,410
Health and welfare	400	410	420	430	440	450	460	460	470
Recreation and culture	10	10	10	10	10	10	10	10	10
Debt service	0	0	0	0	0	0	0	0	0
TOTAL	4,620	4,720	4,820	4,920	5,020	5,130	5,230	5,320	5,400

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-16. Lea County Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Own source									
Taxes	2	7	14	15	10	6	6	7	7
Charges and miscellaneous	3	9	15	12	6	6	7	7	7
Intergovernmental transfers									
State	1	5	8	6	3	3	4	4	4
Federal	2	6	10	8	4	4	4	5	5
TOTAL	7	27	47	41	23	19	21	23	23
EXPENDITURES (thousands of 1979 dollars)									
General government	4	12	21	16	8	8	9	10	10
Public safety	2	6	11	8	4	4	5	5	5
Public works	5	18	30	24	12	11	14	14	14
Health and welfare	1	4	6	5	2	2	3	3	3
Recreation and culture	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)	(b)
TOTAL	12	41	68	54	28	25	30	32	32

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]Less than $500.

Table M-17. Carlsbad School District Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
	REVENUES (thousands of 1979 dollars)								
Operational fund	10,090	10,210	10,160	10,370	10,470	10,750	11,060	11,420	11,850
Other funds	3,960	4,040	4,070	4,160	4,220	4,320	4,440	4,570	4,720
TOTAL	14,060	14,250	14,230	14,530	14,690	15,070	15,500	15,990	16,580
	EXPENDITURES (thousands of 1979 dollars)								
Operational fund	10,660	10,780	10,720	10,950	11,060	11,350	11,680	12,050	12,520
Other funds	2,660	2,690	2,670	2,730	2,760	2,830	2,910	3,010	3,120
Debt service	280	280	280	280	280	280	280	280	280
TOTAL	13,590	13,740	13,670	13,950	14,090	14,450	14,870	15,340	15,910

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-18. Carlsbad School District Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Operational fund	109	372	617	493	262	240	290	305	309
Other funds	36	131	231	206	119	94	109	117	119
TOTAL	145	504	848	699	381	335	398	422	428
EXPENDITURES (thousands of 1979 dollars)									
Operational fund	115	393	652	521	276	254	306	322	327
Other funds	29	98	162	130	69	63	76	80	81
TOTAL	143	491	814	650	345	317	382	402	408

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-19. Loving School District Finances: Baseline[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Operational fund	600	600	610	620	640	640	650	670	680
Other funds	210	220	220	220	230	230	240	240	250
TOTAL	810	820	830	840	860	880	890	910	930
EXPENDITURES (thousands of 1979 dollars)									
Operational fund	670	680	690	700	720	730	740	760	780
Other funds	170	170	180	180	180	180	190	190	200
Debt service	10	10	20	20	30	40	50	60	70
TOTAL	850	870	890	900	930	950	980	1,010	1,040

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.

Table M-20. Loving School District Finances: Impact of the WIPP Project[a]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
REVENUES (thousands of 1979 dollars)									
Operational fund	3	17	27	24	12	10	14	17	17
Other funds	1	4	7	6	3	3	4	4	4
TOTAL	4	21	34	30	15	13	17	21	21
EXPENDITURES (thousands of 1979 dollars)									
Operational fund	4	19	31	27	13	11	15	19	19
Other funds	1	5	8	7	3	3	4	5	5
Debt service	(b)	(b)	(b)	1	1	2	2	3	3
TOTAL	5	24	39	34	18	16	21	27	27

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]Less than $500.

Table M-21. Hobbs School District Finances: Baseline[a,b]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
				REVENUES (thousands of 1979 dollars)					
Operational fund	11,220	11,230	11,270	11,310	11,480	11,690	11,830	11,950	12,040
Other funds	2,030	2,040	2,060	2,090	2,130	2,170	2,200	2,230	2,250
TOTAL	13,250	13,280	13,330	13,400	13,610	13,870	14,030	14,180	14,300
				EXPENDITURES (thousands of 1979 dollars)					
Operational fund	11,210	11,230	11,260	11,300	11,480	11,690	11,820	11,940	12,030
Other funds	1,590	1,600	1,600	1,610	1,630	1,660	1,680	1,700	1,710
Debt service	590	610	620	640	660	680	700	710	730
TOTAL	13,400	13,430	13,480	13,550	13,720	14,020	14,200	14,350	14,480

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]The effect of possible new school buildings is not included.

Table M-22. Hobbs School District Finances: Impact of the WIPP Project[a,b]

Revenue source or expenditure	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89
				REVENUES (thousands of 1979 dollars)					
Operational fund	42	150	252	203	108	98	119	124	124
Other funds	7	26	45	39	22	18	21	23	23
TOTAL	49	176	297	242	131	117	140	147	147
				EXPENDITURES (thousands of 1979 dollars)					
Operational fund	42	150	252	202	108	98	119	124	124
Other funds	6	21	36	29	15	14	17	18	18
TOTAL	48	172	288	231	124	112	136	142	142

[a]Data computed by Larry Adcock and Associates. Detail may not equal total because of rounding.
[b]The effect of possible new school buildings is is not included.

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Appendix N

EFFECTS OF LEAVING THE TRU WASTE AT IDAHO

Appendix N

EFFECTS OF LEAVING THE TRU WASTE AT IDAHO

If no TRU-waste repository away from the current storage locations becomes available, there will be three general alternatives for managing stored TRU waste:

1. The waste could be left in place, as is. A delay in making a decision on what to do with the waste would amount to a temporary selection of this alternative.

2. Improved in-place confinement could be provided for the waste.

3. The waste could be retrieved, processed, and disposed of at another location at the storage site.

This appendix discusses these alternatives in terms of the methods that might be used at the Idaho National Engineering Laboratory (INEL), the source of the waste to be received at the WIPP; similar methods might be used at other storage locations.

This appendix is based on a detailed report (DOE, 1979) that contains the full analyses and discussions. The evaluations presented here cover only the TRU waste expected to have been stored at the INEL Radioactive Waste Management Complex (RWMC) by 1985. The effects of waste that might be received after 1985 are addressed in the detailed report.

N.1 LEAVING THE WASTE IN PLACE, AS IS

N.1.1 Description of Operations

In this alternative, the stored TRU waste would be left in place, as is. A cover of plywood, polyvinyl sheeting, and 3 feet of earth over the waste would be maintained. The present environmental monitoring and sampling procedures would be continued, with improved procedures incorporated as they are developed. In accordance with the proposed criteria of the Environmental Protection Agency (EPA, 1978), it was conservatively assumed that the maintenance and monitoring procedures would continue for only 100 years.

N.1.2 Environmental Effects

In the near future (i.e., up to 100 years after the implementation of a waste-management alternative), the environmental effects of this alternative would be essentially the same as those measured to date for operations in the Transuranic Storage Area (TSA) at the INEL. Radiation doses received by people near the covered waste would be approximately the natural-background doses. The nonradiological effects normally associated with construction projects (e.g., excavation of soil, use of motor fuels, emissions from construction equipment, and socioeconomic impacts from an influx of workers) would not be present. Thus, the effects on the environment, in the near term, would be the smallest of any of the alternatives considered.

The long-term environmental effects of this alternative would be associated with the disruptions caused by natural disasters or human intrusion.

N.1.3 Radiological Risk to the Public

The hundred years of monitored, normal waste-management operations would not be a hazard to the public under this alternative. Rather, the hazards in both the near and the distant future would be associated with waste disruption by natural disasters. Table N-1 shows the results of dose-commitment evaluations for the most important natural disasters. The evaluations were based on hypothetical releases occurring in the year 2085, when the monitoring was assumed to stop. The effects from releases occurring in the more distant future are presented in Section N.3, where they are compared with the long-term effects of other alternatives. Risks were not evaluated because of the great uncertainties in estimating the probabilities of disruptive events many years in the future.

The scenarios leading to the largest dose commitments involve waste disruption by volcanic action or by future populations inadvertently intruding upon the site. The RWMC lies near the edge of the Arco Volcanic Rift Zone, which was the site of volcanic action as recently as 10,500 years ago and is likely to become active in the future (Kuntz, 1978). In an explosive eruption, molten lava encounters groundwater at a relatively small depth beneath the surface of the earth; a small but significant number of eruptions in the eastern Snake River Plain have been of this type in the past. A fraction of the waste could thereby become airborne and be carried off the site. This event is of extremely low probability.

In a related scenario, lava flow from outside the immediate area could cover the RWMC. The waste could be disrupted, and a fraction could become airborne and be carried off the site. The lava-flow scenario is the more probable of these two scenarios, because eruptions originating in a larger area could deliver flows to the RWMC. As long as the cover over the waste were maintained, the effects would probably be minimal. However, if the waste were left in place indefinitely after maintenance operations cease, the cover would erode away, and releases of radionuclides could occur (Table N-1). The relative severities of the two scenarios for volcanic action are the subject of continuing studies. The results presented here are based on conservative assumptions and may overestimate greatly the quantity of radionuclides that would be released.

Another important scenario is future intrusion by small groups of people onto the waste site after institutional controls have lapsed. These people are assumed to live on the waste site, plow the land, eat food raised there, and dig into the waste looking for artifacts or construction materials. Over a 50-year period people living on the waste site could receive the dose commitments listed in Table N-1.

Table N-1. Summary of Dose Commitments for Leaving the Stored Waste in Place, as Is[a]

Disruptive event	Maximum individual 50-year dose commitment (rem)		
	Whole body[b]	Bone	Lung
Explosive volcano	6×10^{-3}	8	20
Earthquake	2×10^{-8}	2×10^{-5}	4×10^{-5}
Mackay Dam failure	3×10^{-9}	1×10^{-4}	NA[e]
Volcanic lava flow[c,d]	3×10^{-2}	50	90
Intrusion			
Ingestion	7	400	NA
Inhalation	10	500	700

Disruptive event	Population[f] 50-year dose commitment (man-rem)		
	Whole body[g]	Bone	Lung
Explosive volcano	40	40,000	80,000
Earthquake	1×10^{-4}	1×10^{-1}	2×10^{-1}
Mackay Dam failure	1×10^{-8}	5×10^{-4}	NA
Volcanic lava flow[c,d]	100	200,000	400,000
Intrusion			
Ingestion	70	4,000	NA
Inhalation	90	4,000	6,000

[a]Data from DOE (1979).

[b]The whole-body dose received from natural background radiation during the 50 years is about 7.5 rem.

[c]Overburden is assumed to resist lava flow as long as maintenance is continued. Release is assumed to occur 100 years after implementation, when maintenance has been discontinued.

[d]The dose-commitment calculations for this scenario are subject to large uncertainties.

[e]NA = not applicable.

[f]Population = 130,000 except for intrusion, where it is 10.

[g]The whole-body population dose received from the natural background radiation during the 50 years is about 1,000,000 man-rem for the larger population and about 75 man-rem for the population affected by intrusion.

Flooding of the RWMC could result from failure of the Mackay Dam, which is about 42 miles upstream on the Big Lost River. The dam could fail because of faulty design or construction, degradation, or seismic activity. This disruptive event is also listed in Table N-1.

N.1.4 Hazards to Workers

Experience at the RWMC indicates that hazards to workers for this alternative would be small. Maintenance and surveillance workers would receive radiation doses that are barely distinguishable from those delivered by natural background radiation.

N.1.5 Costs

The estimated cost of continuing the present program of maintenance and surveillance for the Transuranic Storage Area is $600,000 annually. (The number of years for which maintenance and surveillance would be continued cannot be projected with confidence.) Upgrading the program could increase this cost. In addition, capital costs for the periodic replacement of some equipment items would be less than one-tenth of the operations cost.

N.2 IMPROVING IN-PLACE CONFINEMENT OF STORED WASTE

N.2.1 Description of Operations

This alternative provides additional in-place protection for the waste. Protection would be provided against penetration by water and intrusion by people, animals, and plant roots. This discussion covers two approaches for constructing confinement barriers for the waste (a barrier over the top and sides and barriers over the top, sides, and bottom) and one immobilization approach.

In the top-and-side-barrier approach, an additional 10-foot cover of compacted clay and a 3-foot cover of basalt riprap would be built up over the existing mounds on the storage pads.

In the top-side-and-bottom-barrier approach, increased isolation would be provided by pressure-grout sealing of the sediments beneath the asphalt pad. As long as the grout remained intact, it would be an additional barrier against downward migration of the waste. Assurance cannot be given, however, that the grout would remain intact for the thousands of years required for the radionuclides to become innocuous.

In the immobilization approach, the waste would be immobilized in place by injecting grout into the waste and into the sediments beneath the pad. The waste would thereby be encased in a massive, impermeable block of grout. The grout would not penetrate sound waste containers, which would be surrounded by the grout. This immobilization method would make any future retrieval extremely difficult.

For all of these methods of improved confinement, maintenance and surveillance would be continued as discussed in Section N.1.

N.2.2 Environmental Effects

Under normal operational conditions, there would be no near-term releases of radioactivity from any of the three improved-confinement methods and hence no dose commitments to the public. Direct radiation from the stored waste would be reduced by the shielding of the mound over the waste, and radiation exposures at the surface of the mound would be expected to be near background levels. Long-term environmental effects would be associated with the disruptive events considered in the risk analysis below.

Nonradiological effects would be those resulting from the use of materials, energy, and labor. For example, it is estimated that 30,000 cubic yards of clay and 12,000 cubic yards of basalt riprap would be required for the additional protective cover over the waste. An estimated 1000 cubic yards of grout and 13,000 cubic yards of concrete would be required for grouting beneath the waste. The immobilization approach would require an estimated 34,000 cubic yards of grout. The waste-management area is already disturbed, so there would be no additional loss of habitat or use of lands. A possible habitat loss might be expected at the playas from which clay would be extracted to construct the waste overburden. This impact would be minor.

N.2.3 Radiological Risk to the Public

For the three confinement approaches discussed, the risk associated with the confinement operations themselves would be essentially zero. Only in the immobilization operation, in which grout-injection pipes would be forced through the clay cover and the pad, can a release scenario associated with operations be postulated. During insertion and withdrawal, the grout-injection pipes would be provided with external containment to prevent the spread of contamination. The hazards from waste-management operations would be much smaller than those from the disruption of the waste by such events as volcanic activity or human intrusion.

The ability of improved confinement to resist disruptive natural events is difficult to assess. This ability would undoubtedly decrease as the engineered barriers deteriorate. A credit, ranging in value from a factor of 1 to a factor of 1000, has been taken for the beneficial effects of the barriers in reducing the release quantities.

The dose commitments for disruptive-event scenarios, assumed to occur in the year 2085, were estimated. (The effects from releases occurring in the more distant future are presented in Section N.3.) For the two approaches involving confinement barriers, the dose commitments are similar to the corresponding dose commitments listed in Table N-1. The similarity stems from the worst-case assumption that the maintenance of the confinement barriers would cease in the year 2085 and that the erosion of the barriers would occur immediately thereafter.

The dose-commitment results for the immobilization approach are summarized in Table N-2. A comparison of these data with those in Table N-1 shows the beneficial effects of the immobilization in reducing the severity of releases, at least for 100 years.

N.2.4 Hazards to Workers

For this alternative, hazards to workers would be only slightly greater than those for the alternative of leaving the waste as is. A low level of hazard would exist during immobilization operations, but waste-confinement measures for the immobilization operations are being developed.

Table N-2. Summary of Dose Commitments from Disruptive Events for Approach with In-Place Immobilization of Waste[a]

Disruptive event	Maximum individual 50-year dose commitment (rem)		
	Whole body[b]	Bone	Lung
Explosive volcano	6×10^{-5}	8×10^{-2}	2×10^{-1}
Earthquake	2×10^{-10}	2×10^{-7}	4×10^{-7}
Mackay Dam failure	3×10^{-11}	1×10^{-6}	NA[e]
Volcanic lava flow[c,d]	3×10^{-4}	5×10^{-1}	9×10^{-1}
Intrusion			
Ingestion	7×10^{-2}	4	NA
Inhalation	0.1	5	7
50-year background dose	7.5		

Disruptive event	Population[f] 50-year dose commitment (man-rem)		
	Whole body[g]	Bone	Lung
Explosive volcano	0.4	400	800
Earthquake	1×10^{-6}	1×10^{-3}	2×10^{-3}
Mackay Dam failure	1×10^{-10}	5×10^{-6}	NA
Volcanic lava flow[c,d]	1	2000	4000
Intrusion			
Ingestion	0.7	40	NA
Inhalation	0.9	40	60
50-year background dose	1×10^{6}		

[a]Data from DOE (1979).

[b]The whole-body dose received from natural background radiation during the 50 years is about 7.5 rem.

[c]Overburden is assumed to resist lava flow as long as maintenance is continued. Release is assumed to occur 100 years after implementation, when maintenance has been discontinued.

[d]The dose-commitment calculations for this scenario are subject to large uncertainties.

[e]NA = not applicable.

[f]Population is 130,000 except for intrusion, where it is 10.

[g]The whole-body population does received from natural background radiation during the 50 years is about 1,000,000 man-rem for the larger population and about 75 man-rem for the population affected by intrusion.

N.2.5 Costs

The estimated costs for improving the confinement of TRU waste stored at the Transuranic Storage Area are summarized below. The number of years for which maintenance and surveillance would be continued cannot be projected with confidence. The costs are in millions of 1979 dollars (DOE, 1979).

Method	Capital	Annual operations and maintenance
Top and side barrier	1.9	0.6
Top, side, and bottom barriers	5.4	0.6
Immobilization	21	0.6

N.3 RETRIEVING, PROCESSING, AND DISPOSING OF THE WASTE AT THE INEL

In this alternative, the stored TRU waste would be retrieved from its present location, processed, and shipped to a disposal facility elsewhere at the INEL. The retrieval and processing of the stored waste would begin in 1985 or as soon thereafter as practicable.

N.3.1 Description of Facilities and Operations

Retrieval

The waste would be retrieved as described in Section 9.8.2.

Processing

Three possible methods were analyzed for processing the stored waste: (1) incineration by slagging pyrolysis, followed by packaging; (2) compaction, immobilization, and packaging; and (3) repackaging only. The first and third of these methods provide upper and near-lower bounds for the environmental effects of any waste-processing method that might ultimately be selected and implemented. The effects of these two bounding methods are presented here. The effects from compaction, immobilization, and packaging methods are discussed elsewhere (DOE, 1979) and are intermediate in magnitude.

Slagging pyrolysis and repackaging only are discussed in Section 9.8.3. The details of processing would be affected very little by the choice of the ultimate destination for the waste product.

On-site shipment

On-site shipment of processed waste would be by semitrailers pulled by standard truck tractors. The cast slag from slagging pyrolysis would be shipped in DOT-17C 55-gallon drums; each drum would weigh about 1360 pounds. The repackaged waste would be shipped in DOT-17C drums with 90-mil polyethylene liners; each drum would weigh about 260 pounds.

On-site disposal

Four on-site disposal methods were analyzed and are discussed below. Waste processed by any of the methods discussed previously could be disposed of by any of these disposal methods. All disposal methods would be designed to allow retrieval of the waste, if necessary, during an observation period.

Deep-rock disposal: shaft access. This method involves waste disposal in a vault a minimum of 800 feet below ground. Access to the vault would be provided by two shafts. The repository would be similar to the WIPP in design, but smaller and less complex. After waste emplacement and a retrievability period, the shafts would be filled with rock and plugged with concrete.

The conceptual location is in calcareous rocks in the Lemhi Mountain Range, in the northwestern corner of the INEL. Although this location is the only portion of the INEL that is not underlain by the Snake River Plain aquifer, it is believed to be hydrologically coupled to the aquifer. There is also a possibility that limestone in the vault area would be found to be water-saturated. For these reasons, the area would have to be explored by core drilling and hole testing before proceeding further.

Deep-rock disposal: tunnel access. The conceptual location studied for this disposal method is about 3 miles from that studied for deep-rock disposal with shaft access. Two tunnels and a subsurface repository for the waste would be constructed. The repository would be identical with that described for the shaft-access disposal.

Engineered shallow burial at Site 14. This method involves engineered shallow burial in lacustrine sediments at the central area of the INEL known as Site 14. This area has the deepest known surface sediments at the INEL.

The facility would consist of underground concrete structures in a rectangular array. Each structure would be buried so that its top would be well below the original ground surface. Each structure would contain rooms running the length of the structure and would have a high ratio of solid material to void, obtained by the use of massive interlocking concrete blocks and by the use of a thick layer of natural material (clay and basalt riprap) to protect the concrete from the environment. Two hypothetical designs were used in the analysis, one with a less massive construction than the other in order to reduce cost.

Disposal in an engineered surface facility near the RWMC. The location studied for the engineered surface-disposal facility is in the southeastern corner of the RWMC, extending outside and to the south of the present fence. The surface soil in this area is typically 15 feet thick above a layer of basalt approximately 100 feet thick.

The engineered surface-disposal facility would consist of elongated, earth-covered concrete structures, each resting on the basalt base. Including the cover material, each structure would stand considerably above ground level. Each structure would contain a number of disposal rooms extending its full length.

The structure would be massive, with the intention of providing long-term containment of the waste. It would have a high ratio of solid material (reinforced concrete) to void, obtained by the use of massive interlocking concrete blocks. A thick layer of natural material (clay and basalt riprap) on top of the concrete would protect the concrete from the environment.

N.3.2 Environmental Effects

The environmental effects of retrieval, slagging pyrolysis, and repackaging are given in Section 9.8.

The shipment and disposal of waste at the INEL disposal locations would not result in significant radiological effects, at least in the near term (up to 100 years). The waste would be packaged to prevent the release of contamination during normal handling and shipping. There would be no exposure to the general population from normal operations because the waste would be shipped on committed roadways.

After the waste had been put in the disposal facility and the facility closed, long-term environmental effects of disposal would be associated principally with the disruption of the waste by natural disasters.

Nonradiological impacts would result from the use of land, energy, resources, and labor. These impacts are summarized in Table N-3 for the four disposal locations, including the less-massive variation of engineered shallow burial. Implementation of this variation would greatly reduce the amount of concrete required, as shown in the table.

The construction of roadways would remove some sagebrush habitat. The use of Site 14 would cause the loss of some of the crested wheatgrass, which was introduced to increase the grazing area on the INEL. Both of these effects would be minor. The use of either Lemhi Range site would cause a loss of 8000 acres of grazing land for cattle and sheep. (All but about 200 acres of this total would be in the form of a 2-mile-wide buffer zone around the disposal site. The buffer zone might be judged unnecessary after operations ceased, because of the protection afforded by the disposal facility itself.) About 200 acres of wildlife habitat would also be lost in the Lemhi Range, mostly because of the construction of the roadway.

N.3.3 Radiological Risk to the Public

The radiological risks associated with retrieval, slagging pyrolysis, and repackaging of waste are discussed in Sections 9.8.2.3 and 9.8.3.3.

For waste processed by slagging pyrolysis, the risk to the public during waste shipment and the operational phase of disposal would be thousands of times smaller than that associated with processing the waste. For the repackaged waste, the risk from shipment and from disposal operations would be about the same as that from processing.

Some of the disposal methods are designed for long-term integrity of the containment. Thus, calculations of hypothetical releases occurring in the year 2085 are of limited value. Figure N-1 shows the consequences of more distant releases (DOE, 1979) as a function of the time at which they occur. (Risks were not evaluated because of the uncertainties in estimating the probabilities of disruptive events thousands of years in the future.) For perspective, results are also shown for the other two alternatives discussed in this appendix. The figure is simplified in that the degradation of the waste confinement is assumed to occur instantaneously, rather than gradually. The increase in population dose shown for the first 100 years is a result of assumed population growth during that period.

In terms of population dose commitment, the dominant hypothetical release event after disposal is volcanic action; either an eruption up through the waste or lava flow over it from a nearby eruption. A fraction of the waste could thereby become airborne and be carried off the site.

All the other evaluated scenarios were found to produce lower population doses. Flooding is among these. The RWMC could be flooded by high water in the Big Lost River or by failure of the Mackay Dam. Such water would pond on the INEL, where most of it would evaporate. To reach the Snake River Plain

Table N-3. Nonradiological Impacts of Disposal[a]

Disposal method and location	Construction					Operations	
	Man-months[b]	Particulate emissions[b] (10^3 lb)	Diesel fuel[b] (10^3 gal)	Land[b,c] (acres)	Concrete[c] (10^3 yd^3)	Person-nel[c]	Electricity[c] (10^6 kW-hr/yr)
Deep-rock disposal: shaft access	924	36	330	205-210	2	39	3-6
Deep-rock disposal: tunnel access	924	36	330	206-211	5	31	2-4
Engineered shallow land disposal at Site 14	393	10.3	94	288-493	510-1200	19-28	0.13 - 0.26
Less-massive construction than above	288	8.3	76	185-266	14-41	10-19	0.13 - 0.26
Engineered surface disposal near the RWMC	246	8.1	73	41-115	380-1100	21-30	0.10 - 0.17

[a]Data from DOE (1979).

[b]Includes committed roadway.

[c]Ranges of values reflect the different output volumes of waste from the three processing methods studied. Higher values are for the repackage-only approach; lower values are for slagging pyrolysis.

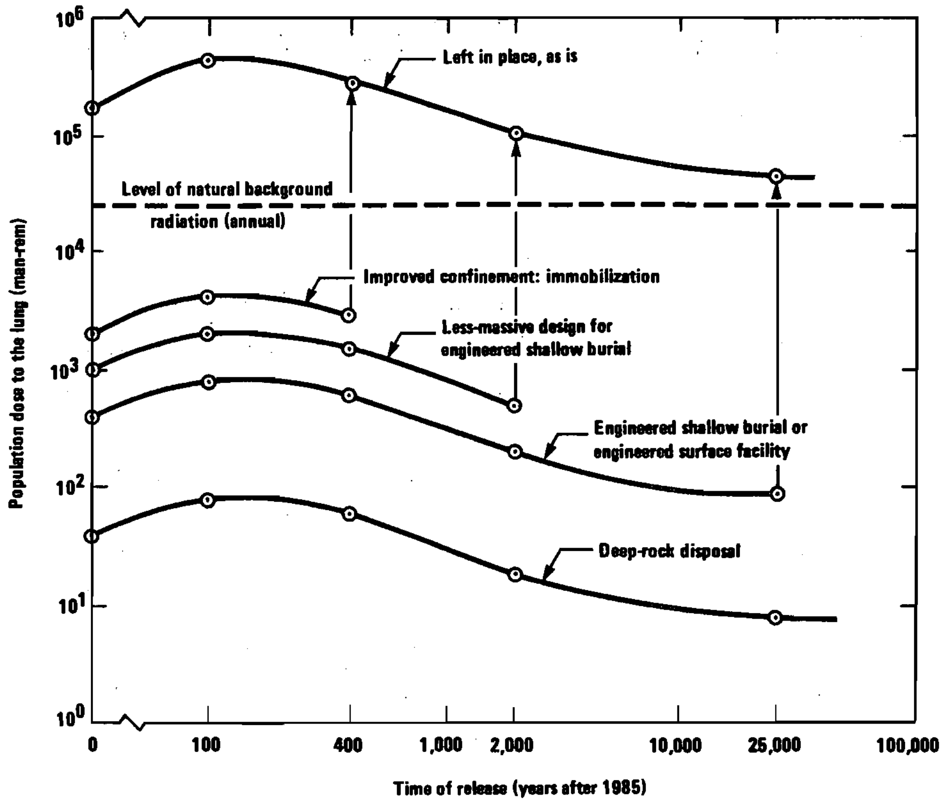

Figure N-1. Summary of consequences from dominant long-term release scenarios for all on-site disposal methods discussed.

aquifer, water would have to percolate downward through 580 feet of sediments and basalt. Flow in the aquifer is at the rate of 4 to 20 feet per day, but sorption would greatly slow the transport of TRU nuclides. Dispersion and decay would cause the resultant concentrations to be low. Indeed, the analysis indicates a greater, but still minor, hazard from the resuspension of TRU nuclides left on the surface after the evaporation of ponded water (DOE, 1979).

A significant scenario from the standpoint of individual doses is future intrusion on the waste site by individuals or small groups of people. These scenarios could result in individual doses as high as 200 rem to the bone or the lung. The population dose would be small because of the small number of people involved.

N.3.4 Hazards to Workers

The hazards to workers during waste-retrieval and processing operations are discussed in Sections 9.8.2.4 and 9.8.3.4, respectively.

During on-site shipment and disposal of waste, small radiation exposures would occur to the work force from direct radiation. Physical controls and administrative procedures would be implemented to keep the radiation doses received by workers as low as practicable and within DOE standards (ERDA, 1977). Present experience with the handling of TRU waste shows that individuals directly involved in the operations do not receive maximum doses near the radiation-worker limit of 5 rem per year.

N.3.5 Costs

The estimated costs of retrieval and of processing for each of the three alternative methods evaluated are given below. These costs are identical with those given in Section 9.8.2.5 and 9.8.3.5; they are in millions of dollars (DOE, 1979).

Operation	Capital	Total O&M[a]	D&D[b]	Total
Retrieval	9	20	1	30
Slagging pyrolysis and packaging	372	226	13	635
Repackaging only	109	92	11	212

[a]Operations and maintenance.
[b]Decontamination and decommissioning.

The estimated costs for on-site shipment and disposal are summarized in Table N-4. For each disposal method, the costs are given for managing the waste form resulting from the two processing methods discussed. The estimated cost of the less-massive version of engineered shallow burial is consequently less than that of the other version; the difference is due principally to the smaller quantity of concrete required.

N.4 CONCLUSIONS

The result of having no off-site TRU-waste repository would be that the TRU waste stored in Idaho could be (1) left in place as is; (2) left in place with improved confinement being provided; or (3) retrieved, processed, and disposed of at the INEL.

No normal operational releases of radioactivity would be associated with the leave-in-place alternative or the improved-confinement alternative. In the short term (i.e., up to about 100 years), the alternative with retrieval, processing, and disposal at the INEL would result in a greater radiological impact than the two other alternatives. The largest radiological impact would result from normal operational releases from the slagging-pyrolysis process. During processing, a whole-body dose commitment of 1.9×10^{-7} millirem per year of operation or 3.6×10^{-3} millirem to the bone could be expected at the point of maximum airborne concentration (Table 9-70).

Table N-4. Estimated Costs of On-Site Disposal for Stored Waste (Millions of Dollars)[a]

Disposal method	Shipping	Capital	Total O&M[b]	D&D[c]	Total
Deep disposal in rock: shaft					
Slagging pyrolysis	2.7	36	103	0.3	142
Repackaging only	1.1	37	111	0.3	149
Deep disposal in rock: tunnel					
Slagging pyrolysis	2.7	37	96	0.3	136
Repackaging only	1.1	38	108	0.3	147
Engineered shallow burial					
Slagging pyrolysis	2.3	263	69	0.3	335
Repackaging only	1.4	604	73	0.4	679
Less-massive variation of engineered shallow burial					
Slagging pyrolysis	2.3	34	65	0.3	102
Repackaging only	1.4	79	69	0.4	150
Disposal in an engineered surface facility					
Slagging pyrolysis	NA[d]	154	70	0.2	225
Repackaging only	NA	451	74	0.2	526

[a]Data from DOE (1979).

[b]For each entry in this column, $60 million of the operations-and-maintenance (O&M) costs stemmed from 100 years of maintenance and surveillance.

[c]Includes only costs associated with decontamination and decommissioning (D&D) of service facilities such as maintenance facilities. No D&D would take place for the disposal facilities themselves.

[d]NA = not applicable.

During handling associated with shipment of processed waste to the INEL disposal locations, workers would be exposed to direct radiation from the waste packages. Experience indicates that the doses received by the workers will be well below the 5-rem/yr limit for radiation workers.

There would be no radiological exposures to the general population during normal operations for disposing of the waste at the INEL. The dominant waste-handling accident would be associated with the waste that has only been repackaged.

Over the long term (i.e., over more than about 100 years), natural disasters (floods, volcanoes, etc.) could occur, disrupting the waste and releasing radionuclides. Also, individuals and small groups of people could inadvertently come into contact with the waste. In terms of radiation doses to the surrounding population, volcanic action was determined to be the predominant event for all of these alternatives. Although significant 50-year dose commitments could be delivered to maximally exposed persons in the volcanic-lava-flow scenario (90 rem to the lung) and the intrusion scenario (500 rem to the bone, 700 rem to the lung), no near-term fatalities from radiation would be expected to result from such events. Dose commitments this large are predicted only for the alternative of leaving the waste as is, without improving its confinement.

Nonradiological effects from any of the three alternatives discussed above would generally be limited to minor commitments of energy, resources, and labor. An exception is the large requirement of concrete for the massive structures for engineered surface disposal and for engineered shallow burial. The latter facility can be made less massive, using less concrete, with some sacrifice in long-term safety. This reduction in mass is probably not possible for the engineered surface-disposal facility, which would be openly exposed to the elements in an area of severe winters; significant rates of deterioration of the containment would then be expected over the long term.

Slagging pyrolysis would be the most costly of the processing methods studied, but the resulting waste product would be the safest. Furthermore, the reduced disposal costs resulting from the decreased volume of waste processed by slagging pyrolysis would tend to offset the increased cost of processing, particularly for disposal in massive concrete structures. Deep-rock disposal and the less-massive variation of engineered disposal would cost much less than the other disposal methods studied.

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Appendix O

INTERPRETATION OF THE RADIATION DOSES PREDICTED IN THIS DOCUMENT

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Appendix O

INTERPRETATION OF THE RADIATION DOSES PREDICTED IN THIS DOCUMENT

Some of the analyses in this document predict the radiation doses and dose commitments that people may receive from activities associated with the WIPP. This appendix begins with a brief discussion of the meaning of these two quantities. It then describes the methods that this document uses for interpreting them.

O.1 RADIATION DOSES AND DOSE COMMITMENTS

The impacts of radiation from the WIPP are predicted in terms of two different quantities--dose and dose commitment--because people can receive two types of exposure to radiation: external exposure and internal exposure. An external exposure comes from a source outside the body; if the source is removed or the person moves away from it, the external exposure stops. A person who stands, for example, on a contaminated surface may receive an external exposure until he moves away from the surface. Internal exposure, on the other hand, comes from radioactive material inside the body. If such material is inhaled or ingested, part of it continues to irradiate body tissues until it decays or is eliminated by biological processes.

When this environmental impact statement predicts that a person will receive an external exposure to radiation, it also evaluates the biological damage done during the exposure by calculating the dose delivered to the person. Strictly speaking, it calculates the quantity called "dose equivalent," but this document, like most others of its type, uses the less awkward term "dose."

Internal exposures are evaluated in terms of "dose commitment," a quantity describing the effects of irradiation that continues after radioactive material has entered the body. A dose commitment is calculated by integrating, or summing, the annual dose received from radioactive nuclides inside the body; usually this integration is performed for a period of 50 years after intake. The integrated dose resulting from 1 year's intake of the material is then, by definition, the 50-year dose commitment from that intake. For radionuclides that decay quickly or are eliminated quickly, most of the dose commitment is received in a short period of time at the beginning of the 50 years; for longer-lived or longer-retained materials, it may be received over the entire 50 years. Tritium, for example, would deliver a dose commitment early in the 50-year period. Among the radionuclides that would deliver a dose commitment over a longer time are the actinide elements that are in the waste to be received at the WIPP.

Both dose and dose commitment are expressed in terms of a unit called rem, a measure of biological damage done by radiation.

When more than a few people are exposed to radiation, the quantities commonly used to describe the effects are population dose and population dose commitment. Expressed in man-rem, these quantities are calculated by multiplying the number of exposed people by the average dose or dose commitment they receive. From estimates of population dose and dose commitment, it is possible, as explained below, to predict the health effects resulting from exposure.

O.2 METHODS FOR INTERPRETING PREDICTIONS OF RADIATION DOSES

Because most people are not familiar with measurements of radiation doses and dose commitments, the main text of this document provides, in addition to the predictions themselves, information intended to help the readers judge their significance. In providing such information, documents like this one can use three convenient methods: comparison of a predicted dose with the dose received from naturally occurring background radiation, comparison of a predicted dose with official standards intended to insure public safety, and estimation of the health effects that might arise from a predicted dose. This appendix briefly discusses these three methods of interpretation and explains how they are used in this document.

The remainder of this appendix is primarily a short summary of the more complete discussion in the draft generic environmental impact statement (GEIS) on the Management of Commercially Generated Radioactive Waste (U.S. Department of Energy, 1979). This appendix is not intended to be a complete tutorial essay on the effects of low-level radiation, nor does it take a position in the current controversies about the effects of low-level radiation. Interested readers can find full discussions elsewhere; the GEIS, for example, contains an extensive list of references, only a few of which are repeated here.

O.2.1 Method 1: Comparison with Natural Background Radiation

All people are exposed to radioactivity from natural sources. Cosmic rays from space arrive constantly at the earth; people receive radiation doses from the rays directly and from interactions between the rays and matter on earth. People also receive radiation doses from terrestrial sources: radioactive elements that exist in the earth's crust and in living tissue and radioactive elements that are produced when cosmic rays interact with stable elements. Because some of the radioactive elements exist inside the human body, the terrestrial sources contribute internal radiation doses as well as external radiation doses.

The doses received from these natural radiation sources vary from place to place. For example, the dose from cosmic rays increases with elevation, the average dose at about 6600 feet above sea level being double the dose at sea level; the external dose from terrestrial sources is higher in places where the rocks near the surface of the ground are richer in natural radioactive elements. The GEIS contains tables and text describing the doses from natural background radiation, and detailed discussions appear in the references cited there. Table O-1, taken from the GEIS, summarizes the average doses from natural radiation. In the text of this document the value usually used for the average whole-body dose from natural radiation is 0.1 rem per year, slightly lower than the value in the table. This choice insures that the comparisons do not overestimate background doses even though they vary from place to place as explained above. When discussing events in Idaho, the text uses 0.15 rem per year because in that state the average annual dose from natural radiation is about 0.17 rem.

Table O-1. Estimated Annual Average Whole-Body Doses from Natural Radiation in the United States

Source	Annual dose (rem)
Cosmic rays	0.045
Terrestrial radiation	
External	0.060
Internal	0.025
Total	0.130

This document uses natural-background doses as a reference for comparison with the doses it predicts. Such a comparison is useful for at least two reasons. First, the natural-background dose has been reliably measured and is well understood; it is a number that is not likely to change significantly with new studies or with advances in the understanding of radiation effects. Second, comparisons with natural background are comparisons with radiation levels that all people have experienced; readers may use their own feelings about background radiation in evaluating the significance of the doses that the WIPP may add to the natural doses.

In spite of these two reasons, some opposition to comparisons with natural background radiation was expressed in public comments on the draft of this environmental impact statement. Some commentors seemed to feel that in making these comparisons the statement was tacitly assuming that natural-background levels are safe. Whether natural background radiation is dangerous or not is a complex question. Some authors have suggested that as many as 50% of human cancers are caused by natural radiation. Other investigators have pointed out that this hypothesis is not supported by available data, such as the observed cancer rates in different places where natural radiation varies widely; some investigators have even found negative correlations between natural radiation and health effects. According to the majority of studies, the effects of natural radiation are so small that they are likely to be undetectable among the effects of other sources of human ill health.

Like the GEIS, this document does not take a position on the question of whether natural background radiation is responsible for health effects in human beings. It uses the doses received from natural background radiation only as an easily understood reference. Reasoning from the information that the predicted doses are lower than natural-background doses, members of the public and government officials can decide for themselves whether radiation from the WIPP would be significant.

O.2.2 Method 2: Comparison with Official Standards

Radiation standards are set at levels that, in the judgment of experts, will protect people from ill effects. Comparing predicted doses with these standards is, therefore, a simple way of identifying doses that can be labeled "safe" in a way that has a well-defined meaning.

A difficulty with explaining radiation doses by such comparisons is the confusion that can arise because standards are subject to change. The agencies that set radiation standards have, in fact, recently received requests both to lower and to raise some current standards. A further confusion sometimes arises because the standards that apply to members of the general public are different from those that apply to workers in industries that use radiation. For these reasons, this document seldom uses official standards as a reference for comparison with predicted doses.

O.2.3 Method 3: Estimates of Health Effects

Acute effects

The doses predicted for the routine operation of the WIPP are too low to produce acute, or prompt, health effects, which appear only at higher doses. According to the National Council on Radiation Protection and Measurements (1974a, pp. 44-46), changes in white blood cells are not found easily at doses below 50 rem. Specialized analyses of chromosomes can detect changes from doses in the range of 5 to 25 rem, but "the biological significance, if any, of these changes is unknown at present." The lowest doses that produce visible evidence that a person has been affected by radiation are in the range of 75 to 125 rem, which is the "minimal dose likely to produce vomiting in about 10% of people so exposed." The routine operation of the WIPP is not predicted to deliver doses in even the lowest of these ranges.

The analysis of accidents during the transportation of waste predicts upper-limit dose commitments of 3T rem to the bone from the worst accidents, which are highly unlikely. These doses would be delivered over a 50-year period and would therefore not be expected to produce acute health effects.

The only higher doses predicted in this document appear in the analyses that study upper limits to intentional destructive acts (Chapter 6) and to hypothetical long-term releases of waste left in storage at Idaho (Appendix N). These whole-body dose commitments might reach levels that would produce nausea and vomiting in some people if the doses were delivered in brief external exposures rather than over 50 years. While such prompt effects are not to be expected from 50-year dose commitments, it is difficult to predict whether they might occur at some time during the 50 years. As the National Council on Radiation Protection and Measurements points out, there are no reliable data on the relation between internal dose and whole-body external dose (1974b, p. 37).

Delayed effects

Although there is little possibility of acute illness from the doses predicted in this document, exposure to them might be expected to produce effects noticeable after times measured in years. These delayed health effects are of two types: somatic effects, which are principally cancers, and genetic effects, which arise from alterations or rearrangements of genes in living cells. The GEIS lists four kinds of disease associated with genetic effects, and it points out that there may also be other genetic influences on physical and mental health. Because these other influences are poorly defined, however, the studies that try to predict the genetic effects of low-level radiation simply assume values that appear to be the highest possible ones.

Using health effects as a method of explaining radiation doses has the apparent advantage that the public can understand numerical predictions of deaths more easily than predictions of doses expressed in unfamiliar units. The disadvantage of using health effects is that interpreting predictions of possible deaths is less simple than it might appear to be; the scientific basis for such predictions is complex and controversial.

The complexity and controversy stem from the difficulty of measuring the effects of low-level radiation. The doses predicted in this statement lie far below the doses for which health effects in people have been measured directly. Almost all of the directly measured data are for doses near 100 rem and higher; they show that the magnitude of health effects increases with the radiation dose (Figure O-1). To predict the effects of lower doses requires extrapolation of these data, and extrapolation to doses like those predicted for the WIPP is subject to large uncertainty; the doses from the routine operation of the WIPP generally lie in the range below 0.1 rem, a thousand times lower than the direct measurements. Some authorities feel that the direct data can be meaningfully extrapolated to lower doses simply by drawing a straight line on a graph that shows health effects as a function of dose (Figure O-1). Other investigators feel that this linear extrapolation underestimates health effects at low doses; they prefer a "superlinear" extrapolation like the one shown in Figure O-1. Still other investigators feel that at low doses the human body can at least partially repair the damage induced by radiation; this theory would support an extrapolation like the one labeled "sublinear" in Figure O-1.

It is difficult to decide experimentally which extrapolation procedure is correct, because the effects of radiation at low doses are almost impossible to separate from similar effects exerted by other agents in the biosphere. In the absence of definitive experiments, most groups of experts recommend the use of the linear hypothesis for making predictions intended to protect the health of the public. The predictions made in this document therefore implicitly contain the linear extrapolation. Because the linear hypothesis remains unproved at low doses, however, the health effects of radiation doses below natural-background levels must be predicted as possibilities, not as certainties.

For the interpretation of radiation doses, the GEIS presents "risk factors" that convert predictions of population doses to predictions of health effects. These risk factors were derived from the literature dealing with the somatic and the genetic effects of low-level radiation. A discussion of the derivation appears in Appendix E of the GEIS. For convenience, the references consulted in the derivation are listed here: the BEIR Report issued by the National Academy of Sciences (1972), the UNSCEAR Report issued by the United Nations Scientific Committee on the Effects of Atomic Radiation (1977), publications on the uranium fuel cycle issued by the U.S. Environmental Protection Agency (1973a, 1973b, 1976), the Reactor Safety Study issued by the U.S. Nuclear Regulatory

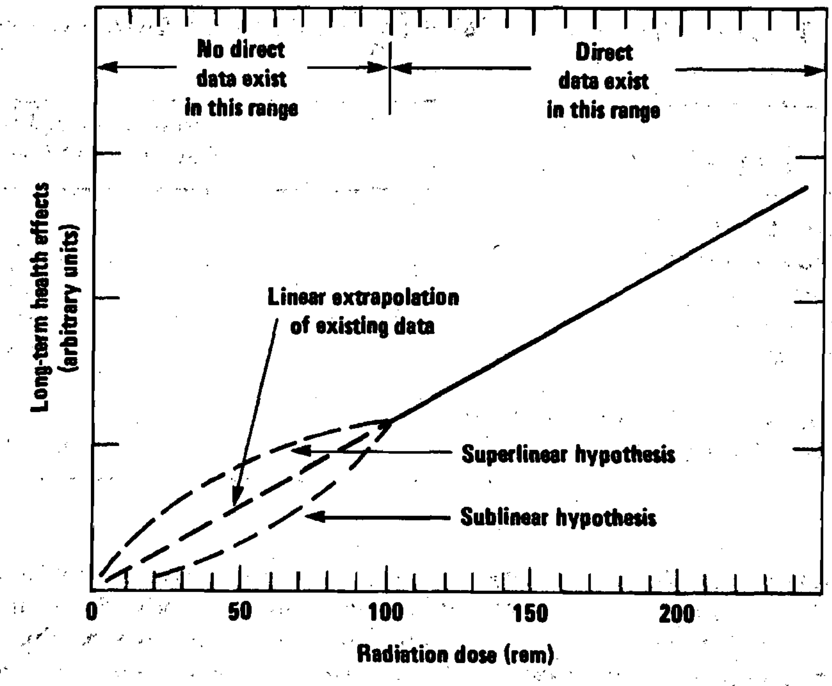

Figure O-1. Suggested methods of determining the effects of low-level radiation by the extrapolation of existing data for high levels. For clarity, the curves exaggerate the differences from the linear extrapolation. Predicted doses from the WIPP are mostly in the dose range below 1 rem, where extrapolations are highly uncertain.

Commission (1975), and a report issued by the Medical Research Council in England (1975).

Table O-2, taken from the GEIS, lists the health-effects risk factors used in this statement. There are two types of risk factors in Table O-2: those expressing somatic effects as numbers of fatal cancers and those expressing genetic effects. The somatic effects are further divided among cancers arising from four different kinds of exposure. The health effects predicted by the risk factors in Table O-2 are delayed effects that would occur years after the exposure. The predicted deaths would occur throughout the lifetimes of the people who receive the dose; the genetic effects are the total numbers that would occur in all generations after the exposure. Because the reports listed above do not agree on single values for each of these risk factors, the entries in Table O-2 are ranges that encompass the reported values.

Table O-2. Health-Effects Risk Factors Used in This Statement

Type of effect	Predicted incidence per 1 million man-rem
Fatal cancers from	
Whole-body exposure	50-500
Lung exposure	5-50
Bone exposure	2-10
Thyroid exposure	3-15
Genetic effects in all generations from whole-body exposure	50-300

The risk factors in Table O-2 can be explained by the example of whole-body exposure. If a population received a total whole-body dose of 1 million man-rem, the number of fatal cancers induced by the exposure might lie between 50 and 500. Such a population dose could arise, for example, if each of 1 million people received a dose of 1 rem; it could arise if each of 100 million people received a dose of 0.01 rem.

Table O-3 illustrates the use of the risk factors. It presents the numbers of fatal cancers that might develop if populations of various sizes received whole-body doses of various magnitudes. The risk factors that count other effects of exposure can be used similarly.

Table O-3. Illustration of the Use of Risk Factors To Calculate Radiation-Induced Deaths

Population	Average whole-body dose (rem)	Population dose (man-rem)	Predicted fatal cancers
10,000	0.01	100	0.005-0.05
10,000	0.1	1,000	0.05-0.5
100,000	0.001	100	0.005-0.05
100,000	0.01	1,000	0.05-0.5
100,000	0.02	2,000	0.1-1
100,000	0.1	10,000	0.5-5
1,000,000	0.1	100,000	5-50

REFERENCES

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U.S. Environmental Protection Agency, 1973a. Environmental Analysis of the Uranium Fuel Cycle, Part I, "Fuel Supply," EPA-520/9-73-003-B, Washington, D.C.

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Appendix P

COMMENTS FROM FEDERAL AND STATE AGENCIES ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE WASTE ISOLATION PILOT PLANT

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Appendix P

COMMENTS FROM FEDERAL AND STATE AGENCIES ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE WASTE ISOLATION PILOT PLANT

This appendix contains comments from Federal and state agencies on the draft environmental impact statement for the Waste Isolation Pilot Plant. Only the cover letters of the state government agencies are presented in this appendix. Copies of these comment letters in their entirety as well as all letters received from citizens groups and private persons, are available for public review at the following DOE public reading rooms:

Albuquerque Public Library
501 Copper Avenue Northwest
Albuquerque, New Mexico 87102

Carlsbad Public Library
Public Document Room
101 South Halaguene Street
Carlsbad, New Mexico 88220

Hobbs Public Library
509 North Shipp
Hobbs, New Mexico 88248

Thomas Brannigan Library
106 West Hadley
Las Cruces, New Mexico 88001

Roswell Public Library
301 North Pennsylvania Street
Roswell, New Mexico 88201

New Mexico Technical Library
Campus Station
Socorro, New Mexico 87801

Zimmerman Library
University of New Mexico
Albuquerque, New Mexico 87138

National Atomic Museum
Kirtland Air Force Base - East
Albuquerque, New Mexico 87115

COMMENTS FROM FEDERAL AGENCIES

KENT HANCE
19TH DISTRICT, TEXAS

DISTRICT OFFICES:
FEDERAL BUILDING, ROOM 611
LUBBOCK, TEXAS 79401
(806) 763-1611

FEDERAL BUILDING, ROOM 208
MIDLAND, TEXAS 79701
(915) 683-5407

Congress of the United States
House of Representatives
Washington, D.C. 20515

May 25, 1979

Mr. Eugene Beckett
Department of Energy
WIPP Project Office
MS B-107
Washington, D.C. 20545

Dear Mr. Beckett:

You will find attached written comments for inclusion and consideration at the public hearings being held on the draft environmental impact statement, DOE/EIS-0026-D, Waste Isolation Pilot Plant, Eddy County, New Mexico.

If you would please keep me advised as to the progress of this project, I would appreciate it.

Sincerely,

Kent Hance

Kent Hance

KH:mpo

Attachment

ECTOR COUNTY DEMOCRATIC WOMEN'S CLUB
P. O. BOX 2944
ODESSA, TEXAS 79760

May 18, 1979

ıue Honorable Kent Hance
The House of Representatives
1039 Longworth Building
Washington, D. C. 20515

Re: Waste Isolation Pilot Plant
Near Carlsbad, New Mexico

Dear Congressman Hance:

he members of the Ector County Democratic Women's Club are opposed to the building of he Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. The club reached his decision after consulting with members of the League of Women Voters of Odessa, exas, and reviewing the League's in-depth study of this pilot plant. We agree with he League that this site is not sufficiently safe for long-term storage of large uantities of nuclear waste for the following reasons:

1. According to the hydrological studies conducted there are high pressure deposits of natural gas and water underlying the site which are potentially dangerous if the high pressure gas should ever force the water into the WIPP site. These natural gas deposits are potentially valuable sources of natural gas, but the WIPP site will remove them from usefulness.

2. There have been earthquakes as recently as the spring of 1978 in Winkler County, Texas, which is adjacent to Eddy County, New Mexico, the location of the proposed WIPP site.

3. The aquifers of southeastern New Mexico and southwestern Texas are too close to the chosen site. If any leakage should occur and seep into these water supplies, it could pollute a portion or the entire water supply of the area.

n addition wastes being delivered to the plant would be transported through the State f Texas, which is certainly a potential hazard to residents along the route.

f, however, the Carlsbad site is chosen we would like to see the following safeguards nstituted as recommended by the League:

1. There should be monitoring of the mine until the mine site is no more radioactive than the natural radioactivity of the region.

2. There should be monitoring of private and public water supplies of southeast New Mexico and southwest Texas as long as it is necessary to monitor the mine. The monitoring should be at the expense of the United States government, not at the expense of the individual water user.

3. If pollution of any water supply should occur from the Waste Isolation Pilot Plant, the water supply should be replaced with potable water. This good, usable water should not be at the expense of the property owner/owners, but rather at the expense of the United States government.

4. There should be security provisions for the transportation of the radionuclear waste to the site.

5. The radioactive waste should be isolated in as retrievable a manner as possible, pending future technology when the waste can be safely disposed of or utilized for fuel.

We feel confident that you will weigh these considerations carefully and help protect the residents of Texas.

Sincerely yours,

Caroline Ater

Mrs. Gene Ater
President

UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY
WASHINGTON

GENERAL COUNSEL

June 26, 1979

Dear Mr. Beckett:

The U.S. Arms Control and Disarmament Agency (ACDA) has reviewed the Department of Energy's draft Environmental Impact Statement (DOE/EIS-0026-D) on the proposed Waste Isolation Pilot Plant (WIPP) which was forwarded to us for comment by Assistant Secretary Clusen's letter dated April 18, 1979.

ACDA would prefer to see more emphasis placed in the draft EIS on the importance to our national nuclear waste management program of the intermediate-scale facility (ISF) demonstration component of the WIPP project. This could be handled relatively easily by placing additional balancing text from the Interagency Review Group Report (1979, p.55) at the end of the third paragraph on p. 2-15 of the draft EIS. Specifically, we would suggest using the following statements:

> "An ISF would also provide valuable experience in constructing, operating, and maintaining facilities and equipment for waste packaging, handling, transporting, emplacement, and retrieval," and
> "Exercising the licensing process for at least one ISF at an early date would be extremely useful preparation for the later licensing proceeding of the first full-scale repository."

We recognize that these statements appear as part of a verbatim

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

reproduction of selected IRG material in Appendix C, but believe they are likely to be overlooked if not included in the main text.

In this regard, it is important to keep in mind that progress in demonstrating that nuclear spent fuel can be stored acceptably in geological respositories has important implications for U.S. nuclear non-proliferation policy. Again quoting from the Interagency Review Group Report (1979, p.68):

> While it is difficult to predict what impact any particular strategic planning basis for the United States waste disposal program would have on other countries, it is fair to say that a strategy perceived as indecisive would almost certainly reduce our influence on achieving overall non-proliferation objectives at the international level. This is important to the United States because of our concern about possible proliferation consequences of nuclear power, our need to influence other countries with regard to the feasibility of permanent disposal of spent fuel, and our desire to protect the global environment by working with other countries to devise acceptable approaches to spent fuel management and waste disposal.

The ISF demonstration could be an important factor in convincing other nations that the U.S. is moving decisively ahead in solving its spent fuel management problems.

Sincerely,

Thomas Graham, Jr.

Thomas Graham, Jr.

DEPARTMENT OF HEALTH EDUCATION AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

SEP 21 1979

Mr. Eugene Beckett
WIPP Project Office
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

Thank you for the opportunity to review the Draft Environmental Impact Statement (EIS) for Waste Isolation Pilot Plant (DOE/EIS-0026-1). We offer the following comments for consideration in preparing the final EIS.

Since this is a new pilot undertaking, we were not able to review the adequacy of the design objectives for meeting radiation protection standards associated with potential individual doses.

The impact statement does not contain a specific criteria for radiological protection relative to general population exposure and occupational exposure. The summary of major impacts described in Table 3-10 is presented as a percent of background radiation for the general population and the current standards for occupational exposure. In order to enable a better evaluation of the radiological impact, DOE should include a discussion of the radiological protection criteria that they consider applicable to the Waste Isolation Pilot Plant (WIPP) operation. Furthermore, such criteria should address the range of doses that DOE considers acceptable as a result of accidents. For example, on page 3-15 the EIS states that as a result of drilling into the stored spent fuel 100 years after a repository is sealed, the drill-crew geologist could receive a dose of 90 rem (18 times occupational dose of 5 rem/year). Please note that section 2.2 and Appendix G of DOE/EIS-0046-D on the management of commercially generated radioactive wastes contains such a discussion.

In assessing the acceptability of the proposed WIPP, the radiological impact from transportation, normal operations, operational accidents, and long-term impacts are critical considerations. Section 1.4 presents an environmental analysis of alternatives. A summary table or matrix showing the radiological impact of each alternative would serve to more clearly identify such impacts.

There needs to be a discussion of the facility emergency plan, particularly with respect to coordination with state emergency radiation plans. Such a discussion should also include coordination efforts with local medical facilities.

There is insufficient information for determining whether environmental pathways and models provide accurate estimates of doses that the population would be subjected to under normal operating conditions and accident situations.

Section 9.2.10 describes the impact of routine releases of radioactivity from facility operations. The estimates of population and individual exposure are estimated using the AIRDOS-II Code. It is not evident from the presentation that there are uncertain ties in the input data that should be identified. It would be helpful to know the range of doses associated with the estimates presented in Tables 9-17 through 9-27.

The use of AIRDOS-II Code to compute doses to populations from environmental pathways as a basis for population dose carries with it an accuracy connotation that may or may not exist. It is not evident from the DEIS or its reference that the dose model has been verified by means of field testing and analysis of real time monitoring data.

Finally, the impact statement lacks information on monitoring associated with drinking water, human food, animal feed and their products, such as milk, and the disposal of radioactive plant wastes.

Sincerely yours,

Charles Custard
Director
Office of Environmental Affairs

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER 79/388

OCT 3 1979

Honorable Ruth Clusen
Assistant Secretary for Environment
Department of Energy
Washington, D.C. 20545

Dear Ms. Clusen:

Thank you for your letter of April 18, 1979, transmitting copies of the draft environmental impact statement for the Waste Isolation Pilot Plant, Eddy County, New Mexico.

As you may be aware, the IRG review of the nuclear waste management program as well as the DOE draft Environmental Impact Statement for Commercially Generated Waste has identified a number of outstanding scientific and technical concerns associated with the disposal of high-level and transuranic wastes. Many of these concerns are reflected in our comments on the review of the WIPP GEIS since the WIPP GEIS contains proposals for the disposal of high-level and transuranic wastes. We are also aware that the WIPP project has been substantially altered in the FY '80 authorization process and that the President is currently deliberating the role of the WIPP Project in the overall nuclear waste management program.

Our comments are principally addressed to the proposal contained in the WIPP GEIS and specifically to the disposal of high-level waste/spent fuel at that site. From a NEPA and FLPMA viewpoint, we believe the current GEIS will have to be substantially revised and supplemented in order for this Department to make use of it in support of any land withdrawal decisions we may wish to make at that site. Thus, our specific concerns are discussed in each of the sections below with a view that DOE's subsequent impact statement will be revised to take into account our concerns, especially those concerns under FLPMA. We will be pleased to work with you in the revision of the WIPP GEIS to the extent that we have the capability to do so.

Relationship to the IRG Report

The President has recognized the immediate and long-term problems of nuclear waste management. In March 1978, he established a Federal Interagency Review Group (IRG) for nuclear waste management. The IRG published a final report in March 1979 specifying recommendations for the overhaul and reorientation of the Federal Government's waste management program. Additionally, the IRG work is considered to be the baseline of policy expertise in the Federal Government. The IRG report devotes considerable attention to the development of an intermediate-scale facility. Although the IRG report does provide that the intermediate-scale facility could be contemplated at the WIPP site, the IRG also defines a process of site selection for high-level, spent fuel, and transuranic wastes in differing geologic media in diverse geologic environments. The final statement should evaluate the WIPP Project in light of the IRG alternatives with a view of how the proposed WIPP Project conforms with the recommended process laid out by the IRG. This should be done in a thorough manner so that it can be readily implemented.

For example, the IRG report indicates that although more is known about the engineering aspects of a repository in salt than other media, on purely technical grounds, no particular geologic host medium is an obvious preferred choice at this time. The IRG report also indicates that the capability must be developed to characterize and evaluate media in a number of geologic environments for possible use as repositories built with conventional mining technology. The WIPP DEIS only discusses salt as a host medium. However, the IRG report discusses the existing and potential alternatives for geologic and hydrologic conditions necessary to store nuclear waste. Thus, the EIS is inadequate because of the omission of a credible discussion of alternative geologic host environments. This point is distinct from programmatic alternatives for disposal of nuclear waste such as burial at sea, rocketing the waste into outer space, etc.

The ultimate criterion for geologic host media is the successful isolation of radioactive waste (TRU, HLW, etc.) for periods of time ranging from 1,000 years to 250,000 years. During such a long time frame, a number of factors may change including climate, geologic stability, and the existence of man on earth, etc. The WIPP DEIS does not offer a credible discussion, in simple English, of the expertise that would be necessary to characterize the integrity of a nuclear waste disposal site for 100,000 years or more, let alone provide institutional surety that such a site could be maintained over that time period.

The Environmental Protection Agency is now preparing final regulations for standards on acceptable levels of radioactivity in the environment. EPA's standards are general rather than site-specific. The IRG and EPA have recognized that zero release of radioactivity cannot be assured. The IRG urges that it is more feasible to defer the choice of waste technology so the ultimate choice of disposal options will factor in EPA's criteria. The WIPP DEIS does not address the need for application of the criteria to an intermediate-scale facility. This issue should be addressed in the final statement. Secondly, since the purpose of the GEIS is to establish the scientific feasibility of pursuing mined repositories and defining the necessary supporting programs, e.g., R&D, etc., to accomplish that purpose, the WIPP EIS should also address the relationship between the WIPP Project and the overall waste management program and its specific role in the overall program.

Outstanding Technical Issues

We recognize that some of the proposals contained in the document may be moot because of Presidential and Congressional decisions. Nonetheless we have responded to the document as it exists.

Before any waste is emplaced on a retrievable basis, the waste-form question will obviously have to be settled. Before any waste that produces significant amounts of heat is emplaced on a retrievable basis, the exact mechanism and significance of migration of fluid inclusions in the salt to the heat source must be determined.

Before large amounts of waste are emplaced on a nonretrievable basis, the hydrologic flow system must be more completely characterized, especially the question of radionuclide retardation and the details of flow-through features in the Rustler Formation. In addition, the permeability and effectiveness of backfill materials and the potential for the successful sealing of shafts must be known. Assurances that there are no large brine pockets in the vicinity of the site must be available. A more precise estimate of long-term risk must also be made including tectonic, climatic, or other factors which might initiate a rele from the repository (such as by breccia pipe formation), shorten the flow path between the repository and Malaga Bend, or result in loss of dilution by the Pecos River at Malaga Bend. Work on all of these topics is currently underway.

Before a decision is made to proceed with licensing at the WIPP site, the difficult issue of future human intrusion and the risk posed by it must be resolved. Whether or not alternative sites and media are indeed comparable in long-term risk, and superior or inferior as regards attractiveness for future intrusion, should be assessed at an early date. An R&D effort to make these comparisons should be part of the national program to achieve satisfactory means of waste disposal. These are all significant technical issues that must be resolved before reliance on the risk assessments model results as contained in the draft EIS can be undertaken with any degree of confidence and credibility.

Format of the Draft Statement

The format of this environmental impact statement is disorganized and confusing. For example, a description of the proposal should be systematically set forth. Without a complete understanding of the proposal, it is not possible to understand the impacts on the environment of that proposal. Unfortunately, the proposal is not clearly set forth in any one section in the EIS. That part of the proposal relating to transportation of the radioactive waste is found in the first half of Chapter 6. Other parts of the proposal are found in the latter part of Chapter 8. To learn of the waste forms that are part of the overall plan one must turn to Chapter 5 and the central section of Chapter 5. The description of geology, hydrology and archaeology are found in Chapter 7. The land use description is partially located at the beginning of Chapter 8 and partially in Chapter 12. A description of the scenic, historic and cultural resources is located in Appendix H in Volume 2 of the document. Appendix I in Volume 1 of the document contains a description of three other environmental parameters. In other words, the description of the environment is spread through three chapters and two appendices. For the reader to put it together is a major undertaking.

Impacts from the proposal are likewise spread throughout various sections in the document. In the alternatives chapter (Chapter 3) the alternative of "no action" is considered in two pages. However, this alternative is not fully discussed there. Part of the alternative of "no action" is to leave the waste in Idaho. The impact of that can be found in Section 7 of Chapter 9. Similar problems can be found within Chapters 6 and 9.

We also recommend that additional effort be taken to reduce technical jargon to make the statement more understandable.

We believe that the exact nature of the proposed action must be described, along with alternatives to the proposed action, the environmental consequences of the proposed action and alternatives; and possible termination of the withdrawal. This site could be disqualified for technical or institutional reasons, found to be ultimately unsuitable, or, alternatively, retrievability problems could occur. We believe the draft EIS fails to adequately analyze these issues. Moreover, the site characterization and evaluation fails to comply with the Federal Land Policy and Management Act of 1976 (FLPMA) and the National Environmental Policy Act of 1969 (NEPA) and hence, is inadequate for the purposes of considering a withdrawal of public lands. Finally, if the Department of Energy has changed the purpose of the WIPP since the draft EIS was released, then the current document is inadequate by definition. In such case, a supplemental EIS will be required at a minimum.

Analysis

The EIS contains outdated data and a consistent lack of an analysis of the environmental impacts of the proposed action in a number of areas. Additionally, a lot of facts and statistics are given, but pragmatic analysis of the effects on the environment of those facts and figures is lacking. Impacts are frequently split up into constitutent parts and are not evaluated cumulatively. For example, the analysis of the impacts of noise by the operation of the plant is found in Section 9.2.5 on page 9-26. It begins with a short statement as to what noise standards are. Why this is contained in the impact section rather than the environmental setting section is unknown. Moreover, the criteria used are outdated. The criteria used were established by the Department of Housing and Urban Development prior to the passage of the Noise Control Act of 1972 and thus are outdated. Additionally, the applicability of HUD standards (for urban areas) to a rural site is also unexplained. We believe the use of more recent criteria developed by the Environmental Protection Agency could alter this analysis.

The material on noise is then broken down into six categories; however, the impacts in each of these categories are not examined cumulatively. For each category the EIS states what the noise level is expected to be with no analysis of what that noise level means. Several times the document states that wildlife "will become accustomed" to the noise levels. However, the probability of, or the length of time for, wildlife acclimitization are not evaluated. Specific effects upon wildlife from noise are not evaluated.

In the transportation of the nuclear wastes the impacts of "intentional destructive acts," discussed in a few lines at Section 6.8, are dismissed by saying that the wastes are packaged so well, the packaging could hardly be breached. And if for some reason they are breached, there would be "relatively limited consequences." Evidence of analysis to support that conclusion should have been presented, particularly since we are unaware of what the state-of-the-art on packaging is today, or what the proposed waste form is likely to be since the Department of Energy doesn't plan making this decision before the early 1980's. In addition, considerable additional information about the transport of radioactive wastes to this specific site should have been included.

It is difficult to find any assessment of mitigation actions in Section 9.1.5. For example, under landscape restoration the analysis is as follows: "At the completion of construction, all areas disturbed by construction and not required for permanent facilities will be regraded and seeded." That is the entire discussion. Issues such as seeded with what sort of vegetation; in what areas; how large of an area; will the reseeding work; what will be the impact of the regrading and reseeding of the area are never addressed. This entire section should be revised to assess the effectiveness of the mitigation actions proposed.

There has been a lot of information in the public press recently on radiation exposure to workers in uranium mines and other high risk areas over past years. We believe the discussion of exposure should be expanded in the final statement. Very little discussion of the indirect impacts on plant and animal life (livestock) attributable to radiation exposure to soils and forage plants near the site, nor at intervals from that site has been presented. Additionally, an explanation should be given as to how radioactivity is measured and how the various units of measure relate to human health and safety. The effects of certain radiation doses should be described so that they may be compared with those possible in the repository area based on dosage estimates given in the draft statement.

The draft statement utilizes three sources of data in various sections of the document which address the amounts of resources and reserves of potash mineralization present in the WIPP area. These sources consist of the Geological Survey Open-file Report 78-828, 1978; U.S. Bureau of Mines report, November 1977, and the American Institute of Mining Engineering report, 1978. Large differences exist in the resource-reserve estimates presented by these documents. These differences are largely due to variations in criteria chosen by each source to evaluate resources and reserves under the definitions of Geological Survey Bulletin 1450-A. Values used in the draft statement have been selected and used without any clear explanation as to why they were chosen.

There also appears to be little evidence of follow-through in the document. For example, Section 9.2.13 is a discussion of mitigation of impacts caused by plant operation. Three of the impacts mentioned in the impact section on plant operation are (a) effects of non-radioactive-waste discharges, (b) impact of routine releases of radioactivity, and (c) radiation exposure of the work force. These three areas of impacts are not even mentioned in the mitigation section. The EIS concludes that the proposed action and all of its aspects throughout 100 years of its life, including the transportation of the waste product, the excavation of the mine, the storage, the testing, the various different radioactive waste products, potential accidents, leakage, etc., and all impacts are small "save two": first, a long-term denial of access of 3 percent of the United States reserves of the mineral langbeinite and, second, if there is any drilling in the site during the next 100 years, members of the drilling crew could be exposed to doses of "above permissible occupational exposures." In view of the many outstanding scientific and technical uncertainties in the GEIS, we do not understand how these conclusions can be supported.

Treatment of Alternatives

A most serious deficiency in the WIPP draft EIS is its treatment of alternatives. The entire discussion of alternatives is limited to 33 pages, approximately half of which is a discussion of the impacts of the proposed action. Six other alternatives are discussed, five of which relate to variations within the proposal and only one is an alternative outside of the proposal, namely, the "no action" alternative. Three deficiencies exist: (1) failure to treat a number of other reasonable alternatives; (2) failure to provide a sufficient analysis of those alternatives which are considered; and (3) failure to comply with the provisions of FLPMA by providing analyses as to why the WIPP site is the best site for its intended use under section 204(c). We believe these must be remedied in the revised draft.

There is some discussion in the EIS of sites in Washington and Oregon. These are lava formations geologically identified as the Columbia River basalts. This formation is very extensive in southeastern Washington and northeastern Oregon. Surface and subsurface management on many tracts in these areas is under the jurisdiction of this Department's Bureau of Land Management. As a result, we are concerned that the statement does not identify environmental impacts for these alternative sites which may be on public lands.

Additionally, the statement does not contain sufficient data to identify or utilize impacts on water resources, range land use for livestock and wildlife, forestry, cultural resources, wilderness, areas of critical environmental concern, oil and gas exploration and extraction, and nonenergy minerals; nor does it quantify impacts to any relevant degree. The GEIS deals only in generalizations with regard to environmental impacts associated with alternatives to the proposed action. We believe these impacts must be more fully addressed in the revised EIS.

Site Selection and Land Withdrawal

The process of selection used between 1973 and 1976 to select the WIPP site included consideration of numerous alternative sites in salt environments only. The process also involved the tacit assumption that complete containment would be provided by the salt formations. Groundwater flow paths from the potential repository to the biosphere were considered in the analysis of alternate sites but not from a regional viewpoint early in the analysis. Sorptive capacity of the rocks along the flow path, as a significant barrier to nuclide movement, was not a factor in the site selection criteria (Powers, et al., 1978, p. 9-23). The approach used to select the WIPP site reflected the historical view at the time that salt would be the emplacement medium. Recently, however, emphasis on the total geohydrologic system in the site-selection process has become the key item of concern. (Interagency Review Group, 1979, p. 42) While we are sympathetic with the notion that it is difficult to retrofit new criteria to existing sites, because of health and safety considerations, we believe the WIPP site-selection process should be reviewed in light of recent technical findings and the systems approach.

An important criterion for suitable geologic host formations is that they have not been extensively drilled, mined, or altered by the hand of man. This is also a prime characteristic for existing and potential wilderness areas. The statement fails to discuss any relationship between potential alternative geologic media and possible environmental impacts on the integrity of existing or potential wilderness areas, such as the WIPP site. The Bureau of Land Management is reviewing public lands for potential wilderness values under Section 603 of the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1782), and Section 2(c) of the Wilderness Act of 1964 (16 U.S.C. 1131). BLM's wilderness review process and all identified potential wilderness areas must be taken into consideration in any discussion of the environmental impacts associated with alternative geologic formations considered for nuclear waste disposal sites. The Bureau's greatest concern is that the site selection, characterization, and evaluation process will involve many potential locations on public lands and subsequent application for withdrawals for future sites, including alternatives to the WIPP site. These must be addressed in order to comply with FLPMA.

A land withdrawal for 250,000 years is necessarily an irreversible and irretrievable commitment of resources. A credible discussion of alternative sites should address the relationship between current, local, short-term uses of man's environment and enhancement of long-term productivity. The argument has been made in the statement that a demonstrated capability to isolate nuclear wastes in geologic host media is necessary to promote safe use of nuclear materials for the nation. However, the trade-offs between storage of nuclear waste and existing uses of public lands have not been given the attention they deserve in the WIPP draft EIS.

For example, section 8.1.3 states that two 5-acre and two 20-acre biological study plots will be formed out of control zone II. However, there is no discussion of the studies to be conducted there nor how the results of this monitoring will be used to promote public safety, or prevent direct impacts of radiation on plants and animals. In section 2.3.2 it is stated that 17,200 acres of public rangelands would be required for the WIPP withdrawal, which, in turn, would require cancellation of existing grazing and mineral leases. However, section 8.1.3 also states that grazing would be allowed in control zones II, III and IV. There is no discussion of how this grazing use would be managed, either by BLM, the WIPP site manager, the State of New Mexico, etc. Similarly, there is a reference that mining may be allowed in zone IV with no discussion of how this mining use would be managed in a way not to interfere with the integrity of the repository. Without this information it is not possible to quantify the economic effects of the withdrawal nor design alternative allotment management plans to attempt to mitigate these effects.

As is the case for all withdrawals, compliance with the requirements of the Federal Land Policy and Management Act of 1976 and the National Environmental Policy Act of 1969 is mandatory. The requirements in FLPMA and NEPA applicable to site characterization and evaluation of a potential site are equally applicable to the proposed action and its alternatives as described in the WIPP draft statement.

The Department of Energy has described the WIPP site as being designed for defense wastes (TRU, HLW), and also for commercial spent nuclear fuel. If the WIPP site is intended as a repository for high-level wastes, and not merely for research and development, then the potential environmental impacts of that proposed action, and alternatives, must be described accordingly. Failure to do so would leave the document inadequate by definition.

In addition, section 9.2.10 describes the impact of routine releases of radioactivity and exposure pathways in the environment, and section 9.3 describes the environmental impacts of accidental releases of radioactivity on humans. A description is needed of the potential adverse environmental impacts of the release of radioactivity, planned or not, on soils, plants, water; and especially the long-term effects of radioactive residuals in the environment. It is not possible to completely evaluate the short- and long-term impacts of the WIPP site on management of adjacent public lands without the above information.

The WIPP statement does not identify socioeconomic impacts of new population moving to the area to build or manage the WIPP site. Such impacts would include required increases in municipal services, infrastructure, etc., and the parallel need for additional tax revenues or other sources of funding to pay for these new services and infrastructure. Additional impacts might be created by increased demand for open space and recreational use of the public lands, especially hunting, fishing and use of off-road vehicles. Further impacts would be experienced after the employment associated with the construction phases left the Carlsbad area. These impacts must also be addressed.

Unsuitability, Retrievability, and Termination of the Land Withdrawal

The WIPP site could ultimately be disqualified for technical or institutional reasons; could be found unsuitable, or, alternatively, retrievability problems could occur. Additionally, after 10, perhaps 20 years, the Department of Energy may decide that an alternative site or sites are more suitable for permanent storage of nuclear waste. If any of these events were to occur, the waste then on the site and all associated infrastructure would be removed and the project would be terminated. Termination of the project and a withdrawal would potentially involve either complete return of the site to multiple use resource management or stipulations as to limitations on use.

The draft statement should discuss how termination of the WIPP site, under a variety of circumstances, would take place and what limitations or restrictions to assure public health and safety might be necessary to return the withdrawal area to multiple use resource management. In other words, the draft statement should indicate whether any radioactive materials would remain, and if so, how would DOE arrange to prevent these materials from having adverse environmental impacts on plants, animals, humans, and the environment in general.

Further, it is unclear whether retrieval is to be considered for 10 years or 20 years. Page 2-18 states (number 1, last sentence) " . . . it can be retrieved during a 20-year period if it becomes necessary to do so." This 20-year figure does not correspond with the figure of 10 years given on page 1-2. The period for which waste can be retrieved must be represented consistently as it has a direct bearing on termination of the withdrawal if an alternative site is ever sought.

These issues should be addressed.

Ground Water

It is stated on page 1-4 that the dissolution front at the top of the Salado Formation is about two miles west of the center of the site and is advancing toward the east at a rate estimated to be 6 to 8 miles per million years. The location of the front is shown on figure 7-25. It would thus appear that with current arid climatic conditions and current hydrogeologic conditions the dissolution front at the top of the Salado would reach the center of the site in about 250,000 to 300,000 years. Furthermore, because changes in climatic conditions are realistically probable within the time frame involved (e.g., U.S. Committee for the Global Atmospheric Research Program, 1975, Understanding climatic change, a program for action: National Academy of Sciences, Washington, D.C., p. 182-190), the statement should also assess "worst-case" effects with respect to the dissolution front that may result from great increases in precipitation. Page 7-75 of the statement suggests that current rates for the dissolution of salt may be slower than those suggested by present geologic conditions; however, an adequate analysis should include effects of the progression of the dissolution front through the project area both with and without accelerated solutioning such as that apparently produced by climatic change during Wisconsin time. Inclusion of at least brief discussion of present knowledge of past and probable future climatic change would aid in the assessment.

It is stated on page 7-66 that lows in the potentiometric surface of the Santa Rosa Sandstone aquifer suggest recharge into underlying rocks, possibly through collapse zones. Because the underlying Dewey Lake Red Beds are said to function as a confining bed (p. 7-65), the regional extent of the Dewey Lake beds should be discussed and the possible significance of such downward leakage should be assessed for the vicinity of the proposed project.

Mineral Resources

A major weakness of the statement is that it failed to address properly the mining problems associated with developing an underground disposal site. Major concerns are the stability of the opening and disposal of mined waste material.

The impact of the surface disposal and storage of the mined rock can be lessened by lining the storage site with hypalon liners and using chemical stabilizers to control wind and water erosion, if the salt crust is not sufficient. Then, after the mined material is returned to the underground areas, the site can be restored.

It is likely that some ground movement will occur; however, with the improvements expected in underground backfilling technology, surface subsidence and induced faulting of the overlying strata could be negligible. If significant faulting did occur, some groundwater penetration could be expected.

The statement did not discuss the necessity of ground and surface water monitoring (i.e., equipment, sampling grid, amount and time intensity of gathering data). This subject should be discussed in the final statement. The statement should also review the problems of maintaining water quality in a disposal site.

One potential accident scenario that should be included in Section 9-3 is the possibility of an undetected high pressure gas pocket located near the storage facility. Over periods of time, carbonaceous material will tend to decompose and produce gases which may build up pressure to the point of fracturing the formation, thereby comprising its integrit Moreover, during the operating life of the disposal site, the potential for fire and explosion is present whether originating from spontaneous combustion or leakage of methane or other gases. In the confined space of an underground mine, such a fire is usually more serious and more damaging than it would be above ground. Consequently, we urge that all wastes, including radioactive combustibles, be placed in a chemicall stable condition before emplacement in the repository.

There is a great deal of discussion on heating of the bedrock and subsequent effects on aquifers and surface uplift. Of equal importance is the deformation of the rock during and after the cooling stage. Generally, fractures and microcracks generated in the bedrock from thermally induced stress would tend to open during cooling and affect air and water flow patterns through increased permeability.

WIPP will not impact significantly on domestic reserves of sylvinite and this aspect of the draft report will not be addressed here. However, according to 10-K reports filed for 1978 by two langbeinite producers, the total U.S. reserves of recovered langbeinite, all near Carlsbad, is 11 million short tons of K2O equivalent. The 4.4 million K2O tons of langbeinite identified in the WIPP site in our IPOC November 1977 report for DOE then equals about 40 percent of Carlsbad reserves of this material, instead of the 11.6 percent given in the third paragraph of page 9-20 of the subject report. The total langbeinite resource in the Carlsbad area is unknown although a consulting firm, Agricultural and Industrial Minerals, Inc., has recently estimated it to be 14 million tons of K2O. We suggest that this is overly conservative.

Total langbeinite capacity of the two producers is about 300,000 tons per year. It follows, then, that langbeinite reserve in the WIPP site would be depleted in about 15 years at the current rate of extraction. The 5-year depletion figure given in the first paragraph of page 9-18 of the subject report is, then, incorrect.

The statement contains two other errors on page 9-20. First, the third paragraph gives langbeinite resource and reserve in K2O equivalents; this should be as langbeinite which contains 22 percent K2O and the data should be multiplied accordingly by 0.22 to give resource and reserve figures of 13.9 and 8.4 million tons of K2O, respectively. Second, the fourth paragraph shows a langbeinite mining rate that is about 3 times too high; the actual current rate is roughly 300,000 tons per year of K2O.

The obvious conclusion from all of the above is that the langbeinite reserves in the Carlsbad area will be impacted by WIPP more significantly than indicated in the subject report. However, the seriousness of this is decreased greatly by the following factors: (a) about three-quarters of the langbeinite reserves in the WIPP are in outer zone 4 of the site and could, according to a likely scenario, be mined at a later date, perhaps in this century, (b) mixtures of potassium sulfate and magnesium sulfate, both of which are in ample domestic reserve or can readily be synthesized, appear to be a viable alternative to langbeinite for agricultural use, and (c) loss of the langbeinite reserve in the WIPP site would not threaten the economic stability of the Carlsbad area or the United States. Nevertheless, we believe that this problem of the withdrawal of mineral resources in the WIPP area should be more fully addressed in the final statement.

A more basic concern, however, was never addressed in the draft statement. The single Waste Isolation Plant may not have a significant impact on the mineral resources nationally; however, this is just a pilot for a number of similar facilities. If these are all to be located in similar salt deposits, the potential loss of mineral resources for the vital production of food and energy may be quite significant. On page 11-1 the document states that development of the repository will deny access to 25 billion cubic feet of natural gas, and 350,000 barrels of distillate. This denial seems to be a high price to pay for a dump, albeit a very necessary one. For this reason, the final statement should include projections on the number of Waste Isolation Plant sites needed and the future demand for the mineral resources. This information may show that alternative burial materials should be used in preference to salt that is in close association with agricultural minerals and petroleum resources.

The geology sections of the statement should mention the potential for scientifically valuable fossils, especially in the Rustler formation. Page 9-11 should contain a discussion of the actions which would be taken to preserve any scientifically valuable fossils if found on site.

Cultural Resources

We are pleased to see the extent of the Department of Energy's commitment to protecting the archeological resources of the Waste Isolation Pilot Plant (WIPP) area. However, we wish to point out that the long-term management of the area, which includes nearly 20,000 acres, requires more than project-specific archeological survey and mitigation work confined to control zones I and II and proposed rights-of-way. Although much of the area will not be directly affected by the physical facilities and construction associated with the WIPP, at least 11,400 acres will be available for oil, gas and potash development leasing, and the entire area is open for stock grazing. Therefore, as mandated by Executive Order 11593, section 2(a), the Department of Energy should initiate surveys of all the area as soon as possible in consultation with the New Mexico State Historic Preservation Officer in order to identify the archeological or other cultural resources under its jurisdiction and control.

The final statement should include plans for avoidance and/or mitigation of the 33 archeological sites determined eligible for the National Register as an archeological district, future cultural resource management for the area, and the appropriate recommendations and opinions of the State Historic Preservation Officer and the Advisory Council on Historic Preservation.

Recreation

The impact of the additional workforce on nearby recreational areas should be addressed. It is mentioned that the primary recreational use of the proposed site is for hunting. However, it is not mentioned if this use or other recreational uses will be permitted on those portions of the site which will not be extensively developed or utilized.

This project does not appear to have impacts or potential impacts on any existing unit of the National Park System or on areas under study or recommendation for possible inclusion in this System.

The WIPP System: Long-term Impacts

The long-term effects, which are the center of earth science concerns for all hazardous waste repositories, are judged in the statement to be very slight, based on a consequence analysis in which the worst possible future scenarios are postulated and their long-term effects calculated. The judgment that long-term effects will be slight stems partly from the low concentrations and low total amount of some radionuclides proposed to be emplaced in the WIPP. If it were planned to emplace higher concentrations and amounts of these nuclides, a new EIS would be required. If a decision is made to incinerate TRU waste as a criterion for acceptance at WIPP, a substantially larger amount of TRU could be disposed of than is considered in this EIS. Such a decision is very probable because of gas generation from radiolysis, hydrolysis, and bacteriological activity in nonincinerated TRU wastes, and also the hazard from mine fires in nonincinerated waste. The waste form for incinerated TRU waste (presumably a concrete?) should contribute an as yet unspecified amount toward commitment. The low level of effects in scenarios involving moving ground water also stems from the assignment of significant retardation for certain long-lived nuclides along the natural flow path from the repository to its present discharge point. The actual degree of retardation has yet to be determined in situ or in comparable rock systems. This optimistic assumption regarding retardation is partly offset by the pessimistic assumption that the release rate for the waste is the same as the rate of dissolution of salt in the invading waters. These latter assumptions are necessary because the form for the TRU waste has not yet been specified. Thus, this EIS does not fully evaluate the total waste disposal system at the WIPP and vicinity because significant parts of the system are either unspecified (waste form and total amount) or uncertain (retardation effects).

The natural geohydrologic system at the WIPP site and vicinity appears to be favorable for containment in many respects. The postulated flow path from the repository to discharge is relatively long and the estimated times of water transit range from 5,000 to 100,000 years depending on the hydraulic conductivity used in the calculations. This hydrologic path should provide a barrier for the short-lived fission products from the spent fuel. Water movement is downward in the rocks above the flow path along its length making the likelihood of short-circuiting by natural or human activities slight. This water would also be nonpotable and unlikely to be utilized by humans. The transit time in itself is not an adequate barrier, however, for the long-lived transuranics; significant retardation must take place along the path if the dissolution rates are as assumed. Sandia has begun experiments to determine the degree of retardation, and the results are encouraging. There are many acknowledged uncertainties, however. One of the principal uncertainties concerns the extent of retardation in the Magenta and Culebra members in which ground water flow is largely through fractures in dolomite and dolomitic sandstone. In such flow, the fluids may be in contact with much less of the sorbing materials than they would be in flow through a porous medium. If retardation in the Magenta and Culebra is substantially reduced for the transuranics, concentrations of these nuclides in the Pecos River at Malaga Bend would still be low but considerably closer to the background unless leach times were on the order of 10^6 to 10^7 years (see GEIS, app. I, fig. 1.3). Given the recent increased concern with low levels of radiation, whether such a risk would be acceptable is not clear. The possible effects of lower retardation are not discussed in the EIS.

The same uncertainties concerning flow through fractures may also affect the estimates of the regional hydrologic flow pattern. The direction, volume, and rate of flow in the fractured Magenta and Culebra aquifers all have large attached uncertainties without more hydrologic data than was used in preparation of the EIS. Values of transmissivity given on page 7-65 for the Rustler are estimated, not "calculated." The 10 percent porosity value for the Rustler, same page, comes from one measurement (Gnome site) and is not an average.

Another important assumption in the long-term impact analysis in the EIS is that the diluting effect of the Pecos River at Malaga Bend will remain constant or possibly increase. Should tectonic, geomorphic, and climatic factors combine to reduce or halt the flow of the Pecos River at the discharge point, the transported transuranics would build up at that point. The hazard from such a buildup would be about the same as that of a sandstone uranium deposit which might or might not be deemed an acceptable risk. The possible impact of such a buildup is not discussed in the EIS.

In summary, the statement does not provide a complete analysis of the system of barriers to waste migration. Even though the waste form has not yet been specified, leach rates over a plausible range of values could be assumed. Additional values for the uncertain hydraulic conductivity of the principal aquifer could be used in addition to those presented. Retardation values could be varied over reasonable ranges including possible low values for flow through fractured media. Analysis of the total system of any proposed repository is called for in the Interagency Review Group's report on waste management, not merely an estimate of worst case conditions.

Engineering Geology

We believe that the EIS should include more engineering details on the proposed underground excavations at the WIPP site. The stability of the underground rooms will be critical to any retrieval of the radioactive wastes.

The "Herring Bone" pattern of the underground CH waste storage area shown on Fig. 8-11 will create areas of weakness at the "points" of the pillars. Experience has shown that the pillars will fail at these places. This is true of mining depths of 700 to 1,100 feet and will certainly be true at 2,100 feet. It does not necessarily create a major hazard, and the oblique angle turns would probably be easier for rubber-tired or mono-rail transportation to negotiate, at least coming from one direction. However, the spalling would need cleanup and/or extra support. If the planned entry widths would not allow turnoffs of 90 degrees, possibly the corners could be stubbed.

Comparison of WIPP with Other Alternative Sites

The EIS states in chapters 3 and 4 that proceeding with WIPP fulfills objectives for TRU recommended by both the Deutch and the IRG reports. The Department's U.S. Geological Survey agrees. It is also argued in chapter 3 and the first page of chapter 4 that in terms of long-term effects, there really is no technical basis for choosing between salt and basalt because "site selection will ensure no increase in predicted risk" (tables 3-12, 3-13) at basalt sites. With regard to shale and granite, the EIS claims that the GEIS "predicts impacts approximately like those of salt and basalt repositories" (p. 3-32). In summarizing the environmental impacts, the EIS asserts (p. 4-1), "the impacts of the remaining six alternatives (2 through 7), on the other hand, are small in both the near term and the long term (centuries and longer) and are not different enough from each other to afford a basis for choice on environmental grounds. The choice must therefore rest on programmatic considerations."

CEQ's "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act" (43 FR 55978-56007, November 29, 1978, 40 CFR Parts 1500-1508) requires that an agency "rigorously explore and objectively evaluate all reasonable alternatives" (paragraph 1502.14). We would argue that a statement that "site selection will ensure no increase in predicted risk" (tables 1-12, 3-13) merely defines a comparison as unnecessary because the problem is solvable. A meaningful comparison would be an in-depth comparison between WIPP, other salt sites, basalt (above and below water table), alluvium (above water table) and tuff, shale and granite (above and below water table). Such a comparison is lacking.

In none of the routine comparisons of impacts from construction of TRU and HLW repositories (or combinations of the two) in alternate locations or media (sec. 3.0) is there any discussion of potential alternate system in which isolation of radionuclides might be more confidently predicted than at the WIPP reference site. As noted earlier, if retardation of radionuclides at WIPP is not as efficient as postulated, small increments to the long-term radiological hazard result (depending on the release rate) which could nonetheless be crucial in the final acceptance of the site. The present discussion of alternatives implies that the hydrology is the same in all regions being considered for HLW and TRU waste disposal, which is certainly not the case. Potential radionuclide transport downdip from gulf coast salt domes, for example, would be in porous media with very long flow paths; prediction of radionuclide containment might be much surer in that environment than at the WIPP. As the EIS notes, there has not been a complete analysis of other sites and systems with which to make a rational comparison; however, as noted above, neither has there been for the WIPP. Contrary to the statement at the top of page 3-27, future studies can significantly change the predicted impacts and risks both at WIPP and in alternate systems.

In summary, the EIS asserts that all sites are likely to be, or can be engineered to be, equal to WIPP. This is unlikely to be the case for hydrology and definitely not the case for future human intrusion.

Future Human Intrusion

A major potential problem with the WIPP site is future human intrusion. The IRG (p. 39) recognized that "it is not possible to predict or to restrict the activities of future generations" and, therefore, "site selection guidelines, site suitability criteria, and repository design criteria must be developed in such a way as to minimize potentially deleterious effects of human activities." The Committee on Radioactive Waste Management of the National Academy of Sciences has stated "no areas with a present or past record of resource extraction, other than for bulk materials won by surface quarrying, should be considered as a geological site for radioactive wastes" (Geological criteria for repositories for high-level radioactive wastes, 1978, p. 13-14).

The EIS acknowledges that there might be future drilling at the site through a spent fuel assembly; and it computes the radiological dose to a geologist examining a core of the fuel. The EIS also correctly points out that the potash ores are above the proposed TRU repository horizons and, moreover, that both the potash and oil and gas (beneath the repositor can be exploited without breaching the TRU waste horizon. The USGS agrees with these statements. Not taken seriously though is the issue of trying to predict the actions of humans 500, 1000, or 10,000 years hence. The presence of mineral wealth is an open invitation to our descendants to explore the subsurface in ways we cannot begin to imagine.

In addition to our general comments, we also have specific comments with regard to the WIPP EIS which can be found in Attachment 1.

We hope these comments will be helpful to you, particularly in light of the fact that the direction of the WIPP program is changing and will continue to do so as the final decisions flowing from the IRG are made and implemented. As noted earlier, we will be more than pleased to work with your staff in revising the additional informational requirements that are necessary to meet our concerns under FLPMA for the revision of the WIPP EIS.

Sincerely,

LARRY E. MEIEROTTO

Assistant SECRETARY

Attachment 1

Specific Comments

It is implied in paragraph 3 on page 2-24 that synthetic high-level waste may have to be used for test purposes. If these tests are to be meaningful, both from a chemical and radiation intensity standpoint, real high-level wastes must be employed. This issue should be discussed.

Page 7-8 in volume 1 and H-83 in volume 2. Mention is made that amphibians are not an important part of the regional fauna. This statement is not accurate and needs to be revised. Thirteen of the 24 species of amphibians found in New Mexico occur in the southeastern portion of the State. These species occur in a variety of habitats and many are well adapted to the most arid habitats of this area.

Page 7-20. In general, oil and gas appears to have been given light treatment in the geology and mineral resources sections. The Pennsylvanian system deserves more detailed discussion as it contains the hydrocarbon reservoir of interest in the area.

Page 7-43, fig. 7-15. Locations of holes D-231, D-233, D-235, D-248, and D-250 should be shown on figure 7-15.

Pages 7-42 through 7-51. It should be noted that the southwest boundary of the withdrawal area was drawn to avoid existing gas wells in the area. It can be shown that the oil and gas industry has interest in drilling within the withdrawal area since there have been six applications to drill approved there. These applications and the subsequent condemnation of the drill sites by ERDA were not mentioned in the EIS. Five of the proposed wells are on Federal mineral leases. Their locations are as follows:

Operator	Well Name	Location
Continental Oil Co.	James Ranch No. 8	Lot 3, sec. 31, T. 22 S., R. 31 E.
Continental Oil Co.	James Ranch No. 8A	SW1/4 NW1/4, sec. 31, T. 22 S., R. 31 E.
Perry Bass	James Ranch No. 10	SW1/4 NE1/4, sec. 30, T. 22 S., R. 31 E.
Perry Bass	James Ranch No. 12	NE1/4 SW1.4, sec. 20 T. 22 S., R. 31 E.
Perry Bass	James Ranch No. 14	NE1/4 SW1/4, sec. 17, T. 22 S., R. 31 E.

One well was proposed by Gulf Oil Company on State land in sec. 32, T. 22 S., R. 31 E.

This aspect of oil and gas activity deserves mention in the EIS.

Page 7-44, table 7-5 and text. The Geological Survey also evaluated reserves. The standards cited in table 7-5 are called resource standards. In fact, the Survey report uses the low-class standard for resources and the lease, and high-class standards for reserves. The lease class standard is based on current economic mining conditions in the Carlsbad area. (John, et al., 1978, p. 26).

Page 7-44, last par. What is the source of the average grade data cited in the first sentence of the paragraph? With regard to the second sentence of the paragraph, the Geological Survey considers the median standard, termed "lease," to be equivalent to current mining costs and market prices.

Pages 7-45 and 7-46, table 7-6, fig. 7-16. The results of the Geological Survey evaluation are treated as resources in the draft statement. In fact, the Survey reports both resources and reserves (John, et al., table 4-A-C). Table 7-6 does not reflect this. Only the low-grade category is reported as resources in the Survey report. Lease grade and high grade are reported as reserves. This fact is not reflected in figure 7-16 either.

Page 7-46. No mention of the specific criteria used in the Bureau of Mines report is given. This information would help clarify the range of values that exist between the Summary and the Bureau of Mines reports. Table 7-7 represents a summary of the Bureau of Mines findings. The findings are based on specific criteria and assumptions which these numbers are dependent upon. An explanation of these factors would put the numbers in proper perspective.

An addition should be made to the first sentence under table 7-7. It should read "only mining unit B-1 meets today's market prices under the Bureau of Mines criteria ($42 per ton of muriate, $94 per ton of 'sulfate' (K_2SO_4), and $48 per ton of langbeinite)." Some explanation as to the source of this price data would also be helpful.

Page 7-49. The Sipes, Williamson, and Aycock study of economic reserves appears to present the most realistic estimates of hydrocarbon resources.

Page 7-51. An attempt should be made at placing a monetary value on the hydrocarbon reserves, as was done for potash reserves on page 7-47.

Water: page 7-61 (para. 2, first sentence) states, "12,000 acre-feet" should be changed to 19,800 acre-feet, and "10,000 acre-feet" should be changed to 19,100 acre-feet. This information is based on a BLM report (1978) - Groundwater Study to the Proposed Expansion of Potash Mining Near Carlsbad, New Mexico.

Section 8.1.4 describes the new highway and railroad rights-of-way to be acquired for the WIPP site, but does not discuss whether these ROW will be fenced. Fencing could have adverse environmental impacts on existing grazing use and also on wildlife use of existing habitat. Similarly, a description is needed of any possible adverse environmental impacts associated with the construction, operation and maintenance of fenced ROW for railroads, paved roads, dirt construction trails, pipelines, or electric transmission lines. Mitigation measures should be specified, if necessary.

Page 9-9. Mention is made that raptor deaths may be caused by electrocution on utility lines. It is unclear if these deaths will result from project-constructed power lines. However, we would like to point out that proper design and construction of power lines can minimize electrocution impacts to raptors. Your agency may wish to consult the publication "Suggested Practices for Raptor Protection on Powerlines" by Dean Miller, et al., Raptor Research Foundation, Provo, Utah.

Roadway construction causes loss of habitat which results in reduced productivity for fish and wildlife resources. Secondary effects may include vehicle accidents and limiting animal movements. While some type of beneficial vegetation may be reestablished in roadway right-of-ways, the establishment of creosote bush would not be highly desirable. This species of vegetation provides little habitat value for food or cover.

Pages 9-9 and 9-10. Mention is made that wildlife species will be displaced from lost habitats. As presented on page 9-9, these habitat losses result in long-term losses when carrying capacities are reached. One mitigative effect that could be considered is management of adjacent habitats to increase carrying capacities and productivity of the habitat and offset losses.

Pages 9-9 and 9-22. Revegetation is one measure that is proposed for mitigation. Grasses, forbes and shrub species of value for wildlife food and cover should be used in the revegetation of disturbed areas. It may be important to manage grazing to insure adequate establishment of vegetation.

Pages 9-11 through 9-19. Estimates of the total potash resource and reserve are considered by the Geological Survey to be accurate within + 20 percent, based on the present drill hole spacing. We agree that 1,000-foot drill spacing would increase this accuracy. It is reasonable to expect that additional drilling would show increased reserves in some areas and decreased in others. This point should be considered. The Survey has made a preliminary estimate of langbeinite reserves for the Carlsbad district since the publication of Geological Survey Open-file Report 78-828.

Our preliminary figures show 1.14 x 10^9 tons of langbeinite reserves at 6.6 percent K_2O weighted average grade present in the Carlsbad district.

Page 9-15, Summary. This section deals with the impact of denial of potash resources, and it is within this section that the variation in reserve estimates between the Bureau of Mines and the Geological Survey have the greatest effect. The criteria used by each group should be related to the presentation of data listed in tables 9-9, 9-10, and 9-11.

Page 9-16, table 9-9. Geological Survey data are here treated strictly as resource numbers. If the data were presented as in the open-file report, sylvite ore resources would be 133.2 x 10^6 tons, and langbeinite ore resources would be 351.0 x 10^6 tons. Table 9-10 would show the following reserves using Survey data: sylvite ore reserves--89.1 x 10^6 tons at weighted average K_2O, equivalent of 11.8 percent; langbeinite ore reserves--264.2 x 10^6 tons at weighted average K_2O, equivalent of 6.10 percent. These figures would also appear in table 9-11. The 500 x 10^6-ton figure for regional resources in table 9-11 is questionable. John, et al., (1978) report 5.4 billion tons of potash ore reserves for the region. The 38 x 10^6 tons K_2O as langbeinite for reserves in the region needs more explanation. The WIPP area is reported to represent 11.6 percent of the total reserves of langbeinite. Recent estimates by the Survey after publication of the open-file report suggest that it may represent as much as 20 percent of total reserves.

Pages 9-20 through 9-21. Discussion of the AIM study referred to in this section needs to be elaborated. What were the criteria used in the study, and how do they compare with those used in the Survey and Bureau of Mines studies?

Page 9-24 in "Effects of Plan Operation" should contain a paragraph on the potential effects of the WIPP action on fossil resources. An important secondary effect of the action is the access to remote areas that would be opened by the new roads created for the WIPP site. While amateur fossil collectors would not have significant impacts, commercial (i.e., illegal) collection of fossils might occur on wholesale basis. Similarly, page B-8 should contain a statement in the geology section, "Permian Beds in this general area are reported to have provided the world's most complete record of early Permian amphibians and reptiles."

Page 9-86. The references to the Bureau of Outdoor Recreation should be corrected to read the Heritage Conservation and Recreation Service.

Page H-62 should reflect the following information: While Colorado had some ice fields during the pleistocene, the ice sheet in the Rocky Mountains went no further south than Montana and Idaho. Thus, glacial action does not appear to be a threat to the integrity of the site.

Pages J-38 and J-39, sec. J.4.3. There should be mention in this section of the environmental analyses that are prepared by the Geological Survey for proposed oil and gas operations. It should be noted that, through this process, an assessment of environmental impacts would be made before any further development of Federal mineral resources would be allowed.

Editorial Comments

In order to make the EIS more intelligible to other professionals and concerned lay people, editorial improvement is essential.

An index map showing the precise location should be one of the first figures in the report.

The WIPP site should be located on maps wherever practical and it should appear at the same place on all maps. It is badly mislocated on figure 7-12. Township and Range should be shown on maps where practical (fig. 7-12, for example).

Page 7-7, fig. 7-2. It is now generally agreed that the Pleistocene Epoch probably began between 2 million and 3 million years ago (e.g., Holmes, Arthur, 1964, Principles of physical geology, 2nd edition: New York, Ronald Press, p. 360-361; Obradovich, J.D., 1965, Age of marine Pleistocene of California: Am. Assoc. Petroleum Geologists, v. 49, no. 7, p. 1037).

Page 7-7, fig. 7-2. Deposition of Ogallala fan sediments and the formation of the caliche capping these sediments occurred during the Pliocene rather than during the Pleistocene, as shown.

Page 7-28, fig. 7-11. "pre-Cambrian" in upper left should be "Permian."

Page 7-59, table 7-14. "Dayton, Texas" should be "Dayton, New Mexico."

Page 7-64, fig. 7-22. An explanation of units and patterns, a scale, and location of WIPP site are needed.

Page 7-65, par. 4, line 4. "west" should be "east."

Page 7-68. The heading "Groundwater Quality" refers only to the succeeding paragraph. The rest of pages 7-68 and 7-69 is part of "Groundwater Flow."

Page 7-73, par. 3. "Jones (1972)" should be "Jones (1973)."

Page 7-74, fig. 7-27. A better explanation is needed. Show WIPP site; show line of section on a map; identify "solution front" referred to in text; label irregular line "Top of Rustler salt" not "Top of Rustler."

Page 7-76, par. 1. Add reference "Nicholson and Clebsch (1961)."

Page 8-39, last par., first line. This should read "Southwestern Public Service Company," not "Pacific Service Company."

Page 9-112, par. 5. The proper figure number would appear to be K-3 and/or K-5 rather than K-6.

Page H-101, line 3. Loving County is in Texas, not New Mexico.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SEP 26 1979

Mr. Eugene Beckett
WIPP Project Office, Mail Stop B-107
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

In accordance with Section 309 of the Clean Air Act, as amended, we have reviewed the Draft Environmental Impact Statement for the Waste Isolation Pilot Plant (WIPP), DOE/EIS-0026-D. Our detailed comments are enclosed.

The final environmental statement should bring out more conclusively the adequacy of the site and the bedded-salt host medium, and, further, that the deficiencies revealed in this environmental statement are no worse than might be expected at other carefully selected sites. If sufficient information cannot be provided in the final environmental statement to this end, a program for resolving those matters should be specified and a course of action proposed that will be taken if the results are not favorable to the WIPP project.

The question of the adequacy of the site relates in part to the continuing integrity of the salt formation and the probability of adequately sealing boreholes and shafts against subsidence stresses and other phenomena. The draft statement does not adequately address the problem of detection of existing boreholes and of small-scale dissolution features within the repository formation. There appears to be little information on dissolution below the host salt formation and the potential for failure from below. The hydrologic modeling appears to have the potential for large uncertainties, and the analysis should treat the sensitivity of the results to the range of potential error.

A major concern is the assumption implied in this proposal, that transuranic wastes and spent fuel are compatible with each other and with the bedded salt and hydrology of this site in the proposed repository configuration. No case is made for putting spent fuel, with its high radionuclide content but chemically resistant uranium dioxide ceramic form, in a repository selected for its chemical barriers to radionuclide migration and, likewise, putting into the same repository transuranic waste with its multitude of chemicals. Although it is desirable to combine disposal facilities to decrease costs, such combining of facilities should be supported by an assessment in the final environmental statement of the compatibility of the different waste forms. The presence of organic chemicals in the TRU waste should receive particular attention in this assessment.

The EPA is also greatly concerned with the lack of a positive commitment in the DEIS to the development of mitigation plans. We are equally concerned about the need to monitor environmental impact conditions, and implement mitigation measures during all phases of construction and operation of the WIPP. Mitigation and monitoring is needed, not only to avoid violation of existing standards, but also to minimize negative impacts on the environment. The mitigation plans should allow the inclusion of "current knowledge" and "best management practices" as developed after initiation of operations at the selected site. The EPA strongly urges that DOE require the design of a dynamic monitoring and mitigation plan before either licensing or approving construction of WIPP.

On the basis of these concerns, we have environmental reservations about the actions proposed in this draft statement and consider that the statement provides insufficient information. Therefore, we have rated this draft statement ER-2, i.e., environmental reservations and insufficient information.

Should you or your staff have any questions about our comments, please call Ms. Betty Jankus (NEPA matters, 755-0770) of my staff, or Dr. Jerry J. Swift (technical matters, 557-7604) of EPA's Office of Radiation Programs.

Sincerely yours,

William N. Hedeman, Jr.
Director
Office of Environmental Review

Enclosure

U.S. ENVIRONMENTAL PROTECTION AGENCY

Detailed Comments
on the
Department of Energy's
Draft Environmental Impact Statement
for the
Waste Isolation Pilot Plant

General Comments

The final statement should bring out clearly the adequacy of the site and long-term integrity of the host medium, and, further, that the deficiencies revealed in this environmental statement are no worse than might be expected at other carefully selected sites.

The combination of a facility for the disposal of transuranic wastes with facilities for testing of high-level waste forms and disposal of spent nuclear fuel is not adequately supported. There should be a showing in the final environmental statement that the differences in waste forms and the configuration of the respository do not significantly diminish the protection that would be provided by separate facilities. It is not clear that the proposed approach is consistent with the near-term objective "to proceed by deliberate steps in a technically conservative manner."

The principal problems with the proposed projects are:

1. It has apparently been assumed that transuranic wastes and spent fuel are compatible for disposal in this repository. The list of alternatives considered is limited and rests heavily upon this same assumption.

2. There are appreciable mineral resources at the site. There is also a reliance on long-term institutional controls to prevent human intrusion. The DEIS addresses only the point that natural resources in the WIPP area will be lost for future exploitation because of the presence of the respository. However, it should also consider that institutional control could be lost after hundreds or thousands of years while the hazard from the waste remains substantial. The natural resources could be explored without knowledge of the remaining hazard.

3. The host salt formation is under solution attack from above and from the side and may also be under attack from below.

4. The groundwater Eh may be in the range where it will make actinide elements more mobile.

5. The assessment of potential impacts on the surrounding population appears to disregard the workers at the potash mines nearby.

6. There has apparently been no question of the desirability of having two levels in the respository rather than one.

7. Impacts of potential releases of radionuclides are regarded in this draft environmental statement as short-term impacts; the potential impacts of releases of radioactivity over long time periods should be addressed.

8. As a research tool, the project should provide valuable information on the effectiveness of various waste disposal methods. Much of this data, of a generic nature, should be applicable to future waste disposal projects.

9. Criteria for the acceptance of the various waste forms have not yet been made firm. Firm criteria would help resolve the nature of the interactions that might occur between the wastes, the salt, and any water that is present.

10. The site selection process has been successful in finding a location with a low population density, much lower than in Michigan, Kansas, and Ohio. This is a clearly advantageous feature of the Los Medanos site. With respect to site selection criteria, however, some of the data gathered from WIPP may not prove useful in future siting decisions, primarily because of differing geologic formations. Other geologic structures, such as salt domes, basalt, granite, shale, and tuff are currently being investigated, and the EIS notes that future sites will be evaluated on a case-by-case basis. We believe that the recognition of site specific differences is critical to the selection of regional repositories, and strongly endorse this approach.

11. The EPA is also greatly concerned with the lack of a positive commitment in the DEIS to the development of mitigation plans. We are equally concerned about the need to monitor environmental impact conditions, and implement mitigation measures during all phases of construction and operation of the WIPP. Mitigation and monitoring is needed, not only to avoid violation of existing standards, but also to minimize negative impacts on the environment. The mitigation plans should allow the inclusion of "current knowledge" and "best management practices" as developed after initiation of operations at the selected site. The EPA strongly urges that DOE require the design of a dynamic monitoring and mitigation plan before either licensing or approving construction of WIPP.

Detailed Comments

12. In addressing the population distribution around the site, there are statements like that on page 1-3, "Sixteen people live within 10 miles of the center of the proposed site." This overlooks the approximately 650 workers at potash mines and mills within 12 miles, plus other people employed in the oil and gas producing industry. Table 2-2, "Application of Site-Selection Criteria," also shows this distortion. Another example is on page 7-1, "Thirteen people live within 10 miles of the proposed site." Such pertinent features as the potash mines should also be shown on the maps of the area; e.g. in Figure 8-1, the railroad spurs are shown — they probably end at potash refineries.

13. Although the low annual rainfall and limited runoff are mentioned in several places (e.g. page 7-59), the flash flooding associated with rainstorms in arid lands is not mentioned, nor is there mention of its potential for influencing the repository or transportation accidents. Section 9.3.3.2 should be revised to include discussion of the potential for flash flooding, which may occur much closer than the Pecos River.

14. Comparison of radiation exposures to those from natural background can be meaningful when they are exposures to an individual. When the exposures are to a population group, they become less meaningful because the relative values can be altered by including more people who get the same background exposure but little or none from the other source in question. Such comparisons should always include the maximum individual exposures. The last statement on page 1-6 is an example: "An accident of the extreme severity postulated in the transportation analysis could deliver a 50-year radiation-dose commitment that might reach 25 percent of the dose from natural background radiation." This provides only the average value and does not provide information on those most affected.

15. It is correctly indicated on page 1-8 that for an alternative action involving a delay in construction, th estimated additional costs of $280 million are mostly due to inflation and therefore do not represent real additional resource expenditures. If put into 1978 dollars, this large sum would become almost zero. Its use in this statement tends to be misleading.

16. This draft statement quotes various solution rates for the Salado salt, such as the 500 feet per million years (on page 2-12). The final statement should also provide the uncertainty in the solution rates.

17. The second "basic reason" given on page 2-16 is illogical. This draft statement proposes to use the facility for both transuranic waste and 1000 spent fuel elements; therefore, it is not "dedicated only to TRU waste."

18. The second basic reason on page 2-16 contains a clear example of the concept that there is no significant loss in safety or protection of the environment occasioned by putting more than one type of radioactive waste in a repository. This concept, used extensively throughout the draft statement, appears without scientific support. The IRG objective, stated on page 1-2, "to combine compatible facilities, where suitable," must certainly have been written in the belief that compatibility and suitability would be established rather than assumed. The result of disregarding the differences in the

chemical nature of waste types is seen in the statement on page 3-26, "There is no reason to expect that adding TRU waste to a HLW repository at either site would appreciably increase the probability of long-term releases of radioactive material." The TRU waste contains various organic substances which can form complexes and greatly increase the mobility of the actinide elements.

19. It is recommended that the final statement be revised to state a practical purpose for the reference repository as designed. On page 2-22, the draft statement states, "The reference repository is intended for the disposal of only that amount of readily retrievable waste expected to be stored at INEL through 1990," and further, "Some 100 acres of repository space will be more than adequate for this purpose." As the design is for a 2000 acre facility and a 30 year lifetime, it is only practical to specify instead that the facility is intended to be used to capacity (70 million cubic feet, per Table 2-3). If the design is successful, to use it at such a small fraction (2.4 million cubic feet) of its capacity would be wasteful.

20. The statement on page 2-23 regarding the policy announced on October 18, 1977, should be corrected to state clearly that the fee includes disposal costs as well as storage costs.

21. The draft statement, on page 2-28, contains the peculiar argument that "while some useful generic information could be obtained from a stand-alone ISF (Appendix C), only a portion of that information could be transferred to another site." It appears, however, that unless it is intended to use the WIPP site for large-scale disposal of spent fuel or high-level waste, only about the same information can be transferred from WIPP to another site, i.e., the amount of information gained is essentially the same. This statement and Figure 8-11 also raise the question again as to what eventual use will be made of this repository and whether it would not be a better approach to seek approval for full utilization at this time.

22. In Table 3-10, all estimated accidental exposures are compared to background except the case of drilling through spent fuel, which is compared to occupational exposure limits. Because there is no reason to believe the drillers would have been classified as radiation workers, there is no justification for comparing their estimated exposures to occupational limits.

23. The comparison of the impacts is not correctly constructed in the case (on page 3-16) where leaving spent fuel in storage pools "is estimated to give a worldwide population exposure of 10^{-7} of background." Spent fuel in storage pools cannot reasonably be considered to irradiate a significant fraction of the public, much less the worldwide population.

24. It is questioned whether, as the discussion on page 3-19 asserts, heat-producing waste can be emplaced more densely in basalt than in salt. Such an approach would appear to subject high-level waste, for example, to significantly higher temperatures than emplacement in salt, and would raise the repository to higher ambient temperatures. Other technical documents have indicated that, because of the poorer thermal conductivity and heat capacity of basalt, a spent fuel or high-level waste repository in basalt should be loaded to a lower heat generation density than in salt.

25. The discussions in Section 3.5.2 indicate that no conceptual designs exist for TRU repositories in dome salt and basalt. This suggests that consideration of these alternative media was quite limited, and perhaps not adequate as a consideration of alternatives required by NEPA.

26. The question of whether pyrophorics will be permitted to be included with the TRU wastes does not appear to be adequately answered. It is stated that "small quantities" of pyrophoric materials may be accepted (page 5-3), but the waste acceptance criteria include the criterion of "no pyrophoric materials." The absence of pyrophorics is assumed in predicting the environmental impacts of shipping and handling, and yet the impact estimations are described as yielding "maximum environmental-impact predictions." If pyrophoric materials are to be permitted in TRU waste packages, the term "small quantities" should be defined in numerical terms (as was done for gas-generating materials in Table 5-1) and the acceptance criterion given in Section 5.1.2. If significant quantities are to be permitted, appropriate assumptions should be factored into the impact analyses for the retrieval, transportation, handling, storage, and accident scenarios.

27. Additional criteria appear to be needed for waste forms that "cannot be immobilized" (page 5-3). With few exceptions radioactive waste can be immobilized if the resources are available to do so. For some waste categories, immobilization may not be practical in terms of cost versus cost of overpacking, or low potential dose savings per dollar spent, or because of excessive volume of the final waste product. The final EIS should contain numerical criteria on immobilization requirements so potential impacts can be better evaluated.

28. The discussion of transportation in Chapter 6 would be greatly improved by the addition of expected doses to individuals in the public in the discussion of routine, non-accident exposures. Statements such as "it exposes the nearby population at a very low dose rate" (page 6-15) immediately raise the question of very low relative to what. The collective exposures of Tables 6-9, 6-10, and 6-11, while they are good information, only set upper bounds to the individual dose.

29. The discussion of possible transportation accidents in Section 6.7 indicates that exposures to airborne radioactive materials released by accidents in urban areas are calculated using a dispersion model and parameters (page 6-23) appropriate to flat, smooth, open terrain, and thus inappropriate to a location where buildings interfere with the airflow. Turbulences around buildings, while providing more mixing action for dilution, could also bring the plume to ground level much closer that one half mile and perhaps appreciably increase maximum individual exposures. Similarly, although a low wind-speed is conservative once the material is in the plume, it is clearly not conservative with regard to lifting the material from the ground into the air. Furthermore, even if a low-wind speed is the existing condition, a larger fraction of the material might be entrained in the plume by locally higher wind speeds induced by fire or by passing vehicles during the period before authorities close off the area.

30. The food pathway should be examined again; while health authorities, acting after an accident, would remove contaminated food from distribution, they would have to notify people quickly in order to intercept food being eaten.

31. Frequencies such as in the last column of Table 6-16 tend to mislead when they include a fraction for the stability category and wind direction. In an urban area, almost 100 percent of the time the wind will carry the material in the direction of a number of people. Therefore the risk from such an accident is greater that that indicated by the combination of Table 6-15 and the last column of Table 6-16.

32. The Final EIS should identify the sources of high-level waste and possible transportation routes available to carry this material to the WIPP site. The transportation scenarios developed in the Draft EIS used a maximum city size equal to Albuquerque, New Mexico. In Figure 6-1, on page 6-9, the typical rail routes depicted for transportation of waste materials pass through metropolitan areas much larger than Albuquerque. Transportation scenarios should be developed under worst possible conditions for each type of waste material to be transported to the WIPP site (TRU, HLW, spent fuel canisters). These scenarios should depict the adverse impacts which might be incurred in a densely populated metropolitan area such as Dallas or Houston.

33. At the end of Chapter 6 there is a short section devoted to the possibility and consequences of "intentional destructive acts." It claims that the consequences from an intentional act of terrorism or sabotage "will not produce consequences more significant than the accident consequences calculated in Section 6.7." Acts of terrorism (using explosives for example) could create more serious situations than conceivable truck or train wrecks.

34. In the section on accidents involving contact-handled TRU waste (beginning on page 6-23), a fire should be assumed to be taking place. Surely this would create a worse hazard than if a fire was not present. Previously on that page, DOE stated, "...the conditions that lead to the greatest population dose have been chosen." This statement and the cited scenario do not seem to correspond. In addition, the release fractions used on page 6-26 should be documented.

35. In Section 6.7.3, Results of the Analysis, the results were not converted from person-rem to health effects. In this case, one accident yields non-negligible impacts, the accident involving spent fuel. Based on DOE estimates this accident will result in a 50-year whole body dose commitment of 3700 person-rem for a small urban area and 8300 person-rem for a large urban area. Using EPA's conversion factor of 600 health effects per million person-rem, estimates of total health impacts are about 2 and 5, respectively.

36. There appears to be a considerable seismic risk. An earthquake with an epicenter at the WIPP site could disrupt the repository and break containers; this would result in wastes coming into direct contact with salt sooner than anticipated. Considering the magnitude of possible consequences, this scenario should be explored further. The final statement should include among the accident cases it discusses, the case of an earthquake-induced rock fall in the repository (analogous to those reported in the nearby potash mines). Such a rock fall could damage a number of waste containers in open rooms. Though unlikely, an earthquake could also simultaneously degrade the HEPA filter installation.

37. The discussion of rates of removal of salt by dissolution (page 7-74 ff) illustrates well the difficulty in determining such rates. First one estimate is referenced of 0.33 foot vertical per thousand years average but the suggestion is made that most of the dissolution occurred long ago at a faster rate, and that the present rate is slower. Then an alternative approach is referenced which gives a present vertical dissolution rate of 0.5 foot of salt in 1000 years. Although it is unlikely that these estimates are so greatly in error that there would be a threat to the repository in the next thousand years or so, it would, in any case, help the presentation in the final statement if the uncertainity in these estimates were presented.

38. The physical properties of vertical solution features and wells can be very similar relative to ground water movement. Chapter 7, page 74, states that "extensive investigations" at the site show no evidence of continuing deep dissolution. Small scale vertical solution features are very difficult to detect utilizing surface geophysical

methods such as the resistivity surveys mentioned in the report. The probability of locating a vertical "chimney" while drilling a test hole is even more remote.

39. On page 7-75, the last paragraph states, "The rate of deep dissolution is difficult to assess, and Anderson (1978) does not believe that estimates can be made with any degree of confidence from the available data." Then, without further support or reference, the conclusion is drawn "In any case, deep dissolution does not occur near the site." We recommend that this conclusion be deleted unless some evidence in support of it can be referenced. Whether the limestone under the site is subject to dissolution like that in neighboring Carlsbad Caverns should be discussed.

40. On page 8-28 is stated "The amount of material released through cracks is assumed to be proportional to the ratio of the area of the cracks to the total area of the drum." In view of widespread current experience with salt shakers and the past record of hourglasses, in which all the material has exited the holes, this assumed limitation on the amount of material released needs experimental verification to give it credibility. The final statement should provide at least a supporting reference to such verification.

41. On page 8-39, it is indicated that a 24-inch waterline is proposed to bring water to the site from a tie-in with an existing 10-inch main; this appears to be a typographical error. If not, it should be explained.

42. The use of carbon-steel pipe (page 8-49) for canisters for the spent-fuel assemblies as indicated in this draft statement represents a much better use of natural resources than earlier proposals for thick canisters of stainless steel containing large amounts of chromium and nickel.

43. On page 8-50, it is indicated that "The backfilling of the storage drifts will not greatly affect the results of the demonstration or monitoring program." It should be explained why the ventilation air will not carry away heat that would otherwise be stored in and conducted through the salt, raising its temperature.

44. On page 8-52, the statement indicates that stress-induced creep closure of the storage room "may possibly" damage the waste containers. If, in due time, such closure is expected to eliminate almost all voids in the salt, damage to the containers would seem a certainty.

45. The Demonstration of Spent-Fuel Disposal (Section 8.10) has some serious problems. Based upon the distribution coefficients on page K-20 it appears that the overlying aquifer is oxidizing. This is inferred from the high mobility of U and Tc. It is possible that the high distribution coefficient for Np is either from a selective adsorption of NpO_2+ or from reduction of that species to NpO_2. Because the overlying aquifer, if diverted by natural or human factors through the repository, will dissolve the spent fuel, the risk is much higher (a thousand times or more) than it would be if the overlying aquifer were reducing. This oxidizing aquifer raises serious questions concerning the site suitabliity for spent fuel disposal. This consideration does not affect the impact from the TRU wastes so severely, since those wastes (mostly Pu) are not as sensitive to oxidation. It appears that either the rock is such that it makes a Ph and Eh condition where Np is reduced to Np (IV), or the rock selectively removes NpO_2+ from solution. C-14 should be added to the distribution coefficient table portion of table K-3. It would also be helpful if the density and porosity of the Rustler formation were used to translate the distribution coefficients which are given, into Equilibrium Adsorption Constants, as defined by Equation K-9. These Equilibrium Adsorption Constants (sometimes called "Retardation Factors") are more directly useful in groundwater migration calculations than distribution coefficients. It is also likely that some of the distribution coefficients have a high degree of error associated with them; presentation of the percent error will indicate those values for which the uncertainity is high.

46. The environmental impacts of the experiments to be performed (pages 8-45 to 8-53) cannot be evaluated without more information on the nature, and especially the scale, of the experiments. There appear to be no plans for participation in decisions on the experimental program by non-DOE agencies. There should certainly be a review process before plans for the experiments are finalized.

47. In view of the concerns expressed in years past about existing drill holes at the Lyons, Kansas site, it is surprising to read (page 8-56) "that the long-term consequences analysis (Section 9.5.1) shows that an unplugged hole has but small environmental or safety consequences." It would, perhaps, be reassuring to include a comparison of the Los Medanos site with the Lyons, Kansas site. Section 9.5.1 contains several scenarios which have been modeled for calculations. Scenario 1 is postulated to be the worst case. However, there are several factors which could be reasonably expected to alter Scenario 1 such as the pressure difference between the Rustler and the Bell Canyon aquifers, the number of undiscovered boreholes, the amount of casing in the boreholes, waste container leaks, etc. Appendix Section D-2 flatly states that "the repository and control zone III are

free of pre-existing holes that extend through the salt, shafts, and mining activity." This statement is questionable on its face value in the absence of conclusive data -- none appeared to be provided. There is no mention of holes in the remainder of Control Zone I and in Zones II and IV.

48. In Section 9.1.5, Plans for Mitigation of Impacts, the discussion of erosion control should also address controls against wind erosion for those parts of the site where the soil is particularly susceptible. As indicated on page 7-53, the potential for wind erosion is high if the vegetative cover is seriously depleted. On page 7-72, it is indicated that Laguna Plata and Laguna Gatuna were formed as blowouts. The discussion should also address controls for any areas that may be subject to flash flooding. In addition, when impacts of the proposed action are being discussed in several places (page 9-8) mitigating measures are discussed as optional approaches. If a decision is made to proceed with a repository at this site, the decision should include a positive commitment to utilize those measures to limit pollutant impacts.

49. It should be made clear in Section 9.2.10.2 how the populations of miners at the potash mines, and of oil and gas workers in the vicinity, are included in the exposure calculations. The draft statement indicates that the miners are treated as if they were home in Carlsbad rather than at the mines. The discussion on page 9-55 also should be enlarged to specify how potash miners and oil workers are treated in the calculations.

50. In as much as use of diesel-powered waste transporters is contemplated (Chapter 8), among the conceivable accidents that should be considered in Chapter 9 should be those including fires involving the transporter and its fuel tanks.

51. On page 9-51, the air-entrainment factor is quoted at 0.014 percent per hour, one tenth the factor quoted earlier in the draft statement; this discrepancy should be cleared up.

52. The Department of Energy has put together a high quality evaluation of the economic and social impacts of the WIPP project. The economic impacts are based on an input-output analysis of the direct and indirect impacts of both the construction and the operation periods of the project. The draft points out the uncertainties inherent in the economic impact projections, due to the uncertainty in projected alternative employment opportunities, specifically in mining and in a projected large dam project in the area. A minor criticism of the analysis is that the input-output evaluation of indirect impacts should have been based on an area somewhat larger than Eddy and Lea Counties. It is appropriate that the direct effects be measured for those two counties only, but the indirect effects can be expected to impact an area larger than these two counties. If the analysis had encompassed a larger area, the estimated multipliers of the input-output analysis would be expected to be somewhat larger.

53. The cost estimates of the WIPP are given in 1978 dollars: construction--$225 million; engineering, construction management, and technical support--$205 million; yearly operation--$36 million. An estimate of these costs, however rough, needs to be made using 1980 dollars. Also, the effects of lengthened construction time on total costs in constant dollars should be discussed.

54. In Section 9.4.1.2, mention is made of a reservior project on the Pecos River between Artesia and Carlsbad. The final statement should address the potential of this reservior to induce seismic events as a result of the load from its filling, and its potential to induce changes in the ground water flows.

55. The discussion (in Section 9.5) of ground water flows and their potential transport of leached materials from the site should also address the potential for changes to be induced in the ground water flows, and for transport of leached materials to Carlsbad Caverns.

56. Although some of the assumptions used in Section 9.5 provide bounding analyses that appear to be beyond potential differences due to leaching, waste-matrix degradation, and changes in the valence states of important radionuclides, these matters and their potential impacts on radionuclide transport should be addressed directly or by reference in the final statement.

57. The labels of Tables 9-43 and 9-44 are unclear. If they present concentrations in waste in still-intact and unaltered containers, this should be specifically stated.

58. The suitability of the hydrologic transport model employed in the dose rate analysis for the postulated four scenarios is questionable. As was stated in Appendix K, Section K.1.2, the basic equation used in the numerical model was multi-dimensional and temperature dependent. However, the actual models representing scenarios 1, 2, 3, and 4 were one-dimensional and temperature independent. Therefore, the basic system equations for the numerical model could be greatly simplified. The result of reducing the numerical model from multi-dimension and temperature dependent to a single-dimension and temperature-independent model may result in inducing additional unnecessary error of analysis. The combination of the above error and the additional numerical error for a transport distance of 70 meters has been demonstrated by the Intera Environmental Consultants, Inc. in a report to the U.S. Nuclear Regulatory Commission. The report analyzed the transport of a radionuclide with a half-life of 433 years, in an aquifer with hydraulic conductivity of 2 ft/day, by the same numerical model and by the analytical solution

model. The concentrations of radionuclide at a distance of 70 meters were 10^{-4} and 1.5 X 10^{-3} of the original mass respectively for the numerical model and for the analytical model. The combined error was evaluated to be 10 or 1000 percent at a distance of 70 meters. This combined error is expected to increase exponentially with the increase in the transport distance. Therefore, the results of the analysis using the numerical model could have large uncertainties.

59. On page 9-100 is a discussion of compilations of scenarios. The work by S.E. Logan and M. C. Berbano (EPA 520/6-78-005) seems to be appropriate for inclusion in this discussion. This work was specific to this New Mexico site.

60. Section 9.5 should also include discussion of the potential use of waste-contaminated water closer to the site than Malaga Bend, via wells for drinking water or stock watering. Figures 7-23 and 7-24 indicate a number of wells closer than Malaga Bend. While it is unlikely that anyone would drink water that is 100,000 ppm salt, they might use some that had been diluted by other ground water. Any potential pathway through the Laguna Grande de la Sal should also be discussed.

61. Section 9.5.1.5 should have its sequence of "events that must occur" revised:

(a) For the first event, it is only necessary that institutional control <u>fail</u> rather than be lost. There are many examples of institutional controls failing; a recent one is the waste tank leak at Hanford that went uncorrected for over a month although monitoring duly recorded the decreasing level of waste in the tank. Perhaps the state of fire prevention at the Browns Ferry Nuclear Power Plant in January 1975 could also be put in this class.

(b) With regard to the second event, it is not necessary that knowledge of the repository be lost. Fear of its hazards could be overcome by avarice, as may have happened with kepone in Hopewell, Virginia. It is also not unheard of for people to become complacent about hazards; experience in this respect is given by flood-control levees being allowed to fall into disrepair when the period between floods grows long.

62. Section 9.5 addresses subsidence (page 9-131 ff) and concludes that 1 to 1.6 feet of subsidence will be insignificant. The discussion should be enlarged to include the effects of subsidence and its concommitant distortion of the rock strata upon the borehole and shaft sealing, and whether it could induce failures that should be included in the radionuclide release scenarios. In this respect,

although it is reassuring that water has not flowed into the local potash mines in spite of more severe subsidence, the experience time period is relatively short.

63. The subject of liquid inclusions in the salt at the WIPP site and brine migrations along thermal gradients is important. In the discussion of brine migration in Section 9.5.3.2, some mention should be made of the potential case in which brine migrates to open spaces around the canisters and then evaporates and moves through the voids in the backfill salt upward to the room above. It is not clear that the bounding analyses of radioactive releases (Section 9.5) are so broad that they envelope all potential problems from brine migration and canister corrosion.

64. In the course of salt closure in the repository, in perhaps 200 years (page 9-135) it is possible that volumes of noncondensible gases will be trapped and pressurized by the inward creeping salt. The discussion of scenario 5 (Section 9.5.1.5) should be expanded to address the potential for drilling into a pressurized gas volume, including the possibility that the gas includes radionuclides released from the wastes. This drilling sequence should also be examined for any mode in which it could trigger a release of stored energy from radiation damage.

65. The discussion of stored energy in Section 9.5.3.5 appears to consider only the case in which the radionuclides remain in the waste containers. The discussion should be expanded to cover the potential for nuclide migration into the salt where the beta and alpha energy would also be available.

66. In preparing the TRU waste from INEL, the slagging pyrolysis process uses makeup soil blended with the waste in the ratio 1.5 pound per pound of waste (page 9-155). This will require some 50,000 to 100,000 tons of soil through 1985. The draft EIS makes no mention of the source of soil or soil type to be used. We suggest that TRU-contaminated soil be obtained and used for this purpose. This activity appears to present a rare opportunity to solve at least part of some existing waste disposal problems at several locations around the country.

67. The criteria in D.1 and D.3 that the repository will not be breached while the wastes remain hazardous should be qualified. Minor breaches may and probably will occur. The period should be stated more definitely.

68. The discussion on page D-8 should address the effect of the brine on the ion-exchange properties of the geology. Brines are used to remove adsorbed nuclides from ion-exchange systems.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SEP 24 1979

Mr. Eugene Beckett
WIPP Project Leader
U.S. Department of Energy
WIPP Project Office
MS B-107
Washington, D.C. 20545

Dear Mr. Beckett:

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the draft environmental impact statement issued by the U.S. Department of Energy (DOE) related to the Waste Isolation Pilot Plant (WIPP) located near Carlsbad, New Mexico. On the basis of our review, the staff offers the following general comments. Detailed comments on the WIPP draft environmental impact statement (DEIS) are enclosed.

Background

The DEIS evaluates the environmental effects of the WIPP reference repository along with six other alternatives. The DEIS assumes that all options would be licensed by NRC except option 1. The seven options presented in the DEIS on page 1-5 are as follows:

1. No action. No ISF is built, and TRU waste remains stored at the Idaho National Engineering Laboratory and elsewhere as it is now.

2. The WIPP reference repository in southeastern New Mexico. This includes an Intermediate Scale Facility (ISF) with up to 1000 commercial spent fuel elements as well as limited military high-level waste.

3. The WIPP reference repository, but without the ISF.

4. Disposal of TRU waste in the first available HLW repository. By 1982 or soon thereafter, sites in the Gulf Interior region salt domes and Hanford basalt should be available for consideration. An HLW repository would be built at one such site, and TRU waste would be put into it. The initial retrievable-storage phase of the repository would take the place of the ISF.

5. Delay of Alternative 2. By 1982 or so, the WIPP may also have the choice of dome salt and basalt sites as well as the bedded salt site at Carlsbad.

6. Delay of Alternative 3, similarly.

7. A longer delay. By 1985 or somewhat thereafter, sites may also be available in granite, tuff, or shale for a HLW repository as in Alternative 4.

The DEIS concludes that none of the alternatives is superior to the others based on environmental considerations; however, alternative 1 does not appear viable over the long term. The DEIS further concludes that from a programmatic standpoint, alternatives 2, 3, and 5 appear attractive. While the DEIS does not explicitly state which of these alternatives is the preferred option, the document implies that the WIPP reference repository is the alternative that will be pursued. Indeed, most of the document is devoted to an evaluation of environmental impacts resulting from the development of this option.

The WIPP reference repository as described in the DEIS could provide for the ultimate disposal of 70 million cubic feet of TRU waste. However, current plans call only for the disposition of that amount of readily retrievable waste expected to be stored at the Idaho National Engineering Laboratory (INEL) through 1990. This waste will amount to about three million cubic feet or about 800 kg of TRU. The DEIS states that the WIPP reference repository will have the capacity to receive TRU waste from the dismantling and decontamination of obsolete weapons-production facilities such as the Hanford plutonium reactors. Estimates of the volume of such waste range from 5 to 95 million cubic feet. The transportation impact analysis, however, does not evaluate the effects of shipping any of this dismantling and decommissioning waste to WIPP.

<u>Comments</u>

1. The NRC staff considers that the EIS does not present the basic information needed to make a reasonable comparative assessment of the alternatives. For example, cost information which would permit a rigorous comparison is not explicitly provided. In addition, where comparative information is discussed, it is done in a rather judgmental and qualitative way which does not facilitate independent review and assessment (e.g., land use, resources, transport, socioeconomics, potential for future disruption, isolation potential). The staff considers that a more rigorous comparative analysis of the alternatives may indeed sharpen the differences among them and lead to clearer conclusions regarding which alternatives are preferred.

2. In re-evaluating the alternatives on a more rigorous basis, the NRC staff considers that particular attention should be given to the following points:

   (a) The DEIS states that the capital cost of the WIPP reference facility (alternative 2) is about $430 million. This would result in a construction cost of more than $500,000 per kilogram. Figuring in the operating costs would likely run the costs up to in the order of $1,000,000 per kilogram of TRU disposed.

The DEIS points out that alternatives such as 4 and 7 could result in a 40 percent reduction in land use while increasing the cost of the HLW repository only four to ten percent. This would appear to be an enormous cost advantage.

This evaluation should be made explicit and quantitative so a direct cost comparison can be made.

(b) The DEIS states that although the WIPP reference facility is sized for disposal of 70 million cubic feet of TRU, only the material expected to be stored at INEL through 1990 is being definitely intended for disposal at this time. The DEIS implies, however, that this additional capacity could in the future be used for the large quantities of TRU waste which would result from dismantling of surplus facilities largely at Hanford (estimates range up to 95 million cubic feet).

Elsewhere, the DEIS observes that there would be a small transportation advantage if the TRU (at INEL) were eventually disposed of at a HLW repository at Hanford; however, the DEIS goes on to conclude that this advantage is small since the differential distance from INEL to Hanford and Carlsbad is small.

If all of the TRU material requiring disposal at the other DOE sites (particularly Hanford) is considered in the transport effects, however, substantially different conclusions would likely emerge. The NRC staff feels that consideration of the known TRU requiring disposal should be explicitly considered.

(c) The DEIS discusses generally that the mineral resources situation at the WIPP reference site would have two adverse impacts. Firstly, resources would be denied to future generations; and secondly, the existence of resources at and near the site could invite future disruption. The DEIS concludes that these effects are small. The DEIS points out, however, that these undesirable effects could probably be avoided with almost all the other alternatives.

The treatment of this issue in the DEIS is general and somewhat qualitative. DOE should reassess this important issue on as quantitative basis as possible comparing it with the other alternatives.

The potash and hydrocarbon resources at the WIPP site should be monetized and factored into the alternative site analysis. Mineral resources at alternative sites, if they exist, should also be considered in the comparison of sites. Furthermore, the final environmental impact statement should elaborate on any tentative

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Mr. Eugene Beckett

plans for recovering these resources prior to construction, during operation, or after closure of the repository. Any such discussion should put primary emphasis on the potential consequences these recovery operations might have on the integrity of the repository to function satisfactorily.

(d) The Final Statement should reconsider the relative merits of proceeding ahead at the WIPP reference site without comparative information which will be available in the mid-1980's from several other site characterization efforts resulting from the HLW program. The merits of proceeding to fully characterize (i.e., at depth exploration and R&D) the WIPP reference site in parallel with those being evaluated in the HLW program (but not making any construction commitments to the site until the comparative exploration and R&D information is available) should be quantitatively analyzed.

3. The analysis for the WIPP referenced facility (alternative 2) assumes it will be licensed by NRC. The DEIS emphasizes that this will provide an opportunity to try the licensing process at an early date and discusses the institutional advantages of this approach. The WIPP reference case also emphasizes the considerable technical advantages of an early ISF using spent fuel where experiments involving high temperature HLW could be performed and evaluated at an early date.

   Recently, DOE officials have stated that DOE no longer will pursue WIPP as a licensed facility nor the ISF involving the 1000 fuel elements. This would appear to greatly reduce the utility of the reference alternative from a technical development standpoint and would appear to render any previously positive institutional advantages non-existent or negative.

   The changed nature of the reference alternative should be explicitly included in the more rigorous comparative analysis discussed in comment 2 above.

Finally, it must be pointed out that by commenting on the DEIS, the NRC staff does not intend to preclude itself or the Commission in any way from (1) carrying out a licensing review, if subsequently authorized by law, in accordance with procedural and substantive rules and statements of policy of the Commission, or (2) denying a license or incorporating conditions on any license that may be issued for the WIPP facility at a later date that may reflect a more restrictive position than that taken in these comments on the DEIS.

Mr. Eugene Beckett

SEP 24 1979

Thank you for providing the NRC with the opportunity to comment on the WIPP DEIS. We hope that these comments will be of assistance in preparing the final environmental impact statement. We would be pleased to discuss these comments with you or members of your staff if you so desire.

Sincerely,

John B. Martin, Director
Division of Waste Management

Enclosure: NRC Comments on
WIPP DEIS

COMMENTS ON

DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE
WASTE ISOLATION PILOT PLANT
(U.S. DEPARTMENT OF ENERGY, DOE/EIS-0026-D)
APRIL 1979

BY
THE STAFF OF THE
U.S. NUCLEAR REGULATORY COMMISSION

AUGUST, 1979

Specific Comments - Chapter 1

The document does not address the issue of safeguards requirements for protection of WIPP facilities or for protection of waste materials in transit to or between such facilities. The Final Environmental Impact Statement should discuss safeguards requirements for the facility and the impacts of these requirements.

Section 1.1, page 1-1, second paragraph The location in the text containing the definitions for HLW and TRU should be referenced.

Section 1.1, page 1-1, third paragraph The document states that "progressive elimination of less desirable sites led to the bedded salt of southeastern New Mexico and to the WIPP reference site described later in this document." Either in Chapter 1 or at some other appropriate point in the text, the process of site elimination should be discussed. Included in such a discussion should be the basis, including both the technical and economic factors, for elimination of the less desirable sites.

Section 1.2, page 1-2, item 1 It is recommended that the following revision be made in line 7: "for the disposal of TRU wastes from other DOE sites."

Section 1.2, pages 1-2 and 1-3, items 1 and 3 The waste retrieval period is stated to be 10 years for TRU waste and 20 years for spent fuel. The current staff opinion regarding retrievability of wastes disposed in deep geologic repositories is that the repository design should permit the waste to be retrieved throughout the operating life of the repository and 50 years thereafter.

Section 1.1, page 1-3, Geology, second paragraph The last sentence states that there will be ". . . only a temporary denial of access to approximately one-third of the natural gas, three-quarters of the langbeinite, and all of the sylvite at the reference site." This implies that zone IV will be exploited for hydrocarbons and potash. However, on page 9-21 it is stated that "mining and drilling may be allowed in this zone if they would not affect the integrity of the site," which means that potash mining may not be permitted. Therefore, the sentence should be reworded to state that there may be only a temporary denial rather than there will be only a temporary denial.

If it is necessary to indefinitely deny the extraction of resources at WIPP, then this would apparently require long-term reliance on institutional controls. However, this requirement conflicts with EPA's draft criteria for radioactive waste disposal, which states that "Controls which are based on institutional functions should not be relied upon for longer than 100 years." Therefore, the final environmental statement should address DOE's plans for denying these resources after 100 years.

Section 1.2, page 1-2, Item 1 The document states that WIPP will receive TRU waste from the Idaho National Engineering Laboratory (INEL). However, a recent Department of Energy document (DOE/ET-0081) states on page 1-4 of that document that "Before a decision is made for long-term management of INEL TRU stored waste, a Programmatic EIS, covering both buried and stored waste, will be prepared." The document further states on page 7-5 that the draft EIS will be completed in late 1979. It would appear that the issuance of the WIPP EIS should have been subsequent to the issuance of the programmatic EIS discussed in DOE/ET-0081. The final environmental statement on WIPP should reconcile and discuss the sequencing and objectives of the various environmental impact statements that have been or will be issued by DOE.

Section 1.2, pages 1-2 and 1-3 An important concern about mineral resources at the WIPP site is the probability that these resources will attract future exploration and intrusion. The final environmental statement should discuss the impacts that future mineral exploration activities could have on repository performance.

Section 1.2, page 1-3, Geology, third paragraph The basis for stating the "low seismicity" of the site area should be provided.

Section 1.2, page 1-4, fourth paragraph The document indicates that underground dissolution of salt is an active process in the region of the site ("At the site itself dissolution has removed some salt from above the Salado"). Although Anderson (1978) believes that the site is in an area of the Delaware Basin that is relatively free of deep dissolution features, he indicates that localized features are present in the vicinity (see page 7-74). He also indicates that the rates of deep dissolution are difficult to assess and does not believe that estimates can be made with any degree of confidence from the available data (see page 7-75). Thus, the draft statement does not convey confidence that dissolution processes or rates are sufficiently understood to locate WIPP in an area of active dissolution processes. The staff believes that additional information is needed on current rates of dissolution and on changes which might occur in dissolution rates in the future. The final statement should discuss the effects that boreholes, wells, changes in hydrological conditions, and mineral exploration activities could have on dissolution rates in the site vicinity.

Section 1.3, page 1-5, first paragraph The document states that the reference site in southeastern New Mexico and the plant design were chosen because they were "the most completely analyzed of the alternatives." The selection of the reference case should be based on a comparative evaluation of the relevant environmental, economic, and technical factors of each alternative considered.

Section 1.3, pages 1-9 , third paragraph This document states that the alternative of no action (i.e., leaving the TRU waste at INEL) is unacceptable in the long term. However, a comparison of Table 3-1, which illustrates the long-term radiological consequences of no action, with Table 3-5, which displays the radiological impacts of transportation of waste to the WIPP site, shows that the radiological impacts are of the same order of magnitude. For example, the exposure resulting from a transportation accident involving a rail shipment of CH TRU waste is provided in Table 3-5 to be 0.49 rem, 0.025 rem, and 0.012 rem to the bone, lung, and whole body respectively. Table 3-1 shows that for improved confinement at INEL, the respective doses assuming a lava flow release mechanism would be 0.5, 0.9, and 0.0003 rems, respectively.

In view of the similar long-term impacts between the reference case (WIPP) and the no action alternative, the final environmental statement should examine in greater detail the need for the proposed action.

Section 1.4, page 1-6, fourth paragraph Justification should be given for the statement that, ". . . an estimated 3% of the U.S. reserves of this mineral (langbeinite) would be denied for perhaps several decades." This statement implies that the langbeinite in control zones I, II, and III will be mined in perhaps several decades. Such a statement should be accompanied with a full analysis of the impacts of mining in control zones I, II, and III with special emphasis on waste isolation.

Use of the WIPP site may entail the long-term denial of mineral resources in control zones I, II, III, and IV. These resources are stated in Section 9.1.4.2 to include 11.6% of the U.S. reserves of langbeinite. This statistic should be included in Section 1.4.

Section 1.4, page 1-6, sixth paragraph It is suggested that the 50 year dose commitment to the maximally exposed individual and to the population from the postulated tranportation accident should be stated numerically as well as a percentage of natural background.

Section 1.4, page 1-8, second paragraph An expected release is equal to the sum of the probabilities of release times the amount of release. Since the probabilities for all releases are not zero, the expected release of radioactivity is not zero.

Section 1.4, page 1-8, fourth paragraph For clarification, the basis for the $280 million cost estimate should be referenced.

Section 1.4, page 1-9, second paragraph The following statement is made: "It appears that the alternative of no action (alternative 1) is unacceptable for the long term and that there is no clear environmental basis for choosing among the remaining alternatives." No discussion is presented for the acceptance or rejection of the no action alternative for the short-term. Please provide the omitted discussion. Also, it is not obvious that, "there is no clear environmental basis" for choosing among the alternatives. The environmental impacts addresssed throughout this section should be evaluated and compared. An analysis based upon "policy objectives" is not sufficient for an environmental impact statement.

Specific Comments - Chapter 2

The draft statement should consider alternative disposal methods for the DOE TRU wastes.

Section 2.1.2, page 2-2, third paragraph It appears that "desiderata" should be "criteria."

Section 2.1.3, pages 2-3 through 2-6, Stage 1 of the process The DEIS does not provide the logic needed to proceed from stage 1 of the site selection process to stage 2. Stage 1 is defined in Table 2-1 (page 2-3) as the step which would "select storage media; define geographic regions where they occur; consider their characteristics in terms of tentative selection criteria." The discussion presented does not provide the rationale or supporting data for selecting bedded salt as the preferred media or eastern New Mexico as a region for further study.

Section 2.1.3, pages 2-3 through 2-12 Table 2-1 (page 2-3) describes a four-stage site selection process, however, the text presents only three steps.

Section 2.1.3, pages 2-7 through 2-12, Stage 3 of the process Table 2-1 on page 2-3 states that stage 3 of the site selection process will include conducting detailed field studies of candidate sites. However, the discussion of the stage 3 process does not indicate that detailed field studies were undertaken for the eight candidate sites.

It is not clear whether the criteria outlined on pages 2-7 and 2-8 were developed prior to the selection of the eight site areas identified in Table 2-2 (page 2-10), or if the sites were selected and the criteria developed and applied later. If the criteria were used to select a site, then one could question why several of the sites were selected for comparison. For example, the first criterion states that "the site should be at least 6 miles from the Capitan reef." Yet five of the eight sites do not comply with this criterion. If sites within 6 miles are not viable sites, then the analysis presented in Table 2-2 compares only three real alternatives.

The alternative site investigation should contain information and comparisons of the relative environmental effects of each of the alternative sites. For example, Table 2-2 (page 2-10) contains no information on the relative importance of the ecological aspects of each site.

Table 2-2, page 2-10 The weight (i.e., degree of importance) given to each criterion should be shown. Those criteria which, if not complied with, would rule out the use of a site should be identified.

Criterion 2 (central 3 miles should not be in potash district) and 4 (avoid known oil and gas trends) should take into account future exploration that may result from the known presence of potash, oil and gas. Although this future exploration is acknowledged in the text, it is treated as a non-problem. Substantiation for the non-problem view should be provided.

Criterion 5 (at least one mile from the nearest dissolution front) considers only present or accumulative rate of dissolution. The discussion should clarify whether consideration was given to potential increases in rate of dissolution due to climatic changes in the distant future, i.e., the extreme rates of dissolution.

Criterion 9 (distance and population of nearest town) considers only present population. It should consider future growth.

Section 2.1.3, page 2-11, fifth paragraph   References to the analyses in the document should be given to support the conclusion that the remaining questions in area 1 (i.e., criteria in conflict) "either do not affect repository integrity or are found to be nonproblems."

Section 2.2.2, page 2-16, item 2   The document points out that it is unlikely that there will be another opportunity to build a repository dedicated only to TRU wastes because future HLW repositories are expected to be available for storage of both HLW and TRU waste. This is not necessarily correct unless it includes a basis for assuming that TRU wastes and HLW will be compatible (after breach of the respective containers). For example, TRU wastes from dismantling and decommissioning may contain chemicals that could increase the mobility of radionuclides in HLW.

Section 2.3.3, page 2-22, second paragraph   The document states that WIPP has the capacity to receive some TRU waste from dismantling and decontamination of obsolete weapons production facilities. It should be noted that dismantling and decommissioning (D&D) wastes can be very radioactive and provisions for assuring their safe disposal should be discussed. Further, the DEIS states that the transportation impact analyses presented later in the document do not assume that any of the D&D waste is sent to the WIPP. The assumption that none of this D&D waste is transported to the WIPP is not conservative. The final statement should include D&D waste in the transportation impact analyses.

Section 2.3.3, page 2-24, first paragraph   For completeness, a brief discussion should be included concerning the ultimate disposal of the experimental waste recovered and removed from the WIPP. The discussion should also address whether the waste would be processed or packaged at the WIPP for transportation.

Section 2.3.3, page 2-24, second paragraph   Provide the basis for stating that "little defense high-level waste has been produced."

Section 2.4.1, page 2-26, second paragraph, second item   This item states that the commitment to remove all nuclear waste brought into the experimental area means that the experiments introduce no long-term environmental risks of their own. The experiments may result in providing a pathway for water migration or may increase the risk of mechanical failure, particularly when thermal testing is performed. Therefore, long-term effects may result from the experiments and this possibility should be factored into the analysis.

A more specific system of referencing should be used. The statement that is referenced should be keyed to the reference. Page numbers of the references, where applicable, should be given.

Specific Comments - Chapter 3

Chapter 3 In the economic comparisons between alternatives, the document does not clearly specify which cost differences are for the WIPP project alternatives (e.g., WIPP costs with an ISF vs. WIPP costs without an ISF) and which represent the difference in cost to society (e.g., cost of interim storage for spent fuel and saved opportunity cost of the WIPP investment).

There should be a section that compares the relative costs and benefits of alternatives. The comparison should include a cost estimate in constant dollars and an estimate of the environmental impacts (both radiological and nonradiological) for each alternative.

Section 3.1, page 3-1, second paragraph This discussion indicates that no releases of radioactivity are expected to occur at INEL as a result of natural disasters for the next 100 years. The discussion should state the basis for this assertion and why such events are not expected during this period. A stronger case should be made for the urgency of moving the wastes to the WIPP.

In the third line, "produce in" should be "produce."

Section 3.1, pages 34 and 32 The alternatives that are offered are either no action or programmatic delays of 2-6 years to qualify other sites in salt (bedded and domed) and in other geologic media. The statement points out that there is no significant increase in risk to the health and safety of the public over the near term if the TRU waste intended for the WIPP repository remains in INEL. Thus, without an urgent need for geologic disposal of the TRU waste at INEL, the draft statement fails to make a strong case for the proceeding with WIPP before the analyses of alternate geologic media and alternate sites are completed.

Section 3.1, page 3-2, first paragraph This discussion predicts that an individual lung dose of 9 rem and references Table 3-1, Subalternative 3. However, Table 3-1, Subalternative 3 shows a lung dose of 0.2 rem. The discrepancy (a factor of 45) should be resolved.

Table 3-1, page 3-2 The basis for the estimated doses due to volcanism and intrusion should be discussed. It seems unlikely that consequences of a future volcanic eruption and resulting lava flow would be ten times higher than that resulting from intrusion by man. Also, there appear to be other release mechanisms that are not accounted for but which should be assessed, i.e., releases due to accidents (plane crash, nearby explosions), glaciation, climatic changes and tornadoes. The action of groundwater should be accounted for.

The individual bone dose of 0.8 rem for the volcano mechanism, Subalternative 2, should be 0.08 rem (see Table 9-63, page 9-171).

Section 3.2, page 3-3, second paragraph The denial of mineral resources should be added to the list of site impacts resulting from WIPP.

Specific Comments - Chapter 3

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Section 3.2, page 3-3, second paragraph The denial of mineral resources should be added to the list of site impacts resulting from WIPP.

Table 3-2, page 3-4 The footnote states the TRU waste volume from INEL for the CH level as 2.4 x 10^6 ft^3, and full capacity of the CH level as 70 x 10^6 ft^3. Provide the source(s) of the TRU for the remaining 67.6 x 10^6 ft^3 of TRU waste not from INEL. Also, it is previously stated in Section 1.2 (page 1-4, ninth paragraph) that the receipt rate is 1.2 x 10^6 ft^3/yr. At this rate, approximately 60 years would be required to receive and store the 70 x 10^6 ft^3 of waste, contrary to the 30 year design life (Section 1.2, page 1-4, eighth paragraph).

Table 3-3, page 3-5 The 11.6% of U.S. reserves estimate for langbeinite should refer to footnote "b" rather than "a."

Section 3.2.1, page 3-6, first paragraph The first sentence states that mineral resources "will eventually" be released for exploitation. The second sentence states that subsurface development "would probably" be allowed in the outer control zone (emphasis added). These statements are not entirely consistent with one another and should be reconciled. If the conclusion is that mineral resources will be recovered, justification for that conclusion should be provided.

The reference to Section 8.1.2 in the second sentence should be Section 8.1.3.

Rules under which some of the subsurface development rights could be restored are not clearly defined in either this section or in Section 8.1.3.

Section 3.2.3, page 3-9, first paragraph Radiological dose estimates in this section should be made on an annual basis. For example, if a truck driver receives an average exposure of 40 mrem per trip and makes a few trips during a one-year period, the total annual exposure would be on the order of background. Additionally, transport workers, although they may receive an occupational radiation dose, are not considered to be radiation workers in accordance with the definition in 10 CFR 19. It may be more proper to compare their exposure to the levels permitted in unrestricted areas which should not result in an exposure exceeding 500 mrem in a year.

Tables 3-6 through 3-9, pages 3-10 through 3-13 These tables present dose or dose commitments to individuals and the population. The 50-year dose commitments calculated are due to repository operation in a period of one year. However, the natural background dose commitment was obtained by multiplying the natural background radiation received in one year times 50 years of exposure. This is not a consistent comparison. The latter is not a 50 year dose commitment due to one year's exposure, but is a cumulation of 50 years of background exposure. To be consistent, the background radiation dose commitment for one year's exposure (∿ 0.1 rem) should be presented. This will in turn alter the percentage comparisons between exposure due to repository operation and natural background. Such comparisons should be revised accordingly throughout the document.

Section 3.2.5, page 3-10, first paragraph The document states that no release of radioactive material is expected after the repository is sealed.

The basis for this assumption should be presented taking into account all the reasonably likely events that could affect the repository. (See comment on Section 9.5.)

Table 3-7, page 3-11 The superscript on "worst sector" should be "b" instead of "a."

Section 3.2.7, pages 3-13 and 3-14, second paragraph, item 1 It is stated that "about one-thirtieth of the know U.S. reserves of the mineral langbeinite will be kept from exploitation for a long time, possibly several decades." This statement implies that the langbeinite will be mined at some time in the near future (several decades). Such a statement should be accompanied by a full analysis of the potential impacts of mining with special emphasis on waste isolation.

Table 3-10, page 3-14 Please clarify how the employment percentage figures presented under Socioeconomic impacts were calculated (i.e., whether the figures apply to population, employment, or labor force).

Section 3.3, pages 3-17 and 3-18 The summary fails to emphasize the degree change of environmental impacts between a TRU/ISF facility and a TRU facility. It is not apparent that the reduction of doses from normal operation, transportation, and accidents is insignificant. For example, this summary conflicts with the statement presented in the discussion on possible long-term impacts in Section 3.4, page 3-25: "In the analysis of long-term impacts at the reference repository, the releases from spent fuel have much more severe effects than the releases from TRU waste (Table 3-7 and Section 9.5.1)."

Section 3.4, page 3-23, fifth paragraph Please provide the references or the employment predictions ranging from 1,000 to 1,500 employees at a HLW repository in salt.

Section 3.4, page 3-24, fourth paragraph For clarification, it is suggested that a numerical comparison be made between the estimated dose commitment for a HLW repository and the doses received from natural background sources.

Section 3.4, page 3-25, Possible long-term impacts The discussion should clarify whether the effect of mixing chelating agents and organics (that may have been added to TRU wastes to facilitate dismantling and decommissioning) upon the mobilization of HLW was considered.

Section 3.5.1, page 3-27, second paragraph The document implies that the generation rate of defense TRU waste is dependent upon the timing of WIPP. It is not apparent how the delay of WIPP would increase the quantities of defense TRU waste.

Section 3.5.1, page 3-27, fourth paragraph Please explain in greater detail how the estimated delay cost of $280 million was calculated. Does it include (1) the saved opportunity cost of the WIPP investment, and (2) the cost of interim storage elsewhere? Also this figure should be recalculated and presented in constant dollars to reflect the true cost of delay and reinitiation of present efforts.

Section 3.5.2, page 3-31, second paragraph The document states that "no rigorous comparison of the long-term impacts of TRU-waste repositories at alternative sites can be made." It is the view of the NRC staff that such an analysis is required to perform a proper NEPA analysis.

Section 3.5.2, page 3-31, second paragraph The document states that studies to date have shown no reason to expect that any of the sites are clearly safer than the others. A repository in basalt may have a significant advantage over the other considered media due to a reduced potential for intrusion (e.g., basalt sites are not likely to be explored for oil and gas).

Specific Comments - Chapter 4

Chapter 4, page 4-1, second paragraph   Since it is the judgment of the NRC that the DEIS does not present a detailed and comprehensive analysis of alternatives, we cannot accept the conclusion that the choice between alternatives rests "largely on programmic considerations."

Chapter 4   The programmatic impacts should include a discussion of whether the concept of co-storage of TRU and HLW is feasible from the standpoint of interactions between the two types of waste. Although compatibility is assumed, it may not be true. Thus, some alternatives may not be feasible.

Chapter 4, page 4-5, Summary   It is not apparent from the summary that alternative 6 does not merit favorable consideration since it is a combination of alternative 3 (i.e., no ISF) and alternative 5 (i.e., delay and possibly relocate). Please provide the rationale for alternative 6 not receiving more favorable consideration.

Specific Comments - Chapter 5

Chapter 5 This chapter sets forth the acceptance criteria for waste forms. However, the document does not provide a description of the anticipated waste forms and associated packaging. The final statement should provide a detailed description of the anticipated waste forms, including a description of the containers, packages, overpacks, and any other additional engineered barriers, for all radioactive wastes to be emplaced in the WIPP facility.

This chapter considers alternative processing techniques for finalizing the waste form of TRU waste. A similar analysis should be provided which evaluates the various techniques for processing spent fuel into other waste forms. The analysis should consider on a comparative basis the environmental impacts of each alternative, including the one which is proposed.

Section 5.1, pages 5-1 through 5-7 The criteria and design measures for insuring the preclusion of criticality events should be provided.

Section 5.1, page 5-1, second paragraph The document states that a final waste form acceptance criteria document will be published in July 1979. Please relate whether this document has been published yet for public dissemination.

Section 5.1.1, page 5-2, third paragraph Combustible materials are defined herein as any material that will sustain combustion in air at a temperature of 1475°F for a period of five minutes. The technical basis for this definition should be stated, including the testing method and environment, or the applicable industry code (e.g., ASTM).

Section 5.1.1, page 5-2, fourth paragraph Gas producing materials are defined herein "as any material that produces gas during its decomposition." This definition seems so all inclusive that it should be made more restrictive.

Section 5.1.2, page 5-2, first paragraph Contact handled wastes are defined as waste packages with surface dose rates no higher than 200 mrem per hour. The technical basis for this limit should be presented.

Section 5.1.2, page 5-3, third paragraph The document states that waste form criteria must exclude hazardous materials. Hazardous materials should be defined and the technical support for exlusion of these materials should be provided.

The document sets a limit of 10 percent by weight per room for gas-generating waste. As noted in an earlier comment regarding the definition of gas producing materials, any discussion involving gas generating waste has no meaning until "gas generating waste" is defined more specifically.

Section 5.1.2, page 5-3, fourth paragraph It is stated that any combustible container must be overpacked with a disposable steel container. The final statement should clarify whether steel is the only allowable overpack material and whether the DOT-7A plywood box must be overpacked with a steel box.

Section 5.1.2, page 5-3, fifth paragraph; Table 5-1, page 5-4; and Section 5.1.2, page 5-6, third paragraph The design life of the waste container for CH and RH TRU waste is given as at least 10 years in order that containers may be retrieved intact." This assumes that the required period of retrievability will be less than 10 years. It is the current NRC staff opinion that for a deep geologic repository the wastes should be capable of being retrieved during the operating period and the time period necessary to retrieve the waste.

Table 5-1, pages 5-4 and 5-5 Paragraph 2 of Section 5.1 states that the Waste Acceptance Criteria Steering Committee (WACSC) "reconciles the interests of various agencies involved with the production, treatment, and disposal of defense TRU wastes." The section then goes on to discuss interim criteria for waste forms. It is not clear if the interim criteria listed in Table 5-1 represents the present views of the WACSC on acceptance criteria. Furthermore, it is not known whether the table is a complete listing of the acceptance criteria as they are presently envisioned.

The criteria for containers and packages should be specified as DOT Type A requirements.

The criteria assumed in Section 5.2 indicate that there will be no pressurized gases and no pyrophoric materials in the TRU waste. However, this table, which sets forth the interim acceptance criteria, does not identify pressurized gases as a consideration in setting criteria and indicates that small quantities of pyrophorics may be accepted. Please resolve these discrepancies.

Section 5.1.3, page 5-6 Acceptance criteria for spent fuel should be developed and presented in the final environmental impact statement. These criteria should be consistent with the criteria applied in the environmental evaluations (e.g., Section 9.2.7). In addition, a detailed description of the anticipated waste forms and their associated packaging for spent fuel should be provided in the final statement.

Section 5.1.4, page 5-7, first paragraph Acceptance criteria for the experimental waste form and associated packaging should be described in the final statement. These criteria should be consistent with the criteria applied in the environmental evaluations (e.g., Section 9.3.1).

Section 5.2, page 5-7, second paragraph This section assumes criteria, (stated to be conservative) in estimating the environmental impacts of shipping TRU waste and handling it at the reference repository. These criteria are:

- No explosive materials
- No pyrophoric materials
- No pressurized gases
- No free liquids
- 25 percent combustibles
- 10 percent dispersible powder

The above criteria are not conservative in predicting maximum environmental impacts because there is the potential that the TRU waste will not conform to the assumed criteria. For example, there is potential for small amounts of pyrophoric materials to be included in the waste, and some free liquids could be present. Furthermore, NRC considers there should be no combustibles and the waste form should be non-dispersible. A detailed analysis should be presented to show that the assumed criteria are indeed conservative and that the use of these assumptions would really result in the maximum environmental impact.

Section 5.3.1, page 5-9, fourth paragraph This section presents the DOE finding that the slagging pyrolysis incinerator is "the superior process and holds the highest promise for producing non-combustible, immobile waste products that are free of gas-producing material." The final statement should contain a comparative analysis of the environmental effects of each of the processing methods and the basis for selecting the slagging pyrolysis incineration system should be provided.

Specific Comments - Chapter 6

Section 6.1, page 6-1 It is incorrect to state that DOT "has primary responsibility" for transportation regulations. A description of the overlapping responsibilities of DOT and NRC would be appropriate in addition to a description of their assigned functions under their memorandum of understanding. For example, although the discussion in Section 6.2 recognizes that packages must meet DOT regulations, NRC certification of packages is not mentioned. Although NRC certification of packages used solely by DOE contractors is not required by law, the DOE has been requiring its contractors to obtain NRC certification of their packages (an arrangement not discussed in this chapter). If the WIPP facility were to receive packages from NRC licensees, the NRC regulations would require NRC certification of a Type B package, not authorized as a DOT specification package.

Section 6.2, pages 6-1 and 6-2 It is suggested that the discussion on regulations be expanded. Also, it should be noted that the discussion regarding route control needs to be updated (see comment on Section 6.2.3 regarding route control).

Section 6.2.1, page 6-2, second paragraph The qualification that heat dissipation is important to containment features of package design also applies to shielding and subcriticality features.

Section 6.2.1, page 6-2, Regulations to insure adequate containment, first paragraph The proper reference in the first sentence should be 49 CFR 173.

The word "size" should be replaced by the word "quantity."

In proposed revisions of regulations (revised 10 CFR Part 71; new 49 CFR Part 127 to replace 49 CFR 173.389-173.398), which are still under review, the concept of large quantity is eliminated.

Type A and Type B packages differ not only in quantity of contents, but also in response to the transportation environment. Type A packages must be determined (by the user, with the requirement that the documentation be kept on file at least one year after the latest shipment (49 CFR 173.395 (a) (1))) to meet standards for normal transportation conditions. Type B packages must be certified by the NRC to meet standards for both normal transportation conditions and transportation accident conditions.

Section 6.2.1, page 6-3, first paragraph In place of the clause in the fifth sentence describing Type B package requirements, the following rewording is suggested: "...a Type B package must be designed to withstand a series of specified impact, puncture, and fire environments, providing reasonable assurance that the package will withstand most severe transportation accidents..."

The last sentence in this paragraph is misleading. The regulations require Type B packaging for Large Quantities but there is no Large Quantity package. Thus, no difference exists for Type B packages containing smaller amounts of radioactive materials. One regulation does exist, however, for which the sentence is true concerning advance notice of fabrication for packages designed for decay heat load in excess of 5 kw or for operating pressure in excess of 15 psig.

Section 6.2.2, page 6-4 In the last sentence, the word "special" should be "concept".

Section 6.2.3, page 6-4 Two recently initiated government activities regarding route control should be recognized in the final statement: (1) the DOT rulemaking proceeding on highway movements of radioactive materials (43 FR 36492, August 17, 1978), and (2) the NRC interim regulation on physical protection of spent fuel shipments (44 FR 34466, June 15, 1979). These activities invalidate the sentences stating or implying there are no federal routing controls.

Section 6.2.3, page 6-4, first paragraph In the last sentence, the word "standards" should be "regulations."

Section 6.3.1, page 6-5, second paragraph The use of the ATMX railcar is questionable because it does not meet the requirements of a Type B package.

Section 6.4, page 6-8, second paragraph The statement that the volume of RH TRU waste at ORNL is included in determining the number of shipments, even though the RH TRU waste at ORNL is not readily retrievable, is a non sequitur.

Section 6.4, page 6-9, first paragraph The NFS storage facility at West Valley, New York, may be another source of spent fuel.

Section 6.4, page 6-9, second paragraph Commercial shipments of spent fuel must comply with new NRC requirements for physical protection and route planning. The spirit of this regulation should be observed by DOE contractor shipments as well.

Section 6.4, page 6-10, first partial paragraph This discussion regarding risk is too speculative. Increased chance of accident due to extra mileage is infinitesimal until the extra mileage is on the order of one million miles. It may be useful to point out that the fatality rate for travel on interstate highways is about half that on secondary roads. (Consult the National Highway Traffic Safety Administration, Statistics Division, (202) 426-1470.)

Section 6.4, page 6-10, first paragraph Are random routes ordinarily practiced? It seems to require a conscious managerial decision not to use particular routes, even though they might not be called dedicated, to minimize exposure to particular populations.

Effects of dedicated routes other than routine exposure from route selections should be analyzed and discussed: enhancement of emergency response, political advantages and disadvantages, etc.

Section 6.4, page 6-11, first partial paragraph   Please describe why reduced speed and controlled passing, as would be associated with special trains, do not reduce the radiological risk significantly when, as explained on the previous page, the extra mileage from special routes may increase the probability of accidents.

Section 6.5 through 6.7, pages 6-11 through 6-26   Although the impact due to routine transportation of the experimental high-level waste may be negligible compared to routine shipment of the other wastes, a HLW transportation accident may be the worst case accident situation. It is recommended that these sections address the information and analysis to determine the impact. The accident dose resulting from HLW shipments should be included in Tables 6-13 through 6-15. Table 6-16 should then be revised to show that the frequency of this accident is very low and hence the contribution to the total risk (consequence x frequency) from HLW accidents is very small.

Section 6.5.1, page 6-12, first paragraph   Some indication should be provided regarding the impact of having to build additional ATMX cars and Super Tigers needed to work off the backlog over the 10-year period.

Section 6.6, page 6-15   This paragraph should also recognize NRC regulatory control.

Section 6.6.1, page 6-15, second paragraph   Tables 6-9 through 6-11 do not contain data to support the conclusion described in this paragraph that handlers and nearby workers receive exposures exceeding those of the vehicle crew. Please provide information to support this conclusion and identify whether the handlers and nearby workers are defined as radiation workers in the facilities of the consignor or consignee.

People near the shipments may receive the greatest doses, but the document should state that the observed doses are small.

Section 6.6.2, page 6-15, first paragraph   It should be noted that NUREG-0170 analyzed the transportation of radioactive material in general, not just radioactive waste.

Section 6.7, page 6-20, second paragraph   It would be useful to clarify that empirical data were used for parameters in the accident analysis which differ considerably from the conservative assumptions used in the NUREG-0170 analysis.

Section 6.7.2, page 623, first paragraph   The meteorological conditions used are not conservative for the scenario described of a transportation accident in an urban area. The relationships among the release mode, meteorological conditions, evacuation timing, and resuspension of spilled powders should be reviewed to assure the desired conservatism remains in the analysis.

For an assumed effective release height of 20 meters, a Class F stability condition is not conservative for assessing ground-level concentrations. Rather unstable stability conditions will produce higher ground-level concentrations within several hundred meters of the release. For example, within 200 meters of a 20-meter high release point, ground-level concentrations assuming a Class B stability can be 3 to 15 orders of magnitude greater than if a Class F stability condition was assumed. Also a ground-level release and a Class F stability would provide a more conservative approach from a meteorological standpoint. In an urban area with many buildings, it is more likely that an initially elevated plume will be entrained into the wakes of the buildings and act more like a ground-level release.

Section 6.7.2, page 6-23, third paragraph The removal of contaminated food from distribution does not completely eliminate the food pathway although it may render the pathway as being an insignificant contribution to the dose. Another course of action that local health authorities might take to eliminate the ingestion hazard is to impound contaminated land.

Section 6.7.2, page 6-24, first partial paragraph Please provide the reference for the discussion on the solidification of CH TRU waste after 1981.

Section 6.7.2, page 6-24, second paragraph Provide the basis for selecting a windspeed of 2.5 mph for determining air entrainment of dry powders, and the basis for then increasing the entrainment percentage by a factor of 10. For a conservative assessment, a windspeed should be selected to provide the highest downwind concentration considering both resuspension and atmospheric dispersion.

Are the empirical formulas by Mishima and Schwendiman valid for wind speeds greater than 2.5 mph?

Section 6.7.2, page 6-25, third paragraph The word "breeching" in the fourth sentence should be "breaching"

Section 6.7.3, page 6-26, second paragraph Please explain the basis for determining that the maximum dose for an individual is at one-half mile from the accident (e.g., time for release to occur, release concentrations). Discuss the effects on people at distances within the one-half mile radius. Describe what evacuation measures will be taken, particularly for faster transport resulting from more likely windspeeds of greater than one meter per second.

Section 6.7.3, page 6-27, third paragraph The first sentence is unclear regarding the results of the four hypothetical accidents. Compounding unlikely circumstances make the consequences appear larger, not relatively unimportant. Only when probability is considered will the sentence be true.

Tables 6-13, 6-14, and 6-15, pages 6-27 and 6-28 For clarification, these tables should note that they apply to an assumed transportation accident.

Section 6.8, page 6-29 This discussion does not accurately describe the results of the study by DuCharme. While the results of the DuCharme study may not be applicable to the transport of aged defense wastes, the consequences he described of the successful sabotage of a shipment of spent fuel were certainly significant. It is suggested that this section be expanded to provide elaboration of the topics.

Specific Comments - Chapter 7

Section 7.1, page 7-3, second paragraph   Please state the length of the proposed extension to the railroad spur.

Section 7.2.5, pages 7-26 through 7-31   This section lacks any discussion of the tectonic development of the region with respect to plate-tectonics. Such a discussion should be included. Additionally, discussion of percent tectonic activity in addition to earthquakes should be included (i.e., geodetic movements, residual and tectonic stresses, rates of present day uplift or subsidence).

Section 7.2.6, page 7-32, eighth paragraph   The discussion notes that water injection into wells has been used for recovery of hydrocarbon resources. The effect of this injection on salt dissolution in the site vicinity should be assessed.

Figure 7-13, page 7-38   The figure is considered inadequate for proper seismic assessment. It should delineate major structural features, historic earthquakes, locations of seismic instruments, mines, and producing and abandoned oil and gas wells.

Section 7.2.6, pages 7-39 and 7-40, Earthquakes in the Central Basin platform Salt water disposal wells and secondary hydrocarbon recovery operations exist in the Delaware Basin. The effects of these activities on seismicity and waste isolation should be considered. Studies of these types of activities should consider the likely increase in secondary recovery operations in the future as hydrocarbon resources become more valuable.

Section 7.2.6, page 7-40, second paragraph   The earthquake risk analysis starting on page 7-40 is based on the assumption given in this paragraph that the Central Basin Platform structure limits earthquake magnitude. However, the document states that evidence supports the explanation that minor shocks observed were caused by human activity (see item 3, page 7-40). Justification should be given for ignoring the assumption that minor seismic shocks are related to human activity.

Section 7.2.7, page 7-42, second paragraph   Estimates of reserves are based on "present economic conditions." Estimates based on extrapolations of present economic conditions in the near term and far term should be considered. Also, differences in costs resulting from changes in economic or social structure or the development of more efficient mining methods should be evaluated.

Section 7.2.7, pages 7-42 through 7-46, Methods used to determine potash resources at the reference site   Formal resource criterion have been established by the U.S. Geologic Survey (USGS) and U.S. Bureau of Mines (USBM). Resources are defined as naturally occurring materials such that, "...economic extraction of a commodity is currently or potentially feasible" (USGS Bulletin 1450-A, 1976). WIPP potash resources should be classified according to such a standard definition and justification given for classifying mineral occurrences as being subresource quality or not potentially feasible.

Section 7.2.7, page 7-44, fourth paragraph More distinction should be made between average and minimum richnesses.

Figure 7-16, page 7-46 Justification for the ~~abrupt~~ decline of the dashed extrapolations should be provided.

Section 7.2.7, pages 7-46 and 7-47, Methods used to determine potash reserves at the WIPP reference site The potash reserve estimate is subject to change since it is based on variable prices and production costs. Future changes in potash and potash product prices and production costs should be predicted and their effects on reserve quantity should be estimated. Since waste isolation may necessitate the long-term denial of WIPP site mineral resources, resource denial analyses should consider long-term impacts.

Estimates of the magnitude of potash reserves denied by WIPP are given only in terms of the amount present within WIPP site boundaries. However, restrictions on mining within the WIPP site may prevent the profitable exploitation of potash reserves in adjacent areas, thereby effectively denying reserves outside WIPP site boundaries. Similarly, denial of the mineral reserves of control zones I, II, and III may result in the effective denial of control zone IV deposits (see Section 9.1.4.7). This aspect of mineral resource denial should be considered.

Section 7.2.7, page 7-47, fourth paragraph and Table 7-8, page 7-49 The hydrocarbon resource estimation was considered complete since, "All potentially productive zones were considered in the evaluation . . ." It would appear from Foster, 1974, that some potential resources exist in the Ordovician interval. Justification should be given for not assigning any potential hydrocarbon resources to this interval.

Section 7.2.7, page 7-48, first paragraph The hydrocarbon study by the New Mexico Bureau of Mines and Mineral Resources identified reserves by calculating past and future production. Justification should be given for the presentation of these identified reserves as resources in the final statement. Precise definitions directly applicable to hydrocarbons should be given for reserves and resources.

Section 7.2.7, page 7-50, first paragraph The uncertainty of hydrocarbon resource and reserve estimates should be determined and characterized. Consideration should be given to the uncertainty of decline curve reserve estimates used to define hydrocarbon production. The decline curve estimates made by Sipes, Williamson, and Aycock were based on relatively short production spans which ended in 1976. Discuss how recent hydrocarbon well production figures have affected new well decline curve reserve estimates. Describe whether this updated information would affect hydrocarbon reserve estimates at the WIPP site.

Section 7.2.7, page 7-50, first paragraph The document states that "there has been no actual drilling within control zones I through III." This statement conflicts with the drill holes in zones I through III depicted in Figure 7-15, page 7-43, and Figure J-1, page J-2. Please resolve this discrepancy.

Section 7.2.7, pages 7-50 and 7-51, Results of the hydrocarbon - reserve estimate It is stated in the document that only a single zone, the Morrow Formation of Pennsylvanian age, is worthy of exploration risk. The 1976 Sipes, Williamson, and Aycock study included reserves in the Strawn and Atoka formations as well as the Morrow zone.

The 1976 Sipes, Williamson, and Aycock study identified substantial hydrocarbon reserves in the Bone Springs and Delaware Mountain Group of the Los Medanos field. The reserve potential of pay zones other than the Pennsylvanian should be considered.

Possible drill sites are identified on the basis of subsurface rock structure. Since stratigraphic and combination stratigraphic/structural Pennsylvanian traps may be more common than structural traps in the Delaware Basin (Foster, 1974), the potential for hydrocarbon reserves in WIPP site stratigraphic and combination stratigraphic/structural traps should be assessed.

Justification should be given for the per well estimates of 1.33 billion to 2.09 billion cubic feet for Pennsylvanian natural gas production, particularly in view of New Mexico Bureau of Mines and Mineral Resources estimates ranging from 3.2 to 7.2 bcf per Pennsylvanian well.

No Atoka hydrocarbon reserves were assigned to proposed drill sites 3, 14, and 15 in the Sipes, Williamson, and Aycock study (see Table 3 of the study). Atoka formation hydrocarbon reserves should be evaluated and included for proposed drill sites 3, 14, and 15.

Possible drill sites are ranked according to hydrocarbon presence potential. (For example, see Figure 7-18 which identifies proved undeveloped probable and possible rankings.) Since these rankings (or drilling risk factors) are used to estimate WIPP site reserves, quantitative justification for their magnitudes should be provided.

Potential drill sites in the Los Medanos area of the WIPP site are spaced at about 160 acres per well, while those located at other points at the WIPP site have per well spacing of 320 acres (see page 23 of the Sipes, Williamson, and Aycock study). Justification should be given for per well reserve estimates in light of unequal well spacing.

According to the Sipes, Williamson, and Aycock study, page 20, a large (35.9 bcf) natural gas reservoir exists in the Atoka formation of the Los Medanos field just outside the WIPP site boundary. The potential for the presence of such a large reservoir within the WIPP site should be evaluated.

The results of hydrocarbon resource estimates indicate potential hydrocarbon resources under the site. Thus, detailed discussion appears warranted as to why the site is considered suitable in light of potential future drilling for hydrocarbons.

Section 7.3.2, pages 7-62 through 7-69   Given the importance of hydrology to long-term repository performance, the discussion of hydrologic characteristics of the various formations seems to lack the detail necessary for an assessment. For example, quantitative information such as hydraulic conductivity and porosity is stated without stating how the data was collected, how representative it is, or if local variations are to be expected (as gleaned from the site and off-site measurements). Descriptions of some formations employ terms such as "low hydraulic conductivity" and "confining bed." Such terms should be described quantitatively. In conventional usage, a formation may be a confining bed; however, in assessing long-term performance of the repository, a quantitative assessment of hydrologic properties is needed (even for "confining beds" and beds with "low hydraulic conductivity").

Section 7.3.2, pages 7-62 through 7-69   The document states on page 9-62 that an earthen dam (Brantley Dam) will be constructed on the Pecos River between Artesia and Carlsbad. Would the reservoir created by the Brantley Dam have any effect on the regional groundwater hydrology or any other safety or environmental aspect of the proposed WIPP facility?

Figure 7-21, page 7-63   The title block should state "southeastern New Mexico" instead of "southwestern New Mexico."

Section 7.3.2, page 7-68, third paragraph   The document notes that stable isotope measurements indicate that sampled groundwater comes from rainwater. More information should be provided on this assessment since it may bear on assessments of long-term ground water flow. Also, some indication should be provided whether the rainwater comes from the site or some distance away. Additionally, some attempt should be made to date the groundwater.

Specific Comments - Chapter 8

Section 8.1.3, page 8-6, second paragraph It is stated that permission for mineral exploitation in control zones I, II, and III is contingent upon the results of evalutions in progress. Describe the nature, scope, and timetable for completion of these evaluations.

Section 8.1.3, page 8-6, third paragraph The document states that continuous or drill-and-blast mining in control zone IV for potash may be permitted under DOE restrictions and that new wells for oil and gas production may be drilled in conformance with DOE standards. (emphasis added) These DOE standards and restrictions should be detailed in the Final Environmental Impact Statement.

Section 8.1.3, page 8-6, fourth paragraph The document states that DOE will exercise no control over land outside of control zone IV. Discuss what consideration has been given to the effects of secondary hydrocarbon recovery, salt water disposal, solution mining, and other subsurface operations outside Control Zone IV on the long-term isolation capabilities of the repository. The Final Environmental Impact Statement should address these effects.

Section 8.1.4, pages 8-6 through 8-8 Alternatives to the proposed rights-of-way should be presented and compared with that proposed. An evaluation should be presented which demonstrates that the proposed rights-of-way are the preferred alternatives.

Section 8.2, page 8-15, first paragraph It should be mentioned that surface facilities, particularly where there are accesses to the mine shafts, will be designed to withstand the effects of locally severe precipitation and floods.

Section 8.6, pages 8-27 through 8-34 This section does not discuss the potential release of radioactive materials by the liquid pathways. Although it is recognized that airborne releases are of major concern, as evidenced by the release mechanisms outlined in Table 8-5 (page 8-29), the liquid pathway should not be completely ignored.

Section 8.7.3, page 8-36, third paragraph The infiltration estimate used is not considered reasonable for thunderstorms. The rainfall used in the evaluation is most likely the result of a thunderstorm, and losses during such an event are usually minimal because the rainfall intensity is much greater than the infiltration rate for short periods of time. Also, a 10-year rainfall event is not severe enough even to use in this analysis. A 50 to 100-year event would be a more standard hydrologic engineering design basis.

Section 8.9, pages 8-41 through 8-48 This section takes the position that the experimental and developmental programs to be conducted in the WIPP will result in no environmental impacts. Justification for this position should be provided. The descriptions of the R&D program should be greatly expanded to discuss details of the programs. A partial list of items that should be included follows:

a. A description of the effect of these experiments on the repository environment as a whole or on the long-term behavior of other parts of the repository.

b. A description of experiments with bare spent fuel assemblies or fuel assemblies with exposed fuel pellets.

Section 8.9.2, page 8-43, Studies of radionuclide movement, item 2 This item mentions that studies of leaching of contact handled waste will be conducted to determine the extent to which water can mobilize radionuclides from combustible and non-combustible wastes. Current staff opinion is that no combustibles will be allowed in a repository (see the comment on Section 5.2).

Section 8.9.2, page 8-44, item 3 This item states that laboratory studies of actinide mobility are underway and will be checked by less-extensive in-situ monitoring. The staff comment is that in-situ testing of actinide mobility is as important as laboratory testing and therefore it should be as extensive, not less extensive. To date, lab testing has not been able to represent in-situ conditions adequately.

Section 8.9.3, page 8-44, second paragraph The document states that studies of the interactions of waste with bedded salt were performed between 1965 and 1967 in Project Salt Vault near Lyons, Kansas. A brief summary of the results should be given along with a discussion of how they will affect the current programs.

Section 8.9.5, pages 8-47, Experiments with bare waste Describe what provisions will exist for the retrievability of bare waste. Describe the retrievability process for recovery of the bare waste.

Section 8.10, pages 8-48 through 8-51 The acceptance criteria should be defined for the 1000 spent fuel assemblies that will be emplaced in the facility.

Traceability (i.e., records) of these spent fuel assemblies should be maintained.

Methods of handling breached canisters should be described.

A contingency plan should be presented for the retrieval of the spent fuel assemblies in case the demonstration program does not meet expectations.

Section 8.10, page 8-48 This section is based upon a retrieval period of 20 years for spent fuel. The reference case, as described in Section 2.3.2 (page 2-19), states the retrieval period as 10 years. Please clarify this discrepancy. Also see the applicable comment on Section 1.2 regarding retrievability.

Section 8.10.2, page 8-49 The criteria for determining the storage area configuration are not presented. The proposed configuration may meet the specified thermal loading of approximately 30 kW/acre, but may not provide an optimal thermal distribution in the storage area.

Section 8.10.2, page 8-49, second paragraph   The proposed canister for the spent fuel assemblies is described as a single overpack fabricated from a carbon steel pipe. The basis for selection of carbon steel as the canister material should be given, i.e., a comparison of carbon steel with alternatives should be presented together with selection criteria.

Section 8.10.3, page 8-50   If retrieval of either the spent fuel or the TRU waste were required at some point in the future, describe the plans for storing or disposing of the retrieved waste from WIPP.

A more detailed description of the spent fuel retrieval system should be provided. The description should contain the method that will be used for spent fuel retrieval, the anticipated time that would be required, and the plan for retrieving damaged or deteriorated canisters.

If retrieval of spent fuel were ultimately required, describe how the wastes emplaced at the higher level (i.e., CH waste at the 2,100 foot level) would be affected. Describe the measures that would be used to control the adverse effects of subsidence resulting from retrieval related underground openings.

Section 8.10.4, page 8-51, second paragraph   The document states that significant corrosion effects of spent fuel assemblies in canisters "will probably be minimal or nonexistent." The basis for this statement should be provided, including test data and results of analyses.

Section 8.11, page 8-51 The DEIS states (p.8-51) that the retrievability period for waste stored in the WIPP facility is ten years for TRU waste and 20 years for spent fuel. As DOE is aware, the NRC staff has been considering various approaches to the question of retrievability of waste. A possible approach to the retrievability issue is that the design of the repository facility and the stability of the site be such as to allow the waste to be retrieved throughout the operating life of the repository, and as much as 50 years thereafter. The design should be such that the waste could be retrieved with the same or less effort and in the same or less overall time frame in which it was emplaced. Waste canisters should remain intact during this period. In this manner, if some unfavorable information is developed during the operational life of the repository that indicates the long-term performance objectives will not be achieved, corrective action can be taken. It also provides future generations the option to maintain surveillance of the wastes before closure of the repository, if they choose to do so.

Section 8.11, pages 8-51 through 8-53   The plan for disposition of the contaminated materials (i.e., waste, contaminated backfill and work materials) should be described.

Section 8.12.2, pages 8-55 and 8-56   The reference repository description contained in the document does not take advantage of several types of engineered barriers to radionuclide release that the staff feels could enhance repository performance. The staff feels that consideration should be given to the use of the backfill as a barrier to radionuclide migration, engineered plugs to retard water movement within the repository and radionuclide migration from the repository and multicomponent shaft and borehole seals.

Section 8.12.3, page 8-56 The estimated time period and respective criteria for the administrative controls should be provided. Describe the provisions, if any, that will mitigate the calculated accident exposure resulting from intrusion (i.e., drilling into the stored spent fuel 100 years after closure). This section should discuss the size of the area (i.e., distance from the repository) over which post-decommissioning controls would be exercised to prevent activities that could adversely affect the hydrology of the site or its long-term containment capabilities. This is particularly important for the WIPP site because of the mineral resources at and near the WIPP site.

Specific Comments - Chapter 9

The report should address uncertaintities, probabilities and statistics in much greater detail. These subjects are essentially unaddressed in the DEIS. For example, numerical values are shown in tables and figures (Figure 9-2, page 9-29, is one of many examples) with no indication of the error band or uncertainty in the numbers.

Section 9.1.1.2, page 9-3, third paragraph It is stated that soil impacts from water lines and electrical power lines will be brief because the soil will recover after construction is completed. Please describe the nature of recovery (e.g., protective vegetation) and the estimated duration of the impact.

Tables 9-2 and 9-3, page 9-4 Please provide the references for the numerical estimates of the construction vehicles and equipment and their respective sound levels.

Section 9.1.1.3, page 9-4, third paragraph The reference to "spherical divergence" should read "hemispherical divergence." Also, the amount of attenuation of sound due to the ground cover in the noise path should be indicated and referenced. This figure should be used to support the estimate of excess attenuation beyond the 6dB per doubling of distance attenuation due to divergence and air losses for the predicted noise level at the James Ranch.

Section 9.1.1.3, page 9-4, fourth paragraph If ambient sound level data is available for the receptor site (i.e., the James Ranch), it should be provided.

Section 9.1.1.3, page 9-5, first paragraph The meaning of the term "broad based" in the first sentence should be defined. Perhaps this term should be "broad band."

Section 9.1.1.3, page 9-5, second and third paragraph The overall period of time over which blasting operations will take place, the estimated frequency of blasts, time of day when such activities will occur and estimate of peak overpressure and corresponding dB level to which blasting will be limited should be presented in the Shaft sinking section.

Section 9.1.1.3, page 9-5, fourth paragraph Schedules and time of duration of the other construction activities should be provided as bases for impact assessments.

Section 9.1.1.3, page 9-5, sixth paragraph If available, estimates of the number of truck deliveries per day should be provided along with an estimated equivalent sound level (L_{eq}) for the delivery routes (which should be identified) so that an estimate of the likely total affected population may be prepared.

Section 9.1.1.5, page 9-9, fourth paragraph The referenced documentation by Anderson, Mann, and Schugart, 1977, describes the positive effect of right-of-way corridors on bird populations in the forest of Tennessee. The same conclusion does not necessarily apply to desert vegetation.

Section 9.1.1.6, page 9-10 Appendix I of the DEIS contains correspondence between DOE and its consultants and various federal and state agencies involved in the preservation of archeological and historical resources. A letter on this subject in Appendix I (see pages I-12 through I-13) concludes that there are 33 sites within the survey area that are eligible for the National Register of Historic Places. However, the statement does not address whether construction and operation of the WIPP facility will have an adverse impact on these sites. The final environmental impact statement should set forth any adverse impacts resulting from construction and operation of WIPP on the 33 sites and, if adverse impacts do result, determine whether there is a feasible and prudent alternative to avoid or satisfactorily mitigate any adverse impacts.

Section 9.1.2.1, page 9-11 This section is very brief and, on the surface, appears to underestimate water consumption. Please provide a description of how the estimates were derived.

Section 9.1.3.1, page 9-13 This section does not address the impacts to the terrain and soils resulting from the salt particles discharged from the ventilation exhaust (see Section 8.7.5, page 8-37, second paragraph). To evaluate the effects of the release of these salt aerosols, it would be necessary to know the number and locations of the facility discharges and the dispersion characteristics (i.e., distance and concentration).

Table 9-11, page 9-17 It is not clear whether this table compares WIPP site resources and reserves with deposits that have not yet been exploited or that also include previously exploited deposits. Site resources and reserves should be compared with similarly in-place resources and reserves. Please clarify.

Sections 9.1.4.3 and 9.1.4.4, pages 9-18 through 9-21 The present and projected dollar values of WIPP site mineral resources and reserves should be included in the final statement.

The socioeconomic impacts of the early denial of WIPP site mineral resources are not considered in the WIPP DEIS. For example, it is stated in Sections 9.1.4.4 and 11.2 that construction and operation of WIPP could shorten the life of Carlsbad area langbeinite production by about five years. The effects of the early curtailment of Carlsbad langbeinite production on area socioeconomics should be considered.

The final statement should fully analyze the significance of WIPP site potash deposits, including quantitative economic analysis of alternatives to langbeinite, analysis of the development of future potassium and magnesium sources, and the future worth of WIPP site potash and other minerals. Specifically, such minerals as polyhalite, kieserite, and kainite should be considered. Mineral significance analyses should address impacts over long-term time spans.

Section 9.1.4.4, page 9-20, third paragraph   Langbeinite resource and reserve estimates by Agricultural and Industrial Minerals, Inc. (AIM) are cited. Describe how AIM defines resources and reserves.

Agricultural and Industrial Minerals, Inc. estimates of Carlsbad area langbeinite reserves and resources are quoted in the DEIS in terms of tons K_2O equivalent. However, in the AIM study, the same numbers refer to tons product. The figures in the statement should be made consistent with the AIM estimates. Since the origin of these estimates is not described in the document or the AIM study, the Carlsbad area langbeinite reserve and resource estimates should be justified.

Section 9.1.4.4, page 9-20, fourth paragraph   WIPP site langbeinite reserves are estimated to correspond to five years production at the current Carlsbad area rate. This is based on an annual production rate of 900,000 tons K_2O as langbeinite. This rate may be too high and should be checked. A lower rate of production would increase the production year equivalent of WIPP site potash.

Section 9.1.4.5, page 9-21   Regional and national hydrocarbon resource and reserve statistics are compared with the WIPP site estimated occurrences. It is not clear whether the regional and national figures include previously exploited deposits. Site resources and reserves should be compared with the national and regional amounts of similarly in-place hydrocarbons. Consideration should be given to the long-term relative importance of WIPP site hydrocarbon resources.

Section 9.1.4.6, page 9-21   The present and projected dollar values of WIPP site hydrocarbon reserves and resources should be included in the final statement.

Section 9.1.4.7, page 9-21, first paragraph   The impacts of control zone IV exploitation (mining, drilling, solution mining, secondary oil recovery, etc.) on WIPP waste containment should be considered.

Potash mine pillars for the Carlsbad area are often removed or "robbed" to increase the recovery of ore. As stated in this paragraph, it may be necessary to leave a number of pillars in-place in control zone IV mines in order to control subsidence. This would lead to low extraction efficiency and the effective denial of significant quantities of langbeinite in control zone IV. Therefore, more than one-quarter of the langbeinite at the WIPP site may be denied despite the exploitation of control zone IV.

Section 9.1.5, page 9-24, second and third paragraph   The construction phase noise impact assessment does not address traffic (i.e., materials delivery and commuter) related noises due to the facility. The areas most likely to be affected and the numbers of people involved in each should be presented.

Section 9.2.5.1, page 9-26, Noise standards   The Department of Housing and Urban Development has recently proposed standards, requirements and guidelines on noise abatement and control replacing those previously set forth in HUD

Circular 1390.2 (see 43 FR 60396-60401). These new criteria propose the adoption of the guidelines put forth by the U.S. Environmental Protection Agency in its document entitled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" for the HUD Exterior Noise Goal. This document recommends the use of the Normalized Day Night Sound Level as an indicator of likely effects and community response. Consideration of the use of this indicator should be given for preparation of the final statement.

Section 9.2.7, pages 9-28 through 9-30   It appears that the evaluation set forth in this section relies solely on a thermal loading density of 30 kW/acre to assess creep effects of salt. An evaluation should be presented which assesses near-field creep effects resulting from maximum canister wall temperatures. The evaluation should include the bases for this assessment, including such items as the maximum canister wall temperatures, and physical and mechnical properties of salt at the specified temperatures.

The elevated temperatures discussed in this section and illustrated in Figure 9-2 should be considered when retrievability concepts are evaluated. For example, machinery used in the retrievability operations will have to function properly at temperatures at least as high as about 44°C (120°F).

Figure 9-2, page 9-29   The figure shows the temperature increase in the mined tunnel containing spent fuel elements up to 25 years after emplacement. The figure should be expanded to include an estimate of temperature increase up to several centuries after emplacement (after which the decay heat rate will be greatly reduced).

Section 9.2.10, page 9-32   This section states that releases resulting from routine handling will be held to levels as low as reasonably achievable. Numerical estimates of maximum, routine radioactive releases should be made and the basis for the estimates should be discussed.

Tables 9-18 and 9-19, page 9-38   The dose comparison between calculated exposures and background should be presented as suggested in the comment on Tables 3-6 through 3-9.

The tables should show the period of exposure that corresponds to these dose commitments, for example, "annual" if that is applicable.

Section 9.2.11, pages 9-39 and 9-40   This section discusses the occupational exposure to four job categories. This section should also include an estimate of the number of workers in all job categories, the estimated exposure to each worker and the estimated total annual occupational exposure for the entire facility.

Table 9-23, page 9-51   For clarification, the table should have a column showing the quantity of each radioactive isotope assumed to be in a drum. Also, there should be a discussion of the basis for the assumptions.

Section 9.3.1, page 9-55, third paragraph The distance from the point of release to the James Ranch that was used to estimate dose commitments to the maximally exposed individual should be stated.

Section 9.3.1, page 9-57, second paragraph It is stated that the scenario with the greatest impact (i.e., spent fuel) would result in an individual lung dose of 1.0×10^{-5} rem, and a comparison is made to the dose a person would receive during a 5-hour jet-plane trip. However, consideration should be given to the uncertainties associated with the estimates of scenario consequences to make such comparisons meaningful.

Section 9.3.1, page 9-57, sixth and seventh paragraph The analysis of the accidents considered during facility operation assume that the HEPA filters will be highly effective (by a factor of 10^6) in removal of particulate activity prior to release to the environment. The document presents the doses that might be experienced if the "HEPA filters were not working" and conclude that even in such an event the above dose to the nearest resident would be well below background. This conclusion may be premature; further consideration should be given to the analysis of the consequences of a large fire which simultaneously causes a release of radioactivity and renders the filters ineffective and where any activity previously trapped on the HEPA filters may be released. The statement should indicate the range of consequences of such events and how their probability would be minimized.

Section 9.3.3, pages 9-59 and 9-60 Because of high winds and soil characteristics, dust storms are relatively common in the site area. Therefore, the effects of dust storms on facility operation should be evaluated (e.g., emergency diesels, filters).

Natural gas is commonly found associated with salt deposits. The potential for the occurrence of gas within the mined area and the attendant hazard to both people and the facilities should be assessed.

Section 9.3.3.1, page 9-59, first paragraph Provide an estimate of the maximum earthquake(s) expected to occur at the site following closure of the surface facility and the possible effect of that earthquake(s) on the integrity of the underground facilities.

Section 9.3.3.1, page 9-59, third paragraph Acquisition of comprehensive, accurate data relative to the underground effects of earthquakes is considered quite important. Without this information, extremely conservative assumptions may have to be made to make an impact assessment. Estimates should be made of the effects of ground shaking on the mined shafts and cavities during the operating life of the facility as well as after closure.

Ground displacement and the attendant effects upon both groundwater regimes and natural gas deposits should be addressed. In the event ground rupture were to occur, such that communication between the natural gas/groundwater and the repository were made possible, the potential for an induced explosion or gas/water seepage into the cavities should be addressed. Such an event should be considered during the operational life of the facility as well as following closure.

It has been suggested that seismic events have been induced as a result of mining activities. The likelihood of this type of event should be assessed.

Seismicity, induced as a result of secondary hydrocarbon production (i.e., water injection) has been hypothesized as causes of seismic events in Texas and elsewhere. The potential for such occurrences resulting from secondary (or tertiary) recovery operations in present and future nearby gas fields should be assessed. The resultant effects of induced seismicity (from any scenario) on the proposed surface and subsurface facilities should be determined.

Section 9.3.3.2, page 9-60, fourth paragraph The discussion does not adequately address the effects of locally severe rainfall on the site. Thunderstorms have intense rainfall for short periods of time. Infiltration, even in desert areas, will not normally prevent some ponding and local flooding. Since thunderstorms can be expected often during the operational life of the plant, consideration should be given to mitigating any adverse effects on the plant.

Section 9.3.3.3, page 9-60 Provide the design criteria of the buildings and systems for their resistance to "tornado-force winds, tornado-driven missiles, and sudden pressure changes."

Section 9.4, pages 9-61 through 9-97 There should be a presentation of an established mechanism through which mitigation efforts related to socio-economic impacts would be identified, monitored and handled between the applicant and the cognizant officials of impacted jurisdictions.

Section 9.4.1, pages 9-61 and 9-62, seventh paragraph The document states that the employee-location pattern for scenario II is based on the pattern established by a large mining company in the area. Please provide the basis for assuming that past employee-location patterns for mining companies are indicative of projected patterns for WIPP.

Section 9.4.1.2, page 9-62, second paragraph The construction overlap between the WIPP project and the Brantley Dam project is discussed. Because of a lack of a comparative analysis and discussion of the schedule overlaps of the two projects, it is unclear what changes in anticipated impacts would occur if either of the schedules should change. Please provide this information.

Section 9.4.1.2, page 9-65, second paragraph An anticipated drop in the unemployment rate during the construction period is projected. Are the types of workers expected to be unemployed just prior to the construction period the same kinds of workers likely to be employed by the WIPP project? How many workers does this estimate include?

Section 9.4.3, page 9-70, first and second paragraph   The discussion presented on the projected social structure would benefit from expansion to substantiate the broad statements made. For example, provide the basis for assuming that the inmovers would be of similar background, occupations, and transiency.

Sections 9.4.5.2 and 9.4.5.3, pages 9-75 through 9-80   These sections project a housing shortage for the Carlsbad and Hobbs areas; however, mechanisms for relieving the shortage are not addressed. Preference for mobile homes is mentioned but no discussion of constraints, if any, to mobile home expansion is presented. If housing supply is anticipated to be tight, describe what plans are being considered to alleviate this expected impact.

Section 9.4.6.1, pages 9-85 through 9-87 and 9-92 through 9-94   The discussion should also include the socioeconomic impacts associated with increased traffic through Carlsbad and Hobbs. There may be justification for a bypass highway around each of these population centers to accommodate the increases in general traffic arising from site activities.

Section 9.4.6.2, page 9-89, Education--Hobbs School District   The discussion states that the enrollment capacity at the Hobbs municipal schools will be exceeded beginning in either 1982 or 1983, depending upon the assumed scenario. The discussion does not address the time duration of this excessive capacity and what efforts will be taken to mitigate this occurrence.

Section 9.5, pages 9-98 through 9-146   This section presents an analysis of long-term effects considering a broad spectrum of events that could result in environmental impacts from the facility. Although the document is not meant as a risk assessment, it would be beneficial to include further discussions of (a) uncertainties in data values used in the consequence calculations, (b) possible variations in the geohydrologic system over the time period of concern and the effect of these variations on the consequence calculations, and (c) the compilation of release scenarios for the WIPP site and the reduction to the five scenarios considered for analysis.

Section 9.5, page 9-98, first paragraph   An expected release is equal to the sum of probabilities of release time the amount of release. Since the probabilities for all releases are not zero, the phrase "the expected release of radioactive material is zero" should be revised to read "no radioactive material is expected to enter the biosphere."

Section 9.5.1.1, page 9-98, third paragraph   The DEIS states that the safety analysis indicates that the waste and its containers are not important in hindering the release of radioactivity. The NRC's preliminary thoughts on this matter are that the repository should consist of a series of multiple barriers. The primary barrier to release of radioactive materials is the waste form system. The waste form system includes the waste form, canister, overpacks, absorbent materials, and the first few inches of surrounding rock. For spent fuel, the waste form system should contain the radioactive materials for 1,000 years and as long thereafter as is reasonably achievable assuming early saturation of the repository after closure. This will allow the short-lived nuclides that control the initial hazard associated with the waste to decay to innocuous levels. Beyond that period of time, the waste form system should maintain releases as low as is reasonably achievable but less than ten ppm per year. The limit of ten ppm per year for the release rate is considered by NRC to be achievable based on information presented in the Draft Generic Environmental Impact Statement on the Management of Commercially Generated Radioactive Waste and to be sufficiently low to protect the public health and safety.

maintain releases as low as is reasonably achievable but less than 0.1 ppm per year. The limit of 0.1 ppm per year for the release rate is considered by NRC to be achievable based on information presented in the Draft Generic Environmental Impact Statement on the Management of Commercially Generated Radioactive Waste and to be sufficiently low to protect the public health and safety.

Section 9.5.1.2, page 9-101, Selection of scenarios for analysis   This section discusses the four scenarios for liquid breach and transport (see Scenarios 1, 2, 3, and 4 on page 9-101). The discussion of scenario 4 may lead the reader to believe that it is much less likely to occur that the other three scenarios; however, the discussion neglects the possibility that scenario 2 would evolve naturally into scenario 4 through dissolution of salt along the flow paths. The analysis of scenario 2, therefore, is deficient because it does not consider enlargement of flow paths as a result of salt dissolutioning and it also fails to consider salt replacement by creep. This analysis should compare the rate of salt removal by dissolutioning with the rate of salt replacement by creep for all credible initiating events (e.g., faulting, shaft seal failures). This comparison will determine events for which the repository is "self-healing" and the events that result in massive repository failure.

This section should describe the basis for selecting these five scenarios from the 94 identified through fault tree analysis.

The potential for liquid breach and transport (Scenarios 1 through 4) appears to be directly dependent upon (1) inadequate sealing of known boreholes/ shafts, or (2) flow through unlocated boreholes or other openings. Careful, well-planned investigations and procedures before, during, and particularly following site closure can prevent these scenarios from occurring for the most part. Long-term surveillance both of surface drilling operations and salinity monitoring of the overlying and underlying aquifers may provide assurance that the suggested scenarios, or versions thereof do not occur.

Section 9.5.1.3, page 9-102, seventh paragraph   It is stated that Tables 9-43 and 9-44 list the radionuclides that are the "most important in long-term consequence assessments." Describe how the radionuclides are considered "most important" (e.g., significant contributions to risk, highest inventory, greatest toxicity, most likely to reach biosphere).

It is not apparent whether the radiological impact of carbon-14 was considered since it is not included in the list of fission products modeled. Because of the importance of carbon in biological systems, its radiological impact could be significant even when the inventory of the radionuclide is relatively small.

Table 9-43, page 9-103   The table should clarify whether the concentrations given are per liter of waste material or per liter of repository volume.

Section 9.5.1.3, page 9-103, first paragraph   The document states that the model assumes upper bounds on the amounts of waste released by assuming that when water comes into contact with waste, the radionuclides dissolve with the salt. This assumption does not give an upper bound because the water that comes in contact with the wastes is brackish and will dissolve the salt slowly; however, this brackish water may corrode or leach the waste, thus producing an accelerated release of radionuclides. The estimate of radioactive releases should take this possibility into consideration.

Section 9.5.1.3, page 9-103, second paragraph The document states that the numerical model used in the geosphere-transport calculations is based on a model developed for USGS and modified for the NRC. The staff wishes to point out that the modified geosphere-transport code is under development and NRC has not released it for general use. At this time, the code has not been validated by the NRC and, therefore, the results from the use of this code may not provide an accurate assessment of the geologic transport.

The statement that a detailed mathematical discussion of the model (and its application to the analysis) appears in Appendix K is erroneous. Appendix K presents 6 pages of mathematics; it should be expanded to show how to use the model in an analysis. (See the comment on Appendix K.)

Section 9.5.1.3, page 9-104, item 2 It appears that "fluid velocity" should be changed to "fluid viscosity."

Section 9.5.1.3, page 9-105, first paragraph, item 1 The document states that a computer code modeled the Delaware basin hydrology. The code used should be identified. Also, a reference should be provided for the test information mentioned in the last sentence (i.e., "tested the consistency between model-generated numbers and hydrologic measurements in the field").

Section 9.5.1.3, page 9-105, Bioshpere-transport calculations, first paragraph An important factor that will influence consequences is the path length to the point of release because it will affect the decay time prior to release and thus the activity levels. The path length assumed for the analysis is 14 miles (i.e., Malaga Bend). The effect of shortening the path length should also be investigated. For example, stock watering wells may be driled which could effectively shorten the path length.

Section 9.5.1.3, page 9-106, first complete sentence The document states that the analysis calculates the yearly intake of radionuclides by a person exposed through the biosphere pathways. The modeling of the biosphere pathways should be clarified. For example, the assumed population distributions and usage factors should be defined as well as the pathways that were evaluated.

Section 9.5.1.3, page 9-107, third paragraph The document states that the permeability of the wellbore was calculated. Rather than permeability, it appears that hydraulic resistance was calculated. If not, explain what is meant by permeability.

Section 9.5.1.3, pages 9-111 and 9-112, Rates of dissolution Varying rates of dissolution of the salt as a result of water flow through the medium are addressed, and the resultant eventual dose to man is estimated; however, one obvious effect on the environment as a direct result of continuing salt dissolution does not appear to be considered. This is the collapse of the overlying strata with a gradual propagation to the surface resulting in an ever-enlarging depression. The collapse structure could serve as a collector for rainfall and, because of the resulting direct communication with the aquifer(s) and the salt, accelerate the solutioning process. Once collapse of the salt between the repository levels and the overlying strata occur, corrective measures, such as attempts to seal the breached repository, may not be feasible. Please address this occurrence.

Section 9.5.1.3, page 9-113, second paragraph Identify the daughter products in secular equilibrium with their parents and, therefore, not included in the geosphere-transport model.

Table 9-45, page 9-114 Table 9-45 shows the transport rate of I-129 dropping from 4.5 X 10^{-3} Ci/yr to 5.4 X 10^{-17} Ci/yr in a period of 3500 years for the 3 mile distance. The Malaga Bend (14 miles) transportation rate increases from 3.3 X 10^{-7} Ci/yr to 4.6 X 10^{-3} Ci/yr. Figure 9-14 indicates that the transport rate should be increasing or steady. These discrepancies should be resolved.

Table 9-46, page 9-115 This table is not consistent with Table 9-45, page 9-114. Table 9-45 shows an I-129 transport rate of 4.5 X 10^{-3} Ci/yr at 3 miles, for scenario 2, upper transmissivity. Table 9-46 shows a transport rate of 5.8 x 10^{-5} Ci/yr for the same conditions. Both values are for the same period of time, i.e., 3500 years.

Section 9.5.1.3, page 9-115, first paragraph, item 3 This item states that "to a high degree of confidence, in each scenario the actual geosphere transport must lie within the results predicted by calculations with the two transmissivities." Although the statement may be correct, it is meaningless because, for time spans up to 40,000 years, the range of predicted values for transport rates indicated in Figure 9-14 (page 9-113) is 20 orders of magnitude.

Section 9.5.1.4, page 9-115, first paragraph The document states that exposure pathways for man include ingestion of fish and water, boating, swimming and shoreline activities. Consideration should also be given to the irrigation of crops and long-term buildup in soils and sediments as exposure pathways for man. An explanation should also be given for why only radionuclides originating in spent fuel and CH TRU waste, and not RH TRU waste, were used in the calculations.

Section 9.5.1.4, page 9-121, Summary for liquid breach and transport The doses received by the maximally exposed person from scenarios 1 and 4 are presented. The population exposure should also be given.

Section 9.5.1.6, page 9-127, item 3 The numerical range of maximum doses from CH TRU waste and spent fuel should be given to show the effect resulting from a factor-of-20 difference between the flow rates for upper and lower transmissivities.

Section 9.5.2.2, page 9-132, fifth paragraph The document states that one foot of surficial subsidence is estimated as a result of 70% backfill in a

16 foot cavity. Communication between the Rustler aquifer and the waste repository as a result of subsidence and fracturing of the intervening strata is not presented as a scenario for evaluation. It is suggested that this scenario be considered for analysis.

Section 9.5.3.1, page 9-135, third paragraph The statement regarding the gas generation time span (i.e., much longer than 200 years) is inconsistent with the assumed time span of 100 years for gas production calculations identified in the first partial paragraph of page 9-136. This discrepancy should be resolved.

Section 9.5.3.1, page 9-135, fourth paragraph Please provide the reference for the computer code used to describe the diffusion of gas from the repository.

Section 9.7.1, pages 9-166, last line It is not clear whether the low probability event (4×10^{9} per year) refers to the occurrence of a volcano or the waste becoming airborne and carried off the site. If it is the former, then clarification is needed for the statement on page 3-2, third paragraph, that states that "volcanic action is quite probable."

References for Chapter 9 The Dillion reference should be revised to show that the report was published October 1978.

Specific Comments - Chapter 10

Chapter 10 There is no discussion which presents the unavoidable adverse impacts resulting from construction and operation of the WIPP facility on the 33 sites identified in Appendix I as eligible for the National Register of Historic Places. (See the comment on Section 9.1.1.6.)

Section 10.2, page 10-2, sixth paragraph The dose comparison should be presented as suggested in the comment on Tables 3-6 through 3-9.

Specific Comments - Chapter 11

Chapter 11 There is no discussion which presents the irreversible and irretrievable commitment of historical and archeological resources (i.e., the 33 sites identified in Appendix I as eligible for the National Register of Historic Places) associated with WIPP facility. (See the comment on Section 9.1.1.6.)

Section 11.3, page 11-2 It is stated that the total construction resource requirements do not exceed 1% of the U.S. production during the construction period. A more significant basis of reference would be the local impact on such resources as water, fuel, electricity, and lumber.

Section 11.4, page 11-2 The listing of resources for operation should also include those major resources consumed (either onsite or offsite) for packaging and containment of the waste.

Specific Comments - Chapter 13

Chapter 13, page 13-1, third paragraph   It is stated that approximately 620 acres of land will be used for surface facilities, transportation routes, and the mined-rock pile. Please define what portion of the 620 acres is considered "disturbed area" and provide an estimate of the area which will return to its natural state.

Specific Comments - Chapter 14

Section 14.1, page 14-2, fourth paragraph Please provide the name of the bird species on the State list of rare and endangered species which is likely to be in jeopardy.

Section 14.3, page 14-8, item 7 There should be a discussion on the status of federal impact fund availability as well as a listing of existing federal program funds and assistance for which the impacted jurisdictions would be qualified.

Specific Comments - Glossary

Glossary   The following terms and their definitions are suggested for inclusion in the glossary: tectonics, caprock.

Specific Comments - Appendix A

Section A.2, page A-3, third paragraph   Since brine migration is apparently initiated only when elevated temperatures with thermal gradients are present, an alternative would be the placement of that waste capable of generating adverse temperatures in a temporary storage area until manageable heat levels were attained, then movement of the waste to the permanent respository location. Please address this alternative to mitigate brine migration.

Section A.2, page A-5, second paragraph   Since explosives are not required for mining, another advantage of salt over the other host media being considered (shale, granite, and basalt) is that only minimal fracturing of the cavity walls and floors may occur. This characteristic increases both the integrity of the mined opening as well as improves the ability to grout (seal) the cavity drifts and shafts.

Section A.2, page A-5, third paragraph   Although "waste" salt will result from the mining operations, the possibility of selling some or all of this material by competitive bidding is not addressed. It is suggested that some effort should be made to investigate the marketing potential for this common, but not valueless, natural resource.

The drainage basins of southeastern New Mexico, like adjacent areas of Colorado, Kansas, Oklahoma, and Texas, discharge considerable quantities (many tens of tons) of sodium chloride per day, (Swenson, F. A., 1974, Rates of Salt Solution in the Permian Basin; U.S. Geol. Survey Jour. Research, Vol. 2, No. 2). Therefore, the introduction of salt (per se) into the repository surface runoff systems would not necessarily present a uniquely undesirable environmental impact at least in the Permian Basin.

Section A.3, page A-6, second paragraph   Although it is true that crystalline rock may contain innumerable fractures filled with water, it is likewise true that extensive granite quarries, immediately adjacent to and well below the nearby water level, are essentially dry. A careful and systematic search of those areas of the country underlaid by crystalline rock may identify regions not permeated with excessive groundwater.

Section A.3, page A-7, third paragraph   Drill and blast techniques for mining crystalline rock create numerous fractures in the access shafts and in the drifts, thus accentuating the potential for groundwater migration from overlying water-filled zones. The created fractures will complicate the adequate long-term sealing of the shafts.

Section A.3, page A-7, fourth paragraph   Considerable number of areas in the north-central United States are underlaid by ancient crystalline rocks. These areas have undergone several periods of glaciation. If future glacial advance into these areas were to occur, it would have the potential, because of the weight of the ice mass, to temporarily decrease the fracture size thus decreasing permeability and hence, water flow. However, glacial retreat may lead to isostatic rebound and extensive fracturing.

Section A.4, page A-7 and A-8, first paragraph It should be noted that inclusions of iron pyrite, marcasite, and other minerals are common within large shale bodies and will contribute to the variables involved in assessing a shale repository.

Section A.4, pages A-7 through A-9 The document does not discuss that, although essentially impermeable, near-commercial quantities of natural gas have been found within the shale at many locations, especially in the Ohio-Michigan area. These areas, because of their sedimentary origin, are likewise in regions underlaid occasionally by extensive oil and gas deposits and evaporites. A potential preemption of natural resources may result if repositories are considered in these areas. Likewise extensive drilling, related to exploration for oil, gas, and other resources, has occurred over a period of nearly 100 years. The locations of many of these holes have not been recorded and this would present problems in assessing the integrity of a repository.

Section A.5, pages A-9 and A-10 Since tuff, by definition, is located in volcanic areas, the potential for renewed volcanic activity should be considered for assuring long-term isolation of the waste.

Specific Comments - Appendix B

Section B.3.3, page B-5, first paragraph The definition of an "active" fault should be presented. The definition should address (1) when a fault is classified as "active" and (2) what constitutes a level of activity such that the fault is considered inactive.

Please define what constitutes a sufficient period of quiescence such that the volcanic hazard is nonexistent.

Section B.5.1, page B-15, second paragraph Though the seismicity in the Salina region may be low, the selection of the design earthquake should not necessarily be based upon an event occurring in the Salina Basin. For example, although numerous nuclear power plants are located within the Salina Basin, the design earthquake for each of these plants is based upon an event in western Ohio, near Anna. A similar approach should be taken for selecting the controlling earthquake for a repository located in the Salina region.

Section B.5.1, page B-15, third paragraph Hydrocarbon exploration has been conducted within this region for nearly a century. Many of the older exploratory wells may have penetrated the salt beds; however, the locations of many of these wells are unknown and not recorded. If well sealing was inadequate, salt solutioning through communication with underlying and/or overlying aquifers may have occurred. The detection of these forgotten, perhaps solutioned, wells may prove to be difficult within any proposed repository site area.

Section B.4 through B.8, pages B-6 through B-36 In the geology discussions for the regional studies, it should be noted that the site selection process should be cognizant of and minimize the preemption of natural resources.

Section B.6.1, page B-22, second paragraph Since more tectonic activity has probably taken place within the Paradox Basin (even some activity within the Tertiary period) than the other basins, this aspect of siting should receive closer scrutiny.

Section B.7.1, page B-27, first paragraph It should be noted that the potential for additional hydrocarbon exploration within and adjacent to the many domes in the region will probably continue.

Section B.8.1, page B-35, first and second paragraph As in the case of other candidate areas, current NRC siting positions resulting from nuclear power plant reviews (regarding capable faults, design earthquakes, etc.) should be considered when selecting a waste repository site, since three nuclear plants are presently located at the Hanford site.

Specific Comments - Appendix D

Section D.2, page D-5, Man-made penetrations   The potential hazard of dissolution due to groundwater migration through man-made openings (e.g., shafts, boreholes) can be minimized if effective long-term sealing techniques are developed and used.

Section D.5, page D-9, Natural resources   The recoverable mineral resources underlying and overlying the site should receive careful evaluation. Since this is one of the few site selection criteria (i.e., minimizing the unavoidable conflicts with actual or potential resources) over which control can be exercised, caution should be exercised before finalizing the actual site location. The success of administrative controls to restrict the access and exploitation of natural resources, such as potash, cannot be assured beyond the short-term.

Specific Comments - Appendix F

Appendix F The discussion should be expanded to describe in greater detail the various incineration and immobilization processes and the properties of the resulting products.

Specific Comments - Appendix G

Section G.2, pages G-1 through G-4   It was stated in Section G.1 that X/Q values were calculated using the MESODIF model instead of AIRDOS-II. Therefore, the AIRDOS-II X/Q routine description should be replaced with a brief summary of MESODIF.

Section G.3, page G-5, second equation   The volumetric units are not consistent for X (pCi/m^3) and C_{imm} ($rem\text{-}cm^3/uCi\text{-}hr$).

Specific Comments - Appendix H

Section H.4.1, page H-48, first paragraph   Based upon the methodology presented in Regulatory Guide 1.76 and WASH-1300, it is estimated that the Design Basis Tornado (DBT) would be greater than 300 mph rather than the 183 mph value stated.

Section H.4.3 and H.4.4, pages H-57 and H-58   It has been observed that the vertical growth of plumes in a desert environment are less than the growth reflected by the Pasquill/Gifford plume spread parameters. Therefore, for atmospheric dispersion calculations, it is suggested that the use of the spread parameters which reflect the lessened vertical growth of plumes in a desert environment be considered. (For example, see G. R. Yanskey, E. H. Markee, Jr., A. P. Richter (1966): Climatology of the National Reactor Testing Station, IDO-12048, Air Resources Field Research Office, Idaho Falls, Idaho.)

Section H.4.3, page H-58, first paragraph   It is not clear if the entire model described in draft Regulatory Guide 1.XXX was used. (For example, was the probability level used in addition to the X/Q equations?) Please describe the use of the draft guide.

Section H.4.6, pages H-61 through H-64   A discussion with conclusions should be included regarding the possible climatic changes that could adversely affect the repository in the long-term future (e.g., glaciation, temperature, and precipitation changes).

Section H.4.6, page H-63, fourth paragraph   In the discussion on present and future glaciation, the effect of CO_2 atmospheric buildup, which could cause excessive warming, should be addressed.

Section H.8.4, page H-100, first paragraph   Describe the effects resulting from man-induced atmospheric changes, resulting in either increased or decreased temperatures and rainfall and consequent increased alluviation or erosion. Also, the impact of time and erosion on the removal of evidence of a repository's existence, thereby increasing the potential violation of the site by drilling and mining, should be addressed.

Specific Comment - Appendix J

Figure J-1, page J-2 This figure depicts drill holes of various types in the vicinity of the WIPP reference site, including a number of deep producing and abandoned gas wells. These wells penetrate the salt horizons as well as several aquifers. Since borehole communication with aquifers and the salt could result in uncontrolled solutioning, an assessment should be made of this potential multiple-source solutioning and the effect of this potential hazard on the proposed site. The effectiveness (principally longevity) and nature of the well sealing upon abandonment of each well should be addressed.

Considering the multitude of hydrocarbon related drill holes in the study area, it is imperative that all existing holes be located, particularly within zones I, II, and III on Figure J-1. A detailed description of the procedures and verification methods used to determine the presence (or absence) of hydrocarbon holes within the study area should be presented.

Section J.1.1, page J-1, third paragraph Since a number of exploratory holes have been made within the site area, any hole sealing that may have been completed should be evaluated with respect to any potential solutioning or repository integrity hazards which may have been created.

Discuss the methodology being considered to remove existing borehold sealant, if it was determined necessary to do so.

Section J.1.1, page J-1, fourth paragraph Please discuss the procedures used by DOE in selecting the 26 line miles of seismic data. The discussion should address whether all of the available data were examined for evidence of structural anomalies instead of using a select (or random) sampling of data.

Figure J-2, page J-4 The figure should delineate the 26 line miles of seismic data actually obtained by DOE (see Section J.1.1, page J-1, fourth paragraph).

Section J.1.1, page J-6, second paragraph A clearer assessment of the probable subsurface conditions expected to be encountered within the salt horizons can be made by inspecting working mines. Therefore, to accommodate this assessment, please provide a common map showing the reference site, working and abandoned mines of all types within at least 15 miles of the reference site, and designating those mines examined closely by DOE or its contractors.

Section J.2.1, page J-32, second paragraph As in the case of subsurface verification at nuclear power plant sites, it is recommended that photographic coverage be made of all shafts and drifts for review by cognizant agencies or individuals. Intensive geologic mapping should be conducted at those areas deserving special attention.

Section J.2.1, page J-32, fifth paragraph In addition to surface seismometers, subsurface instruments established at varying levels either within the mined area or elsewhere may prove valuable in assessing the variation of any possible ground motion with increasing depth. The information obtained may permit a more economical design of shafts and drifts, as well enclosed equipment. Additionally, such information may be useful in providing future guidance in selecting one of the many alternative disposal methods suggested in the GEIS. Perhaps these instruments could be installed prior to construction in order to acquire potentially valuable background data. Some consideration should be given to the possibility of maintaining some instrumentation beyond the operational phase of the facility in order to acquire information that can be applied toward the design of future repositories.

Specific Comments - Appendix K

Appendix K More detail should be provided on the hydrologic transport model. For example, the method used to represent (simulate) the WIPP system using the model should be discussed in detail. (See the applicable comment on Section 9.5.1.3, page 9-103.)

Section K.2.1, pages K-9 through K-20 This section discusses the aquifer system in the WIPP area. A group of schematics showing the relationship of the aquifers in the WIPP area to accessible waters (e.g., Pecos River) in the region would be helpful in reviewing the basis for the release scenario selection and the points of reference in the consequence calculations (see Section 9.5.1.3).

Section K.2.2, page K-21, second paragraph The document states that the transport calculations "generally assume that the events in the scenarios begin 1,000 years after the repository is sealed." It is implied in Section 9.1.5.4 (page 9-115, first paragraph) that calculations are made for determining event consequences assuming that the repository is breached after 100 years. Please clarify this apparent discrepancy.

Section K.2.2, page K-21, fourth paragraph The document concludes that the consequences of a scenario beginning with a 100-year breach "are not affected significantly if it begins 900 years later." Section 9.5.1.4 is referenced for containing the calculational results for supporting this conclusion. However, Section 9.5.1.4 presents only the results of a Cs-137 concentration calculation for 100 years (see Figure 9-21, page 9-121). To provide a basis for the conclusion in question, the results of a 100-year repository breach should be elaborated with at least a figure similar to Figure 9-20, page 9-121 (i.e., bounding calculation for the concentration of all radionuclides).

The document states that it is not important to model events at early times because "the travel times to the biosphere are so long that only the long-lived nuclides are still active when the contaminated aquifer water is discharged." The staff points out that this conclusion is valid only for long travel times. The two controlling parameters are path length (assumed as 14 miles) and rate of nuclide release (assumed to be equal to rate of salt dissolution). The values assumed for each of these two controlling parameters are not conservative. Thus, early time events may be important and should be factored into the model.

Section K.3.1, page K-23 In the first sentence after the third equation on the page, "13.4 square miles" should be changed to "13.4 square meters."

Section K.3.3, page K-24 The effects of uncertainties in radionuclide transport by groundwater estimations should be discussed, including some estimation of their magnitude. For example, would uncertainties in the values for the distribution coefficients be encompassed by the upper values for transmissivities presented in the consequence calculations in Section 9.5?

UNITED STATES WATER RESOURCES COUNCIL

SUITE 800 • 2120 L STREET, NW WASHINGTON, DC 20037

JUL 12 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

This to acknowledge receipt of the draft environmental impact statement (EIS) titled, "Waste Isolation Pilot Plant" (DOE/EIS-0026-D).

The Water Resources Council has no comments to offer regarding this EIS.

Sincerely,

Leo M. Eisel
Director

COMMENTS FROM STATE AGENCIES

STATE OF ALASKA

JAY S. HAMMOND, Governor

OFFICE OF THE GOVERNOR

DIVISION OF POLICY DEVELOPMENT AND PLANNING

POUCH AD
JUNEAU, ALASKA 99811
PHONE: 465-3512

June 28, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Subject: Waste Isolation Pilot Plant DEIS
State I.D. No. 79052302ES

Dear Mr. Beckett:

The State Clearinghouse has completed its review of the subject proposal. The following comment was received from the Alaska Department of Commerce and Economic Development:

"The subject of the EIS is obscured by omission of the main purpose from the title. The word 'radioactive' should be included for clarity. WIPP appears to be as good an acronym as any but for clarity, some indication of the nuclear purpose should be provided.

"The purpose of the waste isolation plant appears to be eventual permanent storage of nuclear wastes. Retrieval, however, may become more desirable in the future, when new techniques and treatment of processes can make the present waste valuable. The discussion of the waste handling facility, meanwhile, speaks in terms of ten and twenty year retrieval periods and capacity to year 2000. This appears inconsistent except for a strictly experimental installation. Investment in the plant will be considerable, however, and long-term use should also be part of the plan. The proposed waste disposal and experimental plant is essential to developing acceptable procedures for nuclear power and other applications or radioactive materials.

"The objective appears to be to get a positive program developed and operating at the earliest opportunity. Alternative #2 seems to fit that objective, and also appears to have sufficient room for expansion as new information is developed.

"One very definite requirement for all government documents which deal with acronym designations should be a listing of the acronym's meanings."

We would stress that this DEIS refers to one specific method operating in one pilot plant. The future of nuclear development will depend largely on the provision of safe storage and disposal of nuclear wastes. All methods of disposal and storage should be explored, at least theoretically, while realizing that specific applications will be subject to the EIS process prior to implementation.

Thank you for the opportunity to comment.

Sincerely,

Jerry L. Madden
State-Federal Coordinator

JLM:BR:cl

cc: Bertram Wagnon, CED

Related to 79-80-0040

SIGNOFF

OMB Approval No. 29-R0218

FEDERAL ASSISTANCE

2. Applicant's application — a. Number: — b. Date: 19 __ Year Month Day

3. State application identifier — a. Number: AZ 79-80-0039 — b. Date Assigned: 1979 05 25 (Year month day)

1. Type Of Action (Mark appropriate box): ☐ Preapplication ☐ Application ☐ Notification Of Intent (Opt.) ☐ Report Of Federal Action

Leave Blank: AUGUST 3, 1979 — Terry Murray

4. Legal Applicant/Recipient

a. Applicant Name: Department of Energy
b. Organization Unit: WIPP Project Office
c. Street/P.O. Box: Mail Stop B-107
d. City: Washington e. County:
f. State: D.C. g. Zip Code: 20545
h. Contact Person (Name & telephone no.): Mr. Eugene Beckett (301) 353-3253

5. Federal Employer Identification No.

6. Program (From Federal Catalog)
a. Number: 81.099
b. Title: Unknown
Department of Energy

7. Title and description of applicant's project
WASTE ISOLATION PILOT PLANT - DRAFT ENVIRONMENTAL IMPACT STATEMENT - DOE/EIS-0026-D (2 Volumes)

Seven alternatives are covered: No action; alternatives: to TRU waste disposal; for the intermediate-scale facility; time schedules & potential locations, including AZ. Transportation of nuclear waste with possible routes across AZ. Construction & operations of a waste isolation pilot plant (WIPP) for disposal of transuranic nuclear wastes (TRU), experimental research & development with high level waste forms & for potential disposal of spent fuel assemblies.

8. Type of applicant/recipient
A–State, B–Interstate, C–Substate District, D–County, E–City, F–School District, G–Special Purpose District, H–Community Action Agency, I–Higher Educational Institution, J–Indian Tribe, K–Other
(Specify): Federal Agency — Enter appropriate letter: F

9. Type of assistance
A–Basic Grant, B–Supplemental Grant, C–Loan, D–Insurance, E–Other
Enter appropriate letter(s): E

10. Area of project impact (Names of cities, counties, states, etc.): Statewide, Arizona

11. Estimated number of persons benefiting

12. Type of application
A–New, B–Renewal, C–Revision, D–Continuation, E–Augmentation
Enter appropriate letter: ☐

13. Proposed Funding

a. Federal	$	.00
b. Applicant		.00
c. State		.00
d. Local		.00
e. Other	1	.00
f. Total	$ 1	.00

14. Congressional Districts Of:
a. Applicant:
b. Project: 01 02 03 04

15. Type of change (For 12c or 12e)
A–Increase Dollars, B–Decrease Dollars, C–Increase Duration, D–Decrease Duration, E–Cancellation, F–Other Specify:
Enter appropriate letter(s):

16. Project Start Date Year month day: 19

17. Project Duration: Months

18. Estimated date to be submitted to federal agency Year month date: 19

19. Existing federal identification number

20. Federal agency to receive request (Name, city, state, zip code)

21. Remarks added ☐ Yes ☒ No

Section II - Certification

22. The Applicant Certifies That

a. To the best of my knowledge and belief, data in this preapplication/application are true and correct, the document has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.

b. If required by OMB Circular A-95 this application was submitted, pursuant to instructions therein, to appropriate clearinghouses and all responses are attached:

	No response	Response attached
(1) Arizona State Clearinghouse	☐	☒
(2)	☐	☐
(3)	☐	☐

23. Certifying representative — a. Typed name and title — b. Signature — c. Date signed Year month day 19

Section III - Federal Agency Action

24. Agency name

25. Application received Year month day 19

26. Organizational Unit

27. Administrative office

28. Federal application identification

29. Address

30. Federal grant identification

31. Action taken
☐ a. Awarded
☐ b. Rejected
☐ c. Returned for amendment
☐ d. Deferred
☐ e. Withdrawn

32. Funding

a. Federal	$	.00
b. Applicant		.00
c. State		.00
d. Local		.00
e. Other		.00
f. Total	$	.00

33. Action date Year month day 19

34. Starting date Year month day 19

35. Contact for additional information (Name and telephone number)

36. Ending date Year month day 19

37. Remarks added ☐ Yes ☐ No

38. Federal agency A-95 action
a. In taking above action, any comments received from clearinghouses were considered. If agency response is due under provisions of Part 1, OMB Circular A-95, it has been or is being made.
b. Federal Agency A-95 Official (Name and telephone number)

STATE OF CALIFORNIA—THE RESOURCES AGENCY

EDMUND G. BROWN JR., Gove

DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
DIVISION HEADQUARTERS
1416 NINTH STREET, ROOM 1341
SACRAMENTO, CA 95814
(Phone 916-445-1825)

September 19, 1979

Eugene Beckett
Waste Isolation Pilot Plant Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

Enclosed please find a discussion of the "Waste Isolation Pilot Plant" Department of Energy draft Environmental Impact Statement 0026-D. I hope this information will be useful to you. If I can be of further service please advise.

Sincerely,

James F. Davis
State Geologist

Enclosure

STATE OF CALIFORNIA—THE RESOURCES AGENCY

EDMUND G. BROWN JR., Governor

ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION
11 WE AVENUE
SACRAMENTO, CALIFORNIA 95825

(916)920-6815

September 6, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

The Nuclear Fuel Cycle Committee of the California Energy Commission is pleased to submit the attached comments on the Draft Environmental Impact Statement on the Waste Isolation Pilot Plant (DOE/EIS-0026-D). Our comments are specific to the DEIS as sent out for review; however, because the DOE has tentatively changed the scope of WIPP because of Congressional desires, we have included an addendum addressing some of the implications of having an unlicensed TRU waste repository.

We have been cheered by the inciteful review of the federal waste management program in the "Report of the Task Force for Nuclear Waste Management" and the "Report to the President by the Interagency Review Group on Nuclear Waste Management", the "IRG Report". The WIPP DEIS is out of step with its predecessors. The WIPP DEIS uses the IRG Report to provide a set of "programmatic objectives" by which to rank alternatives, but it fails to fulfill the promise of the IRG that TRU waste management strategies would be thoroughly evaluated in subsequent documents. Instead the WIPP DEIS uses tentative policy objectives as though they were firm policy based on alternatives analyses. Such an approach not only comprises the faith that the public has placed in the DOE, but it also violates the proper order of formulating programmatic objectives subsequent to environmental considerations.

The major fault of the WIPP DEIS is fundamental: it is not an environmental impact assessment at all. Instead of evaluating alternatives, including no action, on the basis of environmental criteria as required under the National Environmental Policy Act of 1969, the no action alternative is rejected as being unacceptable in the long term, and the remaining alternatives are ranked on the basis of tentative programmatic rather than environmental criteria because allegedly "there is no clear environmental basis for choosing among the remaining alternatives."

Mr. Eugene Beckett
Page 2
September 6, 1979

Environmental bases for ranking have been compromised in part by proposing a selected suite of alternatives. We propose the alternative of an extensive research and development program at WIPP without the premature disposal options. This alternative has lower short term and long term adverse impacts than the ranked alternatives in the WIPP DEIS.

Because the WIPP DEIS clearly fails to fulfill NEPA requirements, I recommend that it be withdrawn until the maturity of the scientific basis for the geologic disposal concept is sufficient to justify the issuance of a considerably restructured DEIS.

Sincerely,

EMILIO E. VARANINI, III
Commissioner
Presiding Member, Nuclear Fuel
Cycle Committee

Department of Local Affairs
Colorado Division of Planning

Philip H. Schmuck, Director

Richard D. Lamm, Governor

September 4, 1979

Mr. Eugene F. Beckett
WIPP Project Leader
Office of Nuclear Waste Management
Department of Energy
Washington, D.C. 20545

SUBJECT: Draft Environmental Impact Statement
Waste Isolation Pilot Plant

Dear Mr. Beckett:

The Colorado Clearinghouse has received the above-referenced Draft Environmental Impact Statement and has distributed it to interested state agencies. Comments received from the State Highway Department and the Office of Energy Conservation are enclosed for your information.

Thank you for the opportunity to review this matter.

Sincerely,

SO Ellis/MK

Stephen O. Ellis
Chief Planner

SE/MK/vt
Enclosures

cc: Office of the Governor
Department of Highways
Office of Energy Conservation

520 State Centennial Building, 1313 Sherman Street, Denver, Colorado 80203 (303) 892-235

STATE OF DELAWARE
EXECUTIVE DEPARTMENT
OFFICE OF MANAGEMENT, BUDGET, AND PLANNING
DOVER, DELAWARE 19901

OFFICE OF THE DIRECTOR

PHONE: (302) 678-4271

June 5, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

RE: DRAFT EIS, DOE/EIS-0026-D, WASTE ISOLATION PILOT PLANT

The Office of Management, Budget and Planning, in its function as the State Clearinghouse, has reviewed the subject EIS and has no comments to offer at this time.

Sincerely,

Nathan Hayward III
Director

fb

STATE OF FLORIDA

Department of Administration

Division of State Planning

Room 530 Carlton Building
TALLAHASSEE
32304
(904) 488-2401

R.G.Whittle, Jr.
STATE PLANNING DIRECTOR

Bob Graham
[redacted]
GOVERNOR

[redacted]
SECRETARY OF ADMIN.
Jim Tait

May 30, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C.

Dear Mr. Beckett:

Functioning as the state planning and development clearinghouse comtemplated in U.S. Office of Management and Budget Circular A-95, we have reviewed the following draft environmental impact statement: Waste Isolation Pilot Plant, SAI 79-2123E.

During our review we referred the environmental impact statement to the following agencies, which we identified as interested: Department of Environmental Regulation, Department of Health and Rehabilitative Services, Department of Natural Resources, Bureau of Land and Water Management, and the State Energy Office.

Agencies were requested to review the statement and comment on possible effects that actions contemplated could have on matters of their concern. As of this date the reviewing agencies have not submitted any comments regarding this project. If letters of review and comment are received by this clearinghouse we shall forward them immediately.

In accordance with the Council on Environmental Quality guidelines concerning statement on proposed federal actions affecting the environment, as required by the National Environmental Policy Act of 1969, and U.S. Office of Management and Budget Circular A-95, this letter, with attachments, should be appended to the final environmental impact statement on this project. Comments regarding this statement and project contained herein or attached hereto should be addressed in the statement.

We request that you forward us copies of the final environmental impact statement prepared on this project.

Sincerely,

R. G. Whittle, Jr., Director

RGWjr:cy

TWIN TOWERS OFFICE BUILDING
2600 BLAIR STONE ROAD
TALLAHASSEE, FLORIDA 32301

BOB GRAHAM
GOVERNOR

JACOB D. VARN
SECRETARY

STATE OF FLORIDA

DEPARTMENT OF ENVIRONMENTAL REGULATION

July 27, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington D.C. 20545

Dear Mr. Beckett:

Please consider this public document. As a systems analyst, it expresses a number of my own concerns regarding the WIPP project.

Sincerely,

J. S. Sherman

J. S. Sherman

JSS/js

Enclosure

original typed on 100% recycled paper

State of Florida
DEPARTMENT OF ENVIRONMENTAL REGULATION

INTEROFFICE MEMORANDUM

For Routing To District Offices And/Or To Other Than The Addressee	
To:	Loctn.:
To:	Loctn.:
To:	Loctn.:
From:	Date:

TO: John Outland, Intergovernmental Programs Review Section

FROM: Don Kell, Bureau of Permitting DJK

DATE: June 21, 1979

SUBJECT: Draft EIS, Waste Isolation Pilot Plant (WIPP), Appendices, and Attachments, DOE

I have reviewed subject documents and am concerned about the following initial statements:

> "This...(EIS) has been prepared...to assess the environmental impacts of constructing and operating...(WIPP)."

> "The draft EIS is intended to serve as environmental imput (sic) into future decisions..."

> "Analyses show that there are (sic) no significant radiological health impacts resulting from the alternatives considered, and that there are no clear environmental bases for choosing among alternatives..."

I believe it can be shown that subject documents cannot stand as a legitimate statement of the long term environmental impacts of WIPP. The bulk of this memorandum is devoted to supporting this view.

If subject documents cannot stand as a legitimate WIPP environmental impact statement, then they cannot logically serve as input for future decision making regarding these impacts.

If DOE's first two statements are false, then the third, that WIPP would present no significant radiological health impacts, would be meaningless at best.

If all three statements are false, then an extreme positive bias toward waste isolation and burial would be demonstrated on the part of DOE.

Consider the following sample of quotations taken from subject documents which illustrate the breath of DOE's apparent bias:

HS - Rev 7/76

> "Southeastern New Mexico is arid...The site (Figure 7-1) is monotonous in aspect and covered with desert vegetation... Ranch buildings are many miles apart...one sees an occasional windmill,...drilling rig, or grasshopper pump."

Even ice ages take place within 10% of the time required for some of the wastes that would be associated with WIPP to decay. Populations come and go following climatic changes. Entire civilizations last but 40 - 50 generations, while these wastes would still be hazardous after 50,000 generations. Except for immediate impacts concerning construction and socioeconomic interactions (on the order of 0.01% of total WIPP radiation-impact time), these statements appear to be entirely irrelevant, and further demonstrate a positive bias on the part of DOE toward waste burial in repositories.

> "...(WIPP) is part of the national program for the permanent disposal of radioactive waste. It stems from two decades of analytical, laboratory, and field study..."

This statement conveys the impression of steady, unbroken progress at full effort for 20 years in each of the waste disposal areas. In fact, that 20 years of effort represents a series of relatively minor, uncoordinated attempts at providing a "technological fix" for the nuclear waste problem, each attempt meeting ultimately with failure as the record shows.

> "This document is concerned only with decisions concerning atransuranic-waste depository, an intermediate-scale facility, and associated experiments."

The entire WIPP review process has become too highly fragmented. Looking only at small pieces of the project conveniently avoids analysis of the project's total impacts. Bergson's argument that a collection of anatomical parts cannot comprise a living, functioning human being is applicable and profound. A description of man's separate components would miss all the essential elements of humanity.

> "...experiments performed with all types of nuclear waste will answer technical questions about the disposal of waste, including HLW, in salt...thus gaining further experience in designing repositories."

This statement contradicts the original justification for utilizing burial facilities, which claimed that the needed "technology already exists". The clause, to "build a base of empiracle data," implies that even the basic information upon which tentative repository designs would be based does not exist, a fact abundantly reflected in other DOE documents.

"...the Waste Acceptance Criteria Steering Committee (still has not developed workable criteria)...Data for quantifying the criteria are being developed...The criteria are constantly evolving and...reflect only interim proposals...continually subject to revision."

A circular argument has been developed: WIPP cannot be designed without WACST criteria, yet these criteria cannot be finalized until WIPP is completed and put into operation. But WIPP cannot legitimately be put into operation until this data is compiled.

"...to avoid unnecessary costs..."

Cost cannot be an object concerning research on a facility of such unprecedented import. Already there are in existence upwards of a thousand billion curies of HLW that would be buried in repositories. To subject research on these materials to the agencies of economy and haste would be to foredoom the project to "expediencies" voiced by vested industrial, financial, and political interests.

"Sixteen people live within 10 miles of the center of the proposed site (page 1-3)...Thirteen people live within 10 miles of the proposed site (page 7-1)."

Such a glaring contradiction of even unimportant data belies DOE's solemn presentation of "hard scientific fact".

"This is a truncated list of the isotopes present in commercial high-level waste (Table E-4, Appendices)...This is a truncated list of the isotopes present in one spent-fuel assembly (Table E-5, Appendices)."

Such "truncated lists" conveniently eliminate more than 80% of all actinides and daughters, and 95% of fission products from the high level wastes, and more than 70% of all actinides and daughters, and 95% of all fission products from the spent-fuel assembly. This represents an incredible omission of fact, and is further evidence of DOE's bias toward waste burial in repositories.

"Hamstra (1975)...compared the hazards of buried waste to those of buried uranium ore and concluded that deeply buried high-level waste is safe after about 1,000 years of burial...; Gera (1975)..compared the hazard of nuclear waste to the hazard of unburied uranium - mill tailings piles...Gera concluded that the waste decays to a safe level in 100,000 years."

Aside from the fact that these positively biased guesstimates vary from each other by 2 orders of magnitude in time, both conveniently ignore the fact that the <u>kinds</u> of materials and radiation in nuclear wastes differ fundamentally from those in the original Uranium ore and tailings. Compared with some 37 naturally occurring species of Uranium, Thorium, and respective daughter products in both the ore and tailings, some 68 actinides and daughters, 300 fission products, and an indefinite number of neutron activation products have been identified in spent fuel and HLW. There are, whatismore, no Plutonium and higher transuranides (such as Americium) in Uranium ore or mill tailings. The biochemical properties of most of the spectrum of radionuclides in spent fuel and HLW is unknown.

> "The site...is near a drainage divide...separating two major and actively developing solution-erosion features...The principal groundwater aquifer of the region is the Capitan Formation...Groundwater in the Capitan...has been heavily pumped for oil field flooding. These withdrawals have lowered the potentiomerie surface (of the Capitan)..."

Depending upon final hydraulic gradients, contaminated groundwater from the site could move into the Capitan aquifer which currently is in heavy use. The movement of contaminants into the Capitan might be slow if the relatively low transmissibilities reported are true; however, later statements regarding "rocks (that are) strongly jointed, cavernous, and locally brecciated" cast doubt on the pump test derived transmissibilities. Furthermore, the million years required for the decay of much of the waste components would provide ample opportunity both for the transmission of contaminated wastes into the Capitan, and for major climatic and tectonic events which might completely alter the present geohydrology of the area.

> "Deformation related to salt flow has occurred...accompanied by artesian brine flows...rocks exposed there are strongly jointed, cavernous, and brecciated...The Pecos Valley (in which the WIPP site is located) has widespread solution-subsidence features."

"The greatest deformation in the evaporite sequence at...the site seems to be spatially related to a structural trough trending northwest - southeast and parallel to the base of the Capitan 8 miles north of the site. This trough is 3 to 4 miles wide... The belt of deformation includes salt flow structure...Anderson (1978) has attributed some localized depressions within the evaporite units to "deep dissolution"...these "deep-seated sinks" may be related to other collapse features...as different stages of a general erosion...dissolution of 100 - 200 feet of salt has modified the surface and subsurface structure...In the...mining district...there has been subsidence during and after underground mining."

Wells have penetrated major faults beneath the burial area. Major structural features lie to the East of the site a few miles. The old Ouachita mountain range and structures lie to the Southeast only 125 miles. The argument that, because an area has been tectonically stable for millions of years, that area is suitable for waste disposal activities is not a good one. Tectonic activity may be long overdue and might erupt at any time through reactivation of the old structures. Who would drive across a million year old bridge? That such a bridge were still standing would be amazing; it would definitely not be safe to drive across.

> "(The site lies within a) seizmic zone where the probable maximum intensity would be VIII...From April 1974 to October 1977, 291 events identified as earthquakes were recorded by a station (CLN) 4 miles from the center of the site...rockfalls and ground cracking were reported at an active potash mine (following earthquake events on July 26, 1972 and November 29, 1974)...Very little is known of the effects of earthquakes underground."

Even if major earthquakes occurred with a frequency of only one per 1,000 years, the repository would still be subject to 1,000 major seizmic events before most of its waste had decayed to safe levels.

To any competent geologist, the aforequoted statements on earthquakes and structures would appear ominous. It is incredible that their significance has been omitted or gone completely unrecognized by DOE. The following statements thereby are rendered absurd:

> "Ventilated air...will pass through a filtration system before release to the atmosphere (which could not prevent the release of H^3, C^{14}, Kr^{85}, I^{129}, I^{131}, Xe^{133} and other gases). The release will be continuously monitored...administrative controls will be established to prevent deep drilling, mining, or other activities...fences and other security measures (like sealed doors and periodic inspection) will be needed to prevent public access."

To speak of administrative controls, monitoring, filtration systems, and fences that would need to be maintained for several million years is absurd. Even if man and organized society still existed, and these stopgaps could be so maintained, the spectacular costs associated would reduce WIPP's B/C ratio to essentially zero. Such stopgaps, furthermore, imply the embryogeny of a "garrison state" so widely predicted by critics.

Because truth regarding the future impacts of nuclear waste burial is evidently unknowable now, and must remain unknowable for at least a half million years, due to the infinite number of "incalculables" that lie in the far future, the determination of "truth" has evidently been deemed not only unnecessary by DOE, but positively undesirable. My recommendations follow accordingly:

Regarding the five major decisions under consideration by DOE (page iii):

> "1. Whether to pursue the construction of the proposed ...(WIPP), a mined repository for the disposal of transuranic wastes, with an initial period of retrievable emplacement."

No; unless only for purposes of pure research on a small scale (no more than 100 spent fuel assemblies, a corresponding amount of HLW, and positive prohibitions against use of the facility for disposal for 100 years or more).* Accordingly there could be no plans for retrievability of wastes other than those wastes which had been used for pure research. Retrievability would have the effect of jeopardizing the integrity of any repository design. If wastes are percieved as having value, then they are obviously not wastes, and should be stored at the reactor site.

> "2. Whether the WIPP should include an intermediate-scale facility in which up to 1,000 assemblies of spent fuel from commercial electricity-generating reactors would be disposed of, with an initial period of retrievable emplacement."

No; covered under 1. above.

> "3. Whether the WIPP should include a research-and-development facility in which experiments with all types of nuclear waste, including high level waste, can be performed."

Only under conditions described for 1. above.

> "4. What the timing and location of the WIPP should be."

1990 - 2090, under conditions described for 1. above.

> "5. Whether to commit land now for a potential repository site in Eddy County, New Mexico".

No; this would be premature. Any such committment should be predicated upon 100 years of pure research as in 1. above. New Mexico was picked partly because it is not politically strong. Repeated surveys have revealed that the New Mexican people are overwhelmingly against such a committment. Even DOE's review of letters received revealed that New Mexican citizens were opposed 2 to 1.

Regarding DOE's actions and intentions to date, the following words by W.H. Auden seem particularly apt:

"Oh dear white children casual as birds,
  playing among the ruined languages,
so small beside their large confusing words,
  so gay against the greater silences;

Of dreadful things you did, oh hang the head
  impetuous child with the tremendous brain.
Oh weep child, Oh
  weep away the stain..."

* DOE should be given ample opportunity to demonstrate its continued faith in the perfectability of science and technology in the future. Experimental facilities, constructed with prohibitions against future uses, should be designed, built, and adequately tested by exhaustive means. If, eventually, such experimental development results in a prototype repository unit suitable for actual use, that unit should be mothballed for at least 100 years while second, third, and even fourth generation units are developed. If these later units could be developed, then earlier units would, by definition, be inferior, and thereby unsuitable for use in a project of such import that any imperfection whatsoever could be of incalculable impact.

In the meantime, above ground, plant-site disposition of wastes could provide for adequate storage, access, retrievability, and monitoring, as well as for decreased transportation hazards, a realistic public vision of the magnitude of the waste storage problem, and the elimination of the current propensity toward "expeditious" burial of wastes in an out of sight, out of mind fashion. Should solar disposal prove feasible during the time of advanced repository development, or should waste generation for one reason or another be terminated, then solar disposal should be seriously considered, as should those other alternatives of promise being simultaneously explored.

Above ground containment of spent fuel for a hundred years or more would provide a more nearly sufficient time period for thermal cooling of those wastes. Such a period would minimize thermal geologic disturbances and consequent damages to any repository that might come to be employed, thus minimizing the likelihood of jeopardizing that repository's containment integrity in a fashion that could not provide for safe, permanent isolation of materials which, by the year 2000, could provide enough radiation to kill or deform every person on earth 1000 times.

DK/js

Office of Planning and Budget

Executive Department

Clark T. Stevens
Director

G E O R G I A   S T A T E   C L E A R I N G H O U S E   M E M O R A N D U M

TO: Mr. Eugene Beckett,
WIPP Project Office, Mail Stop B107
Department of Energy
Washington, D.C. 20545

FROM: Charles H. Badger, Administrator
Georgia State Clearinghouse
Office of Planning and Budget

DATE: September 17, 1979

SUBJECT: RESULTS OF STATE-LEVEL REVIEW

Applicant: Energy, U. S. Department

Project: Draft EIS DOE/EIS - 0026-D
Waste Isolation Pilot Plant

State Clearinghouse Control Number: 79-05-14-10

The State-level review of the above-referenced document has been completed. As a result of the environmental review process, the activity this document was prepared for has been found to be consistent with those State social, economic, physical goals, policies, plans, and programs with which the State is concerned.

The following State agencies have been offered the opportunity to review and comment on this project: Department of Natural Resources
Office of Planning & Budget, Executive Dept.

cc: Barbara Hogan, DNR

Enclosure: Comments prepared by Department of Natural Resources, dated Sept. 10, 1979

CHB:if

SC-EIS-4 (4/78)

270 Washington St., S. W. · Atlanta, Georgia 30334

Joe D. Tanner
COMMISSIONER

Department of Natural Resources

270 WASHINGTON ST., S.W.
ATLANTA, GEORGIA 30334
(404) 656-3500

September 10, 1979

M E M O R A N D U M

TO: Chuck Badger, Administrator
State Clearinghouse

FROM: Barbara A. Hogan, Coordinator
Comprehensive Review

ISSUE: Completion of Department of Natural Resources Review of State Clearinghouse Control Number 79-05-14-10

APPLICANT: U.S. Dept. of Energy

PROJECT: Draft EIS - Waste Isolation Pilot Plant

FEDERAL AGENCY: DOE

COMMENTS

Because of the location of this project and constraints on staff time, the Department of Natural Resources does not have any comments to offer on this project at this time.

BAH/ps:lh

cc: Jim Benson

STATE OF ILLINOIS
EXECUTIVE OFFICE OF THE GOVERNOR
BUREAU OF THE BUDGET
SPRINGFIELD 62706

June 22, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

RE: DEIS: Waste Isolation Pilot Plant, DOE/EIS-0026-D
SAI #79 05 09 60

The Illinois State Clearinghouse has reviewed the referenced subject pursuant to the National Environmental Policy Act of 1969, OMB Circular A-95, Revised and the administrative policy of the State. State agencies which are authorized to develop and enforce environmental standards have been given the opportunity to comment on this subject. No comments have been received on the referenced subject.

Thank you for your assistance.

Respectfully yours,

T E Hornbacker/sed

T. E. Hornbacker, Director
Illinois State Clearinghouse

TEH/li

STATE of INDIANA

STATE BOARD OF HEALTH

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INDIANAPOLIS

Address Reply to:
Indiana State Board of Health
1330 West Michigan Street
Indianapolis, IN 46206

May 29, 1979

TO: Mr. Roland J. Mross
Federal Aid Director
Harrison Building

Attention Indiana State Clearinghouse

FROM: William T. Paynter, M. D.
State Health Commissioner

SUBJECT: A-95 Project Review
State Identification No. 790 5010000
DEIS
Waste Isolation Pilot Plant
General

The Indiana State Board of Health has reviewed the documents forwarded from your office on May 11, 1979, relative to the subject project and offers the comments as checked below.

(X) No comments.
( ) No objections to this proposal. However, plans and specifications for the indicated (x) health and sanitary features must be submitted for review and recommendations for appropriate approvals prior to construction.

- ( ) Water production
- ( ) Water distribution
- ( ) Sewage collection
- ( ) Sewage treatment
- ( ) Solid waste management
- ( ) Fuel combustion and incineration
- ( ) Long-term nursing care facilities
- ( ) Schools, hospitals, community health facilities, jails
- ( ) Other

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MAY 31 1979

( ) Cannot endorse this proposal for the following reasons:

- ( ) The community is on the sewer ban list so additional sanitary sewer connections are prohibited.
- ( ) The project site is inadequate for the intended purpose.
- ( ) The economic soundness of the proposal is questioned.
- ( ) Other

SBH64-064
2/79

Clearinghouse Use Only

State Identification No.	79 0501 0000
Date Received	5/9/79
Review Terminated	6/9/79

INDIANA STATE CLEARINGHOUSE
A-95 RESPONSE

TO: Mr. Eugene Beckett

Project Description (Nature, Purpose, Location):

Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant USDOE

Federal Program Title; Agency and FDA Catalog Number.

Amount of Funds Requested

The following agencies have reviewed the above project and make the following disposition concerning this application:

Department of Natural Resources — Reviewing Agency
John Feingold — Contact Person

FAVORABLY xx UNFAVORABLY ______ WITH COMMENTS ______

Board of Health — Reviewing Agency
Jon Satrom — Contact Person

FAVORABLY No comments UNFAVORABLY ______ WITH COMMENTS ______

Energy Group — Reviewing Agency
Clarence Broadus — Contact Person

No comment.

FAVORABLY ______ UNFAVORABLY ______ WITH COMMENTS ______

The A-95 response, along with any reviewing agency comments is to be attached to your formal application being submitted to the appropriate Federal Agency. These comments will be kept on file in the State Clearinghouse for one year.

A E Eaglefield
Indiana State Clearinghouse
State Planning Services Agency
143 West Market Street, Suite 300
Indianapolis, Indiana 46204
317/633-4346

June 18, 1979
Date

State Form 3162

STATE OF KANSAS

Department of Administration

DIVISION OF STATE PLANNING AND RESEARCH
5th Floor—Mills Building
109 W. 9th
Topeka, Kansas 66612

May 30, 1979

Dr. Colin A. Heath
Division of Waste Isolation
Mail Stop B-107
U.S. Department of Energy
Washington, D.C. 20545

Re: U.S. Dept. of Energy
Draft Environmental Impact Statement
Waste Isolation Pilot Plant
#DEIS/DOE - 7208

The referenced project has been processed by the Division of State Planning and Research under its clearinghouse responsibilities described in Circular A-95.

After review by interested state agencies, it has been found that the proposed project does not adversely affect state plans. Enclosed are comments concerning this project for your information and referral. We do ask that you submit 2 copies of your final grant application for our files at the time you submit your application to the funding agency. Please be sure to include our State Application Identifier (SAI) number on the application and any future correspondence.

Sincerely,

Paul V. DeGaeta
A-95 Coordinator

PVD:jc

cc:

C. Frank Harscher, III
Secretary

Julian [illegible]a
Governor

COMMONWEALTH OF KENTUCKY
DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
OFFICE OF THE SECRETARY
OFFICE OF POLICY AND PROGRAM ANALYSIS
CAPITAL PLAZA TOWER
FRANKFORT, KENTUCKY 40601
PHONE (502) 564-7320

October 2, 1979

Mr. Eugene Beckett
W.I.P.P. Project Office
Mail Stop B-107
Department of Energy
Washington, D. C. 20545

RE: Draft Environmental Impact Statement on Waste Isolation Pilot Plant

Dear Mr. Beckett:

The Draft Environmental Impact Statement prepared on the proposed Eddy County, New Mexico, Waste Isolation Pilot Plant has been circulated to selected Kentucky Environmental Review Agencies for their comments. No comments have been returned by them. We would like to review the final report when it becomes available.

Sincerely,

Boyce R. Wells
Environmental Review Coordinator

BRW:bsc

Harry Hughes
GOVERNOR

MARYLAND
DEPARTMENT OF STATE PLANNING
301 WEST PRESTON STREET
BALTIMORE, MARYLAND 21201
TELEPHONE: 301-383-2451

Constance Lieder
SECRETARY OF STATE PLANNING

June 25, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Dept. of Energy
Washington, D. C. 20545

SUBJECT: ENVIRONMENTAL IMPACT STATEMENT (EIS) REVIEW

Applicant: U. S. Department of Energy

Project: Draft EIS - Nuclear Waste Isolation Pilot Plant (DOE # EIS-0026-D)

State Clearinghouse Control Number: 79-5-1203

State Clearinghouse Contact: James W. McConnaughhay (383-2467)

Dear Mr. Beckett:

The State Clearinghouse has reviewed the above Statement. In accordance with the procedures established by the Office of Management and Budget Circular A-95, the State Clearinghouse received comments from the following:

Department of Natural Resources, Department of Economic and Community Development, including their Historical Trust section, Department of Transportation, Department of Agriculture, and our staff noted that the Statement appears to adequately cover those areas of interest to their agencies.

Environmental Health Administration provided comments (copy attached) indicating that continued indecision on the part of the national leadership regarding a national nuclear spent full waste management policy will probably cause less desirable temporary and local alternatives to be utilized.

The State Clearinghouse appreciates your agency's attention to the A-95 review process and hopes that the referenced comments will be useful in your continuing evaluation of this project.

Sincerely,

James W. McConnaughhay
Chief, State Clearinghouse

JWM:BG:mmk

cc: Lowell Frederick/ Wm. Wadsworth/ Clyde Pyers/ Max Eisenberg/ Henry Silbermanr

F/NC

OFFICE OF THE GOVERNOR
Planning & Coordination
1303 Walter Sillers Building
JACKSON, MISSISSIPPI 39201
354-7018

CLIFF FINCH
GOVERNOR

GEORGE F. NEWMAN
DIRECTOR

STATE CLEARINGHOUSE FOR FEDERAL PROGRAMS

TO: United States Department of Energy
WIPP Project Office
Mial Stop B-107
Washington, D.C. 20545

Attn: Mr. Eugene Beckett

STATE CLEARINGHOUSE NUMBER

79051710

DATE: September 7, 1979

PROJECT DESCRIPTION: NATIONWIDE

Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant. Volume 1 of 2.

The State Clearinghouse, in cooperation with the state agencies interested or possibly affected, has completed the A-95 review of the project described above.

None of the state agencies involved in the review had comments or recommendations to offer at this time. This concludes the State Clearinghouse review, and we encourage appropriate action as soon as possible.

A copy of this letter is to be attached to the application as evidence of compliance with the A-95 requirements.

Lester Howell

Lester Howell, Coordinator
Clearinghouse for Federal Programs

OFFICE OF THE GOVERNOR
Planning & Coordination
1303 Walter Sillers Building
JACKSON, MISSISSIPPI 39201
354-7018

CLIFF FINCH
GOVERNOR

STATE CLEARINGHOUSE FOR FEDERAL PROGRAMS

GEORGE F. NEWMAN
DIRECTOR

TO: United States Department of Energy
WIPP Porject Office
Mail Stop B-107
Washington, D.C. 20545

STATE CLEARINGHOUSE NUMBER

79051711

DATE: September 7, 1979

Attn: Mr. Eugene Beckett

PROJECT DESCRIPTION: NATIONWIDE

Draft Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS - 0026-D. Volume 2 of 2 Appendices.

The State Clearinghouse, in cooperation with the state agencies interested or possibly affected, has completed the A-95 review of the project described above.

None of the state agencies involved in the review had comments or recommendations to offer at this time. This concludes the State Clearinghouse review, and we encourage appropriate action as soon as possible.

A copy of this letter is to be attached to the application as evidence of compliance with the A-95 requirements.

Lester Howell

Lester Howell, Coordinator
Clearinghouse for Federal Programs

State of Missouri
OFFICE OF ADMINISTRATION
P.O. Box 809
Jefferson City 65102

Joseph P. Teasdale
Governor

William D. Dye, Director
Division of Budget and Planning

June 26, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

Subject: 79050148 (Waste Isolation Pilot Plant)

The Division of Budget and Planning, as the designated State Clearinghouse, has coordinated a review of the above referred draft environmental impact statement with various concerned or affected state agencies pursuant to Section 102(2)(c) of the National Environmental Policy Act.

Enclosed please find the comments received. None of the other state agencies involved in the review had comments or recommendations to offer at this time.

We appreciate the opportunity to review the statement and anticipate receiving the final environmental impact statement when prepared.

Sincerely,

Lois Pohl c.m.

Lois Pohl
Chief, Grants Coordination

LP:cm

Enclosure

JUL 12 1979
24

RECEIVED

STATE OF NEVADA
GOVERNOR'S OFFICE OF PLANNING COORDINATION
CAPITOL COMPLEX
CARSON CITY, NEVADA 89710
(702) 885-4865

1979 JUL 11 AM 8 35

July 5, 1979

Dr. Colin A. Heath
Division of Waste Isolation
Mail Stop B-107
U.S. Dept Energy
Washington D.C. 20545

RE: SAI NV # 79300067 Project: DOE/EIS 0046-D
79300068 DOE/EIS 0026-D

Dear Dr. Heath:

Attached are the comments from the following affected State Agencies: Division of Environmental Protection,and Dept. of Energy concerning the above referenced projects.

These comments constitute the State Clearing house review of this proposal. Please address these comments in the final or summary report.

Sincerely,

Mike Nolan

Mike Nolan for
Robert M. Hill
State Planning Coordinator

RMH:md

Enclosures

7-31-79 - Xerox cy to:
E. Hardin, AL and 1 cy to R.M. Nelson, NV.

STATE OF NEW MEXICO
OFFICE OF THE GOVERNOR
SANTA FE
87503

September 6, 1979

BRUCE KING
GOVERNOR

The Honorable Charles Duncan
Secretary of Energy
U.S. Department of Energy
Mail Stop 8G-031
Forrestal Building
Washington, D. C. 20585

Attention: Mr. Eugene Beckett
WIPP Project Leader

Dear Secretary Duncan:

I wish to congratulate you on your recent appointment as Secretary of Energy. I know your work will be rewarding and the challenge you have accepted will have a tremendous impact on the future of our country. I look forward to working cooperatively with you and your administration to meet the energy needs of our Nation.

As you know, the State of New Mexico and the Department of Energy (DOE) have been working cooperatively through a process of consultation and concurrence to review and evaluate the proposed Waste Isolation Pilot Plant (WIPP) in Southeastern New Mexico. An important stage in this process has been the issuance of a Draft Environmental Impact Statement (DEIS) by your Department. Our review of this draft was carried out under the leadership of Secretary of Finance and Administration David W. King in conjunction with the Radioactive Waste Consultation Task Force, and includes comments from all relevant Cabinet Departments, the Environmental Evaluation Group (EEG), and the Governor's Advisory Committee on WIPP. These comments are enclosed for your consideration.

We have found three major deficiencies in the DEIS--those portions dealing with transportation, emergency preparedness, and socioeconomics. These problem areas have been recognized by both federal agencies and Congressional delegates, and various efforts have been initiated to remedy them. Of equal importance to the three major DEIS deficiencies cited are the health and environmental concerns expressed by the EEG and the Governor's Advisory Committee on WIPP which have analyzed the scientific and technical aspects of the DEIS. Their evaluations have revealed a number of areas that should be addressed in the final EIS or supplemental documents.

It is my request that the transportation and emergency preparedness issues be adequately addressed through the preparation of supplements to the DEIS and that these supplements be reviewed by New Mexico prior to completion of the final EIS and prior to the initiation of Title II activities. We consider it important that progress on the project itself should be synchronized with progress in the area of transportation, since the success of the project will depend on the resolution of a number of important technical and institutional issues pertaining to transportation.

The socioeconomic issue, currently being studied by the State of New Mexico under a grant from the DOE, must also be thoroughly evaluated as to its ultimate impact on the State. Because the study completion date and the final EIS date are not the same, the State and the DOE need to jointly define how the socioeconomic study results can be fully incorporated through the consultation and concurrence process. A similar definition needs to be determined with respect to the technical and scientific issues raised by the EEG. These issues should be addressed in the context of the current negotiation with the State on consultation and concurrence.

In the event that the DOE is unable to issue supplements on the inadequate portions of the DEIS for timely review prior to the publication of the final EIS, then I must declare the entire DEIS inadequate. It is my hope that supplemental studies can be prepared and the weaker sections of the DEIS can be brought up to standard in time to be incorporated in the final EIS.

Since the issuance of the DEIS in April, there have been important changes in the mission of the WIPP project. When the State initiated the DEIS reviews, it was anticipated that commercial spent fuel would be included in the scope of the project. Commercial waste has now been eliminated, and the project has reverted to a facility for the permanent disposal of defense transuranic wastes and for research and development on high-level waste. This raises the question of whether the DEIS in its present form is an adequate representation of the proposed scope of the project. Under the circumstances, I would request that references to commercial waste be removed prior to the publication of the final EIS.

With this change of mission, it also appears that the sense of national urgency associated with a spent fuel disposal capability has been removed from the project. We understand from hearings before the House Oversight and Investigations Subcommittee and other federal sources that there is no immediate hazardous condition existing at current transuranic waste storage sites, and that we have gained sufficient time to adequately evaluate all aspects of the WIPP as well as other alternative disposal sites. In this connection, it is important that the final EIS should specifically identify the intended scope of the project, including estimates of the amounts and types of radioactive material to be permanently or temporarily located in the repository. We expect to participate in the determination of the final scope of the project with the DOE through the consultation and concurrence process which is now being defined.

Because of the complexity of the WIPP, it is necessary that the final EIS address and respond to all issues identified in the review process. State agencies identified many potential costs in reviewing the effects of this project on their operations. These costs must be further explained and quantified in the final statement. Of great importance among these costs is the liability resulting from loss of life or property related to a project accident or nuclear waste transportation accident. We believe that this issue should be comprehensively addressed in the final EIS, including an evaluation of the adequacy of the Price-Anderson Act and the extent of federal and state liability.

We have stated on many occasions that the WIPP should be licensed by the Nuclear Regulatory Commission. The licensing process will help ensure that the health and safety of New Mexicans will not be compromised. The process of consultation and concurrence will also help to meet our concern for health and safety by providing for active State participation in decision making on the WIPP. The EIS process is an integral part of consultation and concurrence, but it must be appreciated that any approval given to the final EIS will not represent the State's final concurrence on the WIPP project.

To assure continued positive communication and coordination, the flow of information and documentation must be further improved. In addition to the EEG, the State's Radioactive Waste Consultation Task Force and the A-95 Clearinghouse should receive pertinent documentation and notification of all meetings or hearings. Financing should continue to be provided to enable the State to carry out its own independent evaluation of the project.

We further suggest that a summary of the main conclusions of the final EIS should be provided in both English and Spanish languages. Consideration should also be given to translation into appropriate Indian languages for those tribes likely to be impacted by the WIPP.

The attached review provide details of the State's DEIS review. We sincerely hope that our comments aid you in the evaluation of such a complex project and we stand ready to assist you in whatever way we can.

Sincerely,

Bruce King

BRUCE KING
Governor

Attachment

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

ormati...)5/835-5420
lication... 505/835-5410

September 5, 1979

Mr. Dennis Rivera
State Planning Division
527 Don Gaspar Santa Fe, NM 87503

Dear Mr. Rivera:

Our economic geologists, petroleum geologists, hydrogeologist, environmental geologist. chemist, mining engineer, petrologist, mineralogist and mining geologist reviewed the draft EIS for WIPP, April 1979. We had reviewed in detail a draft of Geological Characterization Report WIPP Site, prepared by Powers et al., Sandia Labs, 1978.

Some aspects of the detailed geologic controls, transportation, mining and depository construction, hydrogeology and mineral resources development are site specific and require constant investigation as work proceeds. Minor modifications of development plan are needed to adjust to minor variances in these factors.

The area is tectonically stable, salt solution appears to be relatively slow, and other geologic factors are reasonably favorable. Transportation safeguards appear adequate. Mining and construction plan for subsurface and surface facilities is conservative with safety aspects emphasized.

Potash reserves probably will be lost; slant drilling may recover gas and oil resources. Loss of these mineral resources is our major criticism of the site.

Sincerely yours,

Frank E. Kottlowski

Frank E. Kottlowski
Director

FEK/jp

cc: Eugene Beckett

BRUCE KING
GOVERNOR

DAVID W. KING
SECRETARY

STATE OF NEW MEXICO

DEPARTMENT OF FINANCE AND ADMINISTRATION PLANNING DIVISION

ANITA HISENBERG
DIRECTOR

505 DON GASPAR AVEN
SANTA FE, NEW MEXICO 8
(505) 827-2073
(505) 827-5191

September 11, 1979

Mr. Don Schueler
Project Manager
WIPP Project Office
U.S. Department of Energy
Albuquerque Operations Office
Post Office Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Schueler:

Enclosed for your information is a copy of the State of New Mexico's review of the Draft Environmental Impact Statement (DEIS) on the Waste Isolation Pilot Plant (WIPP). This review constitutes the State's official response to the Department of Energy on the DEIS of the proposed WIPP project.

This review is comprised of four sections based on reviews compiled by the State Planning Division, the Governor's Advisory Committee on WIPP, the University of New Mexico's Economic Resource Group and the Environmental Evaluation Group. The report conducted by the Environmental Evaluation Group is not provided in the enclosed document. That review will be sent to you or can be acquired by direct request to them.

If you desire further information on this matter, please contact Dennis Rivera in Santa Fe at 827-5191.

Sincerely,

Anita Hisenberg.
Director

AH:jeh

Enclosure

"equal opportunity employer"

STATE OF NEW MEXICO

HEALTH & ENVIRONMENT department

ENVIRONMENTAL EVALUATION GROUP
320 E. Marcy Street
P. O. Box 968
Santa Fe, N.M. 87503
(505) 827-5481

September 7, 1979

Mr. Don T. Schueler
WIPP Project Manager
Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. Schueler:

Enclosed you will find an advanced copy of our "Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy",which is now being readied for distribution. I was sure that you would like to have a copy in advance of the release to the news media.

I am estimating that the main distribution of this document will begin Tuesday, September 11, 1979. The release to the news media will be on September 11 or 12.

Very truly yours,

Robert H. Neill
Director

RHN:pt

Enclosure: one

NEW MEXICO TECH SOCORRO, NEW MEXICO 87801

THE GRADUATE OFFICE (505) 835-5513

May 18, 1979

Governor Bruce King
State Capitol Building
Santa Fe, New Mexico 87503

Dear Governor King:

We are writing to report another recent action of our Advisory Committee on WIPP.

The following statement relative to Mineral Resources and the Waste Isolation Pilot Plant has been adopted by unanimous agreement:

> We endorse the findings of the Foster Report to the extent that mineral resources at the WIPP Site represent a threat to long term integrity of a waste repository. Judging from the NAS criterion*, this would be a basis for questioning the suitability of the WIPP Site.
>
> *No area with a present or past record of resource extraction other than for bulk materials won by surface quarrying, should be considered as a geological site for radioactive wastes. Geological Criteria for Repositories for High-Level Radioactive Wastes, Committee on Radioactive Waste Management, National Academy of Science, p. 13-15, August 3, 1978.

A copy of Roy Foster's report entitled "Mineral Resources and the WIPP Site," is attached. If there are any questions that you or members of the Task Force have concerning this action or the report itself please don't hesitate to contact Roy or members of our Committee.

Sincerely,

Marvin Wilkening, Chairman
Governor's Advisory Committee
on WIPP

MW:ccg

Attachment

RESOURCE ECONOMICS GROUP
DEPARTMENT OF ECONOMICS
THE UNIVERSITY OF NEW MEXICO, ALBUQUERQUE

A CRITICAL REVIEW OF THE SOCIO-ECONOMIC PORTIONS OF THE DOE'S DEIS CONCERNING THE WASTE ISOLATION PILOT PROJECT

program in resource economics

working paper series

P-149

STATE OF NEW MEXICO
Office of the Attorney General
DEPARTMENT OF JUSTICE
P.O. Drawer 1508
Santa Fe, N. M. 87501

JEFF BINGAMAN
ATTORNEY GENERAL

August 30, 1979

United States Department of Energy
Washington, D. C. 20545

Re: DOE/EIS-0026-D, Waste Isolation Pilot Plant
Our Ref. No. 30401-201/204/206

Dear DOE:

As comments by the Attorney General on the above indicated draft environmental impact statement, which DOE prepared in response to a request we made in April, 1978, enclosed please find a copy of the testimony given by Attorney General Jeff Bingaman on August 10, 1979, to the House Subcommittee on Oversight and Investigations of the Interior Committee. Our comments address the following legal issues: (1) the Price Anderson Act (discussed in the DEIS at pp. 14-2, 2nd paragraph, and 14-7, paragraph 3); and (2) New Mexico's role of "consultation and concurrence" with respect to the establishment of WIPP.

Technical comments on non-legal issues raised by the DEIS will be provided by other state agencies.

Very truly yours,

STEVEN ASHER
Assistant Attorney General
Director, Energy Unit
Consumer and Economic Crimes Division

SA:pgg
Encl.

ccs: Governor Bruce King
State Planning Division
Attn: Mr. Dennis Rivera

SOUTHEASTERN NEW MEXICO
ECONOMIC DEVELOPMENT DISTRICT

P. O. BOX 6639 R. I. A. C. ROSWELL, NEW MEXICO 88201 505– 347-5425

NICK J. PAPPAS Executive Director

September 6, 1979

Mr. Eugene Beckett
Department of Energy
WIPP Project Office
Mail Stop 8G-031
Washington, D.C. 20585

RE: Draft Environmental Impact Statement - Waste Isolation Pilot Plant

Dear Mr. Beckett:

In accordance with OMB Circular A-95, the Southeastern New Mexico Economic Development District (SNMEDD) has reviewed the above referenced statement and offer the following comments:

1. The SNMEDD will defer judgement on potential environmental impacts to the Governor's Special Task force on WIPP which has the greatest expertise available for analysis of project related environmental concerns.

2. The SNMEDD, which works closely with communities throughout this part of the state, feels that the WIPP project can have positive benefits on the Lea and Eddy County economies and could also provide much needed diversification of the regions economic base. The project must, however, be carefully phased and properly funded so as not to create negative impacts that are typical of rapid growth or "sudden rise" boom town situations.

3. The proposed project will directly benefit low and moderate income wage earners, including minorities, as the construction work force could approach 800 people, many of which will be hired locally.

4. The SNMEDD Board has endorsed the WIPP project as a disposal site for defense generated waste and as a small-scale experimental site for diposal of commercial waste. The SNMEDD has not shown any support for permanent storage of large amounts of commercial waste.

The project obviously represents a decision of enormous regional and statewide impact. This office will not pretend to speak for anyone other than an association of local governments, who had given preliminary endorsement to a concept that has been revised and amended substantially over the past five years. Please do not hesitate to contact this office if we can be of further assistance.

Sincerely,

Nick J. Pappas
Executive Director

BY: Ivan Hall

Ivan L. Hall
Chief Planner

ILH/dlg

cc: Dennis Rivera - SPO

DIRECTOR-
Steven LaBrake
CHAIRMAN-
Howard A. McGee
VICE CHAIRMAN-
Roy Wood
SECRETARY-
Charles Ingram

YATES COUNTY PLANNING BOARD

County Building Annex
431 Liberty Street
Penn Yan, New York 14527
Phone (315) 536-2531

August 2, 1979

Waste Isolation Pilot Plant Project Office
Department of Energy
MS B-107
Washington, D.C. 20545

Dear Sir:

As a county identified for nuclear waste disposal within the Salina Salt Basin, there is particular interest among citizens and public organizations to monitor the ongoing research and development, and any proposed plans dealing with nuclear waste disposal.

The Y.C.P.B. reviewed the Draft E.I.S. for the Waste Isolation Pilot Plant in Carlsbad, N.M., and unanimously supports the enclosed resolution for submittal as public comment.

The Board recognizes the increasing need to develop pilot plants for further research on waste disposal; yet, a project the scope of the proposed WIPP is a large committment financially and to the concept of waste disposal in salt beds. Rather than the WIPP, the Board supports more extensive research on all possible geologic environments and development of pilot plants of lesser magnitude.

We appreciate the opportunity to comment on the proposed project.

Sincerely,
YATES COUNTY PLANNING BOARD

Howard A. McGee
Chairman

HAM/ml

Enc.

DIRECTOR-
Steven LaBrake
CHAIRMAN-
Howard A. McGee
VICE-CHAIRMAN-
Roy Wood
SECRETARY-
Charles Ingram

YATES COUNTY PLANNING BOARD

County Building Annex
431 Liberty Street
Penn Yan, New York 14527

Phone (315) 536-2531

TITLE: Resolution to support further research and development of Waste Isolation Pilot Plants

WHEREAS, The United States Department of Energy has requested input from the general public regarding the proposed Waste Isolation Pilot Plant in Carlsbad, New Mexico, and

WHEREAS, this project will be a pilot program to determine the suitability of salt beds for the disposal of radioactive wastes and,

WHEREAS, Yates County, New York has been identified as part of a general region of possible suitability for radioactive waste disposal due to the Salina salt bed geologic formation, now therefore be it;

RESOLVED THAT, the Yates County Planning Board encourages the comprehensive research of use of all possible radioactive waste disposal media and further be it;

RESOLVED THAT, the Yates County Planning Board hereby encourages the development of small scale on-site pilot projects for the testing of all possible radioactive waste disposal media and further;

RESOLVED THAT, the Yates County Planning Board supports curtailed pilot projects which would not involve the high cost and facility capacity of the proposed Carlsbad, New Mexico, Waste Isolation Pilot Plant.

North Carolina
Department of Administration
116 West Jones Street Raleigh 27611

James B. Hunt, Jr., Governor
Joseph W. Grimsley, Secretary

Division of State Budget and Management
John A. Williams, Jr., State Budget Officer
(919) 733-7061

July 3, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D. C. 20545

Dear Mr. Beckett:

RE: SCH #118-79, Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant - US Department of Energy

The State Clearinghouse has received and reviewed the above referenced project. As a result of this review, the State Clearinghouse finds that no comment is necessary on this project at this time.

Sincerely,

Chrys Baggett

Chrys Baggett (Mrs.)
Clearinghouse Director

CB:maw

NORTH DAKOTA STATE PLANNING DIVISION

STATE CAPITOL · NINTH FLOOR · BISMARCK, NORTH DAKOTA 58505
701-224-2818

June 14, 1979

STATE INTERGOVERNMENTAL CLEARINGHOUSE "LETTER OF CLEARANCE"
ON PROJECT REVIEW IN COMFORMANCE WITH OMB CIRCULAR NO. A-95

To: U.S. Department of Energy

STATE APPLICATION IDENTIFIER: 7905169556

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

Subject: Draft Environmental Impact Statement for the Waste Isolation Pilot Plant.

This Draft EIS was received in our office on May 15, 1979.

Thank you for submitting your draft environmental impact statement for review and comment through the North Dakota State Intergovernmental Clearinghouse.

Your draft was referred to the appropriate agencies, and no comments were received to this date.

Please send me copies of the final environmental impact statement and any supplemental impact statements to the North Dakota agencies that have commented on the draft, and to this office. The opportunity to review your draft is appreciated, and if this office as Clearinghouse can be of further assistance with this project, please let me know.

Sincerely yours,

Bonnie A. Banks

Mrs. Leonard E. Banks
Associate Planner

BAB/gd

STATE CLEARINGHOUSE

30 EAST BROAD STREET • 39TH FLOOR • COLUMBUS, OHIO 43215 • 614 / 466-7461

June 28, 1979

Mr. Eugene Beckett
Waste Isolation Pilot
Plant Project Office
Mail Stop B-107
U. S. Department of Energy
Washington, D. C. 20545

RE: Review of Environmental Impact Statement/Assessment
Title: Draft Environmental Impact Statement, Waste Isolation Pilot Plant, April, 1979, U. S. Department of Energy
SAI Number: 36-471-0002

Dear Mr. Beckett:

The State Clearinghouse coordinated the review of the above referenced environmental impact statement/assessment.

Comments from the Ohio Environmental Protection Agency state that inasmuch as the operations described in the subject document are out of the jurisdiction of the State of Ohio, there is no immediate concern with this Draft Environmental Impact Statement (EIS). However, since Ohio has a well-established ongoing interest in fuel cycle and radioactive waste disposal matters, this document has been examined with considerable interest. The following comments are offered.

At present, Ohio has an active commercial reactor building program; one unit is operation, three are under construction, one has been decommissioned, and four more are in the planning stage. In addition, radioactive waste is generated at the Portsmouth isotope separations facility, the Mound Laboratories and the Fernald uranium feed facility. If the spent fuel from these reactors must ultimately be stored at a Federal Repository, such a program would be more easily established if the management of defense matters were fully in harmony with the commercial waste program.

It is also becoming increasingly apparent that the radioactive waste disposal is beset with a number of (non-technical) institutional, political and social barriers which are more evident in the case of commercial reactor spend fuel elements than for defense related wastes. This EIS does not take these conditions into account.

Concerning the specific alternatives which are presented there are several comments which you will find pertinent.

1. Alternative 1, continue storage at the Idaho National Engineering Laboratory (INEL). While this "No Action" alternative might be cheapest, environmentally benign and backed by the greatest experience, it also has the disadvantages of contributing nothing new or progressive to the state of the art of radioactive waste management. It also might add to a public perception of the U. S. Department of Energy's (DOE) inability or indecision to dispose successfully of defense wastes.

2. Concerninging the other alternatives. It appears that if the Department of Energy really wishes to move carefully in incremental steps, it would be politic to plan the facility originally to handle only CH (contact handling) waste, as much as this would take care of the greatest bulk of the INEL waste easily and expeditiously. After the Waste Isolation Pilot Plant (WIPP) and the Department of Energy have demonstrated the ability to handle this satisfactorily, the facilities for storage of RH (remote handling) waste and spent reactor fuel can be added.

On institutional problems, it is hoped that you would be cognizant of the workshops held throughout the country. Enclosed is a copy of the "Recommendations Toward Establishing a Publicly Responsive and Acceptable National Nuclear Waste Management Policy", adopted at the Denver workshop, for inclusion in the Final Environmental Statement. It is expected that DOE will be responsive to these recommendations. It would be appropriate to include a complete section on institutional problems and how DOE intends to deal with them.

Generally, the draft EIS is thorough and well done. However, it is felt that DOE has been rather vague about the process of decommissioning; also, about what would be done with retrieved fuel or waste.

Specific comments made are that on Page 2-4 et. seq., there are no institutional criteria listed there which point to our general remarks about institutional problems. Page 2.6, if mining the salt beds in the Williston Basin would not be feasible for the WIPP, it would not be feasible for "the richest potash deposits in North America" either so that statement is quite superfluous.

Page 2-7, do "drill holes" include small exploratory core drilling as well as larger holes, page 2-17, Section 2.2.3, point 2. It should be pointed out that transuranic (TRU) waste as compared with high-level waste (HLW) not only generates less heat but also requires little if any shielding and, therefore, under normal operating conditions results in lesser radiation fields and less occupational exposure.

Page 2-26. We concur with the conclusions on this page beginning with the second paragraph.

Page 9-17 and 14-9, the denial of resources to the state and the industry, especially of langbeinite seems the greatest drawback of the present WIPP site, yet the EIS makes no mention of possible monetary compensation for this denial.

It is stated by the Department of Natural Resources that they concur with the elimination of the Salina region for siting of the WIPP. The Silurian rock salt in Ohio would meet few of the tenative selection criteria.

Also, it should be noted the the Ohio Department of Energy has made a specific request to review the final environmental impact statement when it has been completed.

In conclusion, it is recommended that the above comments be addressed in the final environmental impact statement and that there be a expeditious solution to the nuclear waste problem.

Sincerely,

Judith Y. Brachman

Judith Y. Brachman
Administering Officer

JYB/lew

cc: DNR, Mike Colvin
OPEA, Gene Wright

Enclosure

ROBERT W. STRAUB
GOVERNOR

Executive Department
INTERGOVERNMENTAL RELATIONS DIVISION
ROOM 306, STATE LIBRARY BLDG., SALEM, OREGON 97310

June 26, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington D.C. 20545

WASTE ISOLATION PILOT PLANT
PNRS 7905 4 890

Thank you for submitting your draft supplement to the final Environmental Impact Statement for State of Oregon review and comment.

Your draft was referred to the appropriate state agencies for review. The consensus among reviewing agencies was that the draft adequately described the environmental impact of your proposal.

We will expect to receive copies of the final statement as required by Council of Environmental Quality Guidelines.

Kay F. Wilcox
KAY WILCOX, A-95 COORDINATOR

KW:jh

Pennsylvania State Clearinghouse

P.O. BOX 1323 – HARRISBURG, PA. 17120 – (717) 787-8046
783-3133

PSC
Commonwealth
of
Pennsylvania

GOVERNOR'S OFFICE
OFFICE OF THE BUDGET

July 6, 1979

PSCH # 57905006

Mr. Eugene Beckett,
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

The Pennsylvania State Clearinghouse has received from your Office copies of the Draft Environmental Impact Statement (DOE/EIS-0026-D) for the Waste Isolation Pilot Plant.

Please be advised that the State Clearinghouse has no comments to make on the Draft. We would appreciate, however, a copy of the Final Statement.

Sincerely,

Richard A. Heiss a.r.

Richard A. Heiss, Supervisor
Pennsylvania State Clearinghouse

RAH:ar

cc: File (2)

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Department of Administration
STATEWIDE PLANNING PROGRAM
265 Melrose Street
Providence, Rhode Island 02907

July 12, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Dept. of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

This office, in its capacity of clearinghouse designate under OMB Circular Number A-95, Part II, has reviewed the Draft Environmental Impact Statement (DOE/EIS-0026-D), Waste Isolation Pilot Plant, U.S. Department of Energy, dated April 1979, as received in this office on April 11, 1979.

The Technical Committee of the Office of State Planning was presented the staff findings as a result of the review along with the staff's recommendation at its meeting of July 6, 1979. The Committee's decision is that the clearinghouse has no comment on the draft.

We thank you for the opportunity to review this document.

Yours very truly,

Rene J. Fontaine
A-95 Coordinator

RJF/sjc
Reference File: EIS-79-07

STATE PLANNING BUREAU
State Capitol
Pierre, South Dakota 57501
605/224-3661

SOUTH DAKOTA Office of Executive Management

July 10, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Re: Draft Environmental Impact Statement (DOE/EIS-0026-D)
EIS 111079
Waste Isolation Pilot Plant

Dear Mr. Beckett:

The State Clearinghouse has distributed for review the above stated draft environmental impact statement. No comments were received. Thank you for the opportunity to review and comment.

Sincerely,

James R. Richardson
Commissioner
State Planning Bureau

JRR/mjn

OFFICE OF THE GOVERNOR

WILLIAM P. CLEMENTS, JR.
GOVERNOR

July 2, 1979

Mr. Eugene Beckett
WIPP Project Office
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

The draft environmental impact statement (DOE/EIS-0026-D) pertaining to the Waste Isolation Pilot Plant, has been reviewed by the Budget and Planning Office and interested State agencies. The comments of the Department of Water Resources, Air Control Board, Parks and Wildlife Department, State Department of Highways and Public Transportation, Railroad Commission and the Department of Health are enclosed for your information and use.

The Budget and Planning Office appreciates the opportunity to review this document. If we can be of any further assistance during the application process, please do not hesitate to call.

Sincerely,

Donald E. Harley

Donald E. Harley, Manager
Economics and Natural Resources
Budget and Planning Office

Enclosures: Comments of -
- Department of Water Resources
- Air Control Board
- Parks and Wildlife Department
- State Department of Highways and Public Transportation
- Texas Railroad Commission
- Department of Health

DEH:jl

EXECUTIVE OFFICE BUILDING • 411 WEST 13TH STREET • AUSTIN, TEXAS 78701

RICHARD SITZ
COUNTY JUDGE

WARD COUNTY

MONAHANS, TEXAS 79756

March 30, 1979

Honorable Jimmy Carter
President of the United States of America
Washington, D. C. 20510

Dear Mr. President:

Enclosed is a copy of a resolution passed by our Court on March 26, 1979, which is self explanatory.

We would like to have a response from you concerning this resolution to enter into our court records. Even though the final decision has not been made on the site location, we feel it is particularly necessary for you to reply to item # 3 of the resolution.

Yours very truly,

Richard Sitz

Richard Sitz
County Judge

RS:bw

RICHARD SITZ
COUNTY JUDGE

WARD COUNTY

MONAHANS, TEXAS 79756

The following is a true and correct copy of the Resolution passed by the Ward Cou Commissioners' Court at Monahans, Texas, on March 26, 1979, with said Resolution recorded in the Minutes of Commissioners' Court. All members on the Court were present at the meeting, to wit; H. A. Collins, Commissioner Precinct 1, Robert R. Spinks, Commissioner Precinct 2, J.H. Raglin, Commissioner Precinct 3, Lenora Price, Commissioner Precinct 4 and Richard Sitz, County Judge.

R E S O L U T I O N

We recognize the need for the United States to find a place to store the accumulated waste of our nuclear programs. However, there are some basic problems of the proposed Waste Isolation Pilot Plant near Carlsbad, New Mexico, which have not been solved.

First, according to the hydrological studies conducted by Sandia Laboratories in Albuquerque, New Mexico, there are high pressure deposits of natural gas and water underlying the site which are potentially dangerous if the high pressure gas should ever force the water into the WIPP site.

These natural gas deposits are potentially valuable sources of natural gas, but the WIPP site will remove them from usefulness. Also the potash deposits of the area will be rendered useless by the proposed choice of site.

Second, there have been earthquakes as recently as the spring of 1978 in Winkler County, Texas, which is adjacent to Eddy County, New Mexico, the location of the proposed WIPP site. These quakes show the area is not as geologically inactive as has been claimed by the Department of Energy.

Third, the aquifers of southeastern New Mexico and southwestern Texas are too close to the chosen site. The Santa Rosa limestones are actually present in the boundaries of the mine area. If any leakage should occur and seep into these water supplies, it could pollute a portion or the entire water supply of the area.

Because of the above reasons, we feel this site is not sufficiently safe for long-term storage of large quantities of nuclear waste.

If, however, the President of the United States and the Department of Energy choose this site in southeastern New Mexico, we would like to see the following precautions:

1. There should be monitoring of the mine until the mine site is no more radioactive than the natural radioactivity of the region.

2. There should be monitoring of private and public water supplies of southeast New Mexico and southwest Texas as long as it is necessary to monitor the mine. The monitoring should be at the expense of the United States government, not at the expense of the individual water user.

3. If pollution of any water supply should occur from the Waste Isolation Pilot Plant, the water supply should be replaced with potable water. This good, usable water should not be at the expense of the property owner/owners, but rather at the expense of the United States government.

4. There should be security provisions for the transportation of the radionuclear waste to the site.

5. The radioactive waste should be isolated in as retrievable a manner as possible, pending future technology when the waste can be safely disposed of or utilized for fuel.

If the present plans of the Department of Energy are carried out by the United States, the Carlsbad WIPP site will ultimately contain the largest (or one of the largest) concentrations of radionuclear waste in one place that has ever been gathered together in the history of mankind. We certainly feel this justifies extraordinary precautions and safety measures for the humans and animals which populate the area. Also, there are many unique features of the land which need preservation -- to name but two -- Guadalupe National Park in Texas and Carlsbad Caverns National Park in New Mexico.

Introduced and passed by the Commissioners' Court of Ward County, Texas, this 26th day of March, 1979.

Richard Sitz
RICHARD SITZ, County Judge

Attest:

Pat V. Finley
PAT V. FINLEY, County Clerk

STATE OF UTAH
Scott M. Matheson
Governor
Kent Briggs
State Planning Coordinator

Division of Policy and Planning Coordination
Intergovernmental Relations Section
Lorayne Tempest, Assistant State Planning Coordinator
124 State Capitol
Salt Lake City, Utah 84111
533-4981

A/95
State Clearinghouse
533-4976
533-4971

Environmental Coordinating Committee
533-5794

Human Resources Coordinating Committee
533-6081

A/85
Federal/State Coordination
533-6083

Federal Resource Information Center
533-4983

June 27, 1979

Mr. Eugene Beckett
WIPP Project Office,
Mail Stop B-107
Department of Energy
Washington, D.C. 20545

Dear Mr. Beckett:

The Utah State Environmental Coordinating Committee has reviewed the Draft Environmental Impact Statement; Waste Isolation Pilot Plant. The Committee offers the following comments.

1. Bottom of Page 1-2 and top of Page 1-3

   ". . . the WIPP will recieve as many as 1000 assemblies emplaced in such a manner that they can be retrieved for 20 years if necessary, <u>but without the expectations of doing so</u>."

   This last phrase (underlined) should not be voiced as a part of the mission. A change in the White House occupancy could enable the Nation to pursue the reasonable course of fuel reprocessing and breeder reactors for power generation.

2. Page 6-8 - "There are no shipping casks in existence designed specifically for transporting HLW canisters."

   If these High-Level Wastes are moved, most of them would probably go through Utah and Salt Lake City. It is also anticipated that much of the spent fuel will be transported through Utah. The proposed cask for HLW would probably be limited to rail transportation because of its weight (-100 tons). We would hope all of the High-Level Waste could be sent by rail to minimize contact with the public.

If the WIPP is to be constructed, Utah will need an increased capability of monitoring shipments to assure its citizens that they are being protected from unnecessary hazards. We will also need additional emergency response capability and it is our feeling that the added responsibility imposed by a Federal program should be supported by Federal funds.

Thank you for the opportunity to comment.

Sincerely,

Lorayne Tempest

Lorayne Tempest
Assistant State Planning Coordinator

LT/dk
790515138

OFFICE OF THE GOVERNOR

STATE A-95 CLEARINGHOUSE

STATE PLANNING OFFI

AREA CODE 802-828-3

STATE OF VERMONT

MONTPELIER, VERMONT 05602

MEMORANDUM

To: Mr. Eugene Beckett, WIPP Project Office
Mail Stop B-107, Department of Energy
Washington, D. C. 20545

From: Emily Neary, A-95 Coordinator

Date: June 27, 1979

Re: Draft Environmental Impact Statement, DOE/EIS-0026-D, Waste Isolation Pilot Plant (WIPP)

As the State Clearinghouse under OMB Circular A-95 we have notified other public agencies with a possible interest in your:

Copies of comments received are attached: from the Division for Historic Preservation.

:enclosure

Appendix Q

REPORT OF THE HEARINGS PANEL ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE WASTE ISOLATION PILOT PLANT

Appendix Q

REPORT OF THE HEARINGS PANEL ON THE ENVIRONMENTAL IMPACT STATEMENT FOR THE WASTE ISOLATION PILOT PLANT

This appendix contains the report of the hearings panel on the draft environmental impact statement for the Waste Isolation Pilot Plant. The report identifies the significant issues raised during public hearings at Odessa, Texas, on October 1, 1979; Hobbs, New Mexico, on October 2, 1979; and Santa Fe, New Mexico, on October 5, 1979.

November 6, 1979

Ms. Lynda Brothers
Acting Deputy Assistant
Secretary for the Environment
Department of Energy
Washington, D.C.

Dear Ms. Brothers:

The attached report of the hearing panel on the Waste Isolation Pilot Plant Draft Environmental Impact Statement (DOE/EIS-0026-D) identifies the significant issues raised during public hearings held on the draft environmental impact statement on the following dates at the following locations:

Odessa, Texas	-	October 1, 1979
Hobbs, New Mexico	-	October 2, 1979
Santa Fe, New Mexico	-	October 5, 1979.

These hearings were held pursuant to a notice published in the Federal Register on September 5, 1979 (44 Fed. Reg. 51848). Advertisements were also placed in the local press in Spanish and in English in various cities and towns in New Mexico and Texas to encourage participation in these hearings. Earlier hearings on the same DEIS were held in Idaho Falls, Idaho, June 5, 1979, Albuquerque, New Mexico, June 7 and 8, 1979, and Carlsbad, New Mexico, June 9, 1979.

The Panel for the hearings consisted of Robert W. Hamilton, Vinson and Elkins Professor of Law at The University of Texas School of Law, the presiding officer, Dr. John Cumberland, Professor of Economics at the University of Maryland, and Dr. Irwin C. Remson, Professor of Applied Earth Sciences and Professor of Geology at Stanford University.

Since no member of the Panel is an employee of DOE the record of the hearing was not compiled by the Board. That function is being performed by the Albuquerque office of DOE. The attached report ~~is limited to the issues~~ raised in the oral presentations and testimony at the hearings and does not address issues that may have been raised in the voluminous written comments on the DEIS, which have not been examined or reviewed by the Panel.

The Panel has not undertaken to resolve the substantive issues raised or to render judgment on the desirability of the

WIPP Project. In a few instances in the attached report, the Panel has made substantive observations or suggestions which it believes will be of assistance to DOE in evaluating the record of this hearing.

Respectfully submitted,

Robert W. Hamilton
Presiding Officer

Dr. John Cumberland

Dr. Irwin Remson

November 6, 1979

Report of the Panel Identifying
Significant Issues on the Draft
Environmental Impact Statement
on the Waste Isolation Pilot
Plant DOE/EIS-0026-D

This Report describes the significant issues raised at public hearings on the above draft environmental impact statement (DEIS) held on October 1, 1979 at Odessa, Texas, on October 2, 1979 at Hobbs, New Mexico, and on October 5, 1979 at Santa Fe, New Mexico. These hearings were held pursuant to the ground rules established in the notice of the hearings, published at 44 Fed. Reg. 51848.

This Report considers only the issues raised at these public hearings. The Panel has not reviewed the numerous written comments received by the Department of Energy (DOE) relating to the Waste Isolation Pilot Plant (WIPP) project. The full record of these hearings is being developed by DOE.

The format of these hearings was unusual in two respects. First, all members of the Panel were drawn from outside DOE. Second, the morning of each session was devoted to a public presentation by DOE and its contractors on various aspects of the WIPP project. Members of the Panel questioned closely each person taking part in the DOE presentation and a relatively few written questions were asked about this presentation by members of the general public. The afternoon, and where necessary the evening, sessions were devoted to the testimony of interested members of the general public who had requested an opportunity to testify, and to unscheduled presentations by members of the audience.

Many of the significant issues and comments described below were developed during the morning sessions when DOE employees and its contractors made presentations subject to questioning by the Panel. At these sessions the DOE presentation summarized the principal objections to the Project made at the earlier public hearings and in the written comments, and responded to them. In the view of the members of the Panel, this format provides a useful and meaningful role for non-DOE Panel members.

The DOE presentation addressed the following substantive areas:

(1) Transportation of waste to the WIPP site;

(2) Conflict with energy and mineral resources at the site;

(3) Potential contamination of west Texas water supplies;

(4) Geologic suitability of the site;

(5) Effects of low level radiation;

(6) Retrievability capabilities for the waste; and

(7) Socioeconomic impact of the project.

In many of these areas, the DOE presentation adequately responded to questions and concerns that had been raised previously, and clarified precisely what was being proposed at the WIPP project. It would be desirable for the final EIS to incorporate portions of these presentations.

In the view of the Panel the following are the principal problem areas that remain to be addressed by DOE:

I. <u>Recent Changes in the WIPP Project</u>.

As a result of Congressional decisions, there have been two significant changes in the WIPP project since the DEIS was released last

April: the proposal for the intermediate storage facility involving the storage of up to 1000 spent commercial fuel rod assemblies has been deleted and it is no longer proposed that the facility be reviewed and licensed by the Nuclear Regulatory Commission (NRC). (Tr 1073-74) Of course, at a minimum the final EIS should reflect these revisions.

The decision to eliminate the commercial spent fuel rod assemblies increases the conservatism of the project in several respects: the amount of high level waste that must be transported to the site has been greatly reduced, possible problems relating to the effect of long-term heat and radioactivity on salt formations have been eliminated, and the amount of radioactivity released during some of the "worst possible" scenarios discussed in the DEIS has been greatly reduced. (Tr 1075) Since all aspects of this change appear to reduce the possible adverse environmental affects of the WIPP proposal, this change appears to require no further procedural steps other than changing the DEIS so that the final EIS accurately reflects the current scope of the project.

The elimination of NRC licensing presents other problems, however. Several witnesses, including particularly representatives of the State of New Mexico, continued to call for NRC licensing despite the Congressional decision to eliminate it. (E.g., Tr 1210, 1213-14, 1757). In its most definitive statement, the State of New Mexico called for "the creation of an independent review process at the national level" and "a second opinion . . . to provide adequate assurance of the safety of the project." (Tr 1757) DOE employees commented that DOE possessed the technical capability to review the safety of the proposed project with the same degree of sophistication as the NRC, (Tr 1087) but this appeared unacceptable to the State of New Mexico, whose representative objected that "self-regulation should not be relied upon to protect public health and safety when complex and potentially hazardous technologies are involved." (Tr 1757).

The hearings demonstrated that the issues surrounding the WIPP project are as much political as they are engineering and scientific. The question of NRC licensing clearly raises a political issue. In the view of the Panel it is unlikely that an unstructured internal review process by DOE employees, no matter how competent and impartial, will satisfy the persons calling for NRC licensing. DOE should consider the development of an "independent" board of safety review within DOE with scientific and engineering capability to provide a final review of projects such as WIPP. Similar boards have been created by other agencies to investigate air disasters, naval accidents, nuclear accidents, and other similar events. While the safety issues underlying WIPP are prospective rather than retrospective, the procedures would appear to provide the desired "second opinion." (See generally Tr 1451-53)

II. <u>Should DOE Now Proceed to the Final Environmental Impact Statement?</u>

On several occasions during the recent hearings DOE personnel stated that DOE planned to move promptly to the development of a final environmental impact statement. The State of New Mexico, on the other hand, called on DOE to issue "supplements" to the DEIS on the following broad areas:

(a) Transportation;

(b) Emergency Preparedness; and

(c) Socioeconomics. (Tr 1205-1206)

The statement of the New Mexico representative concludes that "in the event that the DOE is unable to issue supplements on the inadequate portions of the DEIS for timely review prior to the publication of the final EIS, the Governor has stated that he will have to declare the entire DEIS inadequate." (Tr 1753-54)

While the DOE presentations at the hearings may have provided some of the detailed information desired by the State of New Mexico, it is clear that some of the information requested by the State was not presented at the hearing and, indeed, may not currently be in existence. The State requested, for example, a "clear" identification of the proposed routes for shipment of waste materials, procedures for monitoring shipments through the state, and the capability of hospitals to respond to a nuclear accident along those routes. (Tr 1749) However, the identification of specific routes has not been made. (Tr 1302)

One witness argued that the DEIS so far failed to meet the regulations of the Council on Environmental Quality that an entirely new DEIS should be prepared. (Tr 1456) This witness also called attention to a number of minor inconsistencies and errors in the DEIS, which should be reviewed in connection with the preparation of the final EIS.

III. <u>Possible Future Changes in the Scope of the WIPP Project</u>.

At the hearings DOE representatives were questioned about the binding nature of the final EIS and the possibility that the project might be increased in scope or magnitude in the future. (Tr 1493) The Panel was advised that any substantial change would require an amendment to the final EIS. (Tr 1497)

The project is described as involving only contact handled TRU waste from the Idaho National Engineering Laboratory (INEL), plus experimentation relating to the effect of high level waste on salt formations. (DEIS 1-1, Tr 1073-74) However, the DEIS contains numerous references and statements that may be construed as authorizing shipment to and storage at the WIPP site of contact and remote handled TRU waste from numerous other locations, e.g., Hanford, Los Alamos, and Savannah River. (See, e.g., DEIS, 6-8 to 6-12).

The low estimates relating to the traffic generated by WIPP at the hearing are all based on the project being limited to INEL stored TRU waste. Yet, again, the DEIS contains data implying that annual shipments will be made from various locations in addition to INEL. (See e.g., DEIS 6-13). For example, Table 6-4 of the DEIS indicates an annual total of 181 rail and 187 truck shipments from INEL but a total of 338 rail and 487 truck shipments.

IV. The Role of the State of New Mexico in Connection with the Approval of the Project.

At the time of the hearings, representatives of both DOE and the State of New Mexico referred to negotiations that were then taking place relating to the precise definition of "consultation and concurrence," the phrase used by the President's Interagency Review Group to describe the role of States in connection with nuclear waste disposal facilities. (Tr 1074-75, 1756) One witness stated that Congressional sources objected to the concept that "concurrence" amounted to a veto (Tr 1273, 1453); the State of New Mexico, however, testified that "a right of concurrence also implies the right of nonconcurrence." (Tr 1209-10)

Assuming that agreement is reached on the appropriate role of the State of New Mexico, this role should be described in the final EIS. In the event agreement is not reached, the final EIS should at least describe the role DOE is willing for the State of New Mexico to play in the final decisional process.

IV. Transportation of Waste.

The DOE presentation gave considerable emphasis to the various issues relating to the transportation of nuclear waste to the WIPP site for disposal. Several members of the general public as well as the representative of the State of New Mexico also concentrated on issues relating to the transportation of waste. Several different problems were raised:

(a) Objections were made that the DEIS was vague and imprecise. Specific routes are not designated, the packaging in which the waste is to be transported is not described (since it is still under development), (Tr 1217-19) and even the form in which the waste is transported is not identified. (Tr 1172, 1299; DEIS 5-2 to 5-3). While it seems clear that absolute precision as to data is neither required nor desirable, additional information and data should be incorporated into the final EIS to the extent it is available.

(b) The most important observation is that problems related to transportation as presented by DOE witnesses at the hearing gave a picture of a safer and more responsible operation than does the DEIS. (Tr 1310) For example, the consequence analysis assumes and starts with an accident and a leak. (DEIS 6-20) This analysis ignores the extensive engineering that is apparently going into packaging and leak reduction, which appears to reduce significantly the probability of a leak in the event of an accident. The analysis in the DEIS is misleading because it assumes that a leak will occur without indicating the low probability of an accident severe enough to breach the packaging. As a result, transportation dangers appear to be overemphasized by orders of magnitude. (Tr 1519)

The possibility of injuries from excess radioactivity in an accident is a function of several possible variables:

(i) The probability of the occurrence of an accident;

(ii) The probability that the package will be breached in the accident; and

(iii) The probability that the accident will occur in an area in which people may be exposed to radioactivity.

These variables, it was felt, should be more specifically addressed in the transportation section of the DEIS. (See Tr 1521-22)

Even though possibility (ii) described above is a small number because of the design of the packaging, there is always the possibility of human error, e.g., in correctly closing the package. Thus, discussion of the "worst possible" scenarios in the transportation area seems appropriate so long as the plausability of the scenarios are put into perspective. (Tr 1308-10) Indeed, a DEIS that posited no excess radioactivity for every conceivable type of accident might lack credibility with the general public in light of well publicized instances of releases of radioactivity in accidents involving non-defense products.

(c) At the hearing, a number of transportation accidents involving commercial radioactive materials were described. (Tr 1630-32) Many were explained on the ground that applicable regulations were not being followed. (Tr 1498-99, 1518) The DEIS may understate the risks of exposure caused by human error despite the existence of adequate regulations. The DEIS should be reassessed in this regard.

(d) Similarly, the risks of exposure due to terrorism also appear to be understated. Both the DEIS and the DOE presentation give no information with respect to terrorism on the theory that such information may give persons contemplating terrorist acts a "cook-book" (Tr 1100) A question may be raised whether in the long run withholding of such information does more harm than good. (Tr 1524) At the hearing, the possibility of terrorism was minimized on the theory that waste shipments are not attractive targets. (Tr 1100; 1294-95, 1515) No documentation to support this theory was set forth.

(e) Information in the DEIS about increases in traffic are related to traffic in the entire State of New Mexico on the theory that routes will be selected by commercial carriers. This obviously understates the impact of the WIPP project on specific routes to the extent those routes are actually to be used by many or all WIPP-bound vehicles. More precise information about impact on specific routes should be provided where feasible. (Tr 1302-1303)

(f) Consideration should also be given to possible benefits and costs of DOE transport, convoys, or escorts. (Tr 1297-99)

V. Geology and Hydrology. (The comments in this section are principally though not exclusively those of Dr. Remson).

(a) Good practice requires aquifer-wide hydrological analysis and consideration of all formations rather than analysis of a small area. (Tr 1329) It appears that the DEIS modeled only a portion of the aquifer which was done before the hydrologic investigation was complete. (Tr 1331) These facts make one wonder how and where boundary conditions were set on the models. Apparently the hydrological modeling did not consider natural aquifer extensions into Texas either. (See DEIS, § 7.3) As a result, it is difficult to see how conclusions expressed at this hearing relating to scenarios involving a radioactive leak into an aquifer and the effects of aquifer depletions in Texas can be justified. (Tr 1329-30) Furthermore, the possible failure to delineate the boundary conditions accurately raises a question as to the validity of the entire modeling effort. (Tr 1329) A broader regional analysis should be undertaken to include a description of systems hydrologically connected with the WIPP site, including the Pecos River and aquifers that receive recharge from the Pecos River. (Tr 1232)

(b) In connection with the hydrology study the need for additional wells for ground water samples was emphasized. It was pointed out that wells downgradient from the disposal site are more than a mile apart. It was also suggested that the frequency of sampling be increased from a quarterly to a monthly schedule. (Tr 1233)

(c) Questions were raised at the hearing about the shallow-dissolution zone. (Tr 1135) The DEIS is confusing in this regard. Figure 7-25 shows the shallow dissolution to the west of the site while Figure 7-27 shows the Rustler thinning, presumably due to dissolution under the site. Conceivably the ambiguity arises from the definition of "shallow dissolution" which may refer either to "near surface dissolution" or to all dissolution above the Salado Formation.

An experienced geologist testified that he believed the thinning of the Salado salt section was due more to offlap than to dissolution. (Tr 1405, 1409) The DOE contractor gave similar testimony which disagrees with a study by Anderson. (Tr 1410-11, 1414) This issue should be clarified in the DEIS.

(d) One witness refers to a "dome" under the site. (Tr 1189). This possibility should be referred to (or negated) in the final EIS.

(e) It appears to be desirable to drill out some of the "dissolution pipes" south of the site. (See Tr 1415)

(f) One experienced geologist proposed that the questions relating to subsurface conditions should be reviewed by an independent panel of geologists. (Tr 1732-3)

(g) The use of groundwater for various purposes (domestic, livestock, etc.) from the Rustler and Santa Rosa aquafers between the site and the Pecos River should be tabulated. (Tr 1231)

(h) The groundwater monitoring program (DEIS, App. J) should be broadened to include chemical analysis of groundwater for dissolved solids such as sodium chloride as well as radionuclides in order to evaluate the effect of WIPP construction on water quality. (Tr 1232-33)

(i) The DEIS should describe measures that will be taken if significant radionuclide contamination of groundwater actually occurs. (Tr 1233)

VI. Socioeconomic Information.

While additional socioeconomic information was presented at the hearing, (Tr 1582-90) additional information was requested in several other areas:

(a) The socioeconomic indicators such as probable effects on crime, divorce, alcoholism, drug abuse, child abuse, and other "boom town effects." (Tr 1183, 1185, 1615)

(b) Energy requirements, e.g., for gasoline and electricity. (Tr 1384)

(c) Quantities of household, sanitary, solid and municipal waste, both primary and secondarily generated, by type and source. (Tr 1382)

(d) Additional state and local fiscal information on added revenues and added costs, by time periods, with the number of unemplyed persons specified. (Tr 1380-81)

VII. Damage to Health by Low Level Radiation.

The Panel recognizes that there is lively scientific controversy over the long-term effects of low level radiation. (Tr 1355) However, a comparison of energy levels between nuclear waste and electric light bulbs seems both irrelevant and self-serving. (Tr 1356) Indeed the public interest and concern about this ussue is so great that any attemped justification of low levels of radiation by a representative of a contractor who may actually operate the project if it is approved is likely to be considered not credible because of a potential conflict of interest. (Tr 1361-62)

(b) The DEIS does not discuss health effects as such but consistently uses doses of radiation as an index of hazard. Such dose related data should be translated into anticipated health effects such as the total number of incremental cancers, person days lost, hospital days, and shortening of life. (Tr 1152-53) The Panel recognizes that such estimates are ranges rather than precise data but suggests that they give a clearer perspective as to the effect of exposure to radiation. (Tr 1154)

(c) Dose related data impacts should be separately estimated, where possible, for high risk groups such as children and pregnant women.

(d) The practice in the DEIS of describing exposure to radiation as a percentage of background, while technically accurate and generally accepted, tends to mask the harmful effect of exposure, which, of course, is in addition to natural background radiation that will be absorbed in any event. (Tr 1554)

(e) The DEIS describes exposures from a variety of different sources, e.g., from transportation and from emplacement of the waste in WIPP. Nowhere is there an aggregation of total exposure of the US population to radiation as a result of the contemplated construction and operation of the WIPP project and the number of health consequences of such exposure. (Tr 1156-57)

(f) The Panel believes that if the credibility of additional information in this area is to be improved, it may be appropriate to have additional studies prepared by respected and competent persons or organizations who are not otherwise connected with the WIPP project.

VIII. The Nature of the High Level Waste Experiments.

The DEIS describes the high level waste experiments only in very general terms. While some additional information about the nature of the experiments and the amount of radioactivity involved was presented at the hearing (Tr 1076, 1495, 1552, 1760-2), additional information about these experiments should be presented in the EIS to the extent feasible. (Tr 1203-1205)

IX. Compensation to Adversely-Affected Persons.

Dr. John Cumberland, a member of the Panel, was particularly concerned about comments that residents of New Mexico were being asked to share an unreasonable portion of the cost of nuclear waste. He raised with several witnesses the question whether compensation might help to alleviate that imbalance. (Tr 1400, 1538, 1684) This suggestion is broader in scope than nuclear waste management since it would be potentially applicable to many projects having adverse environmental consequences, and probably would require enabling legislation. However. the idea has merit. A fuller statement by Dr. Cumberland explaining his suggestion follows:

"THE POTENTIAL CONTRIBUTION OF ECONOMIC INCENTIVES

"One of the major opportunities which has been missed in the

WIPP proposal is to make use of the helpful role which financial incentives could play in achieving a more equitable and efficient distribution of benefits and costs of nuclear waste disposal. A major concern in proposals for large governmental and other projects is the discrepancy between the benefits and costs as between individuals, groups, locations, and generations. Presumably, the entire nation benefits from nuclear weapons (although many would dispute this). What is clear is that the costs are very unequally distributed. In this case, residents of New Mexico are being asked to bear the heaviest burdens as would others along the transportation routes. Therefore, providing financial assistance to those who wanted to move could offer a more equitable distribution of the costs. While most parties would probably reject the concept of a "national sacrifice area," even low levels of risk cause perceived damages which, are true psychological and therefore real social costs, above and beyond any real actuarial risk. While many at the hearings totally rejected the idea of economic assistance for moving, or other forms of financial compensation on the basis that residential preference is an entirely different matter from economic compensation, (Tr 1684) others indicated that for some who are highly risk averse and would like to move, offering relocation assistance would open a new option not previously available. (Tr 1400-1401) This option could be especially valuable to pregnant women and children who might bear a disproportionate amount of risk.

"Providing such relocation assistance need not be especially costly to the government if aid were limited to fair market value of residences and some reasonable amount of relocation and retraining aid with appropriate limitations. This would be an efficient solution, since less risk averse persons could then be offered an opportunity to purchase affected residences and move into any vacated jobs. The fair market value should be determined before the institution of WIPP, as adjusted for inflation.

"Another dimension of equity in sharing the benefits and costs would be to compensate the State of New Mexico for tax revenues lost on minerals at the site. Offers could also be made to provide alternative water supplies for any whose water was contaminated and/or to provide land purchase and relocation for those engaged in agriculture, commerce, or industry which would be adversely affected by WIPP.

"Additional economic instruments should be considered in the case of health and property damage to those who remain as a result of accidents or other types of exposure. The Department of Energy and the Federal Government should address several aspects of this problem which currently are unclear, such as: would the existence of workman's compensation laws prevent adequate compensation to any injured or damaged? If so, alternative adequate compensation should be established. Additionally, a long carcinogenic lag might prevent compensation to those whose health damage was not apparent for many years. In the interest of fairness, appearance of radiation-related types of health damage should be presumed to result from the WIPP project, even if it could not be statistically or medically proven.

"Establishment of these forms of compensation and aid would not satisfy all of those who object to potential damage to their health, property, and land, but it might reduce the perceived level of injustice and recurring discrepancy between the benefits and costs of major nuclear and even other energy facilities and large projects which people now view as beyond their control."

X. Miscellaneous.

During the course of the hearings a number of miscellaneous suggestions and recommendations were made on a variety of subjects, including the following:

(a) Emphasis should be given to the objective of proceeding with waste disposal "by deliberate steps in a technically conservative manner." (Tr 1233-34)

(b) A continuing reassessment of plans for the disposal of transuranic waste at the WIPP site should be undertaken, particularly with respect to other disposal sites. If other sites are shown to provide equally safe storage for this kind of waste, it was suggested, the advantages of reduced quantities of waste storage at a single site should be carefully considered. (Tr 1234) In a similar vein, several persons suggested that the WIPP project should be deferred until other sites are investigated, (Tr 1427) though it was also pointed out that the question is whether this site is suitable, not whether it is the best possible site. (Tr 1077) It was pointed out that with the elimination of spent fuel assemblies, the urgency behind the project has decreased. (Tr 1207) However, the Panel also wishes to point out that earlier hearings revealed that the wastes are currently stored in areas that overlie important aquifers in Idaho, and therefore their present location is not suitable.

(c) Section 7.2.6 of the DEIS should be expanded to describe the effect maximum accelerations caused by seismic effects might have on the stability of the waste-storage area, the retreivability of stored waste, and the potential for liquid breach of the site. If no such effects are likely, the EIS should so state. (Tr 1231)

(d) The DEIS is internally inconsistent since it states that groundwater from the Santa Rosa and Rustler is used only for livestock and potash mining. (Section 7.3.2) but later states that water is used for human consumption at the James ranch (DEIS, J-28). (Tr 1231) This minor inconsistency should be corrected.

(e) It was suggested that analysis of the four scenarios involving breach of the WIPP site by water should be broadened by estimating the effects of a breach immediately following site closure (as well as the 100 year and 1000 year assumptions). (Tr 1232)

(f) One witness pointed out an inconsistency in the DEIS treatment of endangered species, stating in one place that there were no endangered species known to inhabit the site but referring to endangered species at another place. (Tr 1462-63)

(g) While the hearing produced some information about the availability of insurance for accident or injury, (Tr 1292-94, 1096-99) it was suggested that the EIS should contain information about the location of liability (as among the Federal Government, commercial operators and commercial transportation facilities) (Tr 1208, 1362) for such events. The possible effects of workmen's compensation and the Price-Anderson Act should also be discussed. (Tr 1362-63)