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Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington

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Cooperating Agency: Washington State Department of Ecology (Ecology)

Title: *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (*TC & WM EIS*) (DOE/EIS-0391)

Location: Benton County, Washington

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Abstract: The Hanford Site (Hanford), located in southeastern Washington State and situated along the Columbia River, is approximately 1,518 square kilometers (586 square miles) in size. Hanford's mission from the early 1940s to approximately 1989 included defense-related nuclear research, development, and weapons production activities. These activities created a wide variety of chemical and radioactive wastes. Hanford's mission now is focused on the cleanup of those wastes and ultimate closure of Hanford. To this end, several types of radioactive waste are being managed at Hanford: (1) high-level radioactive waste (HLW) as defined in DOE Manual 435.1-1; (2) transuranic (TRU) waste, which is waste containing alpha-particle-emitting radionuclides with atomic numbers greater than uranium (92) and half-lives greater than 20 years in concentrations greater than 100 nanocuries per gram of waste; (3) low-level radioactive waste (LLW), which is radioactive waste that is neither HLW nor TRU waste; and (4) mixed low-level radioactive waste (MLLW), which is LLW containing hazardous constituents as defined under the Resource Conservation and Recovery Act of 1976 (42 U.S.C 6901 et seq.). Thus, this *TC & WM EIS* analyzes the following three key areas:

1. **Retrieval, treatment, and disposal of waste from 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs) and closure of the SST system.** In this *TC & WM EIS,* DOE proposes to retrieve and treat waste from 177 underground tanks and ancillary equipment and dispose of this waste in compliance with applicable regulatory requirements. At present, DOE is constructing a Waste Treatment Plant (WTP) in the 200-East Area of Hanford. The WTP would separate waste stored in Hanford's underground tanks into HLW and low-activity waste (LAW) fractions. HLW would be treated in the WTP and stored at Hanford until disposition decisions are made and implemented. (The analyses in this EIS are not affected by recent DOE plans to study alternatives for the disposition of the Nation's spent nuclear fuel and HLW because the EIS analysis shows that vitrified HLW can be stored safely at Hanford for many years.) LAW would

be treated in the WTP and disposed of at Hanford as decided in DOE's Record of Decision (ROD) issued in 1997 (62 FR 8693), pursuant to the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE/EIS-0189, August 1996). DOE proposes to provide additional treatment capacity for the tank LAW that can supplement the planned WTP capacity in fulfillment of DOE's obligations under the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) as soon as possible. DOE would dispose of immobilized LAW and Hanford's (and other DOE sites') LLW and MLLW in lined trenches on site. These trenches would be closed in accordance with applicable regulatory requirements.

2. **Final decontamination and decommissioning of the Fast Flux Test Facility, a nuclear test reactor.** DOE proposes to determine the final end state for the aboveground, belowground, and ancillary support structures.

3. **Disposal of Hanford's waste and other DOE sites' LLW and MLLW.** DOE needs to decide where to locate onsite disposal facilities for Hanford's waste and other DOE sites' LLW and MLLW. DOE committed in the ROD (69 FR 39449) for the *Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington* (DOE/EIS-0286F, January 2004) that henceforth LLW would be disposed of in lined trenches. Specifically, DOE proposes to dispose of the waste in either the existing 200-East Area Integrated Disposal Facility (IDF) or the proposed 200-West Area IDF.

DOE has identified Preferred Alternatives for two of the three program areas and a range for the three key activities, as presented in this *TC & WM EIS*.

Public Comments: Comments on this draft EIS may be submitted during the 140-day comment period, which will begin when the U.S. Environmental Protection Agency publishes a Notice of Availability in the *Federal Register*. Public meetings on this EIS will be held during the comment period. The dates, times, and locations of these meetings will be published in a DOE *Federal Register* notice, and will also be announced by other means.

Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (Draft TC & WM EIS)

Washington State Department of Ecology (Ecology) Foreword

Note: Ecology, as a cooperating agency, reviewed, provided comments on, and participated in the comment resolution process for the "preliminary draft" of this *Draft TC & WM EIS*. However, this foreword should be considered draft and subject to revision until Ecology has reviewed this *Draft TC & WM EIS* and, if necessary, supporting information.

Summary

Ecology believes that the U.S. Department of Energy (DOE) and its contractors have prepared a *Draft TC & WM EIS* that presents many important issues for discussion. Ecology's involvement to date shows that this document has benefitted from quality reviews and quality assurance procedures. The information in this document will help shed light on many key decisions that remain to be made about the Hanford Site (Hanford) cleanup.

Ecology expects DOE to consider our input through this foreword, as well as through any further comments made during the public comment process. We expect DOE to provide written responses to the major issues and comments prior to completion of the *Final TC & WM EIS*. Ecology will continue to work with DOE with the intent of helping to produce a final environmental impact statement (EIS) that fully informs future decisionmaking.

I. Introduction

Ecology has been a cooperating agency with DOE in the production of this *Draft TC & WM EIS*. DOE prepared this EIS to meet the requirements of the National Environmental Policy Act. In addition, Ecology will review this EIS to determine if it can be adopted in whole or in part to satisfy the requirements of the State Environmental Policy Act (SEPA). The information in this EIS will help inform Ecology and others about critical future cleanup decisions impacting Hanford's closure.

Ecology provides the following comments regarding this *Draft TC & WM EIS* to document areas of agreement or concern with this EIS and to assist the public in their review. Public and regulator input on this *Draft TC & WM EIS* are critical for the completion of an acceptable *Final TC & WM EIS*. Ecology encourages tribal nations, stakeholder groups, and the public to participate in the public comment process for this draft document.

When the *Final TC & WM EIS* is issued, Ecology will include a revised foreword to comment on the EIS conclusions. The foreword will also include the disposition of the comments we provided during the *Draft TC & WM EIS* review process.

II. Ecology's Role as a Cooperating Agency

Ecology is a cooperating agency in the preparation of this EIS. A state agency may be a cooperating agency on a Federal EIS when the agency has jurisdiction by law over, or specialized expertise concerning, a major Federal action under evaluation in the EIS.

As a cooperating agency, Ecology does not coauthor or direct the production of this EIS. Ecology does have access to certain data and information as this document is being prepared by DOE and its contractors. Our roles and responsibilities in this process are defined in a Memorandum of Understanding (MOU) between Ecology and DOE.

DOE retains responsibility for making final decisions in the preparation of the *Final TC & WM EIS*, as well as for determining the preferred alternative(s) presented in the EIS. However, Ecology's participation as a cooperating agency enables us to help formulate the alternatives presented in this *TC & WM EIS*.

Ecology's involvement as a cooperating agency—and the current scope of the *Draft TC & WM EIS*—is grounded in a series of events.

In February 2002, DOE initiated the "Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington," known as the "Tank Closure EIS." On March 25, 2003, Ecology became a cooperating agency for the "Tank Closure EIS." DOE and Ecology developed an MOU outlining respective agency roles and responsibilities.

While the "Tank Closure EIS" was being developed, another DOE EIS, the *Draft Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington (HSW EIS)*, was in the review stage. Among other matters, the HSW EIS examined the impacts of disposal at Hanford of certain volumes of radioactive waste and mixed radioactive and hazardous waste, including waste generated from beyond Hanford.

In March 2003, Ecology filed a lawsuit in the U.S. District Court seeking to prevent the importation and storage of certain offsite transuranic (TRU) and mixed TRU wastes that DOE had decided to send to Hanford prior to issuance of the *Final HSW EIS*. Ecology and intervening plaintiffs obtained a preliminary injunction against these shipments.

In January 2004, DOE issued the *Final HSW EIS*. Based on the *Final HSW EIS*, DOE amended a Record of Decision that directed offsite radioactive and hazardous wastes to Hanford (within certain volume limits) for disposal and/or storage. In response, Ecology amended its lawsuit to challenge the adequacy of the *HSW EIS* analysis.

In May 2005, the U.S. District Court expanded the existing preliminary injunction to enjoin a broader class of waste and to grant Ecology a discovery period to further explore issues with the *HSW EIS*.

In January 2006, DOE and Ecology signed a Settlement Agreement, ending litigation on the *HSW EIS* and addressing concerns found in the *HSW EIS* quality assurance review during the discovery period. The Settlement Agreement called for expanding the scope of the "Tank Closure EIS" to provide a single, integrated set of analyses of (1) tank closure impacts considered in the "Tank Closure EIS" and (2) the disposal of all waste types considered in the *Final HSW EIS*. The Settlement Agreement also called for an integrated cumulative impacts analysis.

Under the Settlement Agreement, the "Tank Closure EIS" was renamed the *TC & WM EIS*. Ecology's existing MOU with DOE was revised along with the Settlement Agreement so that Ecology remained a cooperating agency on the expanded *TC & WM EIS*.

The Settlement Agreement defined specific tasks to address concerns Ecology had with the *HSW EIS*. DOE has now revised information and implemented quality assurance measures used in this *TC & WM EIS* related to the solid waste portion of the analysis. Ecology has performed discrete quality

assurance reviews of that information to help confirm that the quality assurance processes of DOE's EIS contractor have been followed.

Based on Ecology's involvement to date, we believe that positive changes have been made to address data quality shortcomings in the *HSW EIS*. These specifically relate to the following:

- The data used in analyzing impacts on groundwater
- The integration of analyses of all waste types that DOE may dispose of at Hanford
- The adequacy of the cumulative impact analysis

Ecology will review this *Draft TC & WM EIS* to confirm that the terms of the Settlement Agreement have been addressed to our satisfaction.

III. Regulatory Relationships and SEPA

After this *TC & WM EIS* is finalized, Ecology will proceed with approving regulatory actions required to complete the Hanford cleanup. These include actions under the Hanford Federal Facility Agreement and Consent Order (HFFACO, or Tri-Party Agreement) and actions that require state permits or modifications to existing permits, such as the Hanford Sitewide Permit. This permit regulates hazardous waste treatment, storage, and disposal activity at Hanford, including actions such as tank closure and supplemental treatment for tank waste.

Ecology must comply with SEPA when undertaking permitting actions. It is Ecology's hope that the *Final TC & WM EIS* will be suitable for adoption in whole or in part to satisfy SEPA.

In addition, Ecology will have a substantial role in establishing standards and methods for the cleanup of contaminated soil and groundwater at Hanford. These include areas that are regulated under hazardous waste corrective action authority and/or under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) through a CERCLA Record of Decision. Information developed in this EIS will thus be useful in other applications for the cleanup of Hanford.

IV. Ecology Insights and Alternatives Considered

This *Draft TC & WM EIS* considers 17 alternatives. DOE has not identified a specific preferred alternative. However, for the many decisions that are addressed in this EIS, DOE has selected a set of preferred alternatives. Ecology understands that the selection of a smaller number of preferred alternatives, or of a specific preferred alternative from that set, will be considered by DOE throughout public review of the *Draft TC & WM EIS*. When the final EIS is prepared, a preferred alternative will be identified by DOE.

The alternatives and tank closure options considered in this draft EIS include the following key decision areas:

- Additional tank waste treatment options (in addition to the Hanford Waste Treatment Plant [WTP] as provided in the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement)*
- Tank farm closure options
- Waste management options for the Central Plateau (including disposal of offsite defense wastes)
- Fast Flux Test Facility (FFTF) decommissioning

Ecology will update this foreword in the *Final TC & WM EIS* and will express its agreement or disagreement with DOE's preferred alternative for specific decisions in the foreword. In the interim, Ecology's insights, technical perspectives, and legal and policy perspectives are provided below. Areas of agreement with DOE and points of concern are noted.

Single-Shell Tank Retrieval Options

Ecology believes that DOE has presented an appropriate range of alternatives for evaluating tank waste retrieval and tank closure impacts. However, based on the hazardous waste tank closure standards of the "Dangerous Waste Regulations" (WAC 173-303-610[2]) and the HFFACO requirements, Ecology supports only alternatives that involve the retrieval of 99 percent or more of the waste from each of the 149 single-shell tanks (SSTs).

High-Level Radioactive Waste Disposal

High-level radioactive waste (HLW) associated with the tank waste includes, but may not be limited to, immobilized high-level radioactive waste (IHLW) and HLW melters (both spent and failed). It has been DOE's longstanding plan to store these wastes at Hanford and then ship and dispose of them in a deep geologic repository. The idea was that the nature of the geology would isolate the waste and protect humans from exposure to these very long-lived, lethal radionuclides. The Nuclear Waste Policy Act indicates that these waste streams require permanent isolation. By contrast, the immobilized low-activity waste (ILAW) glass, and perhaps other waste streams, may not require deep geologic disposal due to the level of pretreatment resulting in radionuclide removal and the degree of immobilization provided for in the ILAW glass.

However, the final decision on HLW disposal has recently become an issue with significant uncertainty. The *Draft TC & WM EIS* contains the following statement:

> As indicated in the Administration's fiscal year 2010 budget request, the Administration intends to terminate the Yucca Mountain program while developing nuclear waste disposal alternatives. Notwithstanding the decision to terminate the Yucca Mountain program, DOE remains committed to meeting its obligations to manage and ultimately dispose of HLW and SNF. The Administration intends to convene a blue ribbon commission to evaluate alternative approaches for meeting these obligations. The commission will provide the opportunity for a meaningful dialogue on how best to address this challenging issue and will provide recommendations that will form the basis for working with Congress to revise the statutory framework for managing and disposing of HLW and SNF.

Ecology reminds the readers that the Nuclear Waste Policy Act requires permanent isolation of these most difficult waste streams. Leaving these wastes stored at Hanford indefinitely is not a legal option, nor an acceptable option to the State of Washington.

Ecology is concerned about the glass standards and canister requirements for the IHLW. These standards were developed based on what was acceptable to Yucca Mountain. Now that Yucca Mountain is no longer the assumed disposal location, Ecology is concerned about what standards for glass and canisters will be utilized by the WTP. Ecology insists that DOE implement the most conservative approach in these two areas to guarantee that the glass and canister configurations adopted at the WTP will be acceptable at the future deep geologic repository.

In addition, Ecology maintains that DOE should build and operate adequate interim storage capacity for the IHLW and the HLW melters in a manner that does not slow down the treatment of tank waste.

This *Draft TC & WM EIS* assumes that the used (both spent and failed) HLW melters are HLW and, therefore, should be disposed of in a deep geologic repository. This EIS also assumes that the used HLW melters will stay on site before shipment to such a repository. DOE has not requested, and Ecology has not accepted, long-term interim storage of failed or spent HLW melters at Hanford.

Ecology does not agree that the HLW melters will or should stay on site. We do agree with the final disposal in a deep geologic repository. The disposal pathway for both the failed and the spent melters will require further evaluation than is presented in this *Draft TC & WM EIS*. Ecology and DOE will need to reach a mutual understanding and agreement on the regulatory framework for disposal.

Pretreatment of Tank Waste

This *Draft TC & WM EIS* includes numerous alternatives that pretreat tank waste to separate the high-activity components and direct them to a HLW stream. The HLW stream will be vitrified, resulting in a glass waste product that will be sent to a deep geologic repository. However, this draft EIS has one alternative that provides no pretreatment for some portion of the waste in the 200-West Area.

As a legal and policy issue, Ecology does not agree with alternatives that do not require pretreatment of the tank waste. Such alternatives do not meet the intent of the Nuclear Waste Policy Act to remove as many of the fission products and radionuclides as possible to concentrate them in the HLW stream. For this reason, Ecology requests that DOE rule out any alternative that does not pretreat tank waste.

TRU Tank Waste

This *Draft TC & WM EIS* considers the option of treating and sending waste from specific tanks to the Waste Isolation Pilot Plant (WIPP) as mixed TRU waste. This draft EIS also considers WTP processing of the waste from these specific tanks.

Ecology has legal and technical concerns with any tank waste being classified as mixed TRU waste at this time. DOE must provide peer-reviewed data and a strong, defensible, technically and legally detailed justification for the designation of any tank waste as mixed TRU waste, rather than as HLW. DOE must also complete the WIPP certification process and assure Ecology that there is a viable disposal pathway (i.e., permit approval from the State of New Mexico) before Ecology will modify the Hanford Sitewide Permit to allow tank waste to be treated as mixed TRU waste.

Supplemental Treatment

In this *Draft TC & WM EIS*, DOE considers changes to the treatment processes that the WTP would use. Specifically, this draft EIS considers technologies to supplement the WTP's treatment of low-activity waste (LAW). The WTP as it is currently designed does not have the capacity to treat the entire volume of LAW in a reasonable timeframe.

Ecology agrees on the need to evaluate supplemental LAW treatment. An additional supplemental LAW treatment system is necessary to treat all the tank waste in a reasonable amount of time. Ecology fully supports the *Draft TC & WM EIS* alternative that assumes a second LAW Vitrification Facility would provide additional waste processing. Building a second LAW Vitrification Facility has consistently been Ecology's baseline approach. We would prefer a second LAW Vitrification Facility as the preferred alternative for the following reasons:

- LAW vitrification is a mature technology that is ready to be implemented with no further testing.
- LAW vitrification produces a well-understood waste form that is extremely protective of the environment (the bulk vitrification waste form is not as protective).

- Negative data from the last bulk vitrification experimental testing indicate waste form performance and technology implementation issues.
- There has been a lack of significant progress on advancing a bulk vitrification test facility for actual waste.
- The environmental results from the waste performance presented in this *Draft TC & WM EIS* indicate that LAW vitrification is superior to bulk vitrification.
- A recently published DOE report indicates that a second LAW Vitrification Facility would be preferable.

Consistent with the standard of HFFACO Milestone M-62-08, Ecology will analyze the information from the bulk vitrification alternative. From this analysis, Ecology will determine if the performance of the waste forms is comparable with WTP borosilicate glass. Ecology's measuring stick for a successful supplemental treatment technology has always been whether it is "as good as glass" (from the WTP).

As a technical issue, Ecology does not think that the waste treatment processes of steam reforming and cast stone would provide adequate primary waste forms for disposal of tank waste in onsite landfills. This has already been the subject of a previous DOE down-select process, in which Ecology and other participants rated these treatment technologies as low. This draft EIS shows that the waste form performance would be inadequate for both cast stone and steam reforming. These alternatives do not merit any further review.

Specifically related to the steam reforming alternative, Ecology has technical concerns about the *Draft TC & WM EIS's* assumptions for contaminant partitioning and its effects on waste form performance. It is inappropriate to assign the same assumptions to steam reforming as those used for bulk vitrification, given the different maturities of the two technologies.

Secondary Waste from Tank Waste Treatment

This *Draft TC & WM EIS* evaluates the impacts of disposing of secondary waste that results from tank waste treatment. Ecology agrees with DOE that secondary waste from the WTP and supplemental treatment operations would need additional mitigation before disposal. This assumption is not reflected in (and, in fact, is contradicted by) the current DOE baseline, which does not assume such additional mitigation. DOE has not determined what the secondary waste treatment would be, but DOE and its contractor are evaluating various treatment options.

Tank Waste Treatment Flowsheet

In preparing this *Draft TC & WM EIS*, some assumptions were made about highly technical issues such as the tank waste treatment flowsheet, which is a representation of how much of which constituent ends up in which waste form and in what amount.

Certain constituents such as technetium-99 and iodine-129 are significant risk drivers because they are mobile in the environment and have long half-lives. This draft EIS assumes that 20 percent of the iodine-129 from the tank waste would end up in vitrified glass and 80 percent in the grouted secondary waste. The same assumption is made for bulk vitrification and the WTP LAW Vitrification Facility.

Based on its review of the *Draft TC & WM EIS's* contaminant flowsheets for the WTP and bulk vitrification, Ecology has technical concerns with this approach. The design configuration for the WTP indicates that iodine-129 recycles past the melter multiple times, which leads to a higher retention in the glass and less in the secondary waste. Therefore, Ecology believes the retention rate of iodine-129 in the

ILAW glass may be higher than that in bulk vitrification glass. However, Ecology is aware that there is uncertainty in the actual glass retention results.

Through our cooperating agency interactions, DOE has agreed to run a sensitivity analysis to show the information under a different approach. The sensitivity analysis in this *Draft TC & WM EIS* shows that if recycling of iodine-129 is as effective as the WTP flowsheets indicate, then the WTP with a Bulk Vitrification Facility alternative would place 80 percent of iodine-129 in secondary waste (a less-robust waste form). This compares to an alternative that includes a second LAW Vitrification Facility in addition to the WTP, which would place 30 percent of the iodine-129 in secondary waste. This 50 percent difference in capture reinforces Ecology's opinion that choosing Tank Closure Alternative 2B, which would use the WTP and a second LAW Vitrification Facility, would be best from a tank waste treatment perspective.

Waste Release

This *Draft TC & WM EIS* models waste releases from several different types of final waste forms, including the following:

- ILAW glass
- Failed and spent LAW melters
- Waste in bulk vitrification boxes
- Steam reformed waste
- Grouted LAW from tank waste
- Grouted secondary waste
- Waste left in waste sites
- Grouted waste in the bottom of tanks
- Direct buried waste in landfills
- Waste that has been macroencapsulated

Ecology understands the methods and formulas used for the waste form release calculations (for all waste types). However, we will need to see the modeling results and complete our technical review before we can validate this portion of this EIS.

Offsite Waste

DOE is decades behind its legal schedule in retrieving tank waste from SSTs and years behind its legal schedule in completing construction of the WTP. DOE has not even begun treating Hanford's 200 million liters (53 million gallons) of tank waste.

At its current pace, DOE is in danger of falling years behind its legal schedule in processing contact-handled TRU waste for disposal at WIPP. DOE has not yet even completed planning for a facility to process remote-handled TRU waste for such disposal. Massive areas of Hanford's soil and groundwater are contaminated, and many of these areas will likely remain contaminated for generations to come, even after final cleanup remedies have been instituted.

The State of Washington is aware that under DOE's plans, more curies of radioactivity would leave Hanford (in the form of vitrified HLW and processed TRU waste) than would be added to Hanford through proposed offsite waste disposal. However, based on the current state of Hanford's cleanup and the analysis in this *Draft TC & WM EIS*, the State of Washington objects to the disposal at Hanford of additional wastes that have been generated from beyond Hanford.

As this *Draft TC & WM EIS* shows, disposal of the proposed offsite waste would significantly increase groundwater impacts to beyond acceptable levels. Such disposal would add to the risk term at Hanford today, at a time when progress on reducing the bulk of Hanford's existing risk term has yet to be realized. DOE should take a conservative approach to ensure that the impact of proposed offsite waste disposal,

when added to other existing Hanford risks, does not result in exceeding the "reasonable expectation" standard of DOE's own performance objectives (see DOE Manual 435.1-1, Section IV.P[1]) and of other environmental standards (e.g., drinking water standards).

The State of Washington supports a "no offsite waste disposal" alternative as its preferred alternative in the *Final TC & WM EIS*, to be adopted in a Record of Decision. DOE should forgo offsite waste disposal at Hanford (subject to the exceptions in the current *State of Washington v. Bodman* Settlement Agreement), at least until such time as it has made significant progress on SST waste retrieval and the tank waste treatment process. If DOE wishes to use Hanford as an offsite waste repository after that point, DOE should then re-evaluate the potential impacts of any proposed offsite waste disposal in light of the then-existing Hanford risk term.

Waste Disposal Location Alternatives

Ecology agrees with DOE that a preferred alternative locating the Integrated Disposal Facility in the 200-East Area appears better for long-term disposal of waste than in the 200-West Area because of the faster rate of groundwater flow in the 200-East Area.

Black Rock Reservoir

This *Draft TC & WM EIS* considers the groundwater impacts of locating Black Rock Reservoir upgradient of Hanford. This is noteworthy because leakage associated with the reservoir could have impacts on Hanford groundwater contamination. Ecology has reviewed the evaluation basis assumed in this draft EIS. On a technical basis, Ecology accepts that potential groundwater impacts of the proposed reservoir could (or likely would) adversely impact human health and the environment at Hanford.

Vadose Zone Modeling

This *Draft TC & WM EIS* uses the STOMP [Subsurface Transport Over Multiple Phases] modeling code for vadose zone modeling. Based on its current review, Ecology believes that the Hanford parameters used with this code are adequate for the purposes served by this EIS. Ecology notes that the *TC & WM EIS* STOMP modeling code parameters are based on a regional scale and may not be appropriate for site-specific closure decisions or other Hanford assessments. Use of STOMP in other assessments requires careful technical review and consideration of site-specific parameters. Further revisions of these STOMP parameters may be necessary.

Risk Assessment and Cumulative Impacts

This *Draft TC & WM EIS* evaluates risk under the alternatives and in the cumulative impact analyses. The risk assessment modeling presented in this draft EIS should not be interpreted as a Hanford sitewide comprehensive human health and ecological risk assessment, applied to the river corridor or other specific Hanford areas. Specific Hanford areas will require unique site parameters that are applicable to that area's specific use.

This *Draft TC & WM EIS* presents an evaluation of the cumulative environmental impacts of treatment and disposal of wastes at Hanford. The cumulative impact analyses allow DOE to consider the impacts of all cleanup actions it has taken or plans to take at Hanford.

V. Noteworthy Areas of Agreement

Ecology and DOE have discussed and reached agreement on the following significant issues and parameters for the purposes of this *Draft TC & WM EIS*:

- The manner in which DOE presents groundwater data and information (i.e. with pictures).

- The quality assurance requirements that DOE and Ecology identified in the *HSW EIS* (*State of Washington v. Bodman*) Settlement Agreement
- The Technical Guidance Document for *Tank Closure Environmental Impact Statement Vadose Zone and Groundwater Revised Analyses* Agreement, which focused on parameters shown to be important in groundwater analysis
- The location of calculation points for contaminant concentrations in groundwater
- The use of tank farm closure descriptions and alternative analysis
- The use of tank waste treatment descriptions and alternative analysis
- Inclusion of the US Ecology site and the cocooned reactors transported to the Central Plateau in the comprehensive cumulative impacts assessment
- Overall modeling approaches for vadose zone and groundwater
- The use of modeling assumptions for the double-shell tanks
- Alternative assumptions about how processes would treat existing wastes and generate other wastes during treatment processes, and how DOE would dispose of all of the wastes.
- The methods for evaluating and using waste inventory data
- Release mechanisms for contaminants from various waste forms
- An alternative in this *Draft TC & WM EIS* that evaluates impacts of treating and disposal of all tank waste and residue to meet the Resource Conservation and Recovery Act / Hazardous Waste Management Act HLW treatment standard of vitrification
- The inventory assumptions used for the pre-1970 burial grounds

Ecology's agreement on these issues and parameters is specifically for the purposes of this *Draft TC & WM EIS* and is based on Ecology's current knowledge and best professional judgment. Ecology's agreement should not be construed as applicable to any future documents, evaluations, or decisions at Hanford.

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List of Acronyms and Abbreviations

°C	degree(s) Celsius
°F	degree(s) Fahrenheit
AADT	annual average daily traffic
AEA	Atomic Energy Act of 1954
AEGL	Acute Exposure Guideline Level
ALARA	as low as is reasonably achievable
AMWTP	Advanced Mixed Waste Treatment Project
ANL-W	Argonne National Laboratory-West
ATR	Advanced Test Reactor
BLM	U.S. Bureau of Land Management
BRMaP	*Hanford Site Biological Resources Management Plan*
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CH	contact-handled
CH-TRU	contact-handled transuranic
COPC	constituent of potential concern
CSB	Canister Storage Building
CTR	commute trip reduction
CWC	Central Waste Complex
CY	calendar year
D&D	decontamination and decommissioning
dBA	decibels A-weighted
DOE	U.S. Department of Energy
DOE-ID	DOE Idaho Operations Office
DOE-RL	DOE Richland Operations Office
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DST	double-shell tank
EA	environmental assessment
EBR-II	Experimental Breeder Reactor II
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ERPG	Emergency Response Planning Guideline
ETF	Effluent Treatment Facility
Fermi	Enrico Fermi Nuclear Generating Station

FFTF	Fast Flux Test Facility
"FFTF Decommissioning EIS"	"Environmental Impact Statement for the Decommissioning of the Fast Flux Test Facility at the Hanford Site, Richland, Washington" (rescoped in 2006 to the *TC & WM EIS)*
FFTF Deactivation EA	*Environmental Assessment – Sodium Residuals Reaction/Removal and Other Deactivation Work Activities, Fast Flux Test Facility (FFTF) Project, Hanford Site, Richland, Washington*
Final Comprehensive Conservation Plan and EIS	*Hanford Reach National Monument Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington*
FMEF	Fuels and Materials Examination Facility
FONSI	Finding of No Significant Impact
FR	*Federal Register*
FTE	full-time equivalent
Gable Gap	Gable Mountain–Gable Butte Gap
GTCC	greater-than-Class C
GTCC EIS	*Environmental Impact Statement for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste*
Hanford	Hanford Site
Hanford Comprehensive Land-Use Plan EIS	*Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*
Hanford Comprehensive Land-Use Plan EIS SA	*Final Supplement Analysis – Hanford Comprehensive Land-Use Plan Environmental Impact Statement*
Hanford Defense Waste EIS	*Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington*
Hanford NEPA Characterization Report	*Hanford Site National Environmental Policy Act (NEPA) Characterization Report*
Hanford Site Environmental Report	*Hanford Site Environmental Report for Calendar Year 2005 (Including Some Early 2006 Information)*
HCRMP	*Hanford Cultural Resources Management Plan*
HEDR	Hanford Environmental Dose Reconstruction
HEPA	high-efficiency particulate air
HIHTL	hose-in-hose transfer line
HLW	high-level radioactive waste
HSW EIS	*Final Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington*
IDAPA	Idaho Administrative Procedures Act
IDEQ	State of Idaho Department of Environmental Quality

IDF	Integrated Disposal Facility
IDF-East	200-East Area Integrated Disposal Facility
IDF-West	200-West Area Integrated Disposal Facility
IHLW	immobilized high-level radioactive waste
ILAW	immobilized low-activity waste
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IPCC	Intergovernmental Panel on Climate Change
LAW	low-activity waste
LCF	latent cancer fatality
LERF	Liquid Effluent Retention Facility
LIGO	Laser Interferometer Gravitational-Wave Observatory
LLBG	low-level radioactive waste burial ground
LLW	low-level radioactive waste
LOS	level of service
LWPF	Liquid Waste Processing Facility
MCL	maximum contaminant level
MEI	maximally exposed individual
MFC	Materials and Fuels Complex
MLLW	mixed low-level radioactive waste
MMI	Modified Mercalli Intensity
MODFLOW	modular three-dimensional finite-difference groundwater flow model
MRS	mobile retrieval system
MTHM	metric ton(s) of heavy metal
MUST	miscellaneous underground storage tank
NAAQS	National Ambient Air Quality Standards
National Register	National Register of Historic Places
NDA	nondestructive assay
NDE	nondestructive examination
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NI PEIS	*Final Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility (Nuclear Infrastructure PEIS)*
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRDWL	Nonradioactive Dangerous Waste Landfill

NTS	Nevada Test Site
ORP	Office of River Protection
ORR	Oak Ridge Reservation
P.L.	Public Law
PCB	polychlorinated biphenyl
PM	particulate matter
PM_n	particulate matter with an aerodynamic diameter less than or equal to *n* micrometers
PNNL	Pacific Northwest National Laboratory
PPA	Property Protected Area
ppb	part(s) per billion
PPF	Preprocessing Facility
ppm	part(s) per million
PSD	Prevention of Significant Deterioration
PT	Pretreatment
PUREX	Plutonium-Uranium Extraction
Quality Review	*Report of the Review of the "Hanford Solid Waste Environmental Impact Statement (EIS)" Data Quality, Control and Management Issues*
R&D	research and development
RADTRAN 5	Radioactive Material Transportation risk assessment computer code
RCB	Reactor Containment Building
RCRA	Resource Conservation and Recovery Act
RCW	*Revised Code of Washington*
REDOX	Reduction-Oxidation
RH	remote-handled
RH-SC	remote-handled special component
RH-TRU	remote-handled transuranic
RISKIND	Risks and Consequences of Radiological Material Transport computer code
ROD	Record of Decision
ROI	region of influence
RPP	River Protection Project
RPPDF	River Protection Project Disposal Facility
RTC	Reactor Technology Complex
RTP	Remote Treatment Project
RWMC	Radioactive Waste Management Complex
SA	supplement analysis
SALDS	State-Approved Land Disposal Site
SC	special component
SEPA	State Environmental Policy Act
SNF	spent nuclear fuel

SNF PEIS	*Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*
SPF	Sodium Processing Facility
SRE	Sodium Reactor Experiment
SRF	Sodium Reaction Facility
SRS	Savannah River Site
SSF	Sodium Storage Facility
SST	single-shell tank
STOMP	Subsurface Transport Over Multiple Phases
STTS	Supplemental Treatment Technology Site
STTS-East	200-East Area Supplemental Treatment Technology Site
STTS-West	200-West Area Supplemental Treatment Technology Site
SWIFT	*Solid Waste Integrated Forecast Technical (SWIFT) Report*
SWITS	Solid Waste Information and Tracking System
SWOC	Solid Waste Operations Complex
T&ESMP-SS	*Threatened and Endangered Species Management Plan, Salmon and Steelhead*
"Tank Closure EIS"	"Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington" (rescoped in 2006 to the *TC & WM EIS*)
TC & WM EIS	*Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington*
TCP	traditional cultural property
TEDF	Treated Effluent Disposal Facility
The Green Book	*Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements*
TMC	theoretical maximum capacity
TPA	Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)
TRAGIS	Transportation Routing Analysis Geographic Information System
trenches	ditches
TRC	total recordable cases
TRU	transuranic
TSCA	Toxic Substances Control Act
TSD	treatment, storage, and disposal
TWRS EIS	*Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*
U.S.C.	*United States Code*
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VBR	vacuum-based retrieval
VRM	Visual Resource Management

WAC	*Washington Administrative Code*
WAG	Waste Area Group
Waste Management	*Final Waste management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
WESF	Waste Encapsulation and Storage Facility
WIPP	Waste Isolation Pilot Plant
WIPP SEIS-II	*Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement*
WLAP	Wastewater-Land Application Permit
WM PEIS	*Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
WRAP	Waste Receiving and Processing Facility
WRF	waste receiver facility
WSDOT	Washington State Department of Transportation
WTP	Waste Treatment Plant

Measurement Units

The principal measurement units used in this *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (*TC & WM EIS*) are SI units (the abbreviation for the Système International d'Unites). The SI system is an expanded version of the metric system that was accepted in 1966 in Elsinore, Denmark, as the legal standard by the International Organization of Standardization. In this system, most units are made up of combinations of seven basic units, of which length in meters, mass in kilograms, and volume in liters are of most importance in this *TC & WM EIS*. Exceptions are radiological units that use the English system (e.g., rem, millirem).

SCIENTIFIC (EXPONENTIAL) NOTATION

Numbers that are very small or very large are often expressed in scientific, or exponential, notation as a matter of convenience. For example, the number 0.000034 may be expressed as 3.4×10^{-5} or 3.4E-05, and 65,000 may be expressed as 6.5×10^{4} or 6.5E+04. In this *TC & WM EIS*, numerical values that are less than 0.001 or greater than 9,999 are generally expressed in scientific notation, i.e., 1.0×10^{-3} and 9.9×10^{3}, respectively.

Multiples or submultiples of the basic units are also used. A partial list of prefixes that denote multiples and submultiples follows, with the equivalent multiplier values expressed in scientific notation.

Prefix	Symbol	Multiplier	
atto	a	0.000 000 000 000 000 001	1×10^{-18}
femto	f	0.000 000 000 000 001	1×10^{-15}
pico	p	0.000 000 000 001	1×10^{-12}
nano	n	0.000 000 001	1×10^{-9}
micro	μ	0.000 001	1×10^{-6}
milli	m	0.001	1×10^{-3}
centi	c	0.01	1×10^{-2}
deci	d	0.1	1×10^{-1}
deka	da	10	1×10^{1}
hecto	h	100	1×10^{2}
kilo	k	1,000	1×10^{3}
mega	M	1,000,000	1×10^{6}
giga	G	1,000,000,000	1×10^{9}
tera	T	1,000,000,000,000	1×10^{12}
peta	P	1,000,000,000,000,000	1×10^{15}
exa	E	1,000,000,000,000,000,000	1×10^{18}

The following symbols are occasionally used in conjunction with numerical expressions:

$<$ less than
$\leq$ less than or equal to
$>$ greater than
$\geq$ greater than or equal to

Conversions

English to Metric			Metric to English		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area			**Area**		
square inches	6.4516	square centimeters	square centimeters	0.155	square inches
square feet	0.092903	square meters	square meters	10.7639	square feet
square yards	0.8361	square meters	square meters	1.196	square yards
acres	0.40469	hectares	hectares	2.471	acres
square miles	2.58999	square kilometers	square kilometers	0.3861	square miles
Length			**Length**		
inches	2.54	centimeters	centimeters	0.3937	inches
feet	30.48	centimeters	centimeters	0.0328	feet
feet	0.3048	meters	meters	3.281	feet
yards	0.9144	meters	meters	1.0936	yards
miles	1.60934	kilometers	kilometers	0.6214	miles
Temperature			**Temperature**		
degrees Fahrenheit	Subtract 32, then multiply by 0.55556	degrees Celsius	degrees Celsius	Multiply by 1.8, then add 32	degrees Fahrenheit
Volume			**Volume**		
fluid ounces	29.574	milliliters	milliliters	0.0338	fluid ounces
gallons	3.7854	liters	liters	0.26417	gallons
cubic feet	0.028317	cubic meters	cubic meters	35.315	cubic feet
cubic yards	0.76455	cubic meters	cubic meters	1.308	cubic yards
Weight			**Weight**		
ounces	28.3495	grams	grams	0.03527	ounces
pounds	0.45360	kilograms	kilograms	2.2046	pounds
short tons	0.90718	metric tons	metric tons	1.1023	short tons

CHAPTER 5
LONG-TERM ENVIRONMENTAL CONSEQUENCES

Chapter 5 presents the potential long-term impacts on the existing natural and human environment and on human health of implementation of reasonable alternatives for each of the following: (1) tank waste retrieval and treatment and single-shell tank system closure at the Hanford Site (Hanford); (2) decommissioning of the Fast Flux Test Facility and auxiliary facilities and disposition of Hanford's inventory of radioactively contaminated bulk sodium; and (3) management of waste resulting from the above and other Hanford activities and limited volumes from other U.S. Department of Energy sites. Impact analyses for the alternatives and options considered for each of the three sets of proposed actions are presented separately in Sections 5.1, 5.2, and 5.3, respectively. Impact analyses are grouped first by resource area or discipline (i.e., groundwater, human health, and ecological risks) and then by alternative so that impacts of releases to air and groundwater can be meaningfully compared across alternatives. All disciplines are analyzed in a manner commensurate with their importance and the expected level of impact on them under a specific alternative—the sliding-scale assessment approach. The combined impacts of implementing selected alternatives from each of the three sets of proposed actions are presented in Section 5.4. Cumulative impacts associated with the alternative combinations are presented in Chapter 6. Mitigation measures to reduce the potential for environmental impacts are summarized in Chapter 7, Section 7.1. Analyses of comparative impacts across the alternatives are presented in Chapter 7, Sections 7.2 through 7.4. A detailed discussion of each alternative is provided in Chapter 2, Section 2.5.

The long-term impact analysis results for groundwater, human health, and ecological risk through the 10,000-year period of analysis presented in this *Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* are derived from modeling releases to air and groundwater, as appropriate. The air modeling process used for this *TC & WM EIS* is described in Appendix F and Appendix G. Figure 5–1 describes the groundwater modeling process used for this *TC & WM EIS*. The process begins with development of inventories of constituents of potential concern (COPCs) for the alternative and cumulative impact analyses described in Appendices D and S, respectively.

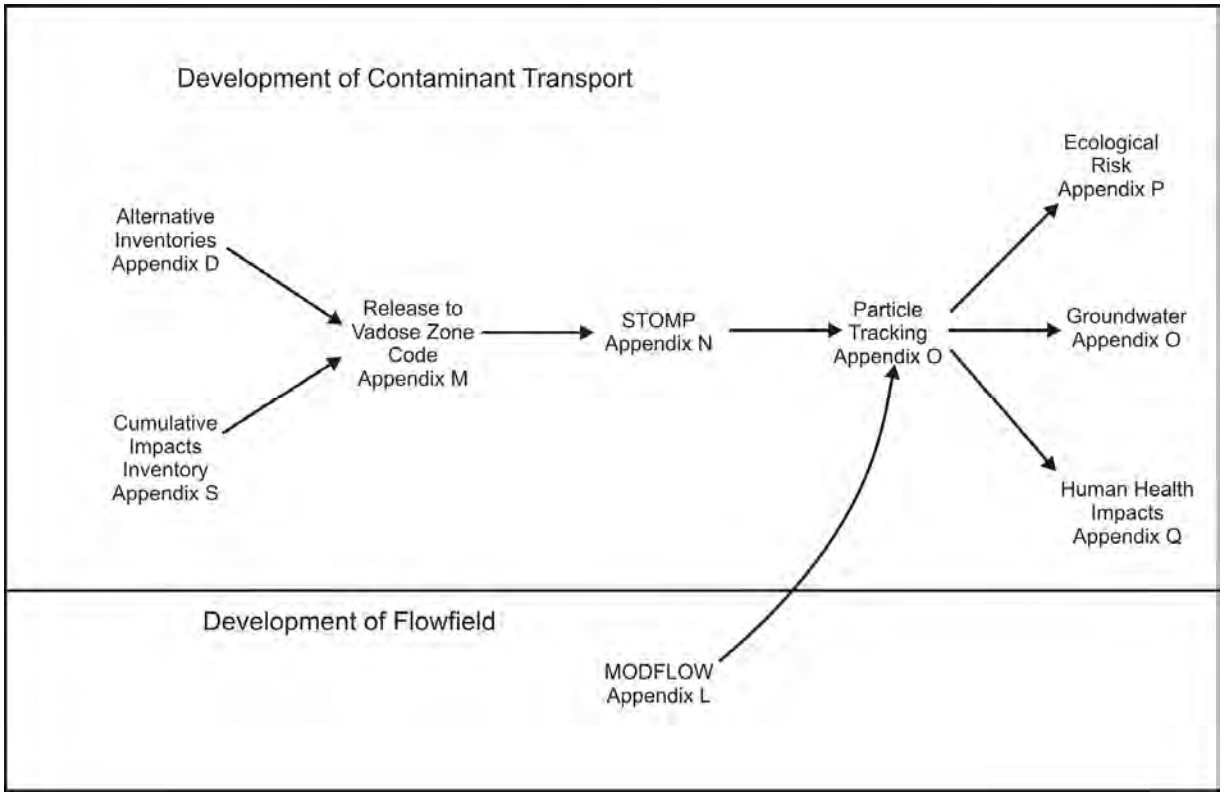


Figure 5–1. Groundwater Modeling Process

The Release to Vadose Zone code uses site-specific parameters to estimate release rates to the vadose zone for each source location analyzed in the alternative and cumulative impact analyses. Parameter examples include contaminant inventories, aqueous recharge, and subsurface geology. Appendix M includes further description of the Release to Vadose Zone code. The output of the Release to Vadose Zone code is an input file to the vadose zone model STOMP [Subsurface Transport Over Multiple Phases] computer code (White and Oostrom 2000, 2006). Appendix M also presents the releases from a number of assumed source forms, some of which are intact and leaching during the entire 10,000-year period of analysis.

The STOMP model uses an integrated-volume finite-difference approach to solve nonlinear water and solute transport balances for the vadose zone. The development and implementation of the vadose zone modeling are presented in Appendix N. The vadose zone modeling provides contaminant and aqueous releases to the aquifer over time, which are incorporated into the groundwater contaminant transport.

A groundwater flow field was developed to determine the direction and rate of water movement in the aquifer, that is, where contaminants entering the groundwater will go and how long it will take to move a given contaminant from the point where it enters the groundwater to any given point along its trajectory toward a location of interest. Groundwater flow through the unconfined aquifer is simulated using the U.S. Geological Survey MODFLOW [modular three-dimensional finite-difference groundwater flow model] 2000 Engine, Version 1.15.00 (USGS 2004). The commercial version used in this *TC & WM EIS* is Visual MODFLOW, Version 4.2 (WHI 2006). A description of the development of the groundwater flow field is provided in Appendix L.

The input for the groundwater contaminant transport runs was based on the output from the vadose zone flow and transport runs that were calculated using the STOMP code. The particle-tracking code (see Appendix O, Section O.2), in combination with the MODFLOW Base Case flow field (see Appendix L), was used to calculate a fully three-dimensional transient analysis of groundwater transport over a period of 10,000 years for each site. The particle-tracking model provides contaminant concentrations in the groundwater over time. A description of the particle-tracking model, along with the listing of benchmarks used to compare COPC concentrations, is provided in Appendix O. These concentrations were used to analyze ecological and human health risk. Detailed descriptions of these risk analyses are provided in Appendices P and Q, respectively. Appendix Q also provides the process to identify the COPCs used for long-term analysis. A map of the Core Zone and barrier boundaries used for the analysis is also provided in Chapter 2, Figure 2–80, and Appendix O, Figure O–1.

5.1 TANK CLOSURE ALTERNATIVES

This section describes the potential long-term environmental impacts associated with implementation of each of the 11 Tank Closure alternatives considered in this *TC & WM EIS* for retrieving and treating the tank waste inventory generated during the defense production years at the Hanford Site (Hanford). The impact analysis also considers different closure scenarios associated with the single-shell tank (SST) system.

Tank Closure Alternative 1, No Action, reflects the environmental baseline against which the impacts of the other action alternatives can be compared. Under Alternative 1, the U.S. Department of Energy (DOE) has assumed for purposes of analysis that construction of the River Protection Project Waste Treatment Plant (WTP) would be terminated in 2008. The tank waste in the SST and double-shell tank (DST) systems would remain in the tank farm indefinitely. DOE would maintain security and management of the site for a 100-year administrative control period (ending in calendar year [CY] 2107), after which the tank waste would be available for release to the environment.

In contrast, Tank Closure Alternatives 2 through 6 involve the construction, subsequent operations, and eventual deactivation of new facilities over varying timeframes (ranging from 34 to 161 years) in the 200-East and 200-West Areas of Hanford to support tank waste retrieval, treatment, and disposal. The waste in the SST and DST systems would be retrieved, treated, and disposed of. With the exception of Alternative 2A, each alternative also analyzes closure of the SST system by either landfill closure (i.e., construction of a surface barrier) or selective or full clean closure (i.e., removal) of the SST system and associated waste and contaminated soils. Each of the 11 Tank Closure alternatives (Alternatives 1 through 6C) are described in detail in Chapter 2, Section 2.5, of this environmental impact statement (EIS).

5.1.1 Groundwater

5.1.1.1 Tank Closure Alternative 1: No Action

This section describes the groundwater analysis results for Tank Closure Alternative 1, including long-term groundwater impacts of contaminant sources within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an Integrated Disposal Facility (IDF) and the River Protection Project Disposal Facility (RPPDF) are presented in Section 5.3, which discusses waste management impacts.

5.1.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Under Tank Closure Alternative 1, no sources would be removed from within the tank farm barriers. Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 1, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 1 that are presented in this section would be common to all of the Tank Closure alternatives.

- The administrative control period was assumed to start in 2008 and end in CY 2107 (100-year duration). It was assumed that during this administrative control period, corrective action or emergency response measures would preclude further releases from the SST and DST systems, but that releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2108 and continue through the 10,000-year period of analysis until CY 11,940. During this post–administrative control period, releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system. In addition, all stored waste at the SST and DST farms (referred to as “other tank farm sources” in this chapter) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.1.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 1. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 1 is focused on the following COPC drivers:

- Radiological risk drivers: hydrogen-3 (tritium), iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 1 were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become major contributors toward the end of the period of analysis. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-11}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 1.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed are the radionuclides carbon-14, cesium-137, neptunium-237, plutonium-239, and strontium-90 and the chemicals acetonitrile, benzene, 1-butanol, lead, mercury, polychlorinated biphenyls, and 2,4,6-trichlorophenol. These constituents do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.1.3 Analysis of Release and Mass Balance[1]

This section presents the impacts of Tank Closure Alternative 1 in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of

[1] A "mass balance" (also called a material balance) is an application of conservation of mass to the analysis of a physical system, i.e., the mass of a chemical or radionuclide that enters a system must, by conservation of mass, either leave the system, accumulate within the system, or decay/react to a different chemical or radionuclide (input = output + accumulation + decay/reaction). By accounting for material entering and leaving a system, mass flows can be identified that might have been unknown, or difficult to measure without this technique.

Applied to this EIS, mass balance refers to accounting for the total amount of COPCs released from key sources to the vadose zone, groundwater, and Columbia River during the 10,000-year period of analysis at various locations and points in time, taking into consideration retardation factors (retention in the vadose zone and aquifer) and radioactive decay. This accounting allows tracking of the mass flows, accumulations, and decays at each stage through transit from source to arrival at the Columbia River.

analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–2 through 5–7). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–2 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–3, the chemical hazard drivers. For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). The predominant sources for tritium are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are other tank farm sources. This suggests that other tank farm sources, which are released in the analysis during the post–administrative control period, are an important impact driver under Tank Closure Alternative 1.

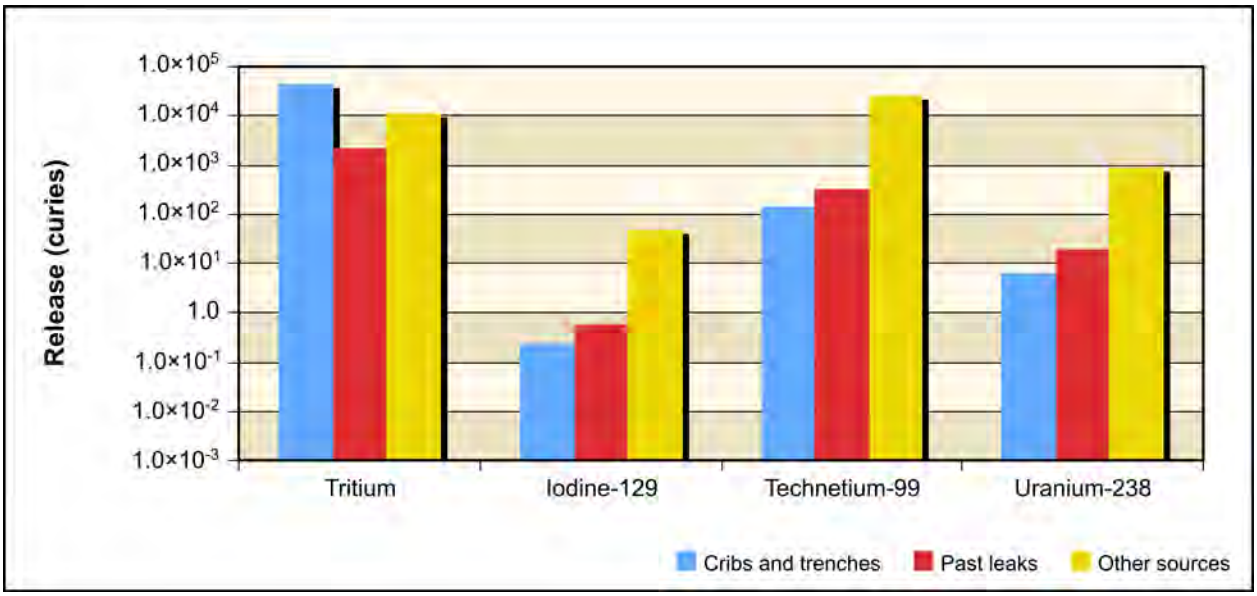


Figure 5–2. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

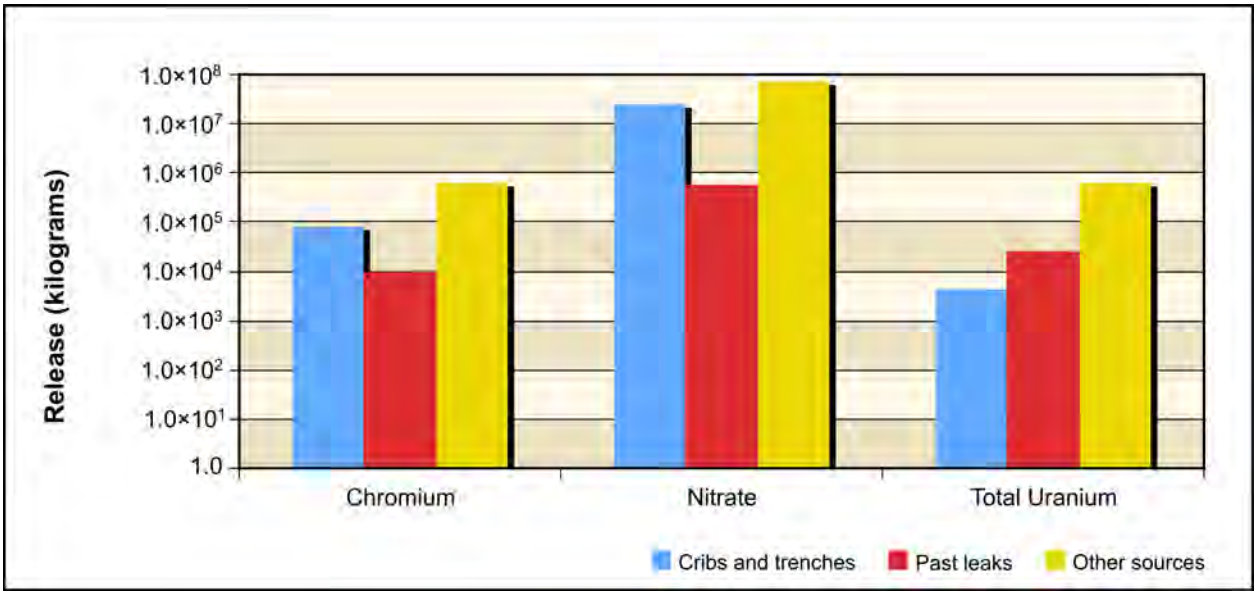


Figure 5–3. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–4 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–5, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

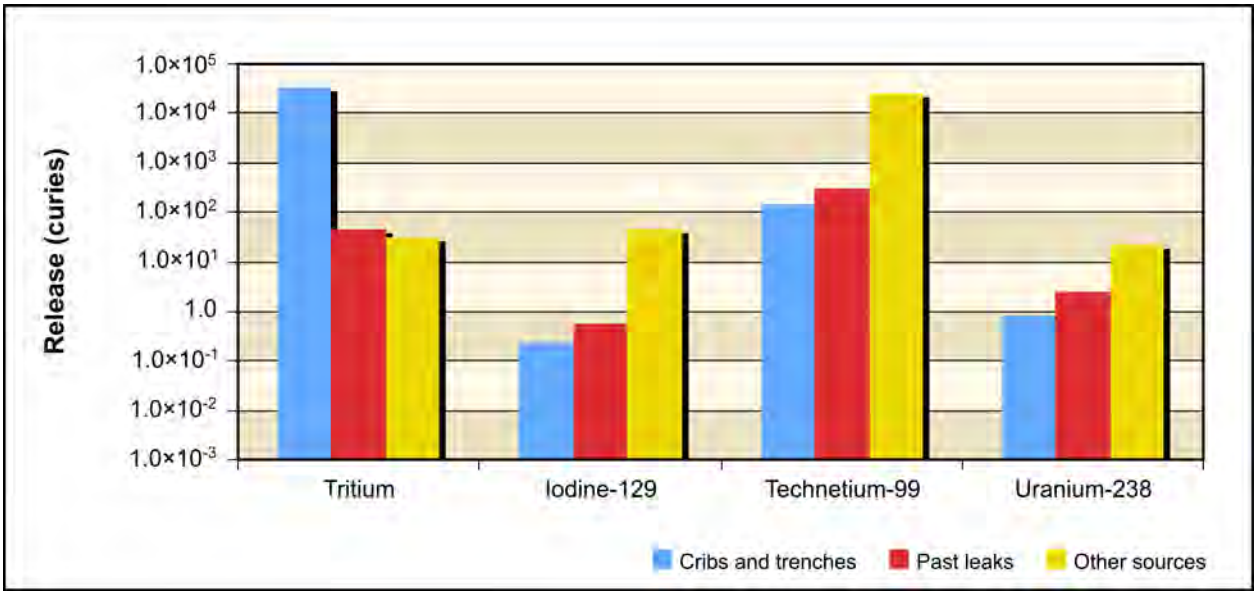


Figure 5–4. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

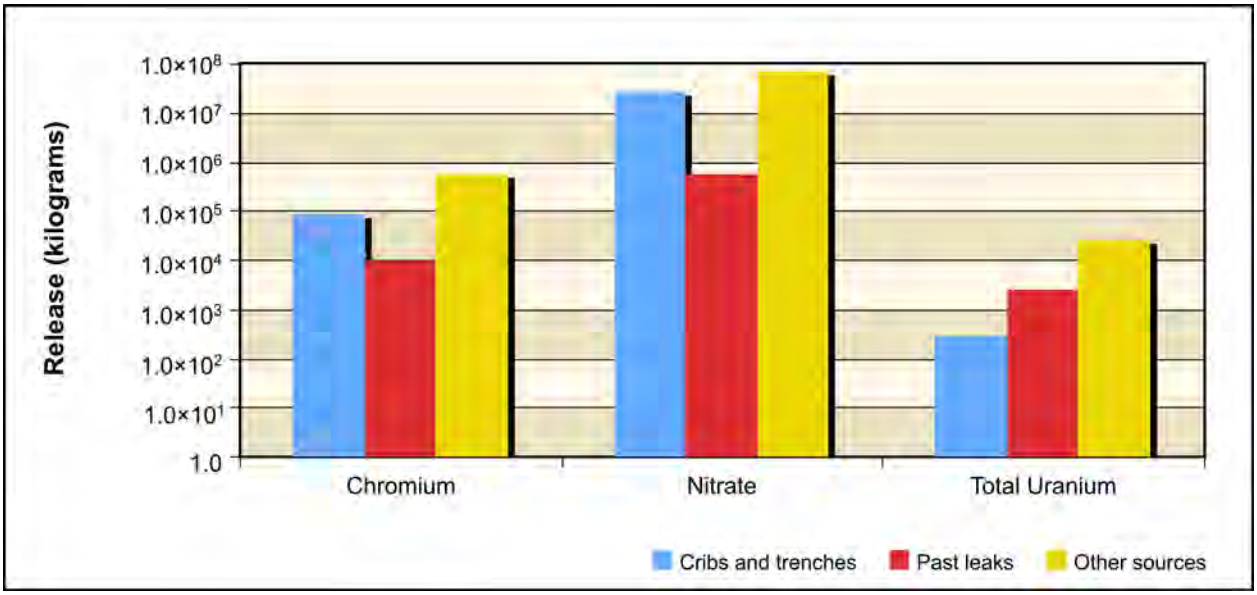


Figure 5–5. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For cribs and trenches (ditches), about 70 percent of the total inventory of tritium reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, less than 1 percent reached the water table. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process.

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture addition and movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 14 percent of uranium-238 and 8 percent of total uranium inventory reached groundwater during the period of analysis. For past leaks, about 18 percent of uranium-238 and 14 percent of total uranium of the total inventory reached groundwater during the period of analysis. For other tank farm sources, about 4 percent of uranium-238 and 7 percent of total uranium of the total inventory reached groundwater during the period of analysis. These results also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times for these COPCs in the vadose zone.

Figure 5–6 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–7, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

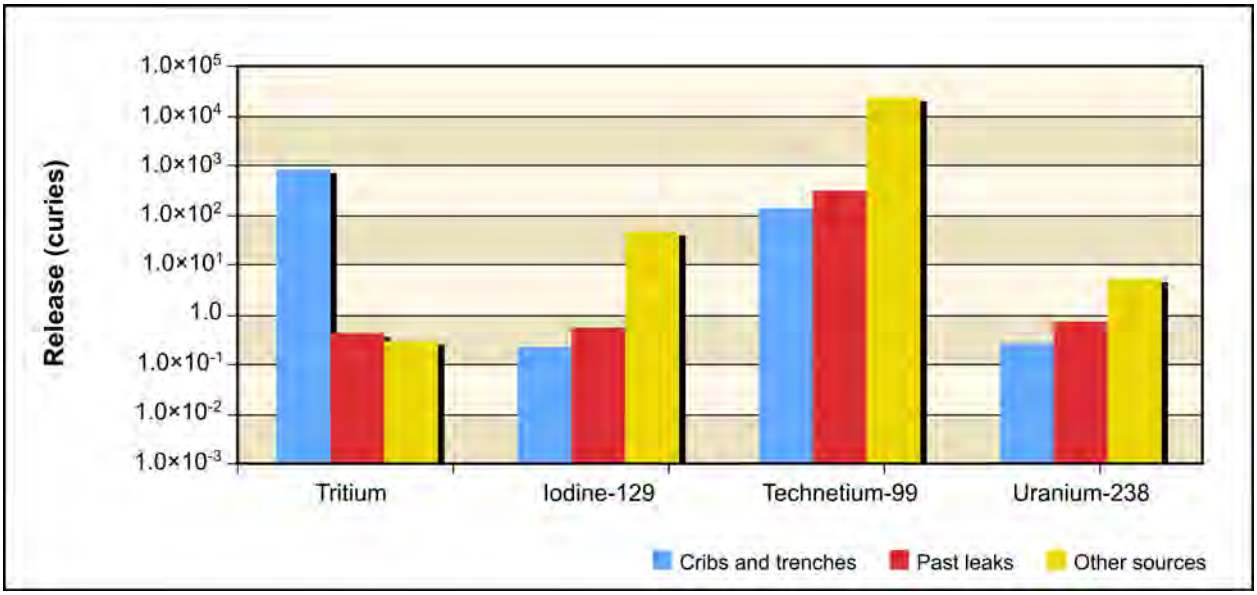


Figure 5–6. Tank Closure Alternative 1 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

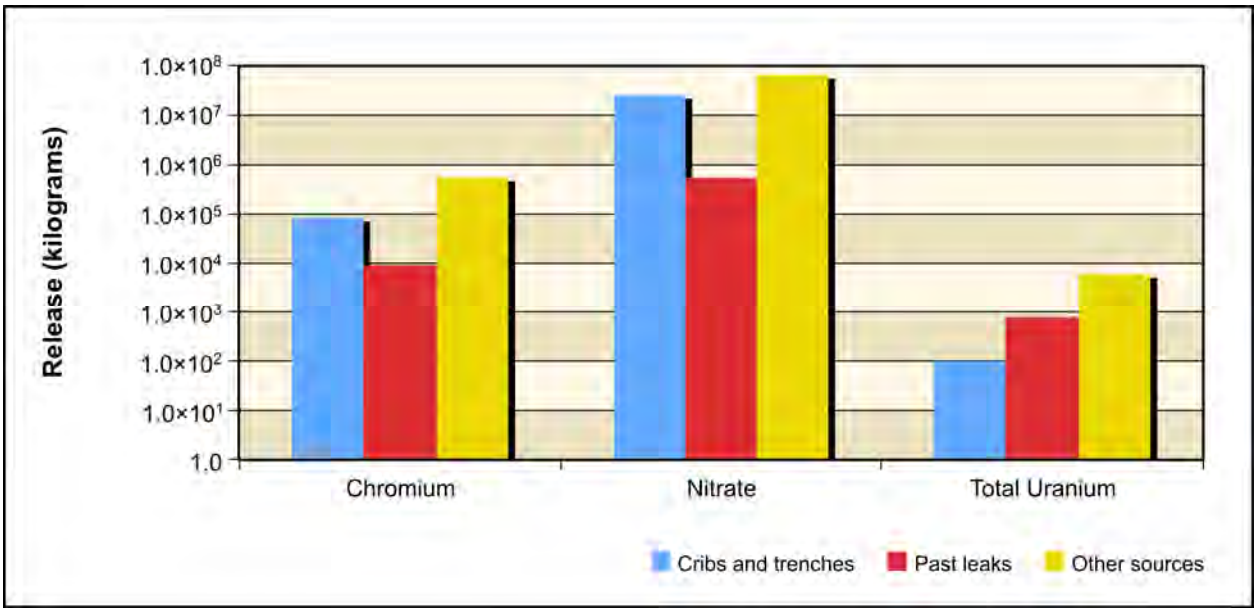


Figure 5–7. Tank Closure Alternative 1 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. Overall, about 25 percent of the amount released to groundwater during the period of analysis reached the Columbia River.

For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

5.1.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 1 impacts in terms of groundwater concentration versus time at the tank farm barriers, Core Zone Boundary, and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–1 and Figures 5–8 through 5–14). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Although the concentration-versus-time plots presented in this section (as well as in the following sections and throughout this *TC & WM EIS*) appear similar in structure to the classic advection-dispersion breakthrough curves, the reader is cautioned that the curves presented in these sections are not amenable to the classic analysis. The classic presentation is a time-series plot of concentration from a single source at a fixed location. In this *TC & WM EIS*, each concentration-versus-time plot is from a multiple number of sources (typically on the order of 30) at a variable location (the location of the highest peak concentration along the line of analysis). Therefore, attempts to apply classic transport theory to these results can, in general, result in misleading conclusions. Table 5–1 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Table 5–1. Tank Closure Alternative 1 Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	4,190	2,690	2,460	5,570	12	3,790	180	20,000
	(2112)	(2052)	(2117)	(2052)	(2051)	(2102)	(2054)	
Technetium-99	**70,100**	**175,000**	**38,700**	**15,000**	**14,800**	**350,000**	**5,230**	900
	(2114)	(3837)	(3238)	(2051)	(3536)	(3837)	(4032)	
Iodine-129	**71**	**398**	**67**	**71**	**29**	**682**	**13**	1
	(2114)	(3801)	(3312)	(3756)	(3536)	(3801)	(4411)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	**23**	**490**	**259**	**102**	**40**	**1,070**	6	15
	(11,789)	(11,749)	(11,730)	(11,820)	(11,758)	(11,683)	(11,918)	
Chemical in micrograms per liter								
Chromium	**284**	**5,050**	**1,650**	**911**	**308**	**12,200**	**165**	100
	(2114)	(3628)	(3172)	(2050)	(3587)	(3524)	(4019)	
Nitrate	**69,600**	**1,740,000**	**107,000**	**201,000**	34,900	**1,130,000**	23,500	45,000
	(2119)	(2087)	(3138)	(2088)	(3654)	(2059)	(3911)	
Total uranium	5	**695**	**281**	**96**	**51**	**1,220**	8	30
	(11,769)	(11,762)	(11,762)	(11,836)	(11,739)	(11,648)	(11,591)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

Figure 5–8 shows concentration versus time for tritium. Note that for visual clarity, the time period shown in this figure is from CYs 1940 through 2440 (500 years), rather than the full 10,000-year period of analysis. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about three orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

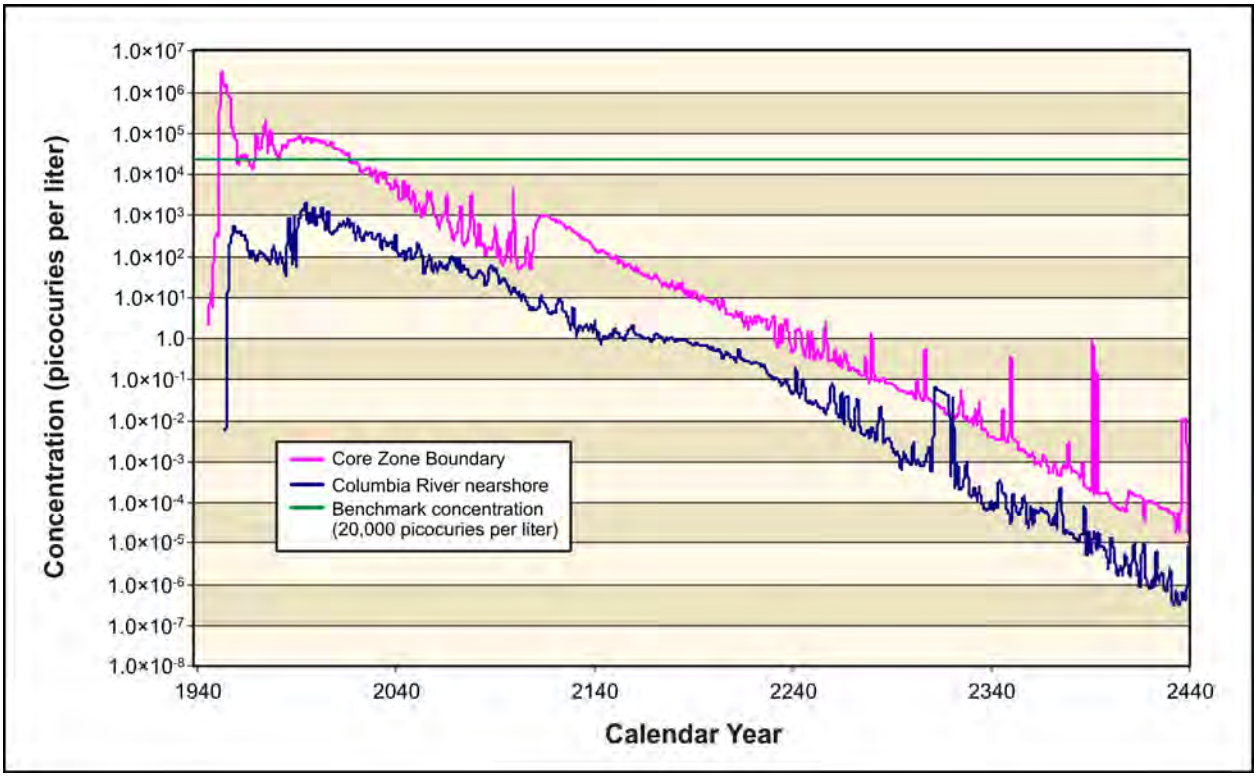


Figure 5–8. Tank Closure Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–9 through 5–12 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations of iodine-129 to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach or exceed the benchmark concentration. Releases from other tank farm sources cause groundwater concentrations to exceed benchmark concentrations by about three orders of magnitude during the middle and latter parts of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore exceed the benchmark concentration by about an order of magnitude, tapering off to near the benchmark concentration at the end of the period of analysis. Technetium-99, chromium, and nitrate concentrations show a similar curve, with chromium and nitrate concentrations at the Columbia River nearshore dropping below the benchmark concentrations.

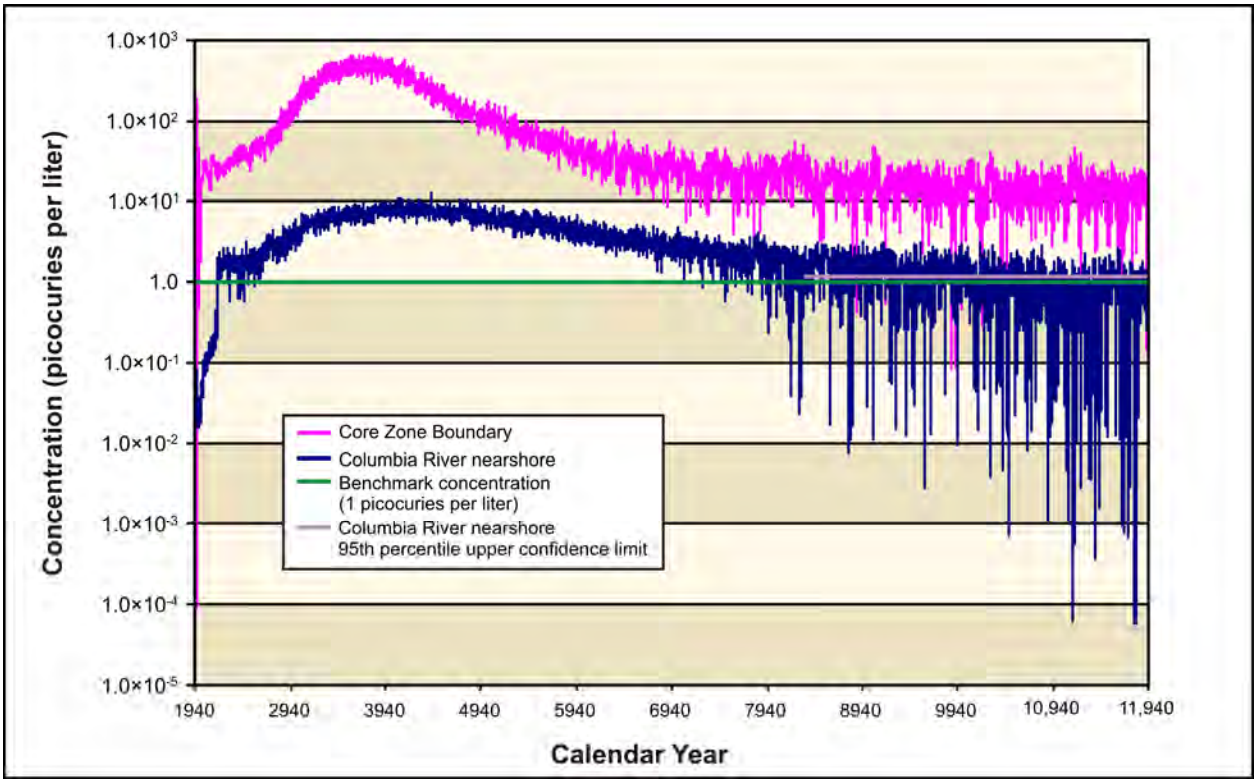


Figure 5–9. Tank Closure Alternative 1 Iodine-129 Concentration Versus Time

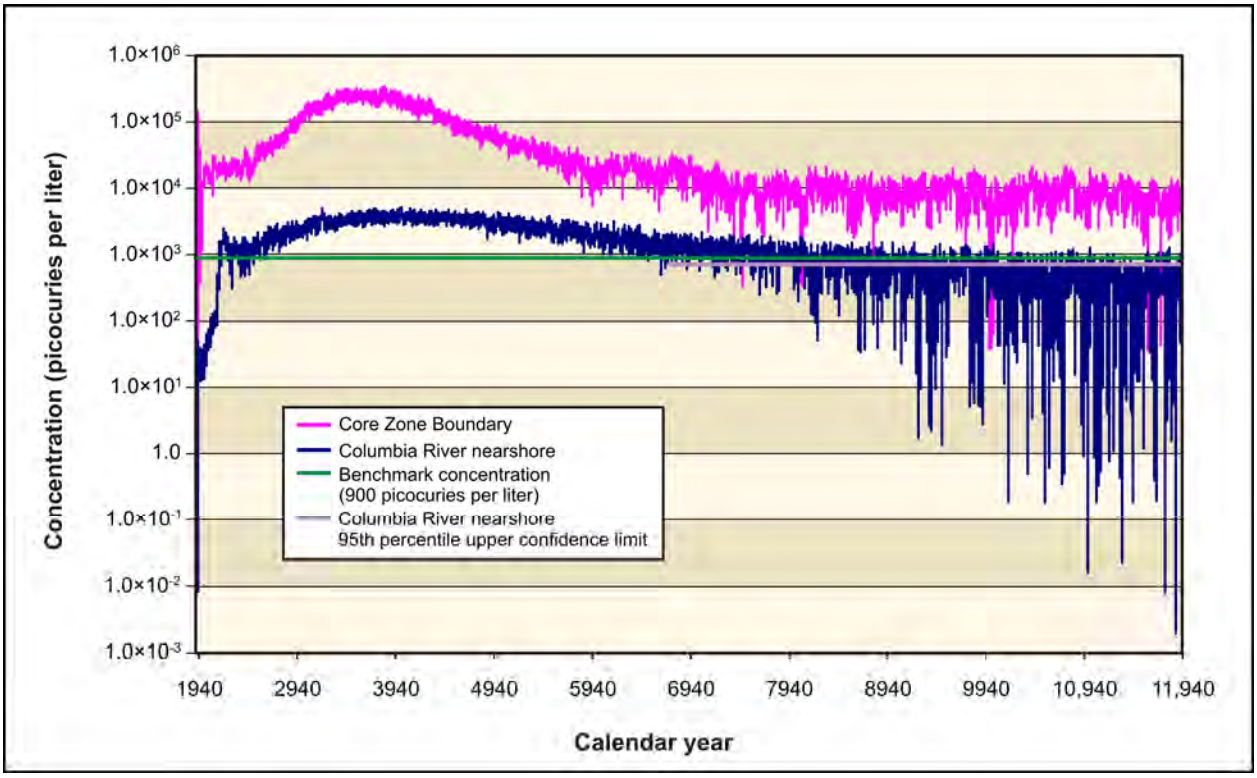


Figure 5–10. Tank Closure Alternative 1 Technetium-99 Concentration Versus Time

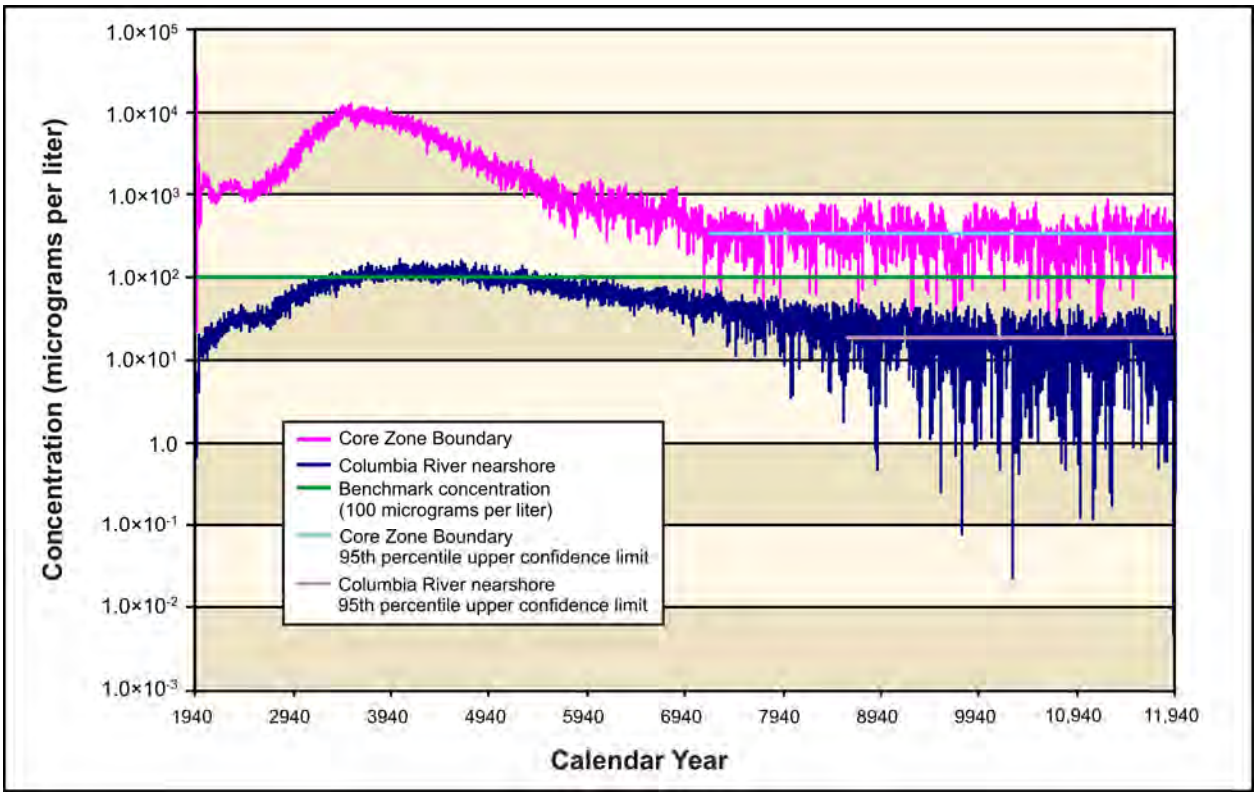


Figure 5–11. Tank Closure Alternative 1 Chromium Concentration Versus Time

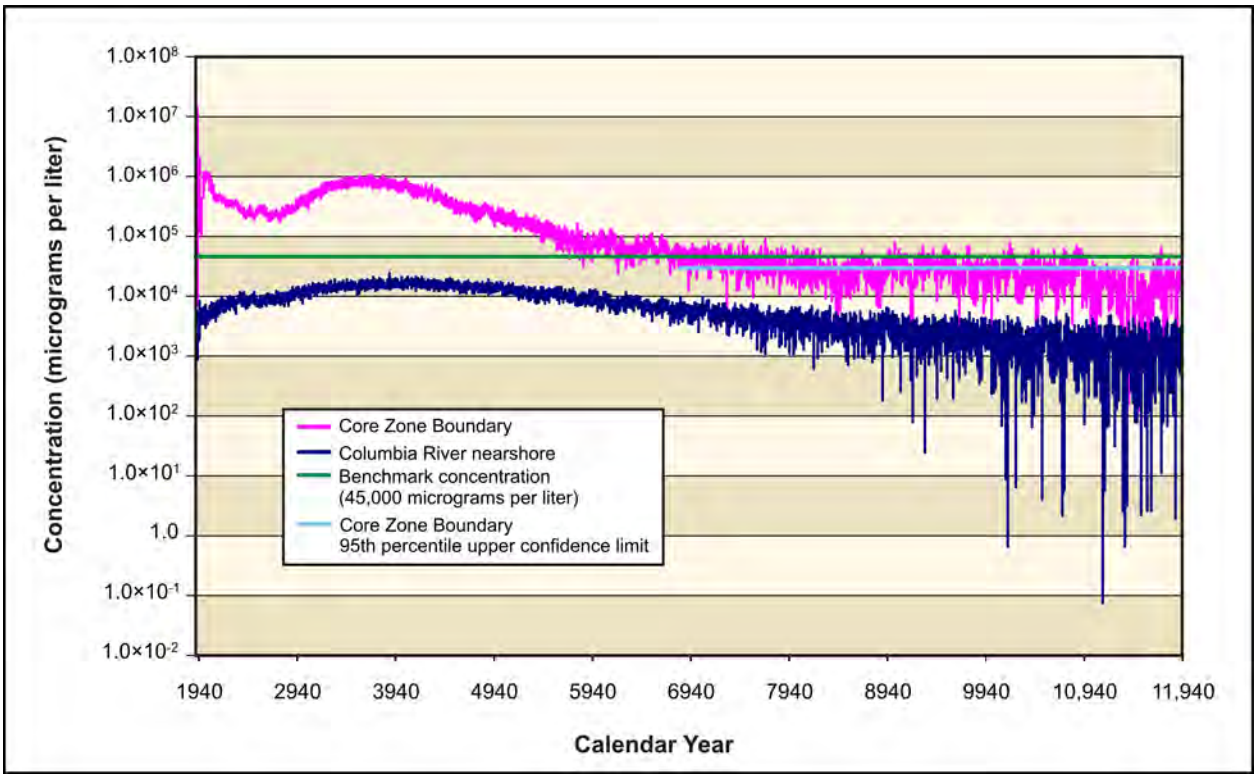


Figure 5–12. Tank Closure Alternative 1 Nitrate Concentration Versus Time

Figures 5–13 and 5–14 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise, nearing benchmark concentrations by CY 6000. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by about two orders of magnitude at the end of the period of analysis. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, nearing the benchmark concentration by CY 11,940.

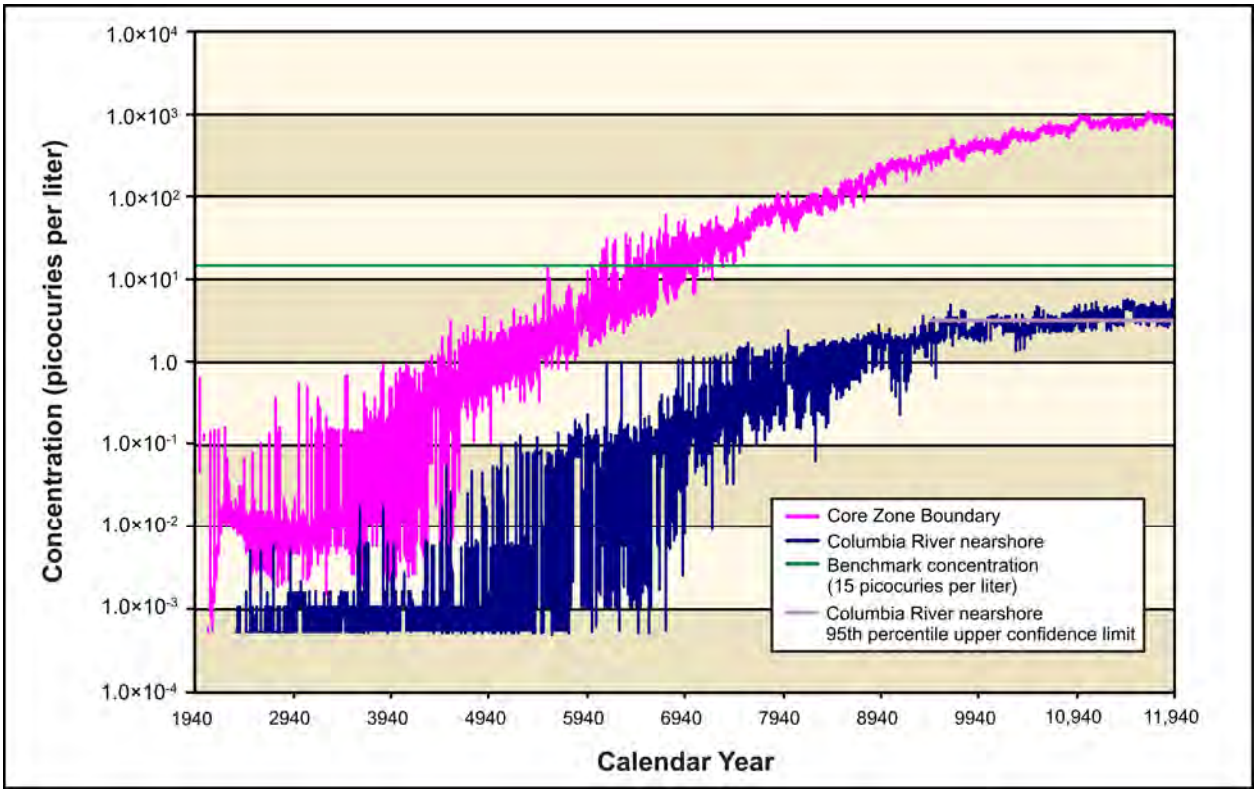


Figure 5–13. Tank Closure Alternative 1 Uranium-238 Concentration Versus Time

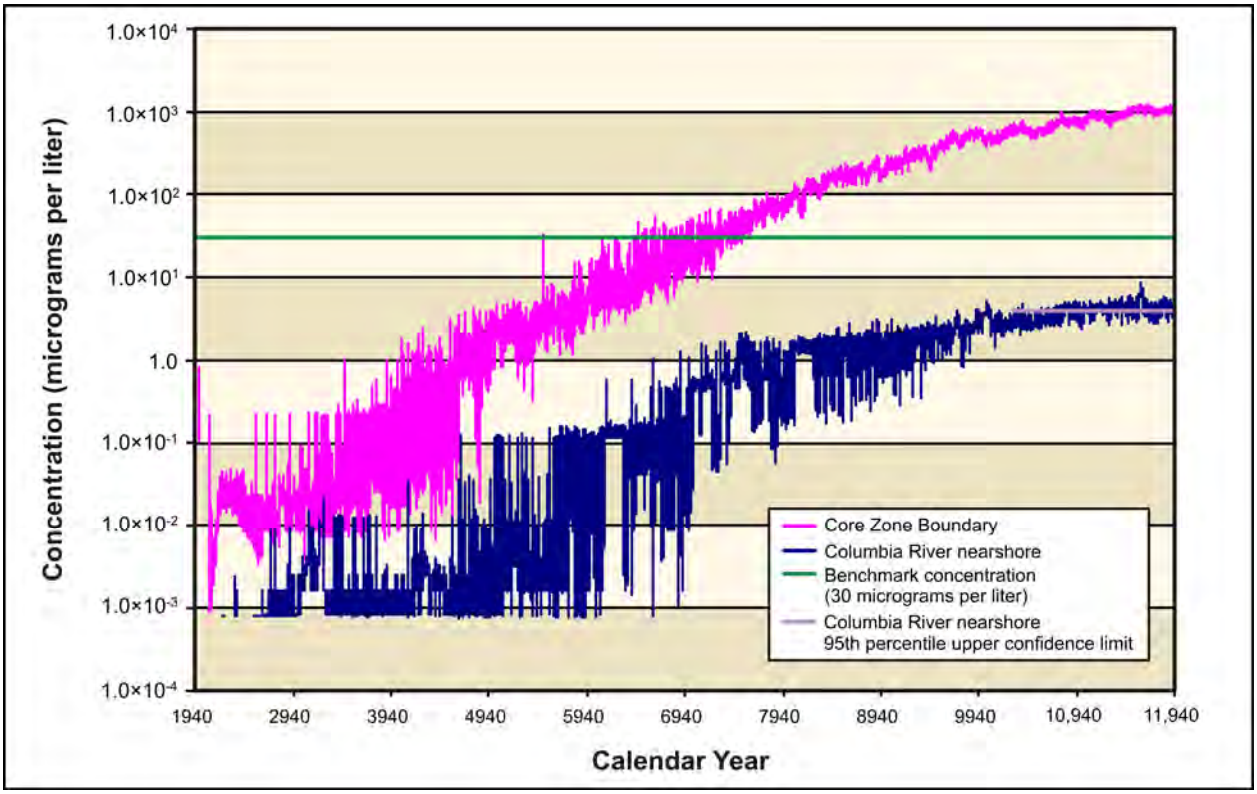


Figure 5–14. Tank Closure Alternative 1 Total Uranium Concentration Versus Time

5.1.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of Tank Closure Alternative 1 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–15 through 5–36). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Note that, in this section and in subsequent sections, the benchmark concentration is identified as "maximum contaminant level" in the legend of the spatial distribution figures. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–15 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward the Gable Mountain–Gable Butte Gap (Gable Gap). Peak concentrations in this plume are about 10 to 20 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135, as shown in Figure 5–8.

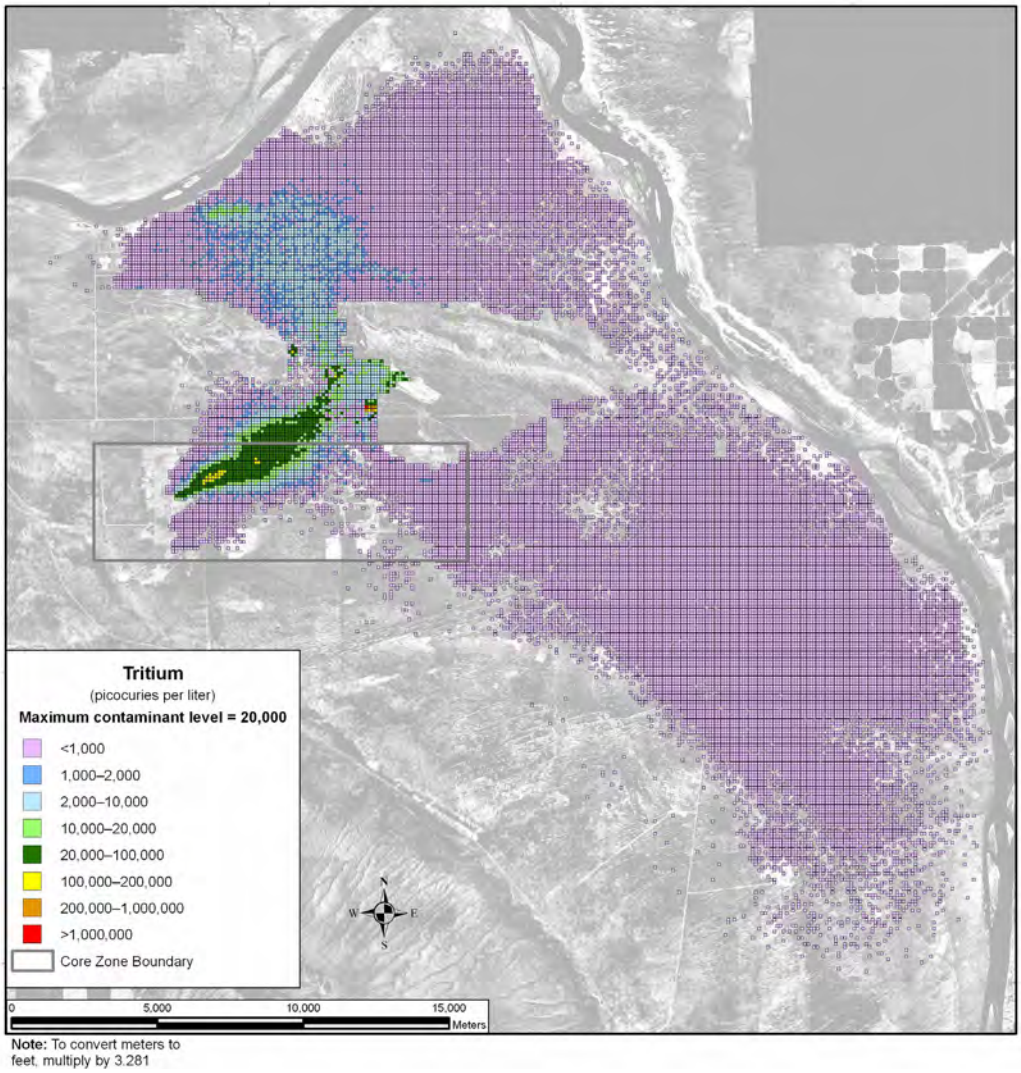
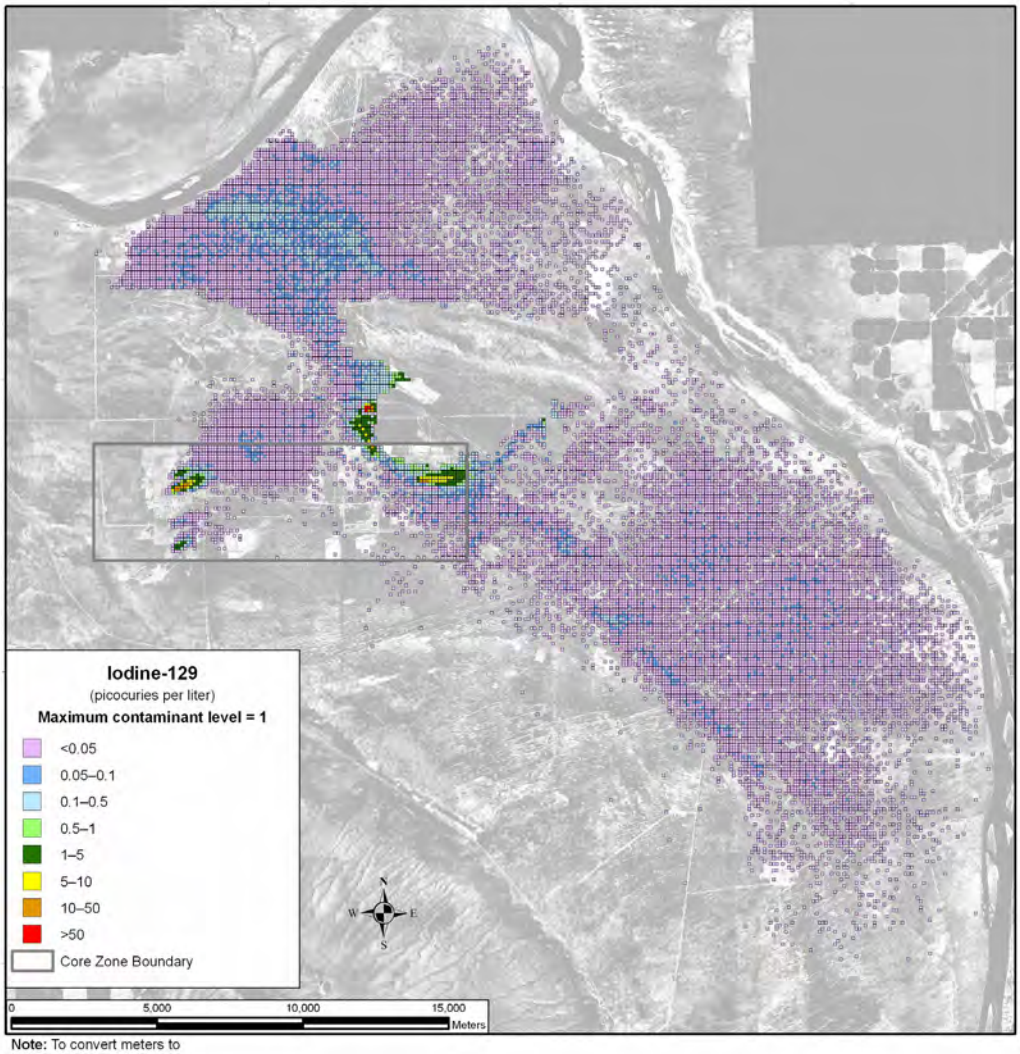


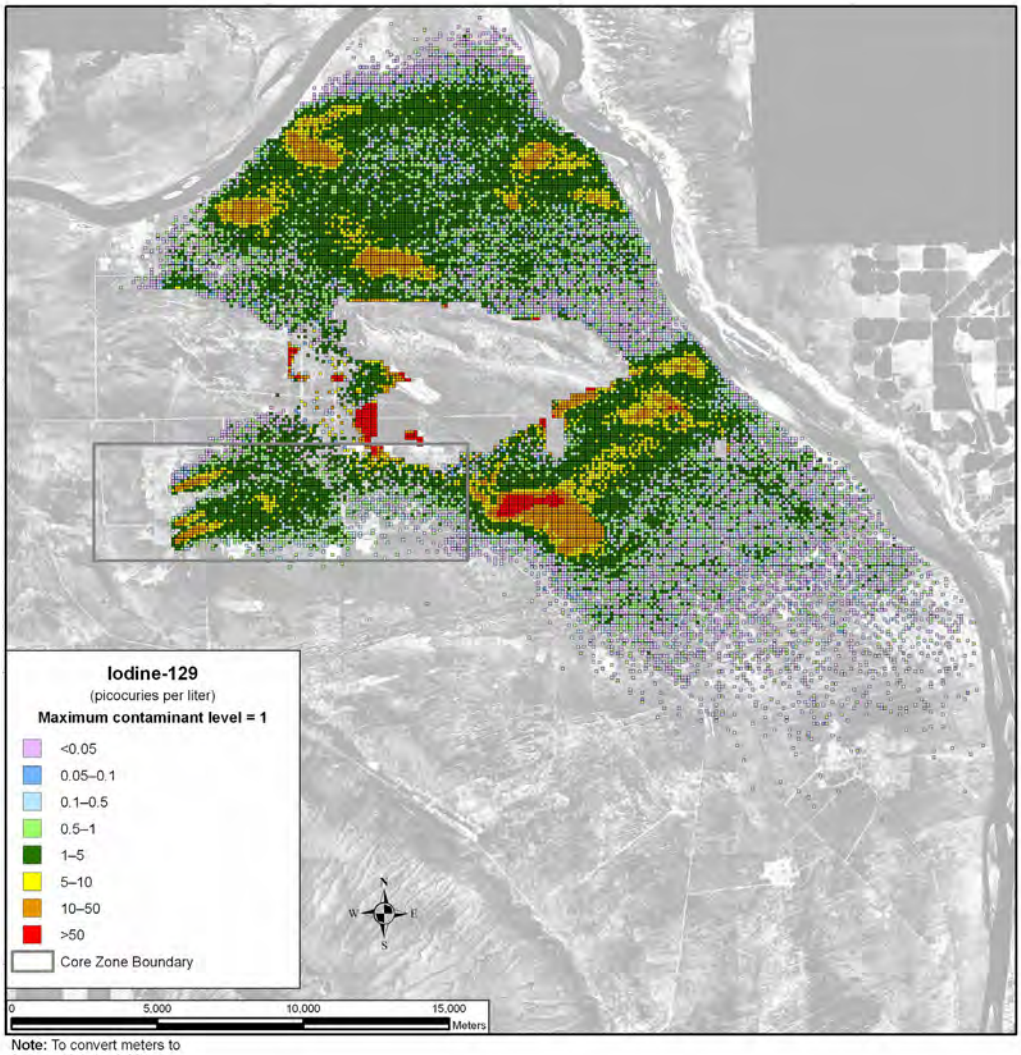
Figure 5–15. Tank Closure Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005

Figure 5–16 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Around CY 3890, releases from other tank farm sources create a large plume exceeding the benchmark, extending from the A Barrier to the Columbia River (see Figure 5–17). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–18). Figure 5–19 shows the total area in which groundwater concentrations of iodine-129 exceed the benchmark concentration in the analysis as a function of time. The area of exceedance peaks between CY 3240 and CY 4540 as a result of releases from other tank farm sources. Figures 5–20 through 5–23 show the spatial distribution at the same three times and the total area of exceedance versus time for technetium-99. The spatial distribution of technetium-99 is similar to that of iodine-129. The other conservative tracers, chromium (see Figures 5–24 through 5–26) and nitrate (see Figures 5–27 through 5–29), show similar spatial distributions at selected times.



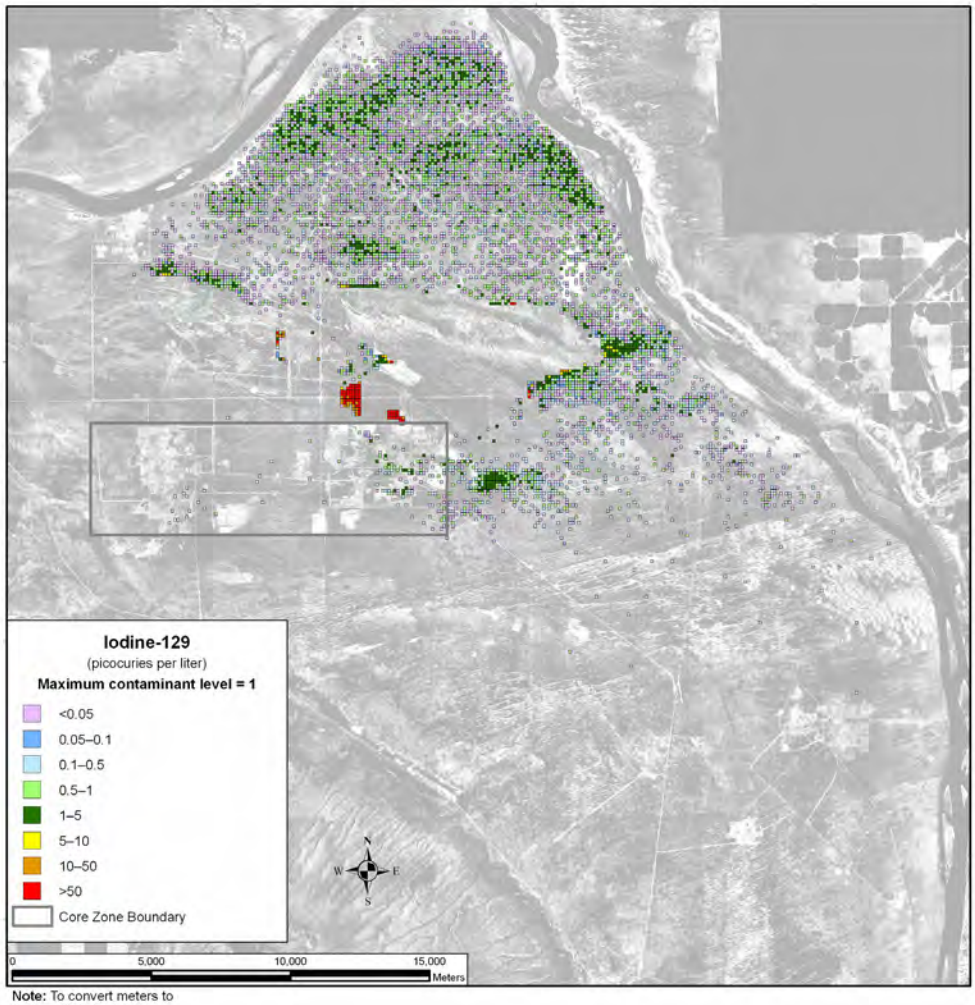
Note: To convert meters to feet, multiply by 3.281

Figure 5–16. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–17. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–18. Tank Closure Alternative 1 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140

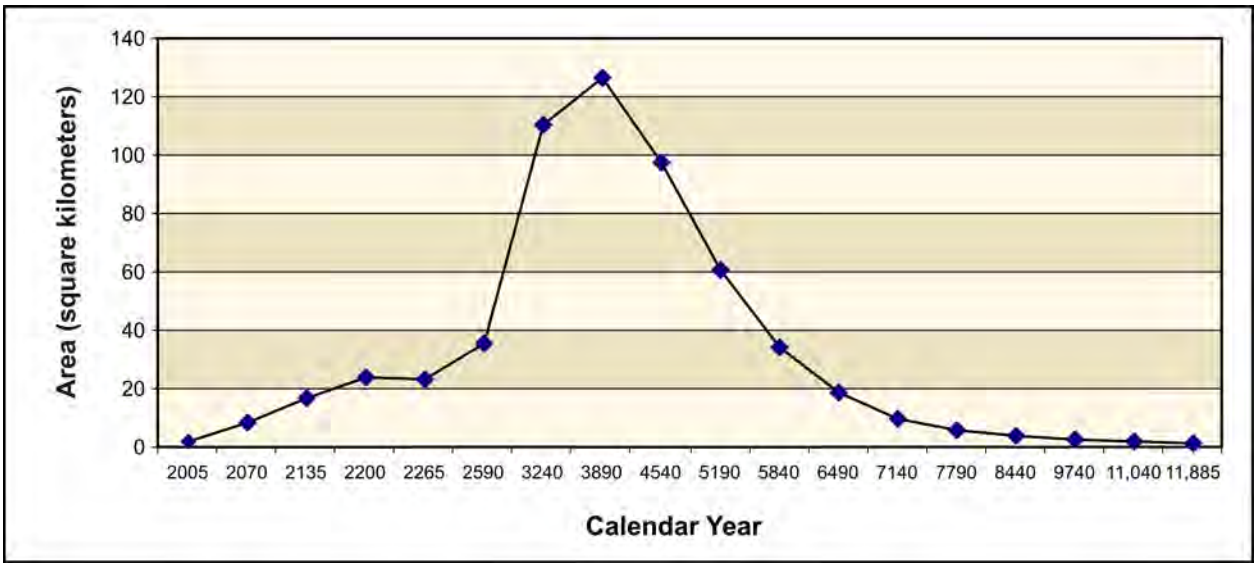
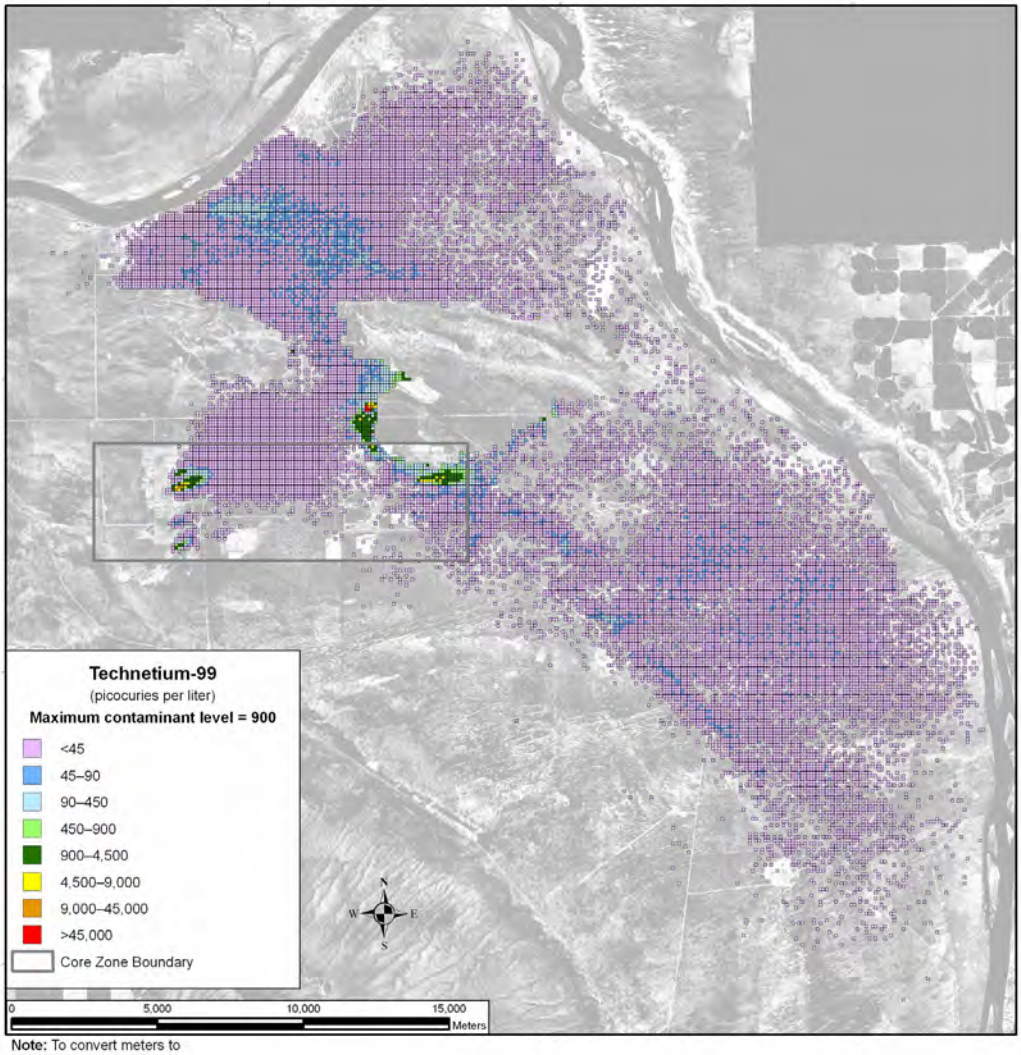
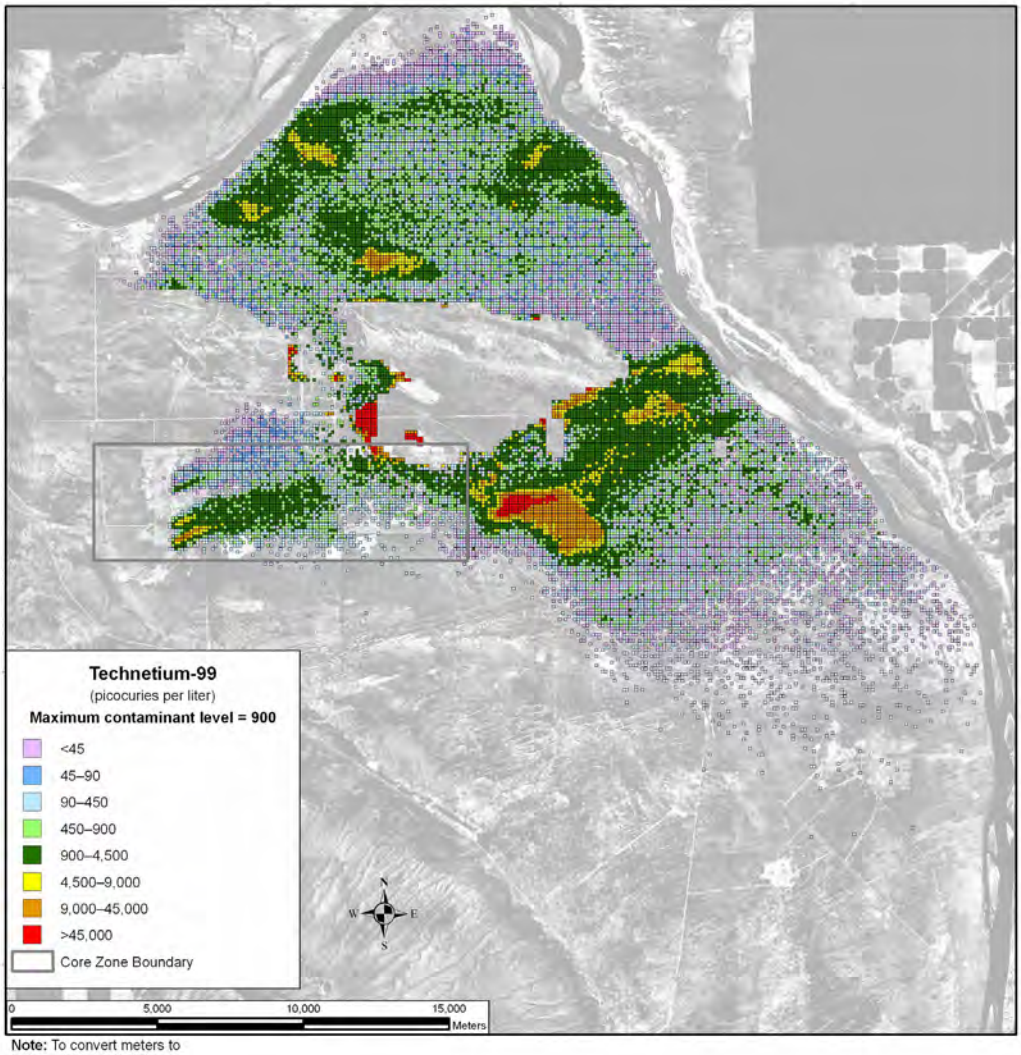


Figure 5–19. Tank Closure Alternative 1 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time



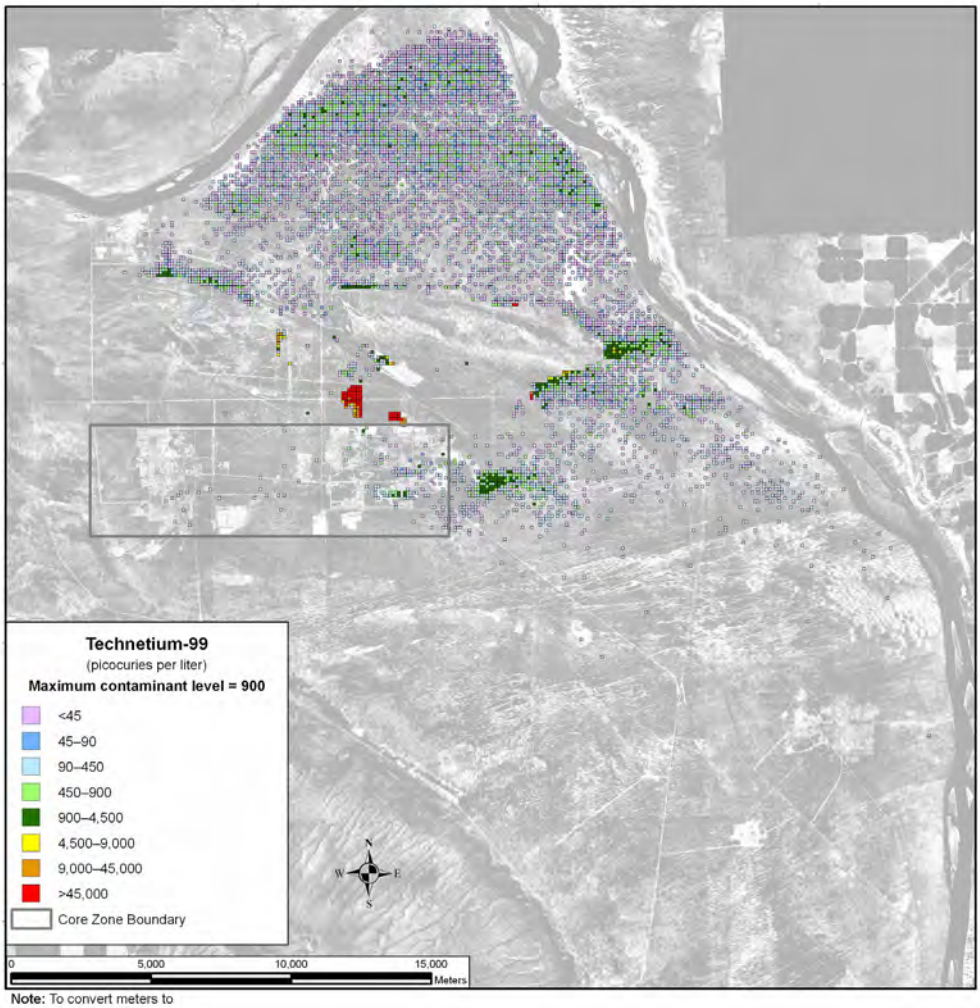
Note: To convert meters to feet, multiply by 3.281

Figure 5–20. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–21. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–22. Tank Closure Alternative 1 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140

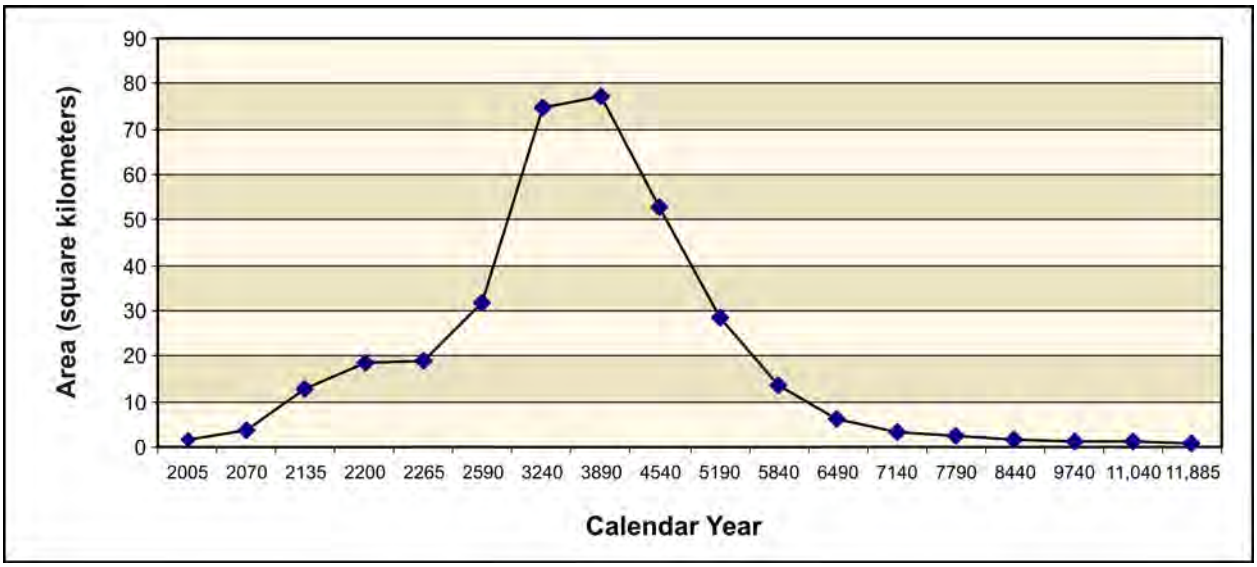
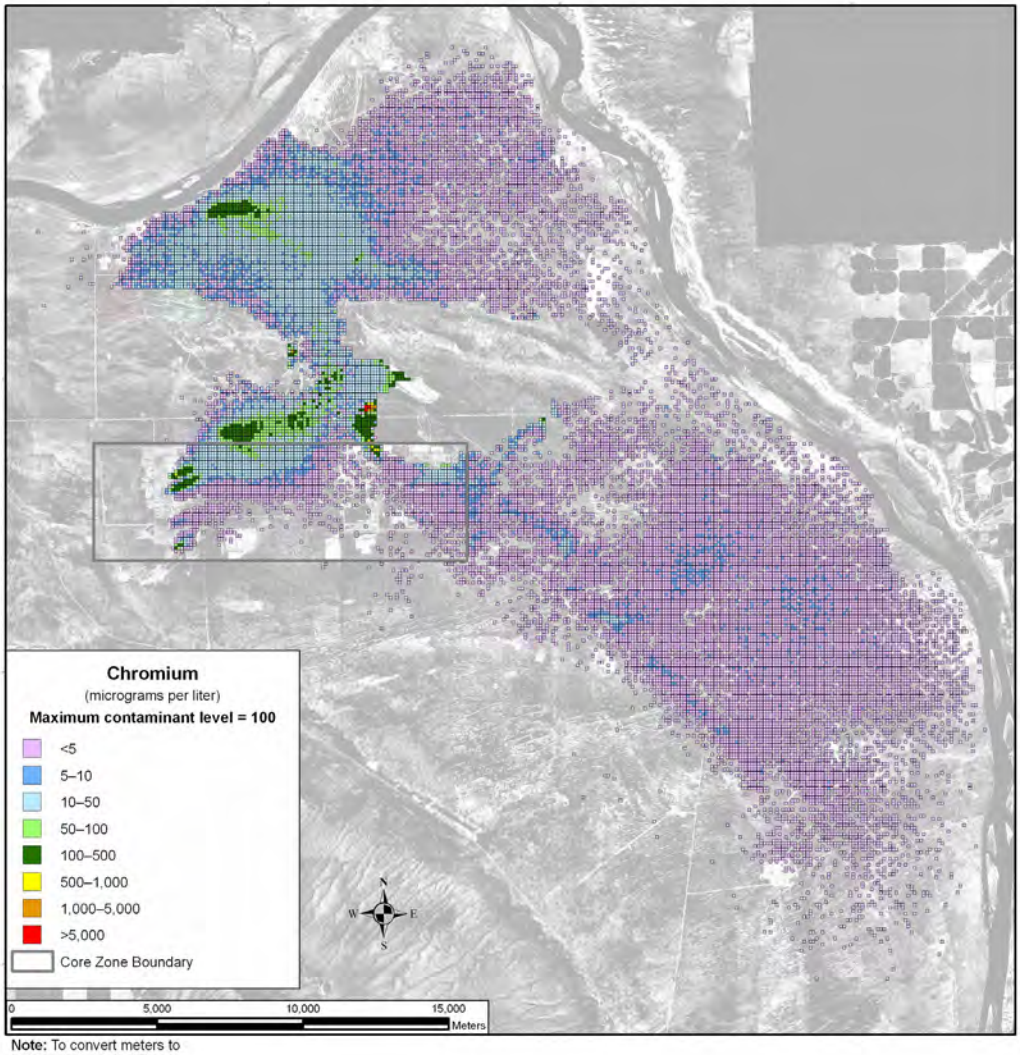
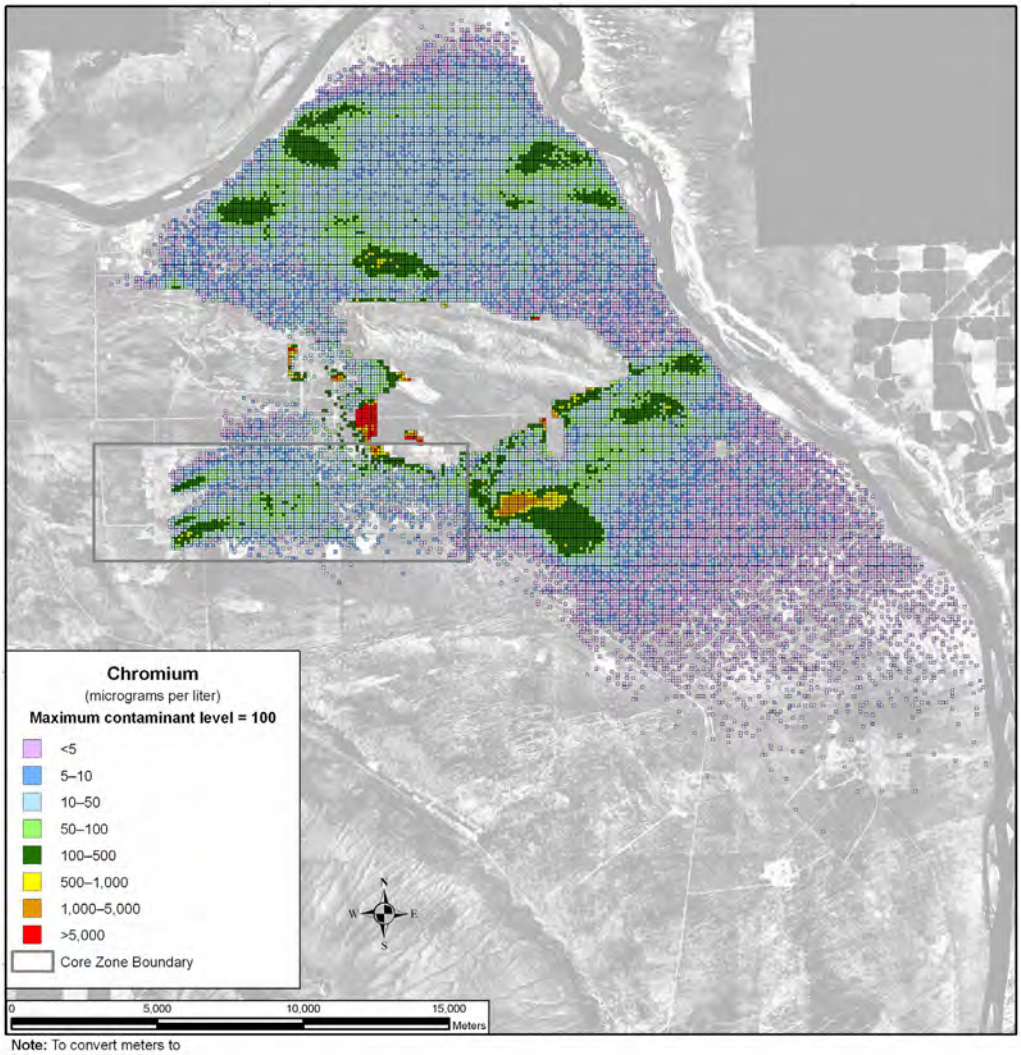


Figure 5–23. Tank Closure Alternative 1 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time



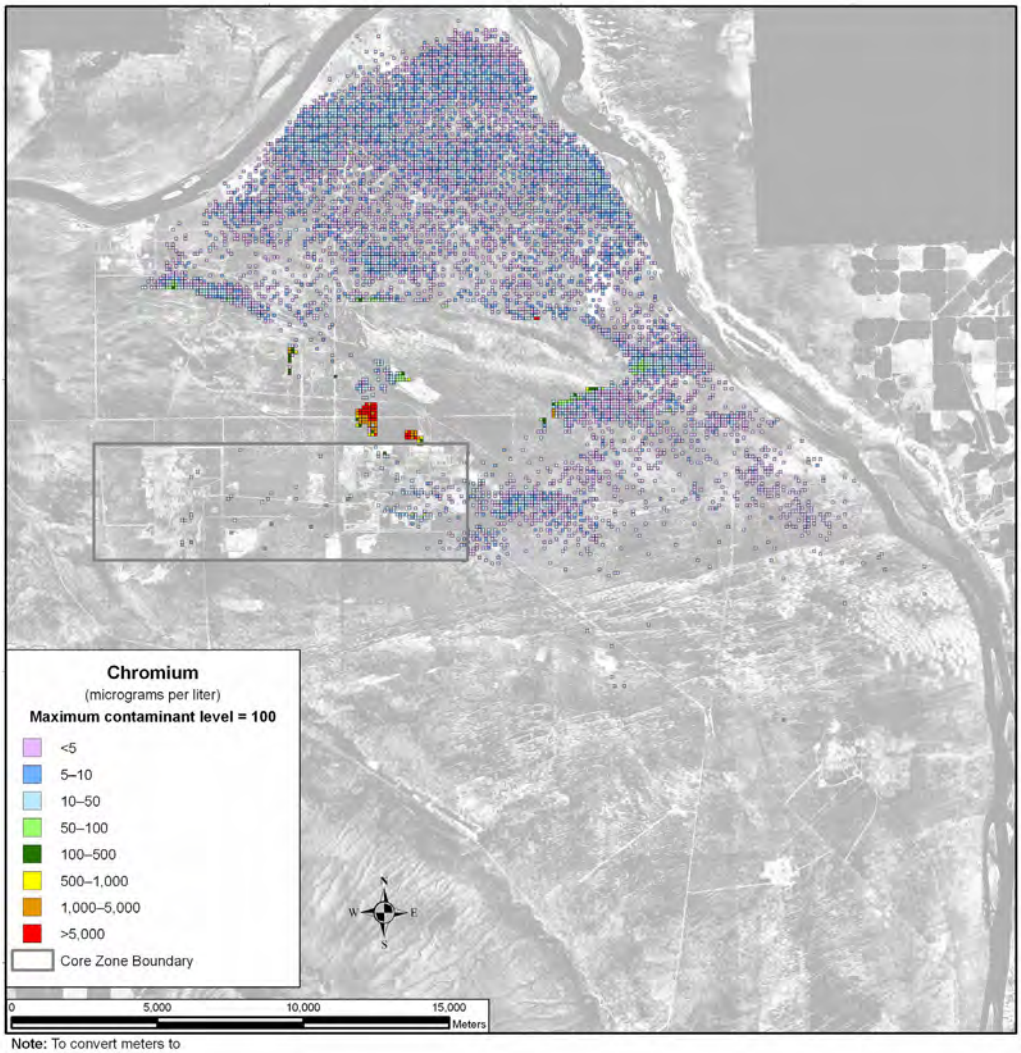
Note: To convert meters to feet, multiply by 3.281

Figure 5–24. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



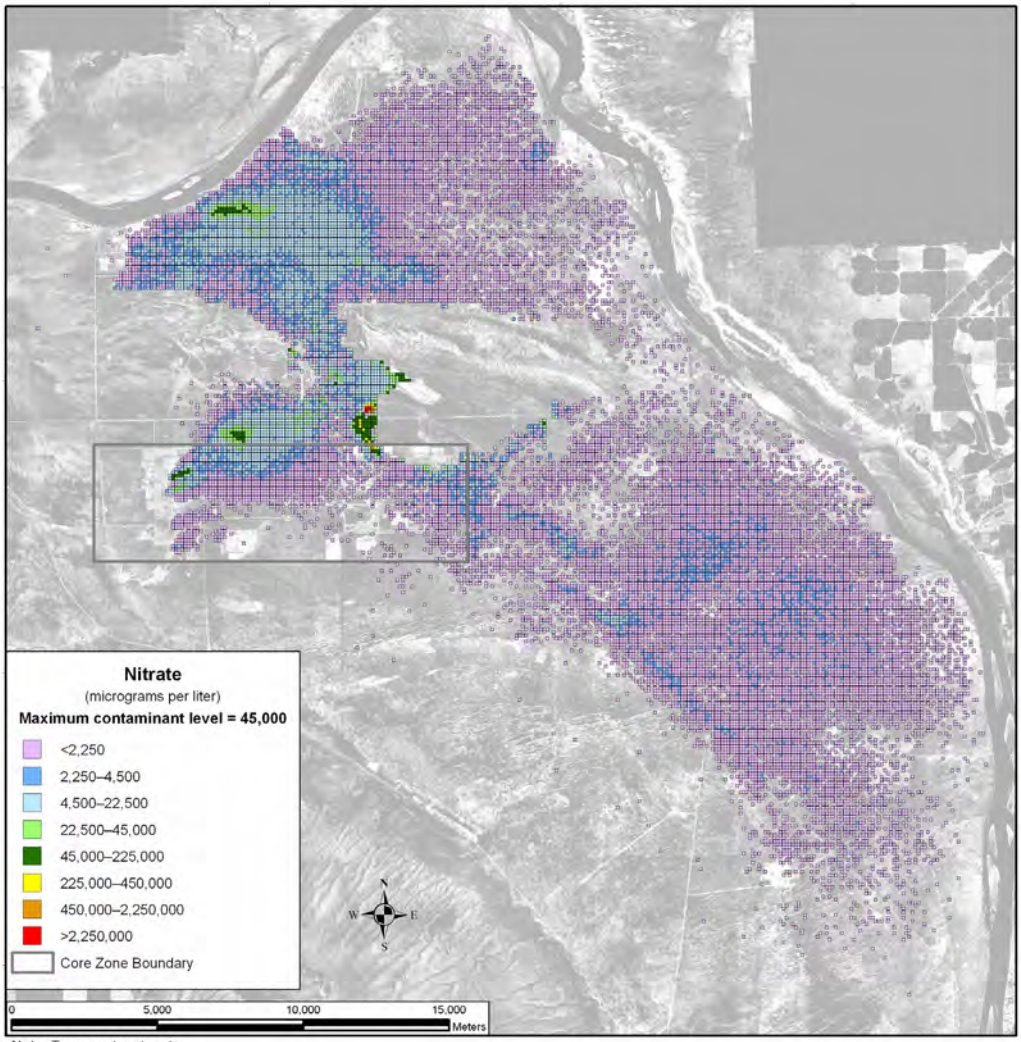
Note: To convert meters to feet, multiply by 3.281

Figure 5–25. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



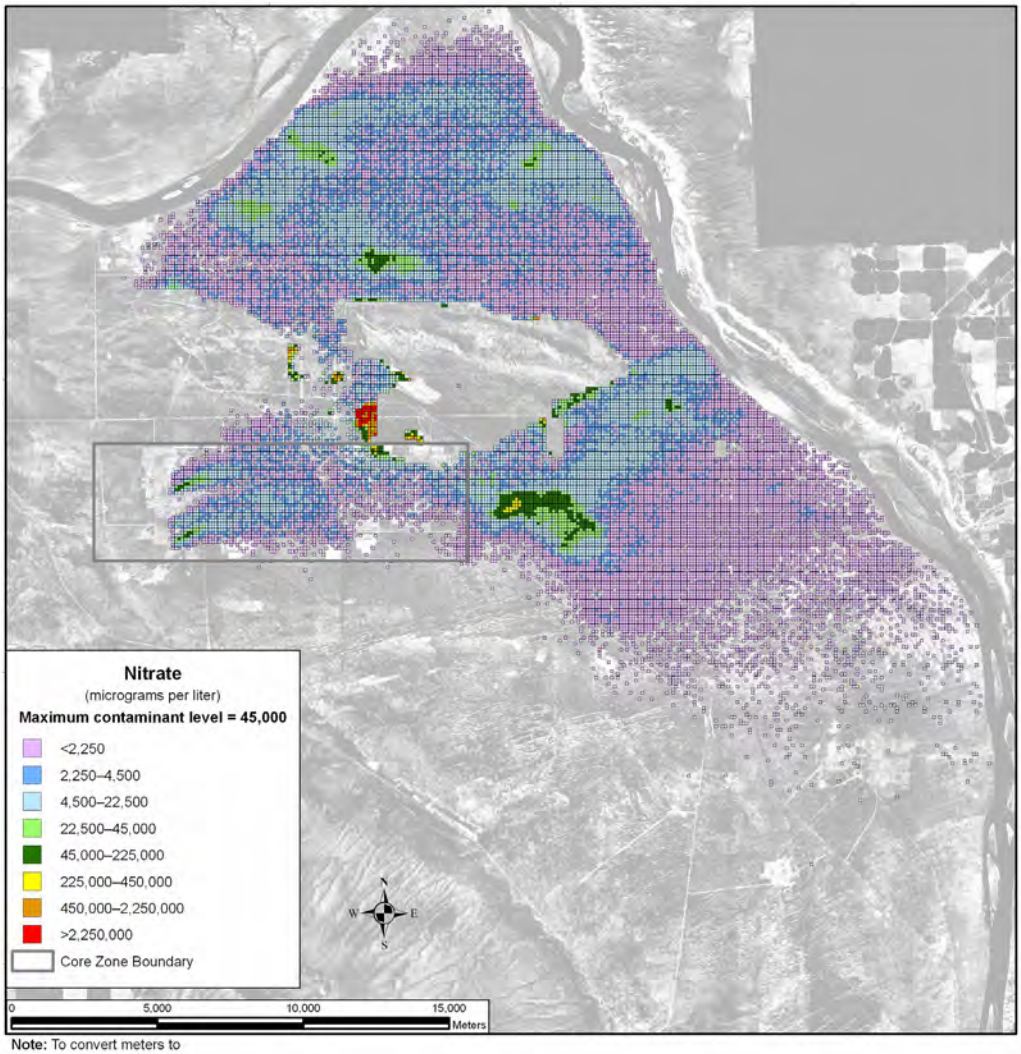
Note: To convert meters to feet, multiply by 3.281

Figure 5–26. Tank Closure Alternative 1 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



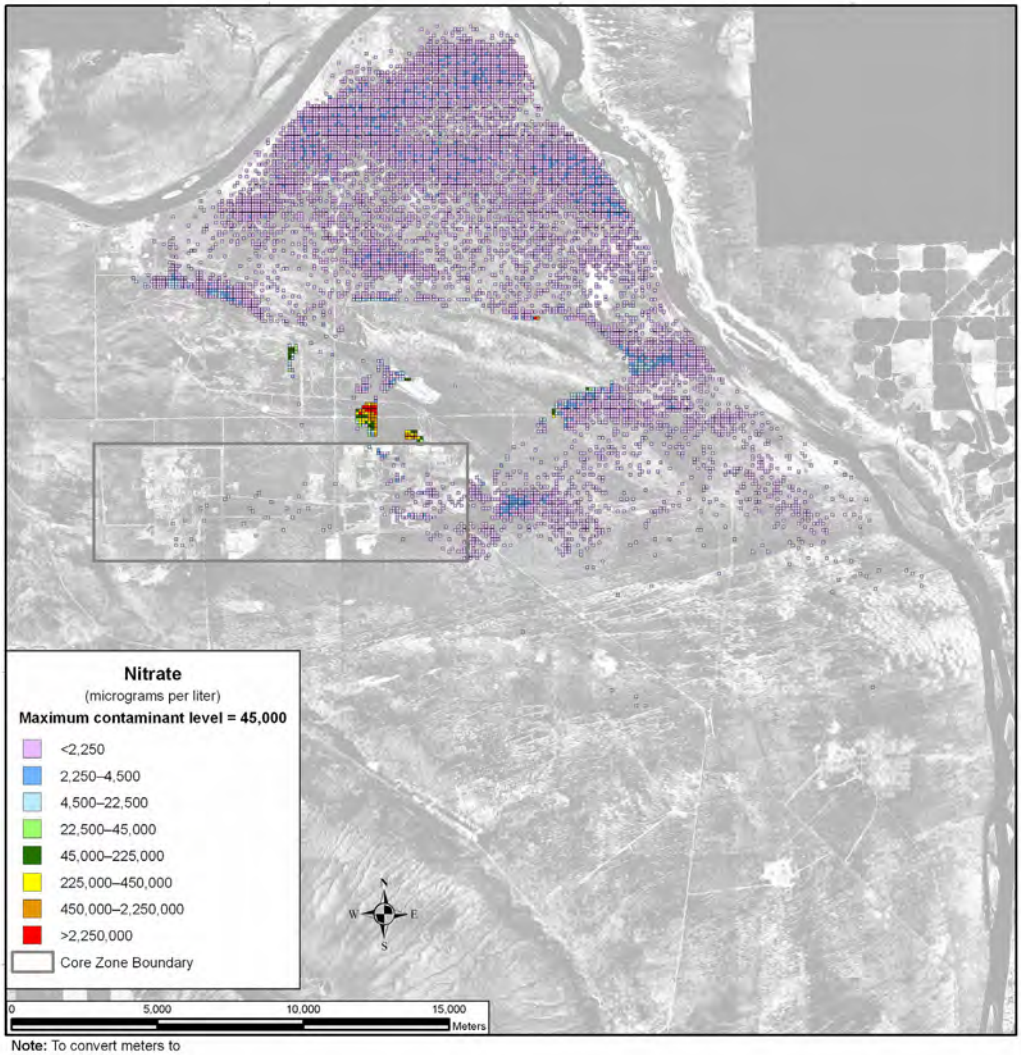
Note: To convert meters to feet, multiply by 3.281

Figure 5–27. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

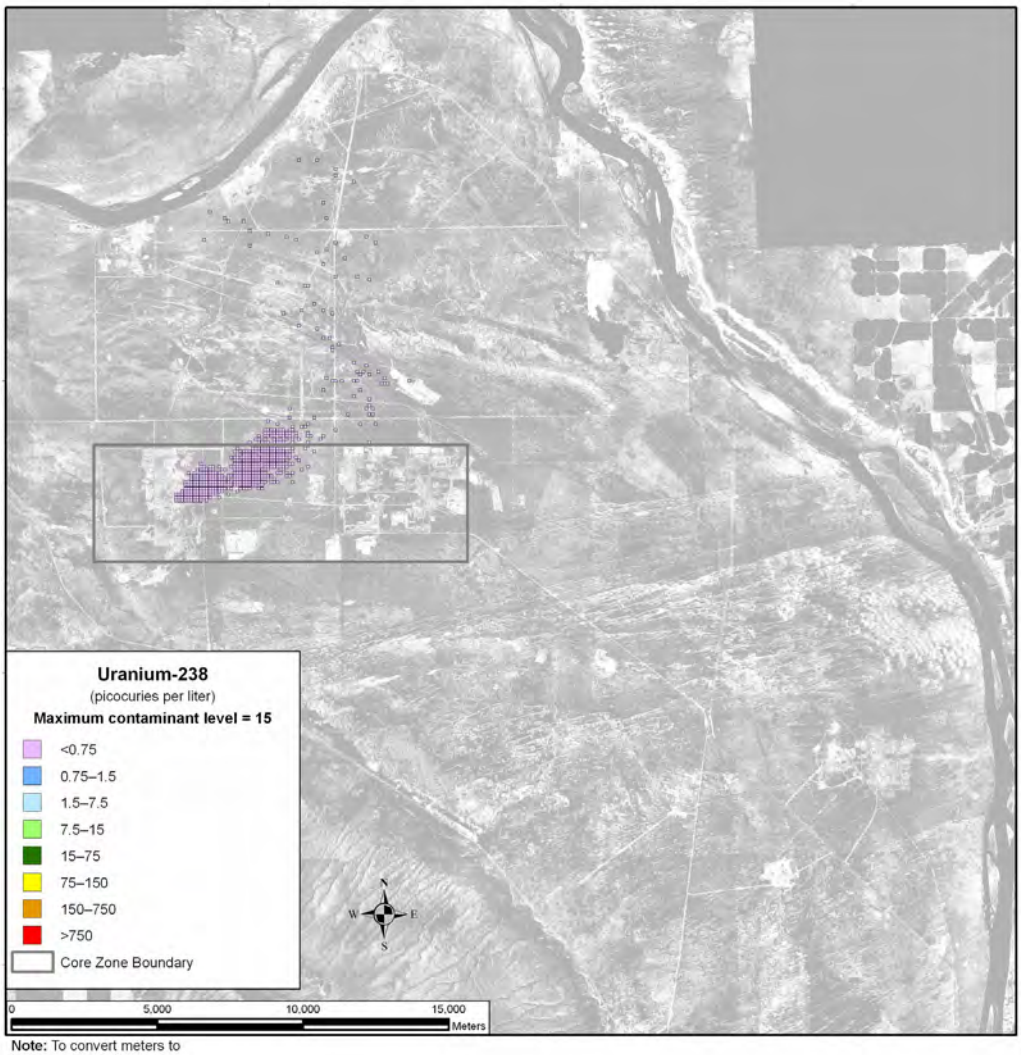
Figure 5–28. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

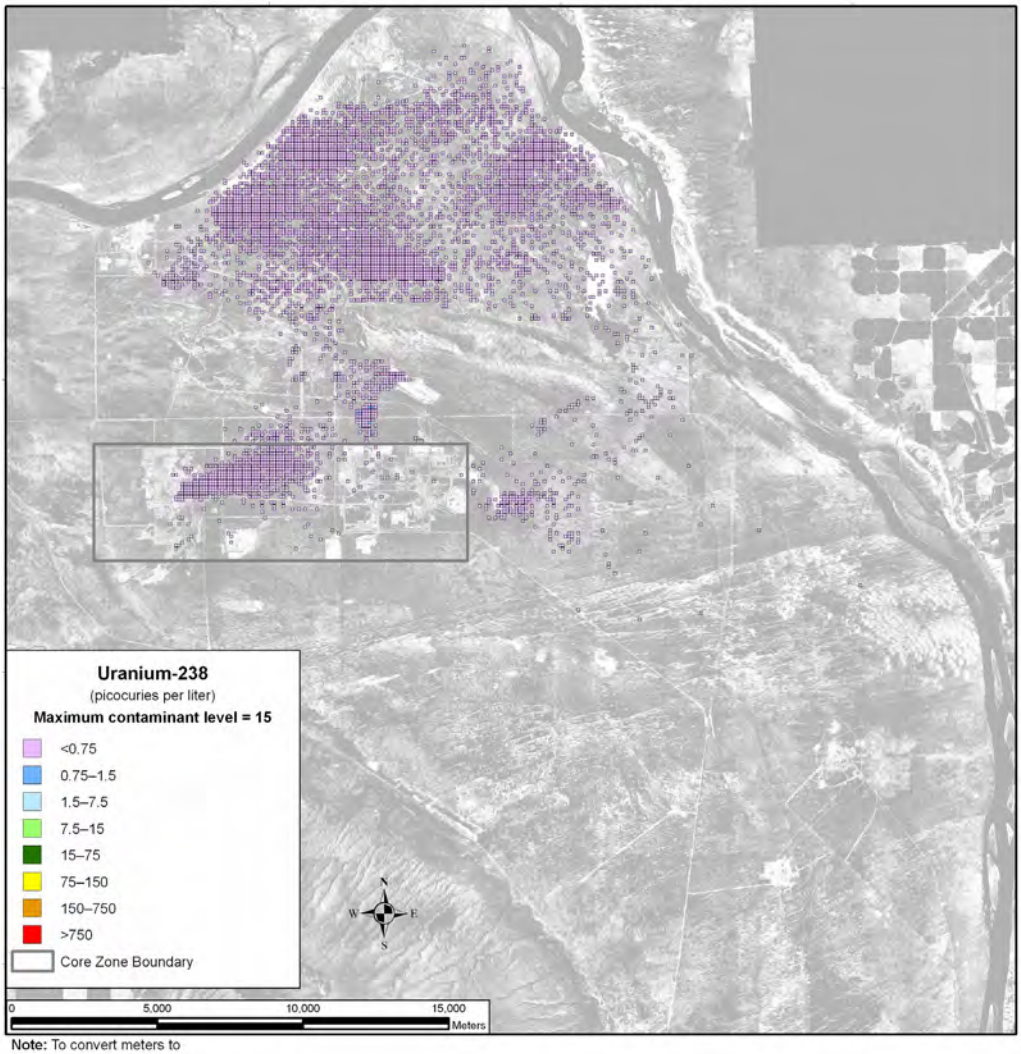
Figure 5–29. Tank Closure Alternative 1 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–30 shows the distribution of uranium-238 during CY 2135. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration that is predominantly contained within the Core Zone Boundary. By CY 3890 (see Figure 5–31), the area of the plume has grown, but there are no significant increases in peak concentration. At CY 11,885 (see Figure 5–32), the greatest development of the plume during the analysis period is seen, resulting primarily from the release of other tank farm sources at the A and B Barriers. Figure 5–33 shows the total area in which groundwater concentrations of uranium-238 exceed the benchmark concentration as a function of time. The area of exceedance is largest near the end of the period of analysis. Figures 5–34 through 5–36 show the corresponding spatial distribution for total uranium.



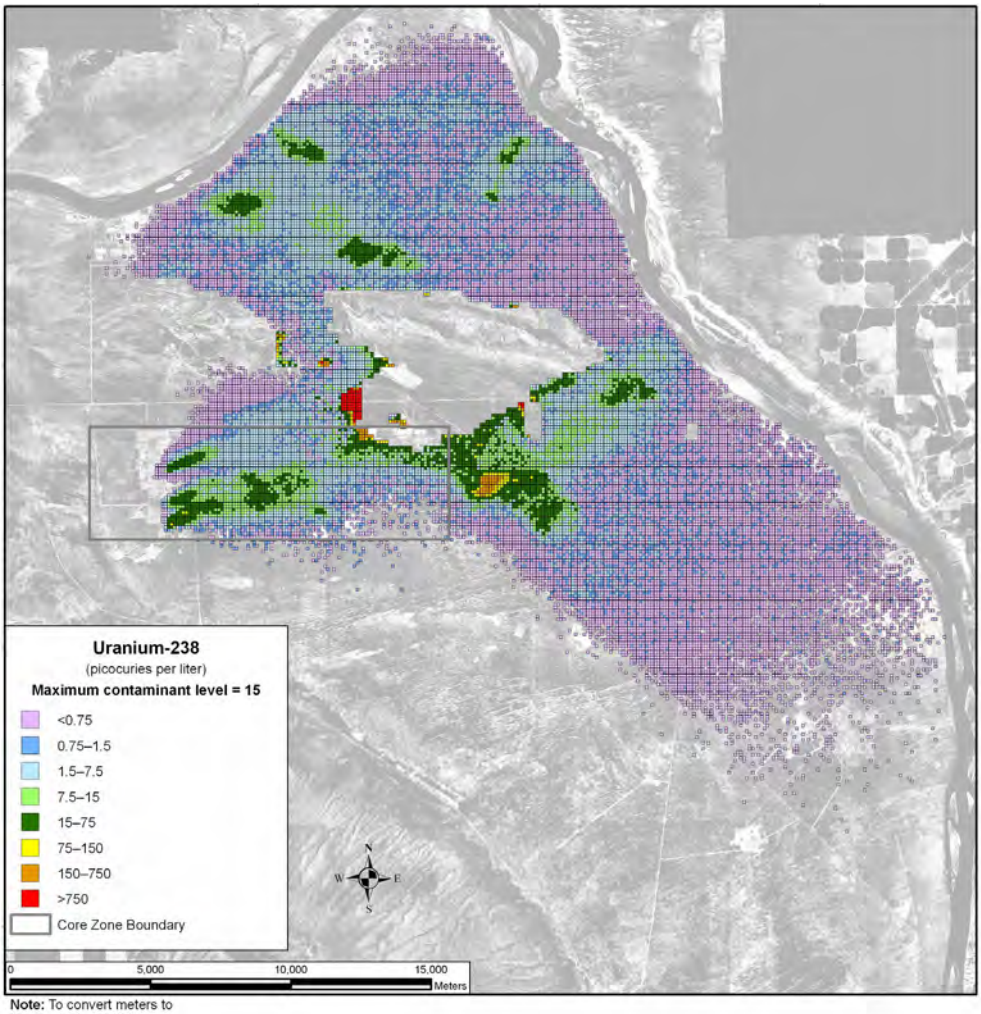
Note: To convert meters to feet, multiply by 3.281

Figure 5–30. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–31. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–32. Tank Closure Alternative 1 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

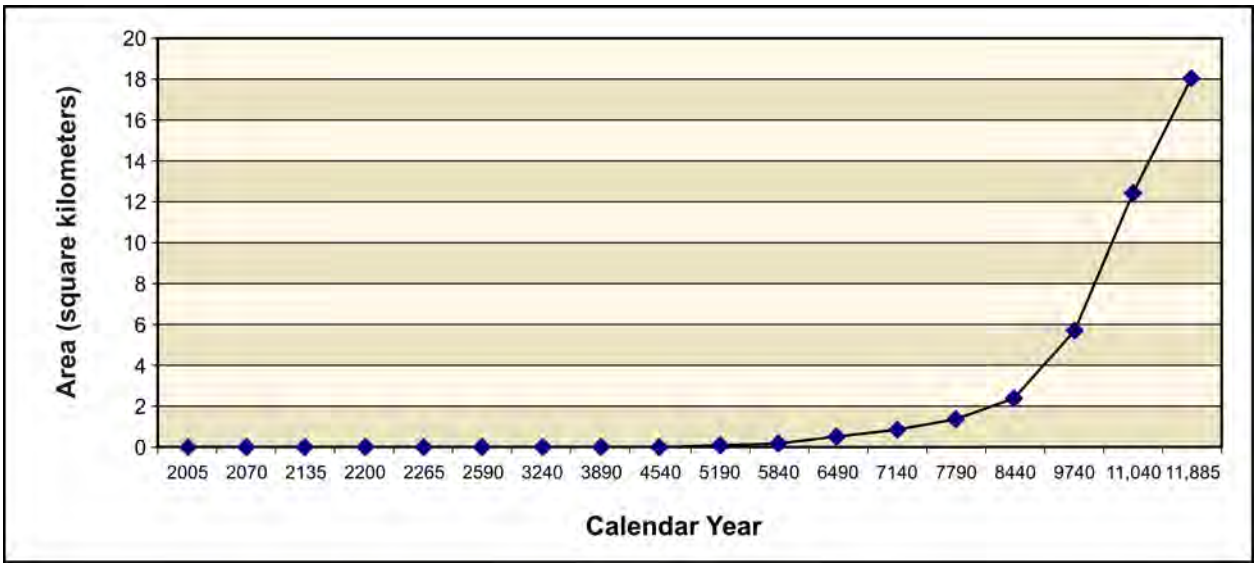
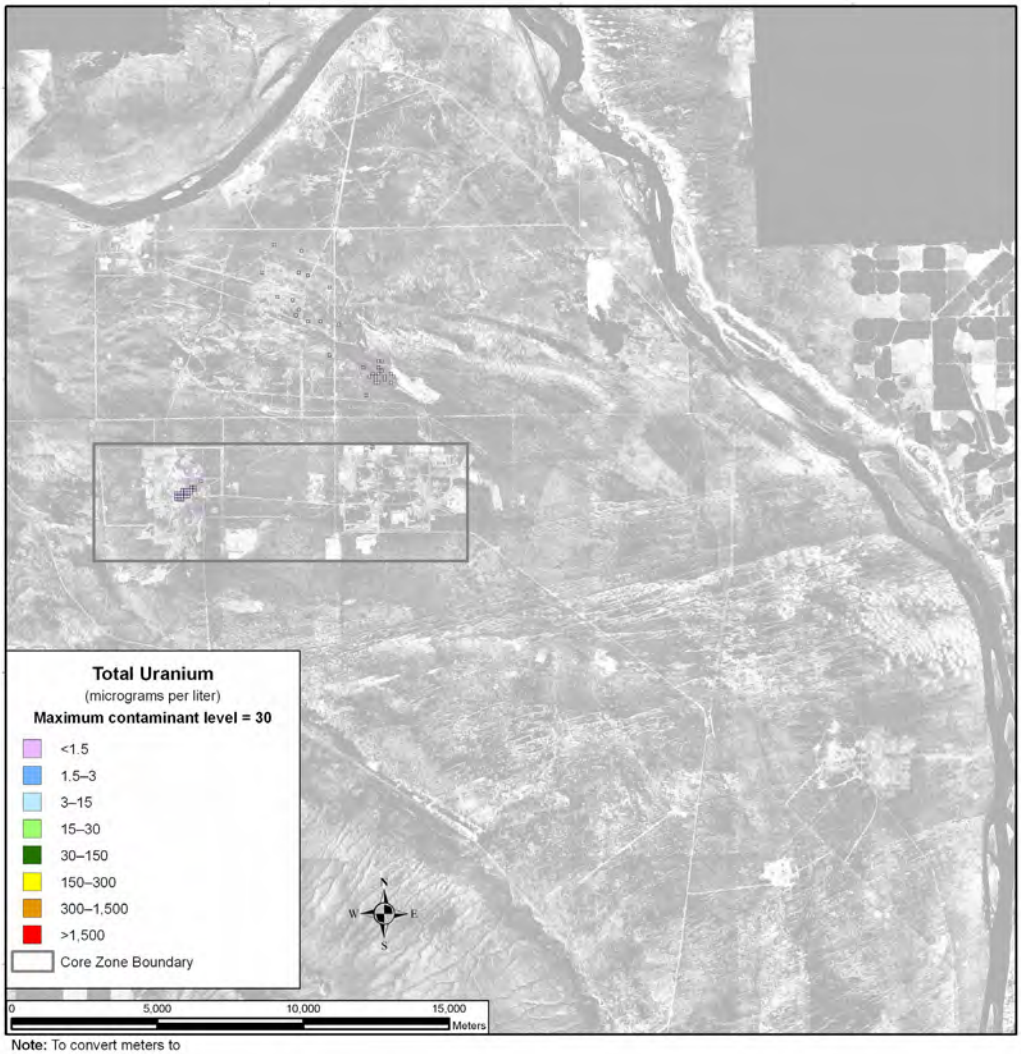
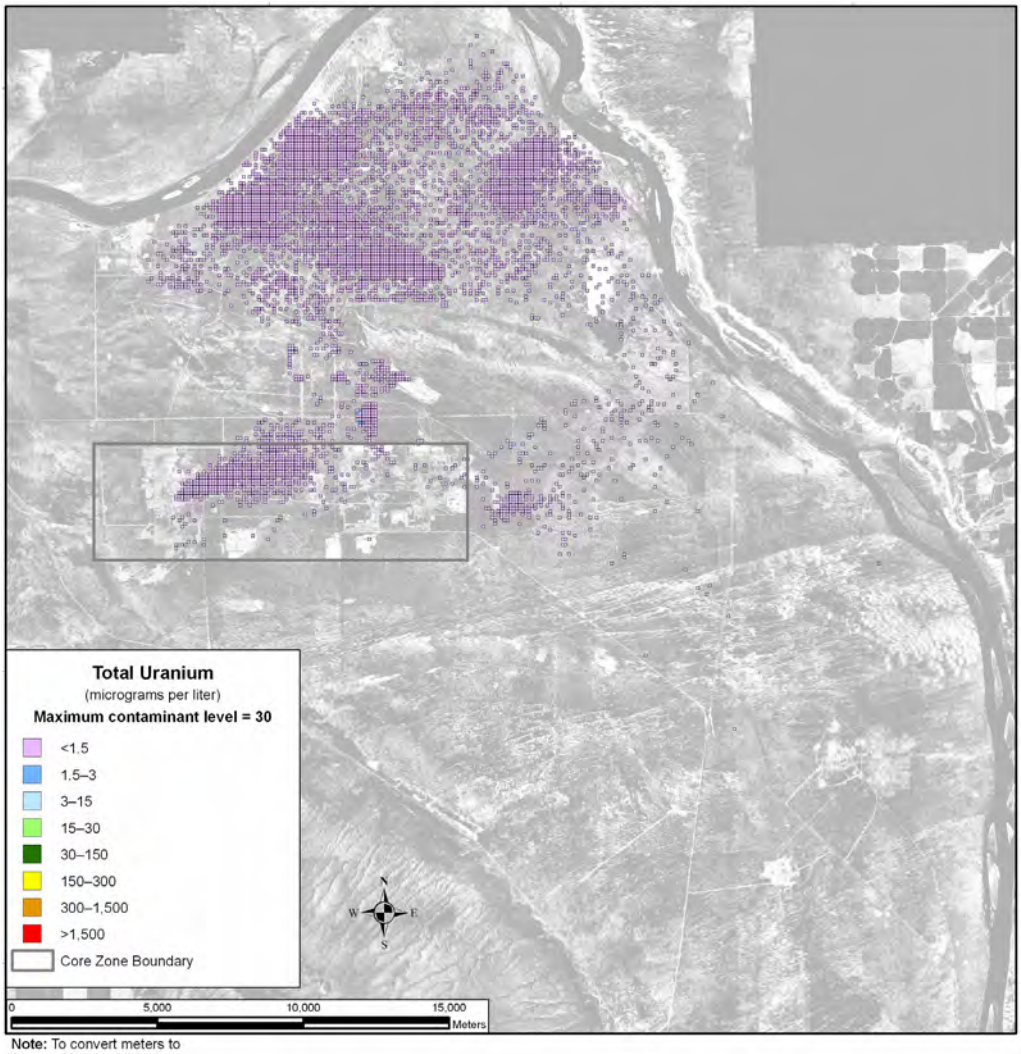


Figure 5–33. Tank Closure Alternative 1 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time



Note: To convert meters to feet, multiply by 3.281

Figure 5–34. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–35. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890

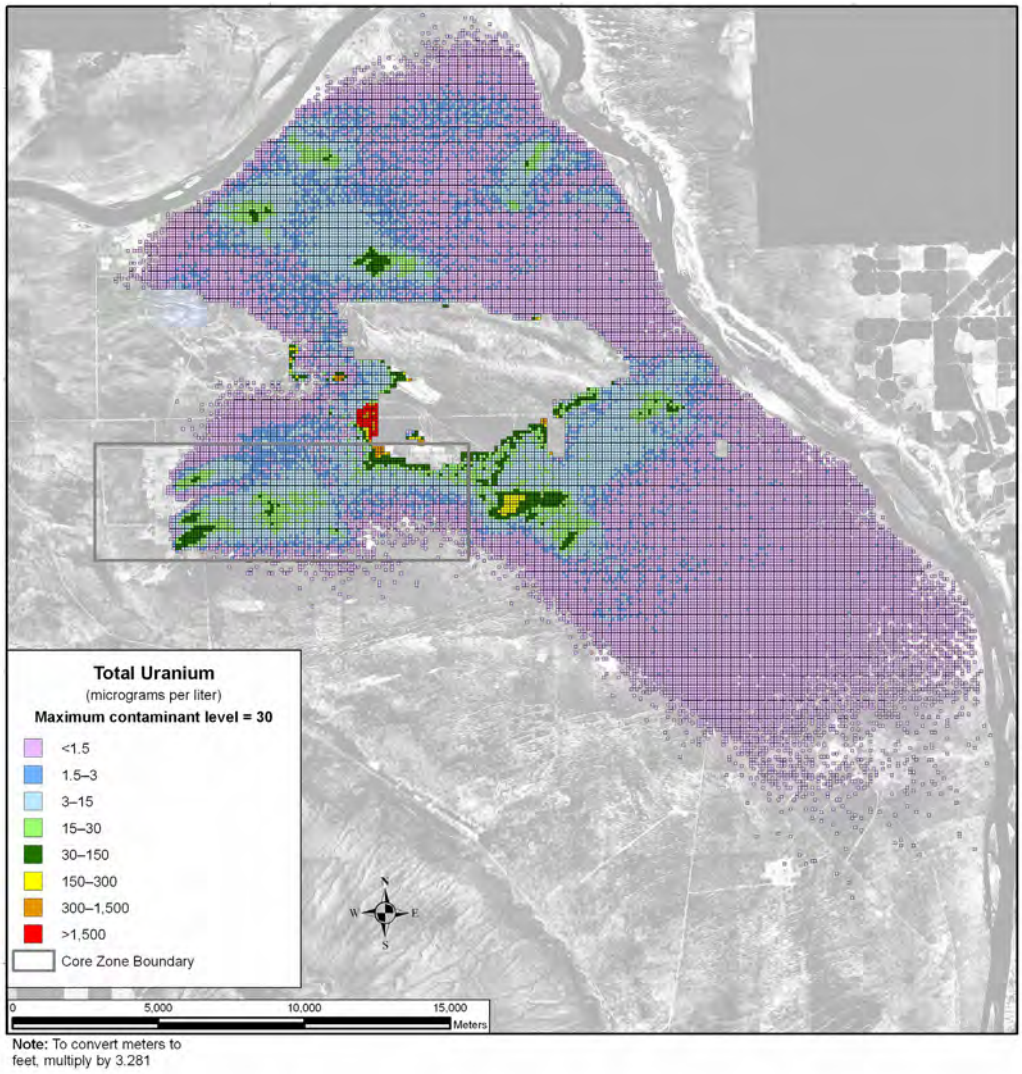


Figure 5–36. Tank Closure Alternative 1 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

5.1.1.1.6 Summary of Impacts

In general, the inventory remaining in the tank farms, available for release to the environment at the start of the post–administrative control period, is the predominant contributor in the analysis. Discharges to cribs and trenches (ditches) and past leaks during the past-practice period are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two orders of magnitude smaller. The intensities and areas of these groundwater plumes peak between CY 3200 and CY 4000.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2100, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark at the Core Zone Boundary beyond CY 6000, and approach the benchmark at the Columbia River after CY 10,000. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

5.1.1.2 Tank Closure Alternative 2A: Existing WTP Vitrification; No Closure

This section describes the groundwater analysis results for Tank Closure Alternative 2A, including long-term groundwater impacts of contaminant sources within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

5.1.1.2.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 2A are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 2A, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 2A that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2193. Waste treatment operations were assumed to be complete for immobilized high-level radioactive waste (IHLW) and immobilized low-activity waste (ILAW) in 2093; starting in 2094, tanks and facilities would be maintained in operational standby condition for 100 years. It was assumed that 99 percent of waste volume would be retrieved from the tanks. The leakage rate for SSTs was assumed to be 15,140 liters (4,000 gallons) per SST. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2194 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. In addition, all remaining waste at the SST and DST farms (other tank farm sources) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.2.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 2A. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 2A is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 2A were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become major contributors toward the end of the period of analysis.

The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-14}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 2A.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e. move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.2.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 2A in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–37 through 5–42). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–37 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–38, the chemical hazard drivers. The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are both past leaks and other tank farm sources.

Figure 5–39 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–40, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone from cribs and trenches (ditches) and past leaks.

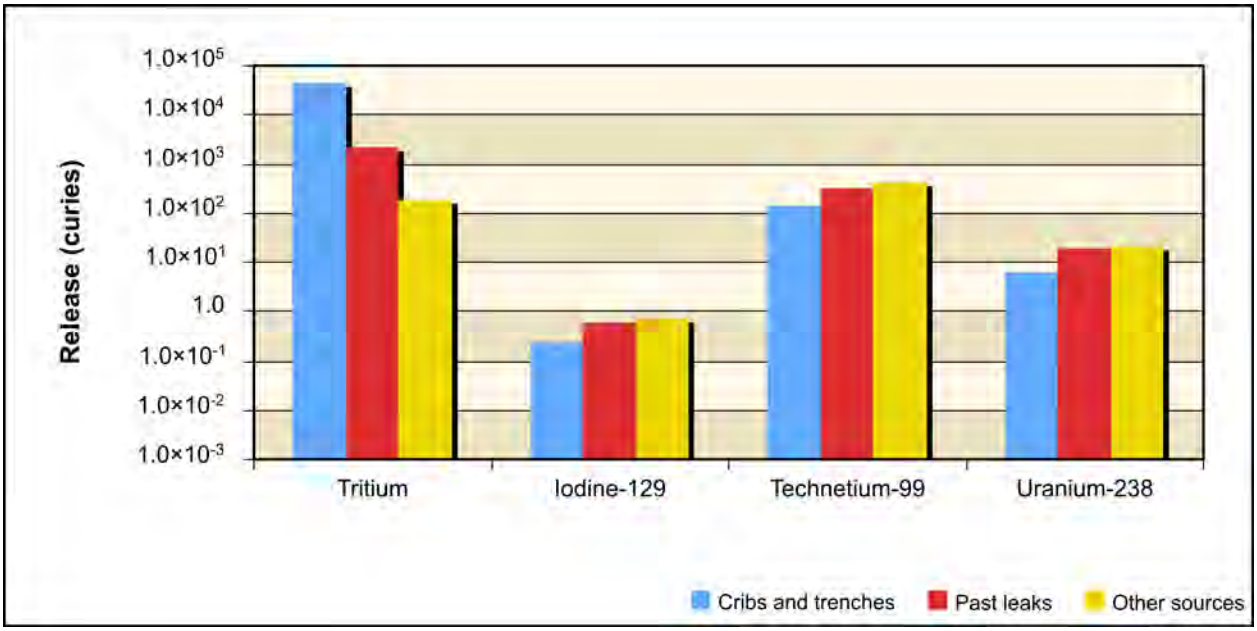


Figure 5–37. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

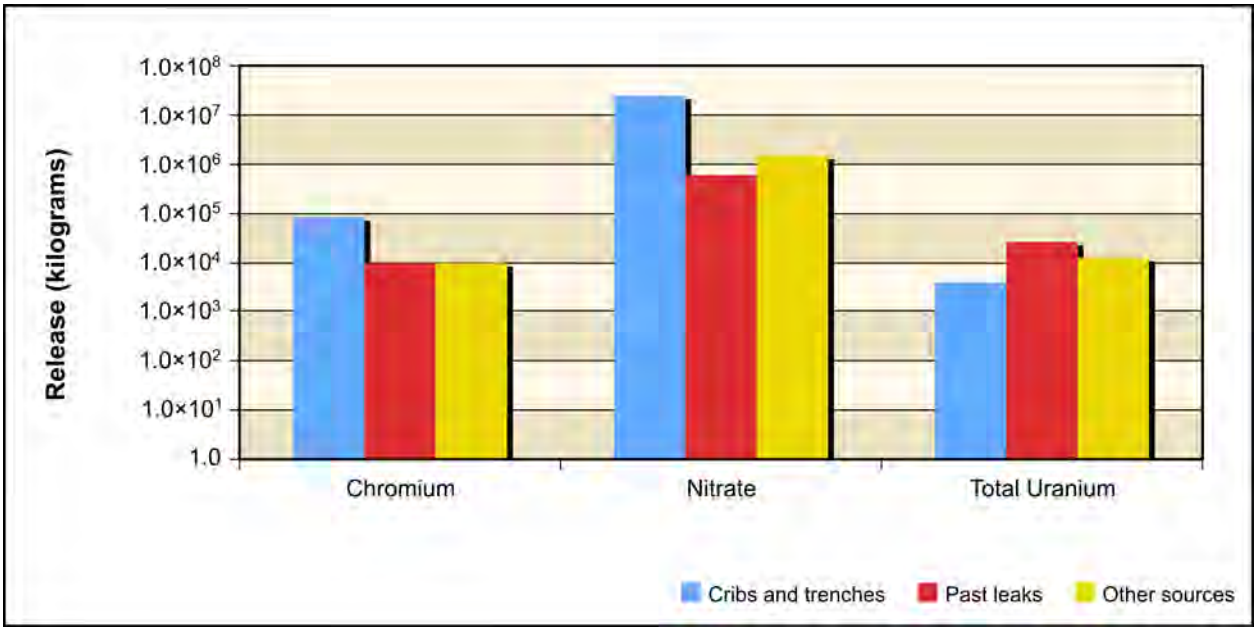


Figure 5–38. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

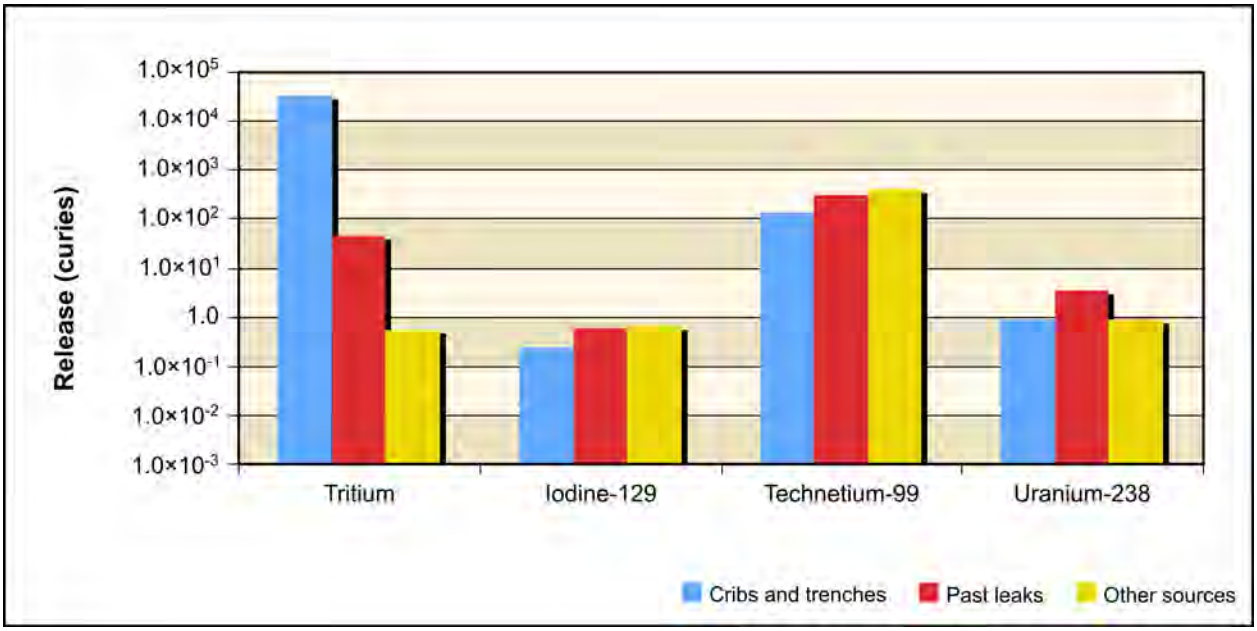


Figure 5–39. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

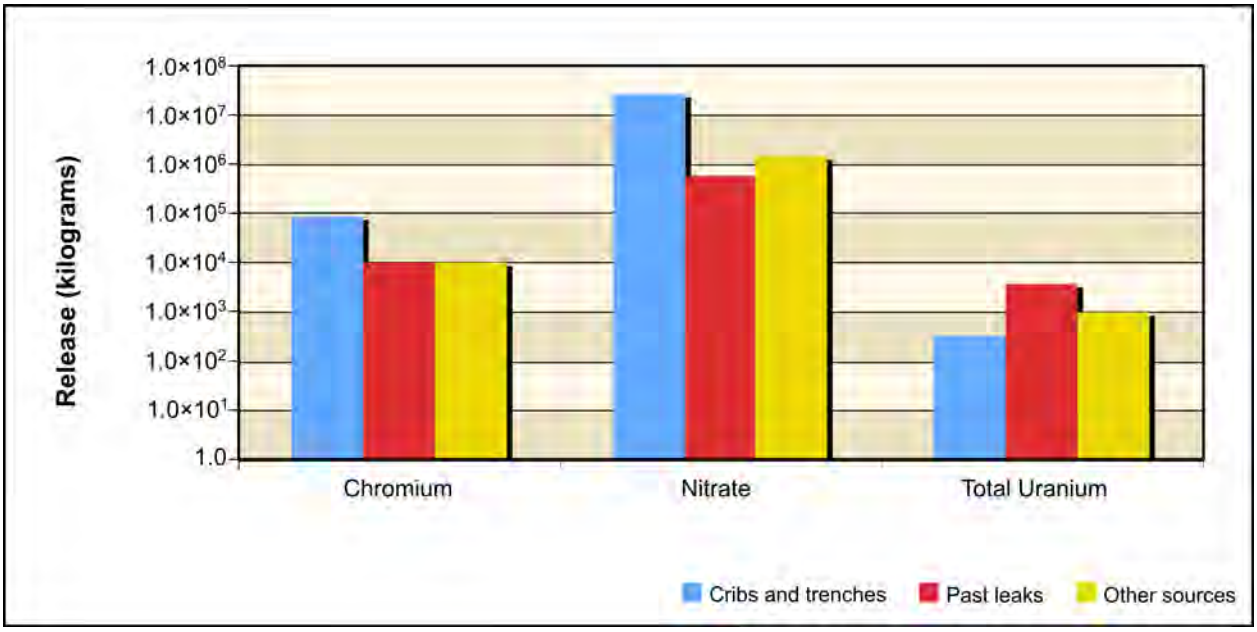


Figure 5–40. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay in the vadose zone. For cribs and trenches (ditches), about 74 percent of the total inventory of tritium reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent of the inventory reached the water table. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process.

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 14 percent of uranium-238 and 8 percent of total uranium inventory reached groundwater during the period of analysis. For past leaks, about 18 percent of uranium-238 and 14 percent of total uranium of the total inventory reached groundwater during the period of analysis. For other tank farm sources, about 4 percent of uranium-238 and 7 percent of total uranium of the total inventory reached groundwater during the period of analysis. These results also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–41 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–42, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. Overall, about 38 percent of the amount of uranium-238 and about 40 percent of total uranium released to groundwater reached the Columbia River during the period of analysis. These results also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

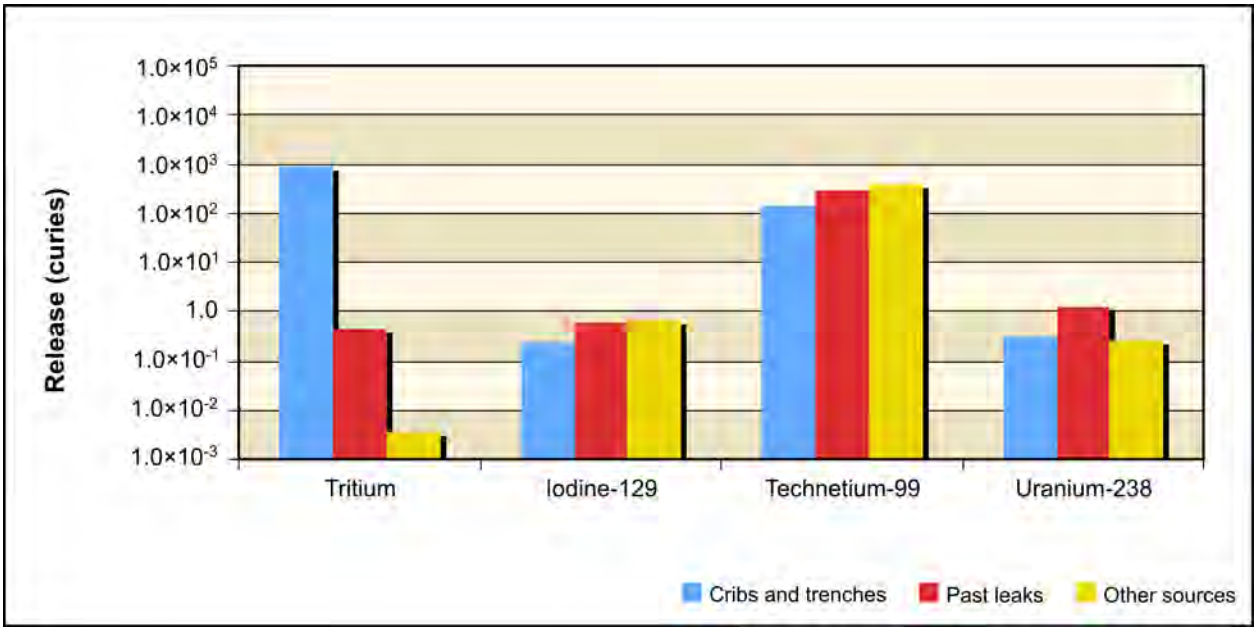


Figure 5–41. Tank Closure Alternative 2A Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

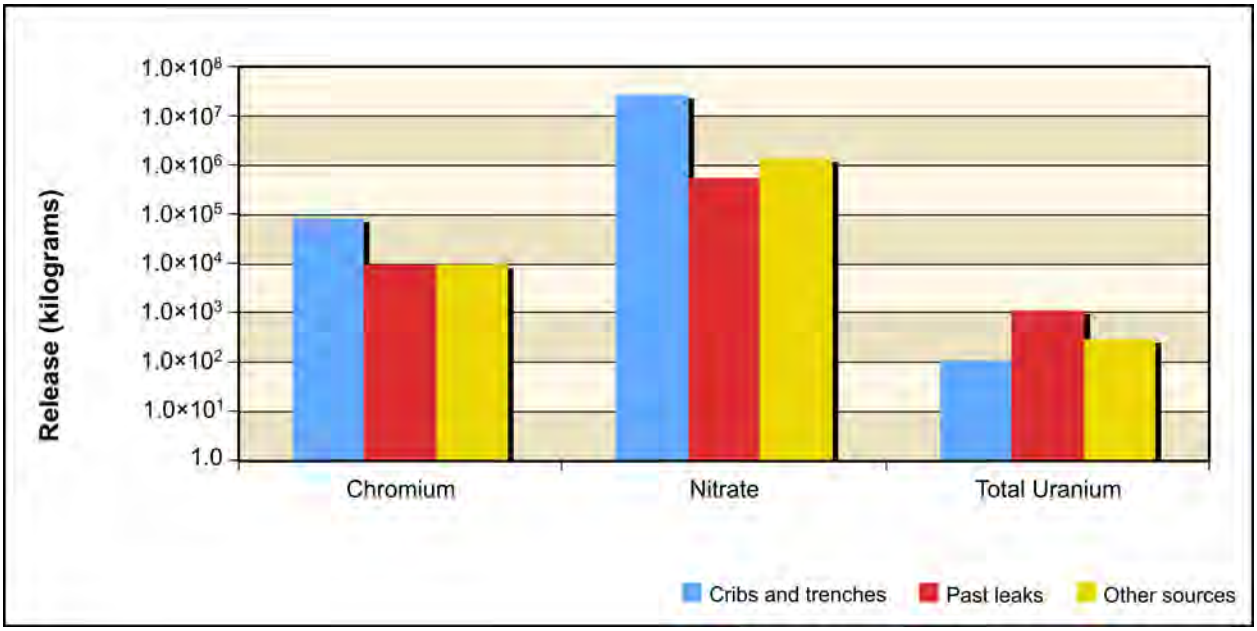


Figure 5–42. Tank Closure Alternative 2A Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.2.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 2A impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–2 and Figures 5–43 through 5–49). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–2 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Table 5–2. Tank Closure Alternative 2A Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	35	5,030	51	5,220	13	5,630	135	20,000
	(2052)	(2051)	(2050)	(2061)	(2050)	(2051)	(2050)	
Technetium-99	**1,590**	**31,700**	**2,820**	**15,000**	546	**27,800**	204	900
	(2055)	(2076)	(2050)	(2051)	(2096)	(2076)	(3464)	
Iodine-129	**3**	**50**	**5**	**30**	**1**	**43**	0.4	1
	(2057)	(2072)	(2050)	(2051)	(2089)	(2072)	(3355)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	3	**142**	7	**42**	11	**148**	1	15
	(11,707)	(11,814)	(11,714)	(11,799)	(11,763)	(11,828)	(11,783)	
Chemical in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3341)	(1940)	(3417)	(1940)	(1940)	(3551)	(3617)	
Chromium	12	**4,260**	**290**	**800**	17	**1,960**	32	100
	(2070)	(2085)	(2050)	(2050)	(2086)	(2066)	(2603)	
Nitrate	11,600	**1,640,000**	10,000	**168,000**	5,800	**1,100,000**	9,100	45,000
	(2068)	(2081)	(2073)	(2086)	(2083)	(2059)	(2400)	
Total uranium	1	**190**	8	20	15	**196**	1	30
	(11,805)	(11,839)	(9863)	(11,709)	(10,978)	(11,624)	(11,809)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern.

Figure 5–43 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore are over an order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2040.

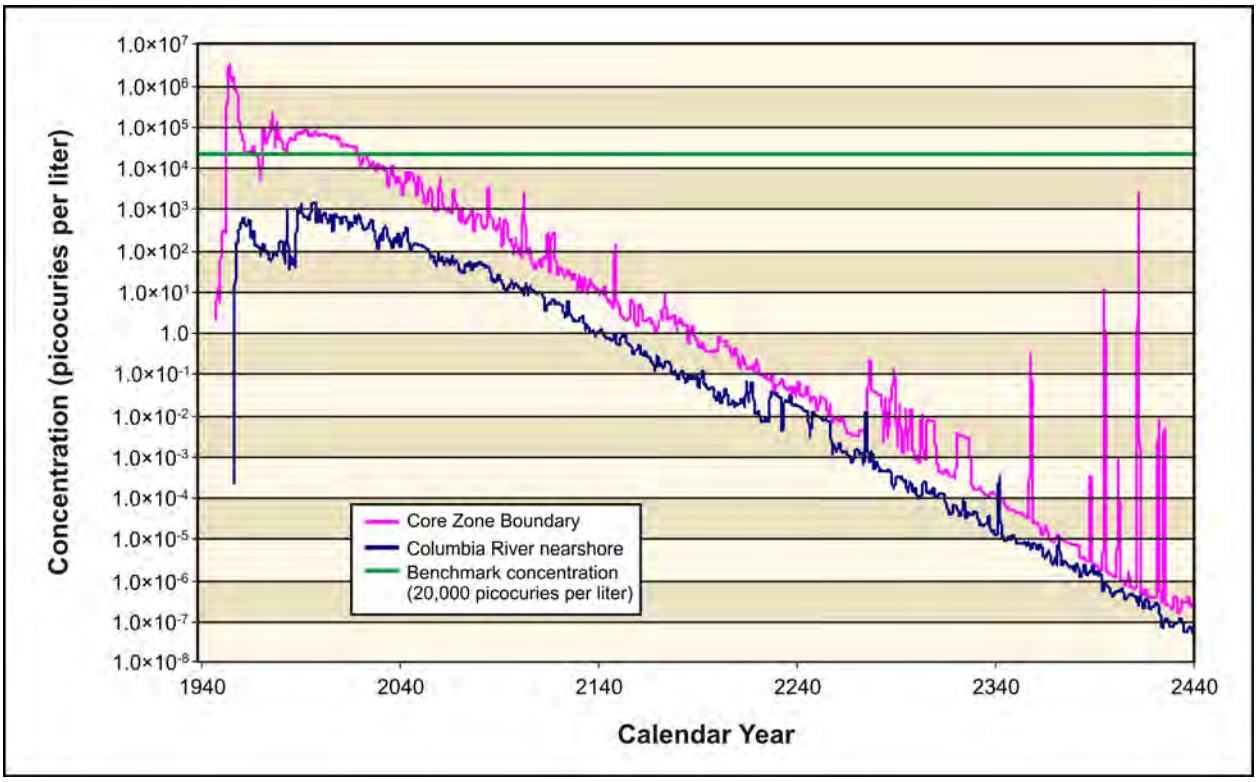


Figure 5–43. Tank Closure Alternative 2A Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–44 through 5–47 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations at the Core Zone Boundary to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis, but return to levels below the benchmark by CY 5000. During this time, groundwater concentrations at the Columbia River nearshore are about an order of magnitude less than the benchmark concentration and gradually decrease to around one to two orders of magnitude less than the benchmark concentration.

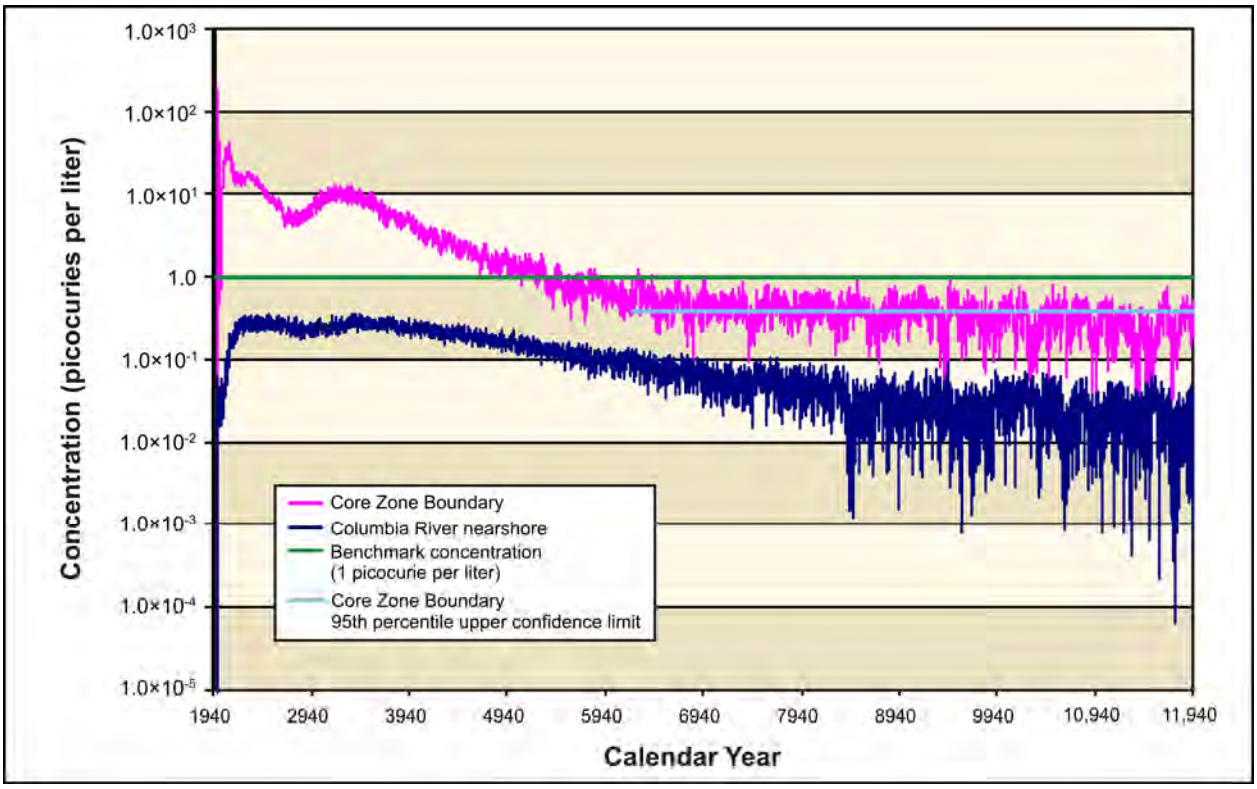


Figure 5–44. Tank Closure Alternative 2A Iodine-129 Concentration Versus Time

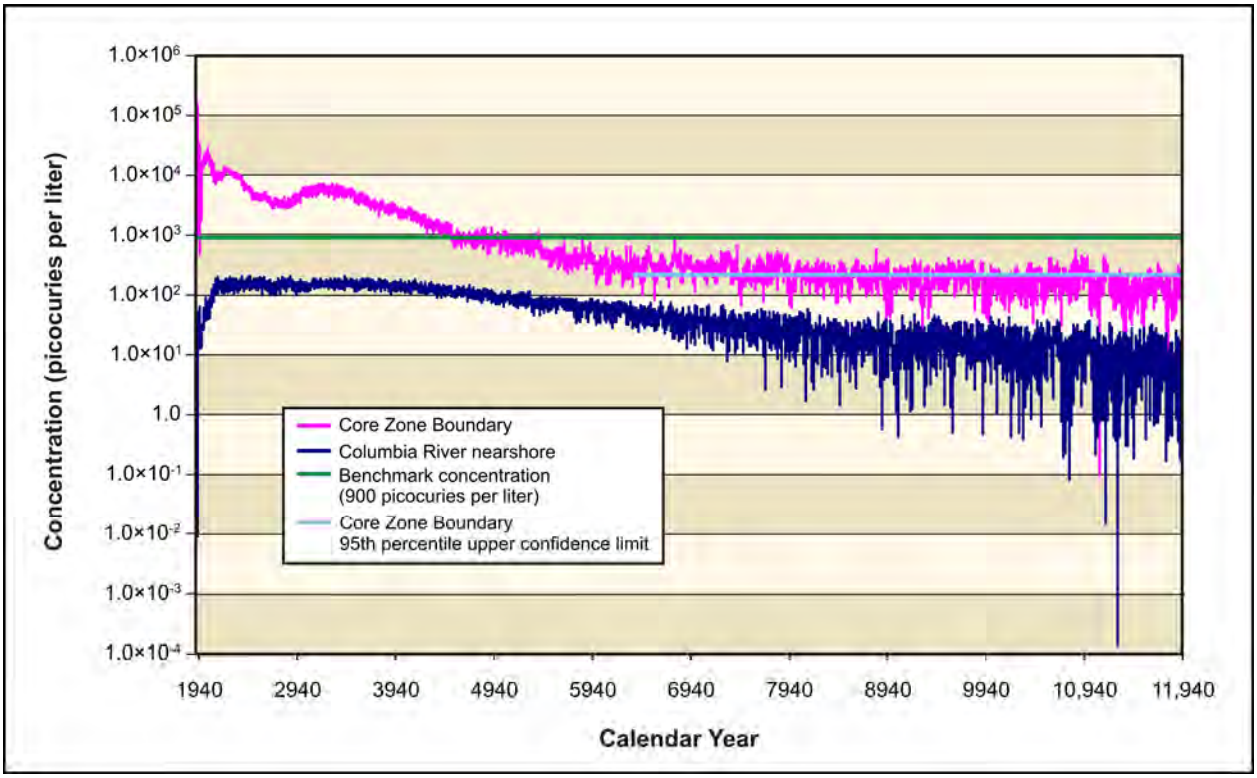


Figure 5–45. Tank Closure Alternative 2A Technetium-99 Concentration Versus Time

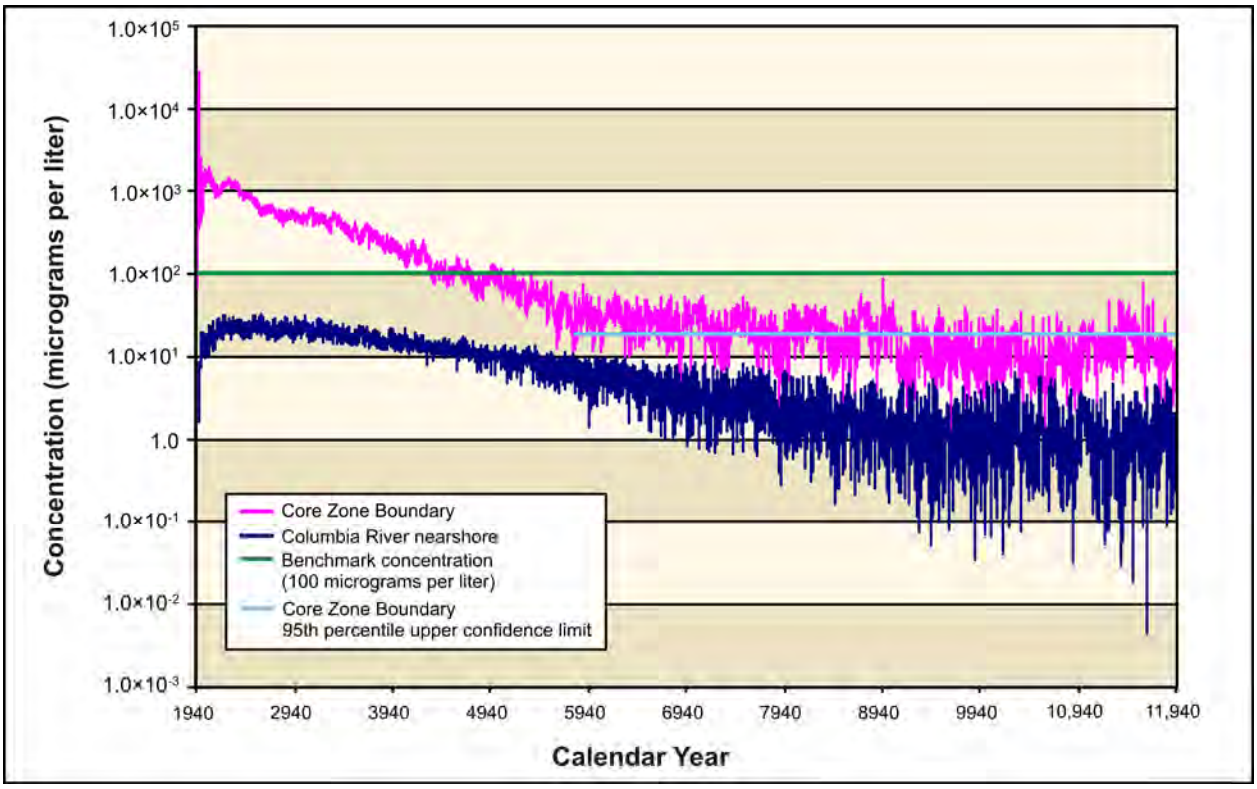


Figure 5–46. Tank Closure Alternative 2A Chromium Concentration Versus Time

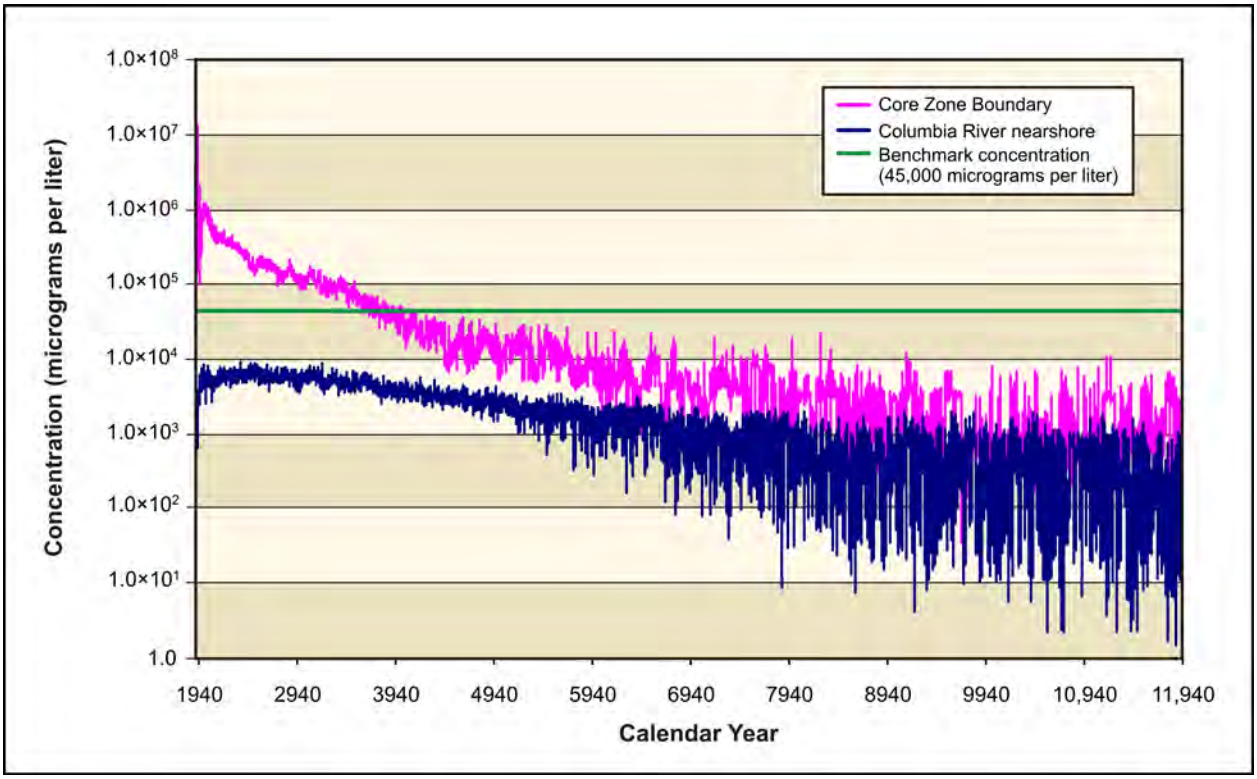


Figure 5–47. Tank Closure Alternative 2A Nitrate Concentration Versus Time

Figures 5–48 and 5–49 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Concentrations continue to rise throughout the duration of the period of analysis, first surpassing the benchmark concentration at the Core Zone Boundary near CY 5900 for uranium-238 and near CY 6900 for total uranium. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but stay below an order of magnitude less than the benchmark concentration.

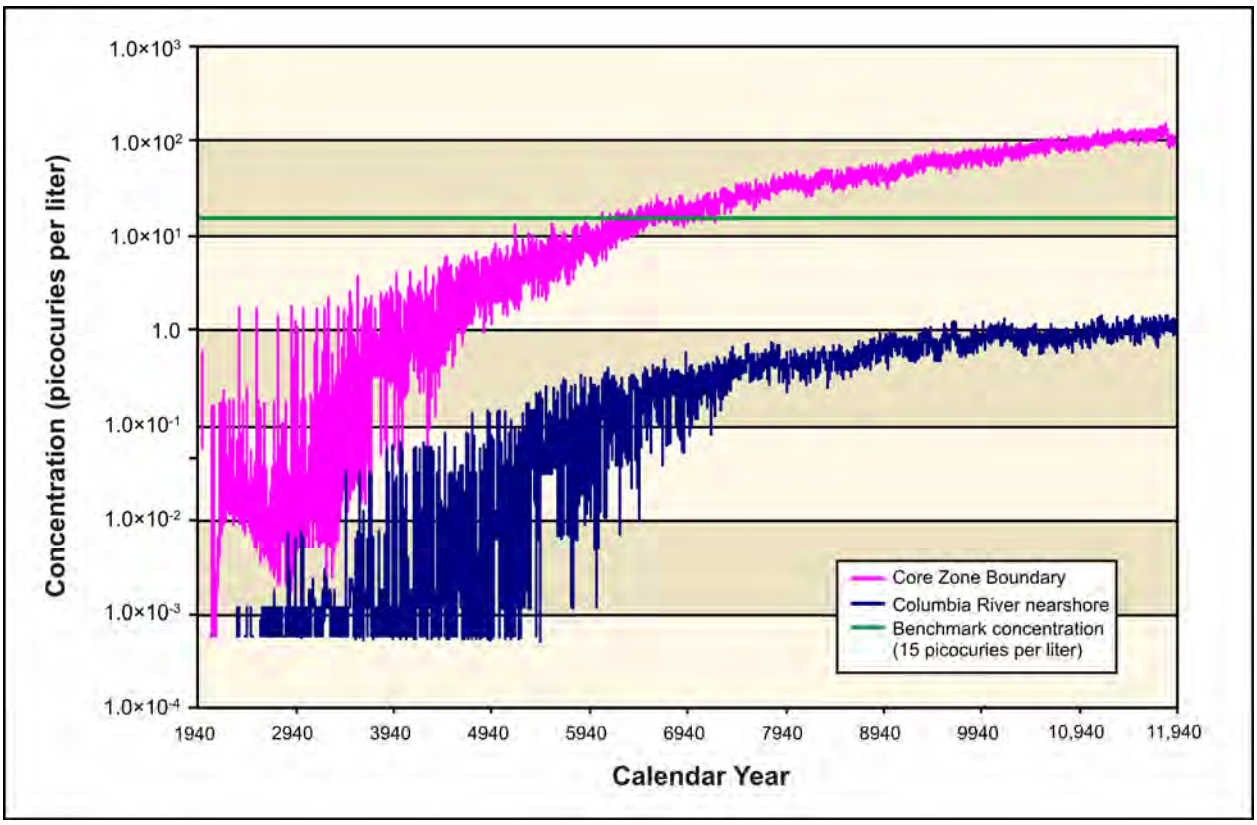


Figure 5–48. Tank Closure Alternative 2A Uranium-238 Concentration Versus Time

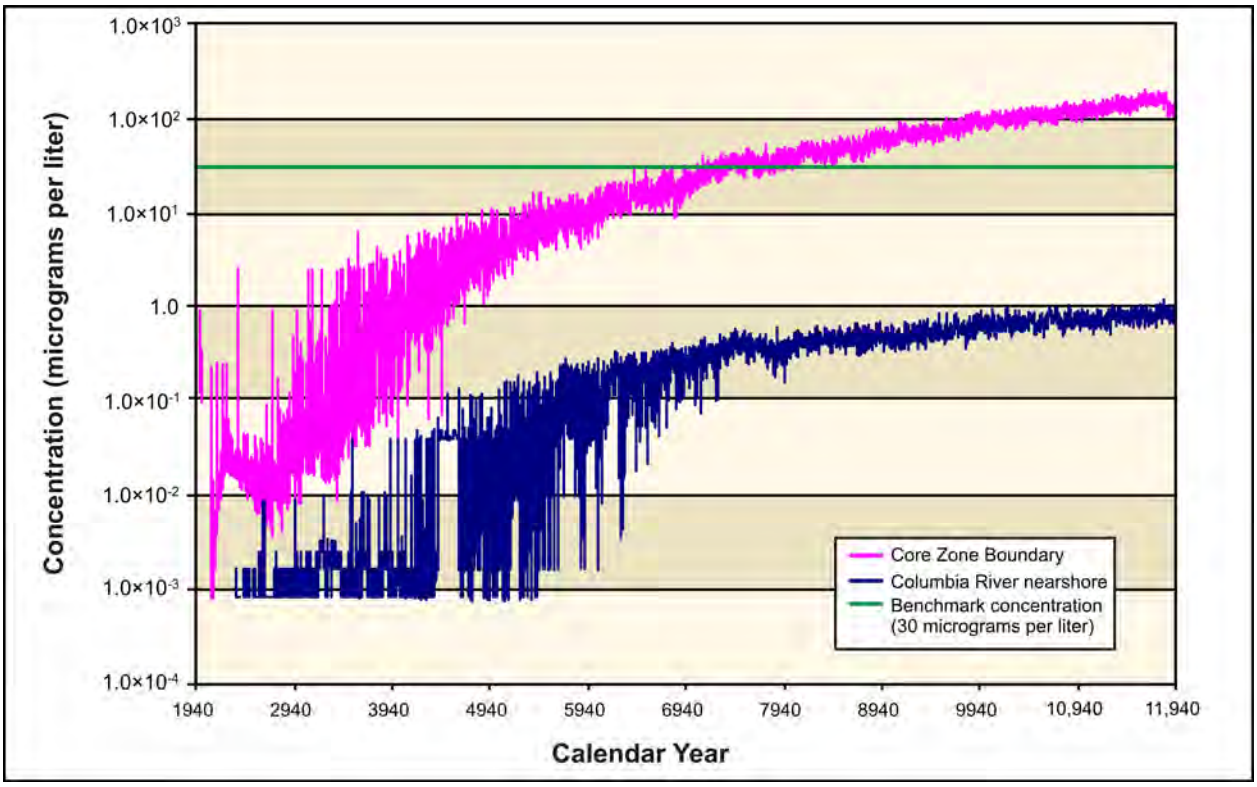
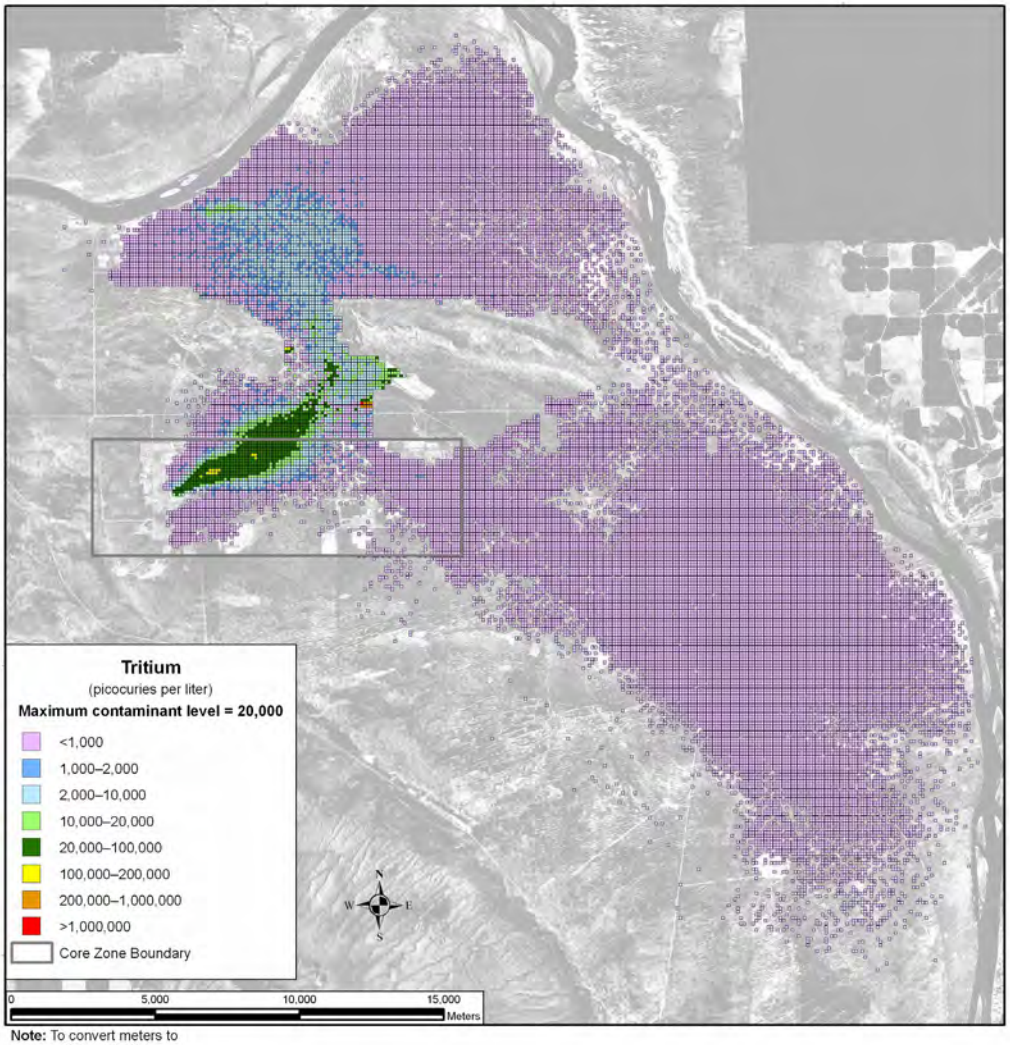


Figure 5–49. Tank Closure Alternative 2A Total Uranium Concentration Versus Time

5.1.1.2.5 Analysis of Spatial Distribution of Concentration

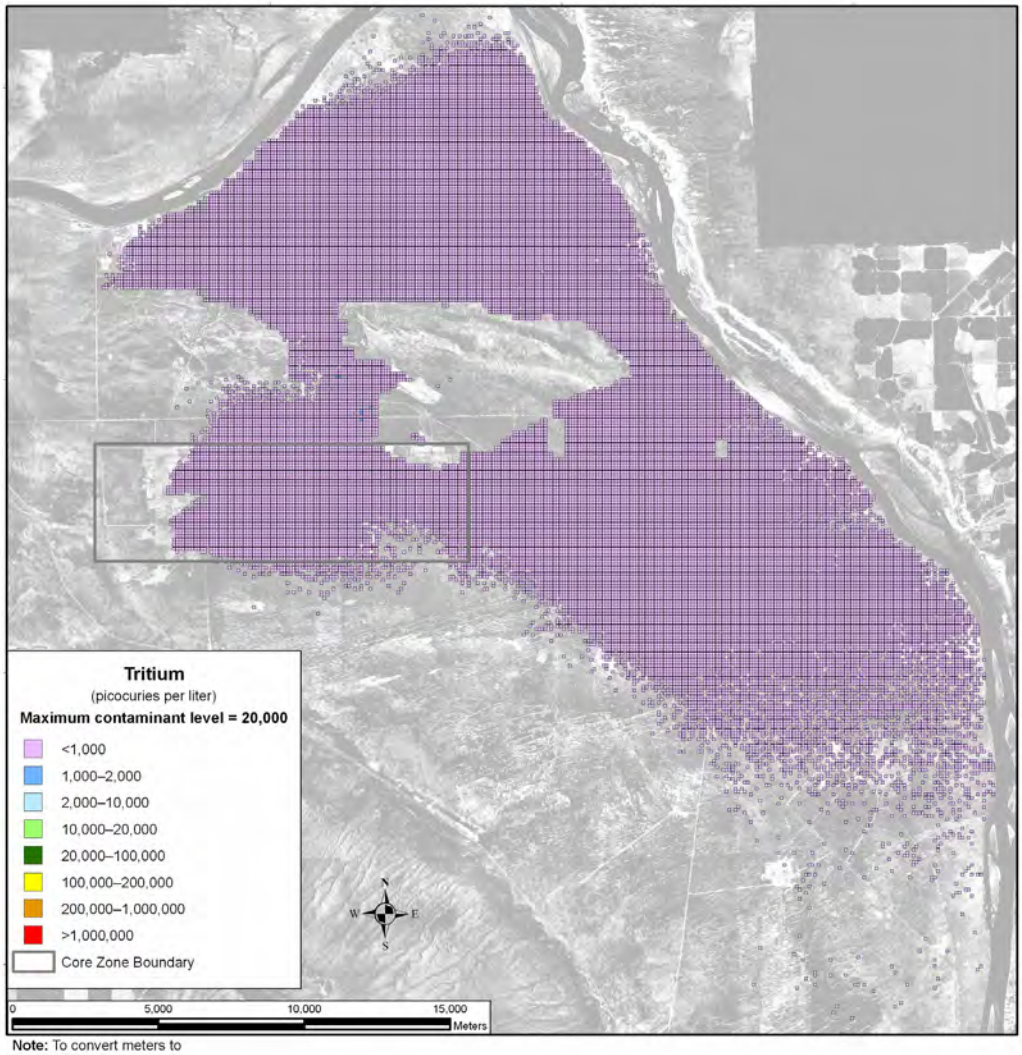
This section presents the impacts of Tank Closure Alternative 2A in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–50 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 5 to 19 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–51).



Note: To convert meters to feet, multiply by 3.281

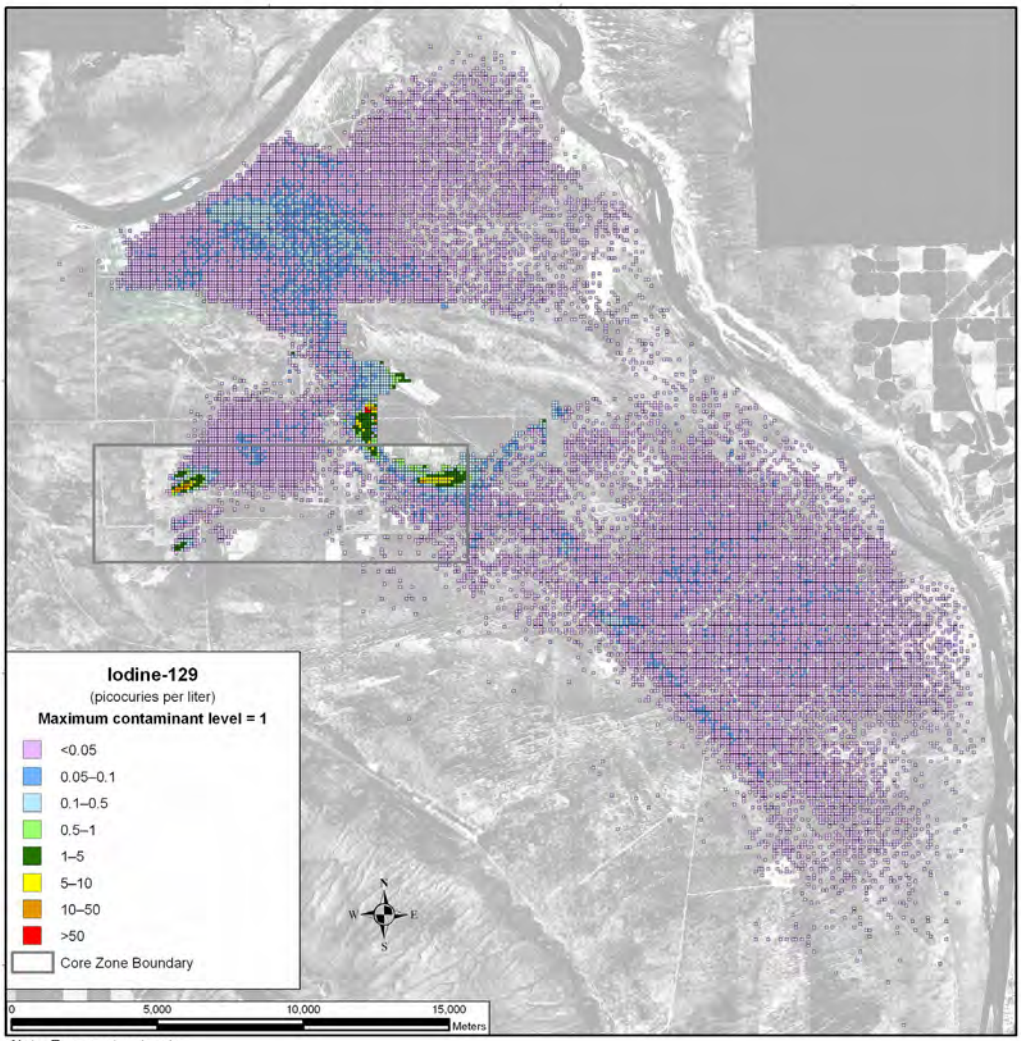
Figure 5–50. Tank Closure Alternative 2A Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

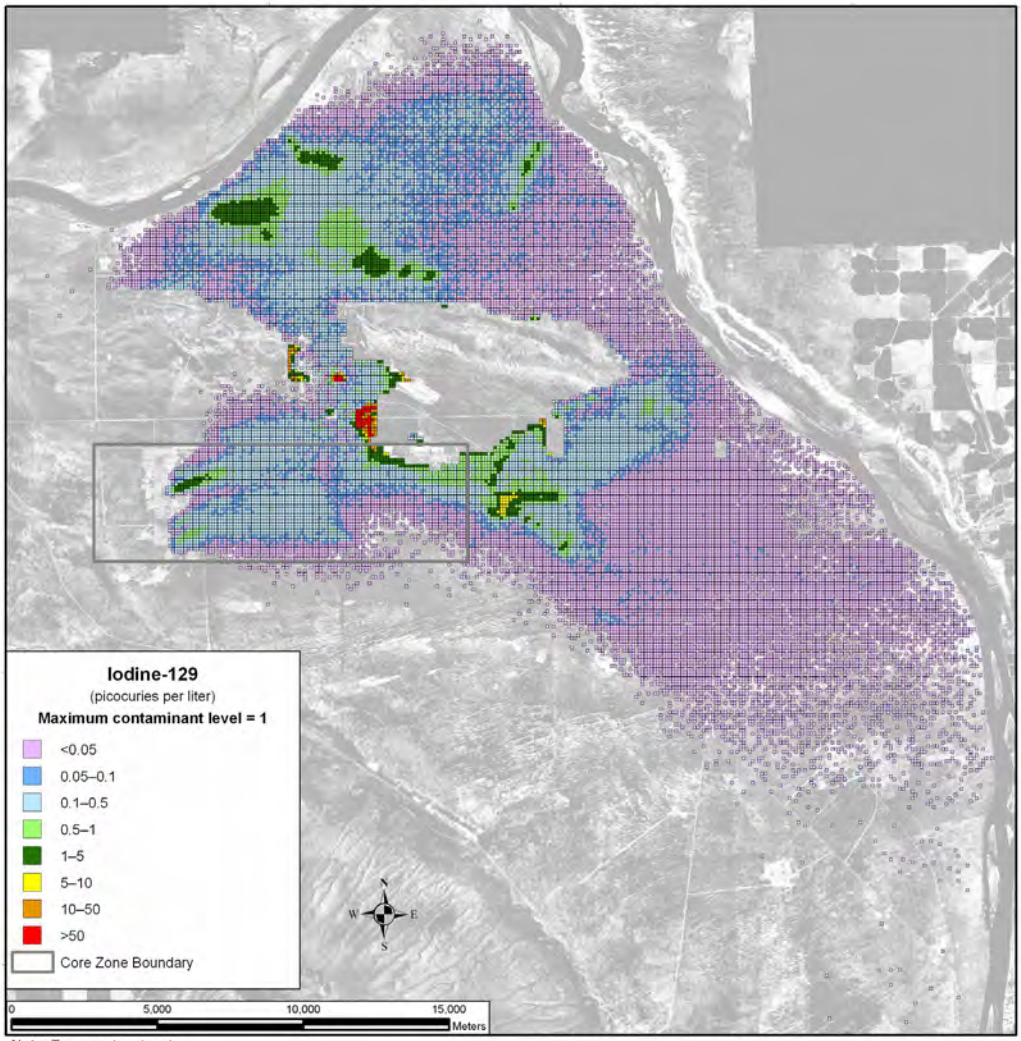
Figure 5–51. Tank Closure Alternative 2A Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–52 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks result in a low-concentration plume that extends over most of the site but exceeds the benchmark concentration in only a few patches in and around the Core Zone Boundary. In CY 2135, the iodine-129 concentration continues to exceed the benchmark concentration in a few areas, just north of the Core Zone Boundary in Gable Gap (see Figure 5–53). At CY 3890, the majority of the plume has concentrations below the benchmark concentration, although there is a high-concentration patch north of the Core Zone Boundary and east of the 200-East Area that remains above the benchmark (see Figure 5–54). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–55). Technetium-99 (see Figures 5–56 through 5–58), chromium (see Figures 5–59 through 5–61), and nitrate (see Figures 5–62 and 5–63) show similar spatial distributions at similarly selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



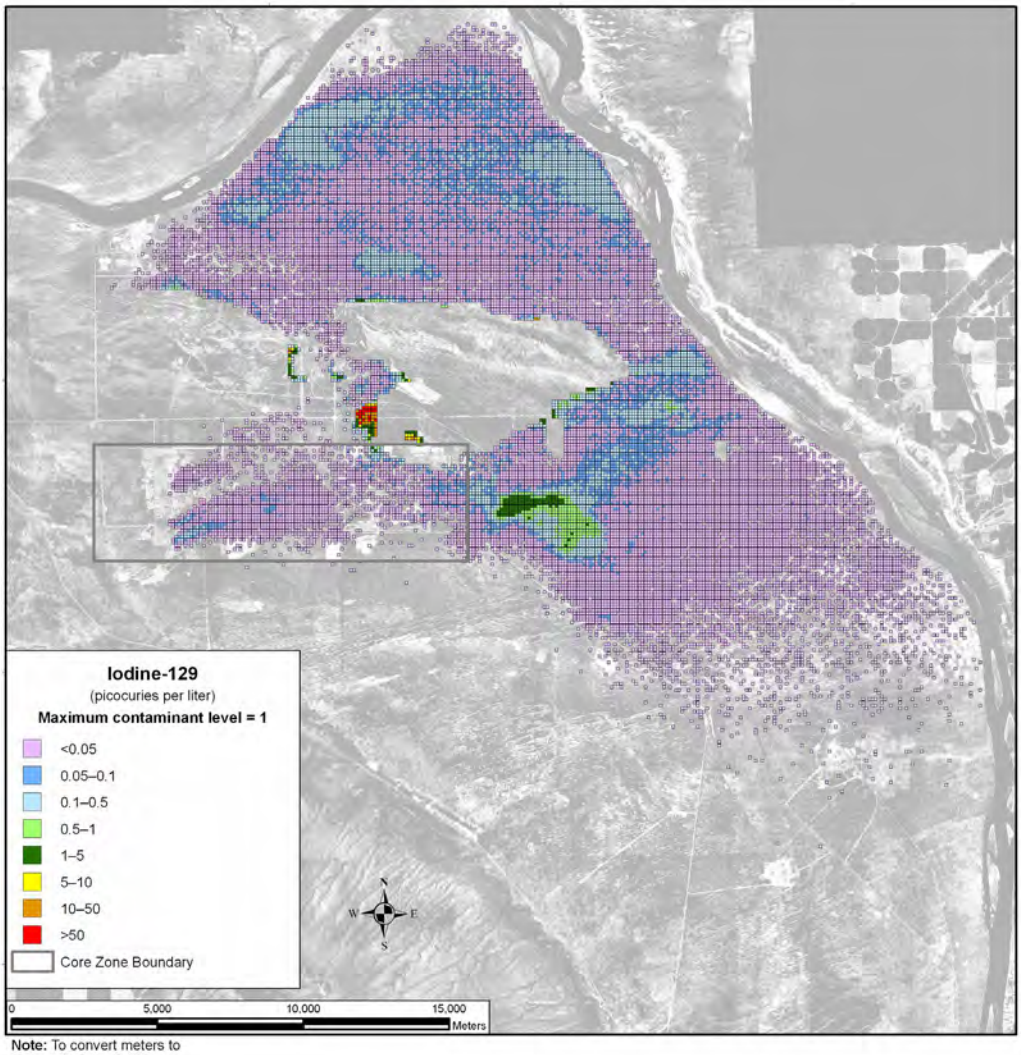
Note: To convert meters to feet, multiply by 3.281

Figure 5–52. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



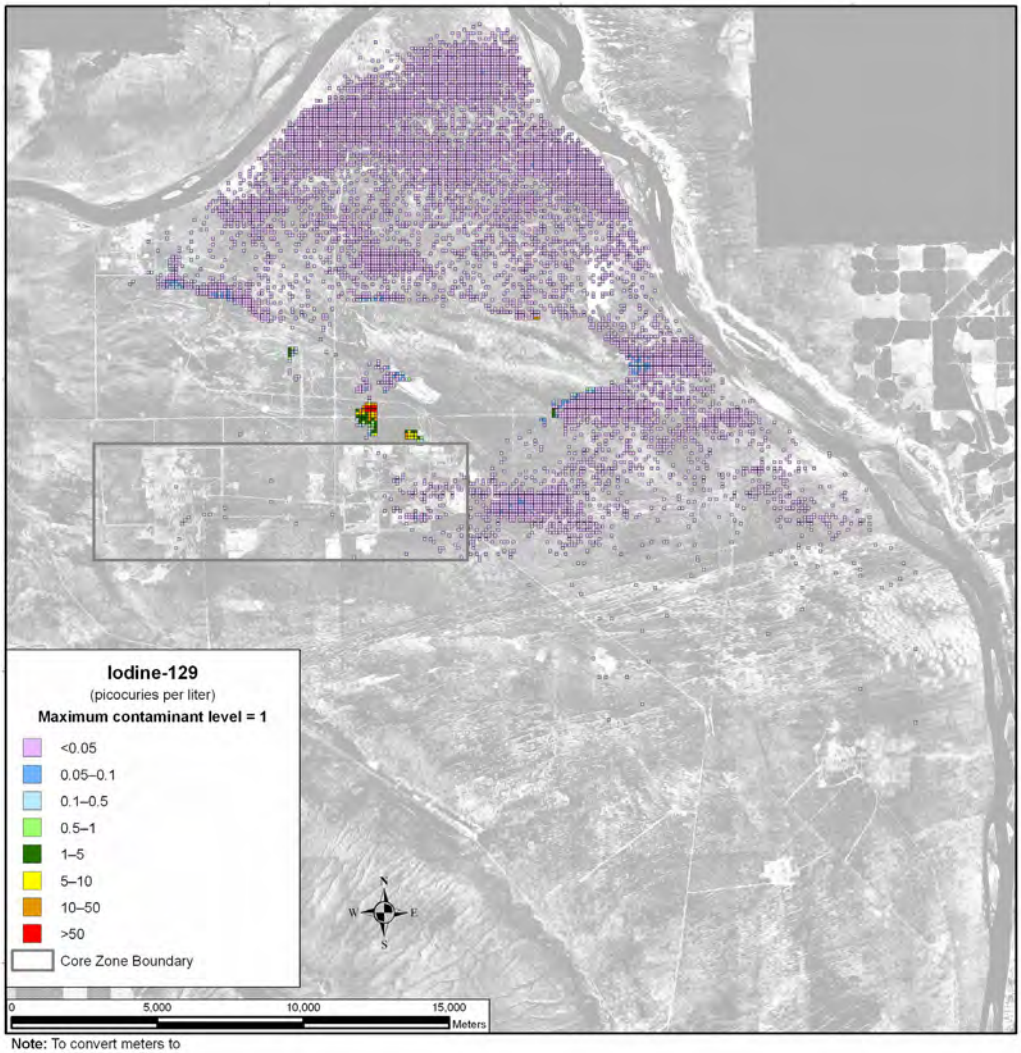
Note: To convert meters to feet, multiply by 3.281

Figure 5–53. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



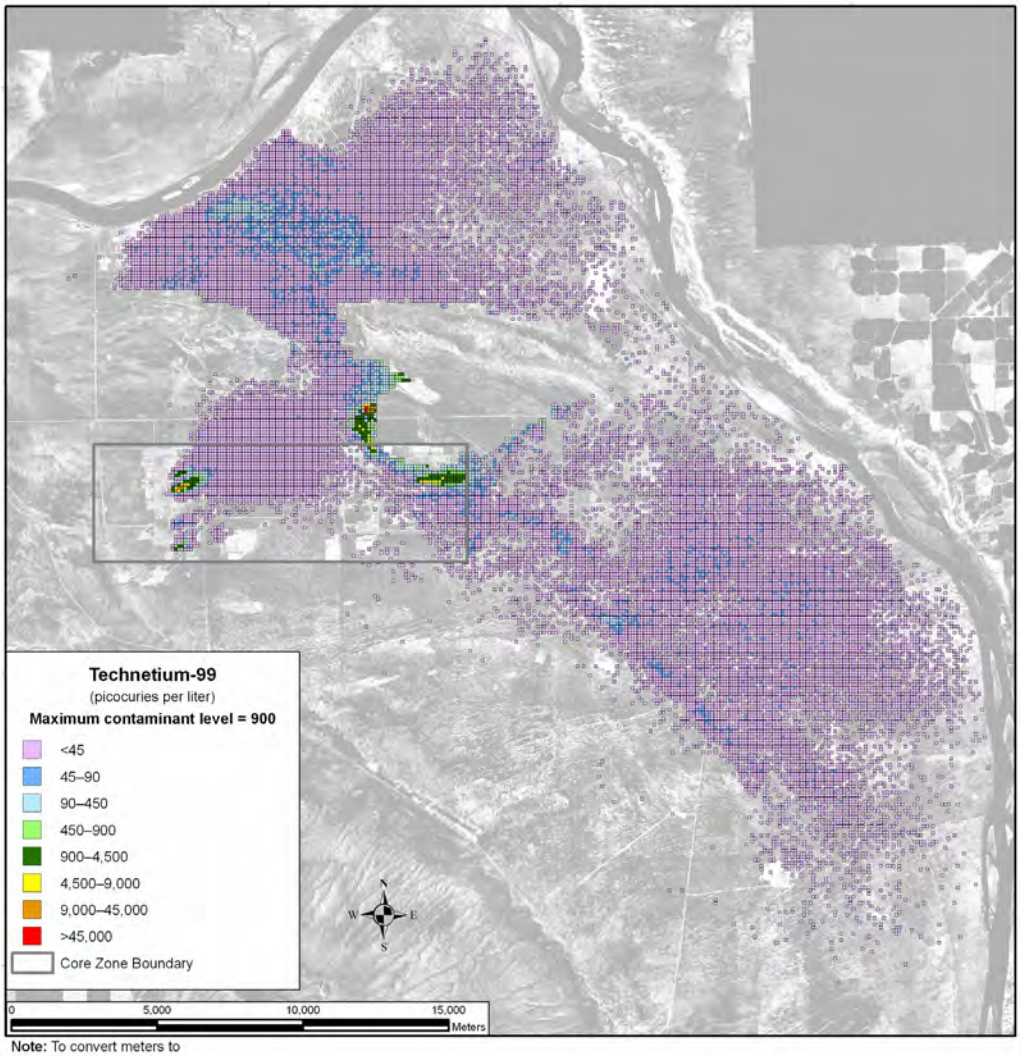
Note: To convert meters to feet, multiply by 3.281

Figure 5–54. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



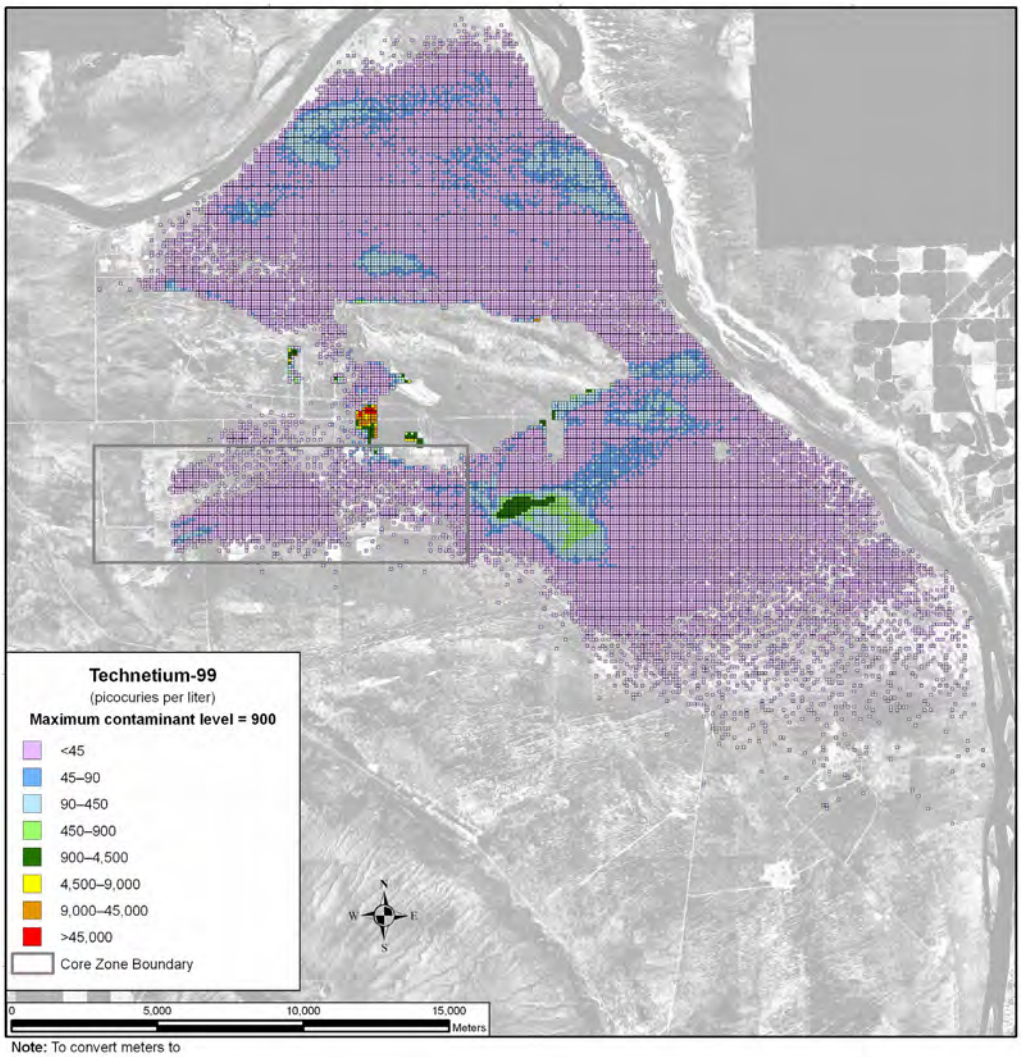
Note: To convert meters to feet, multiply by 3.281

Figure 5–55. Tank Closure Alternative 2A Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



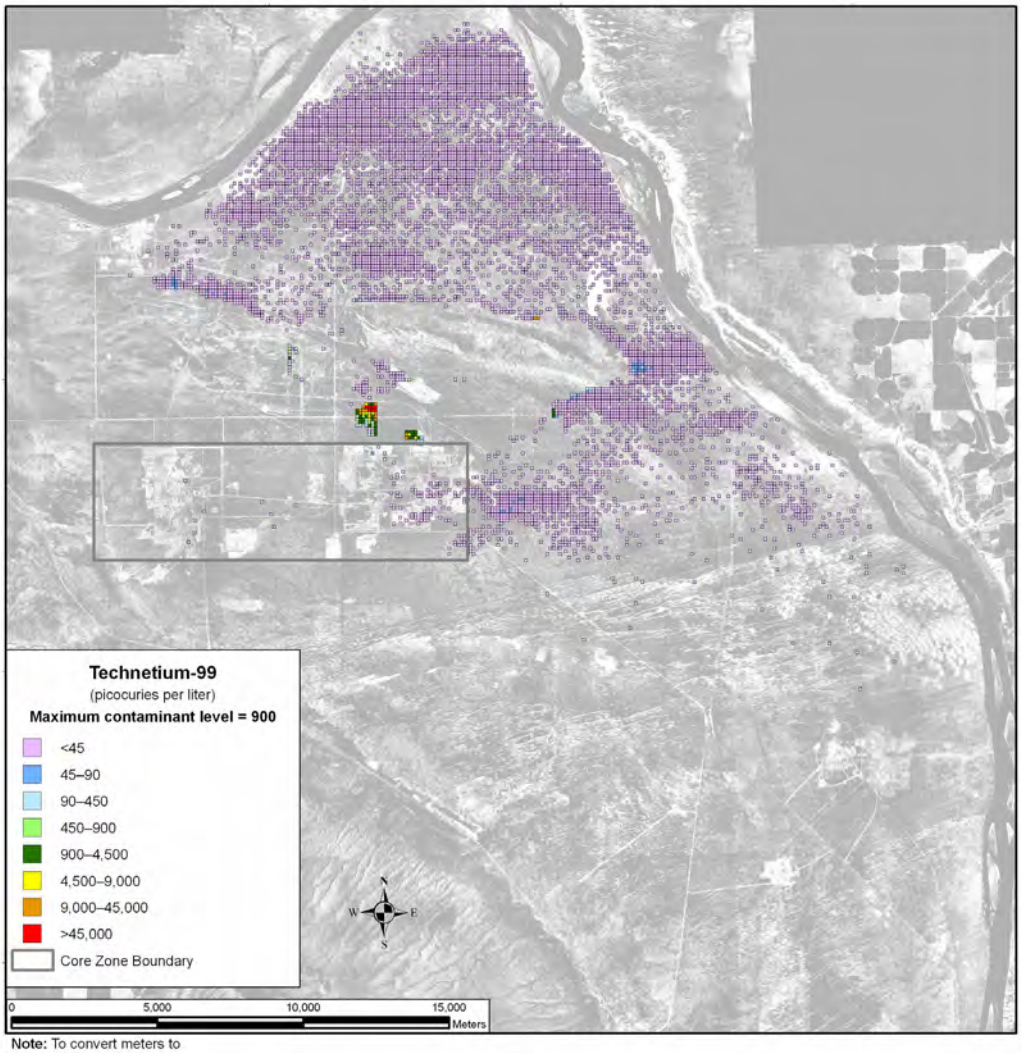
Note: To convert meters to feet, multiply by 3.281

Figure 5–56. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



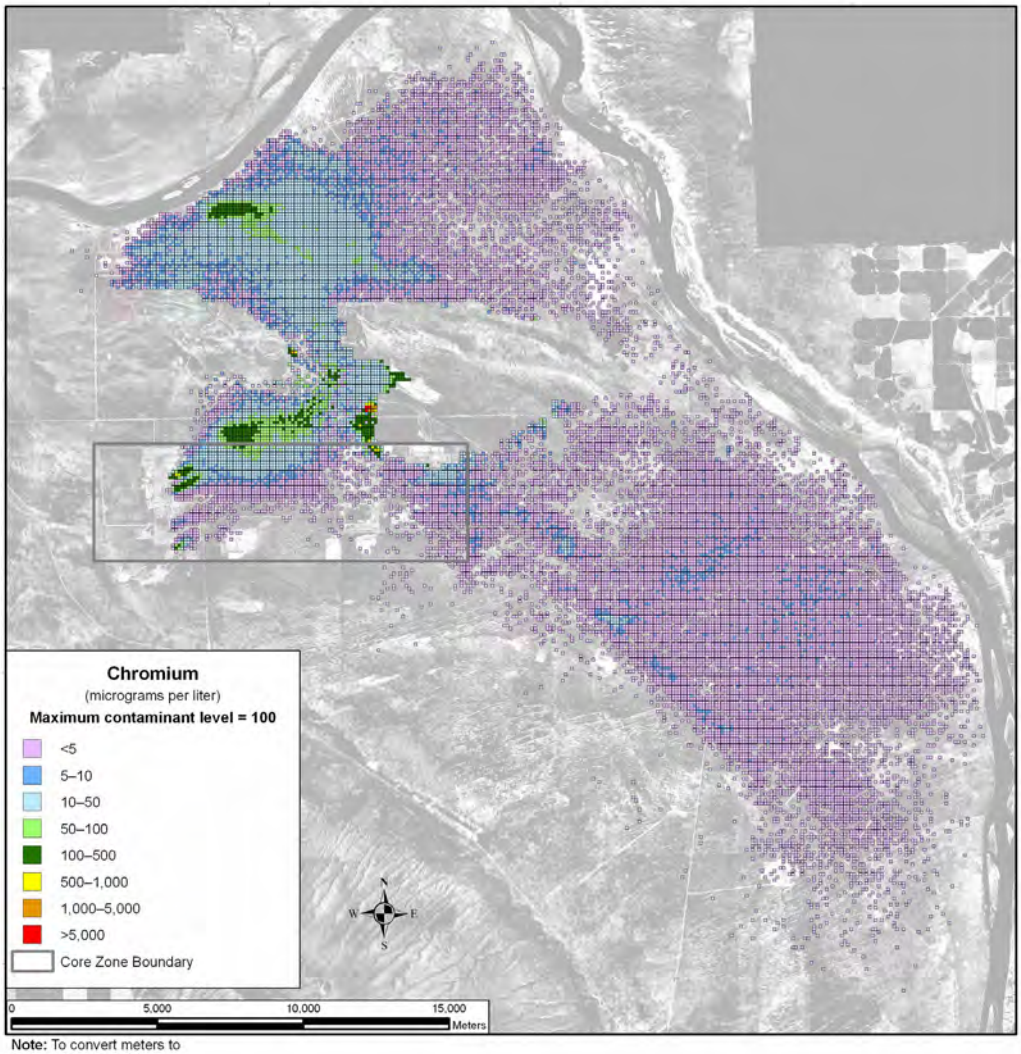
Note: To convert meters to feet, multiply by 3.281

Figure 5–57. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



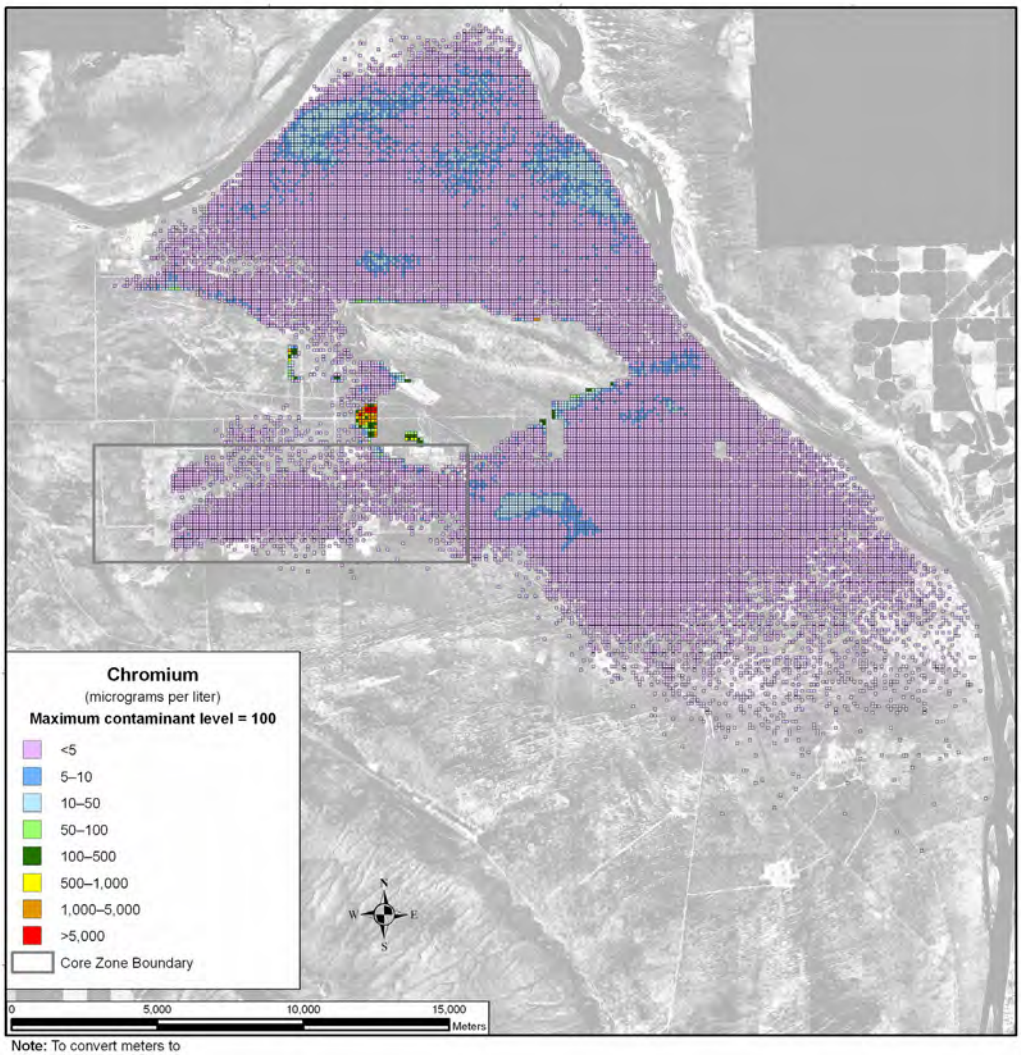
Note: To convert meters to feet, multiply by 3.281

Figure 5–58. Tank Closure Alternative 2A Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



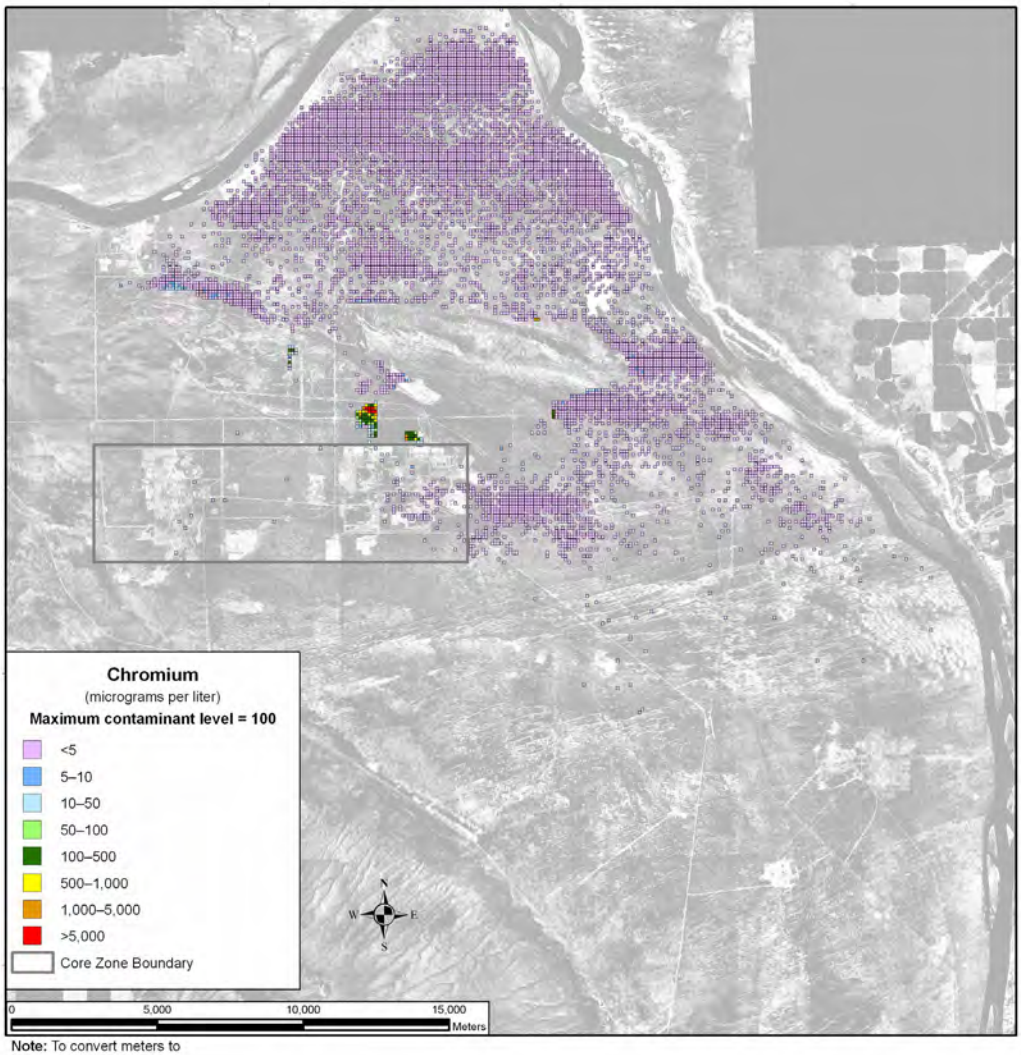
Note: To convert meters to feet, multiply by 3.281

Figure 5–59. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



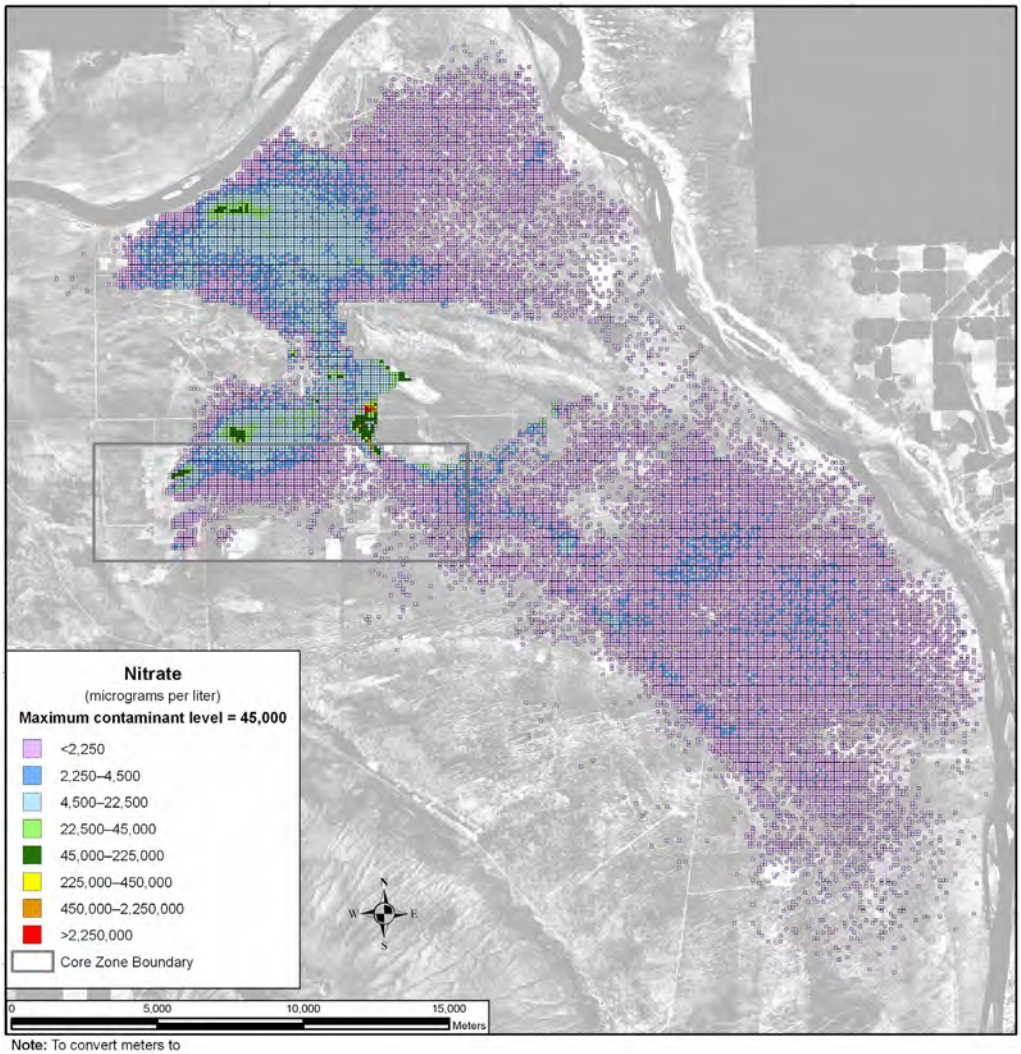
Note: To convert meters to feet, multiply by 3.281

Figure 5–60. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–61. Tank Closure Alternative 2A Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–62. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005

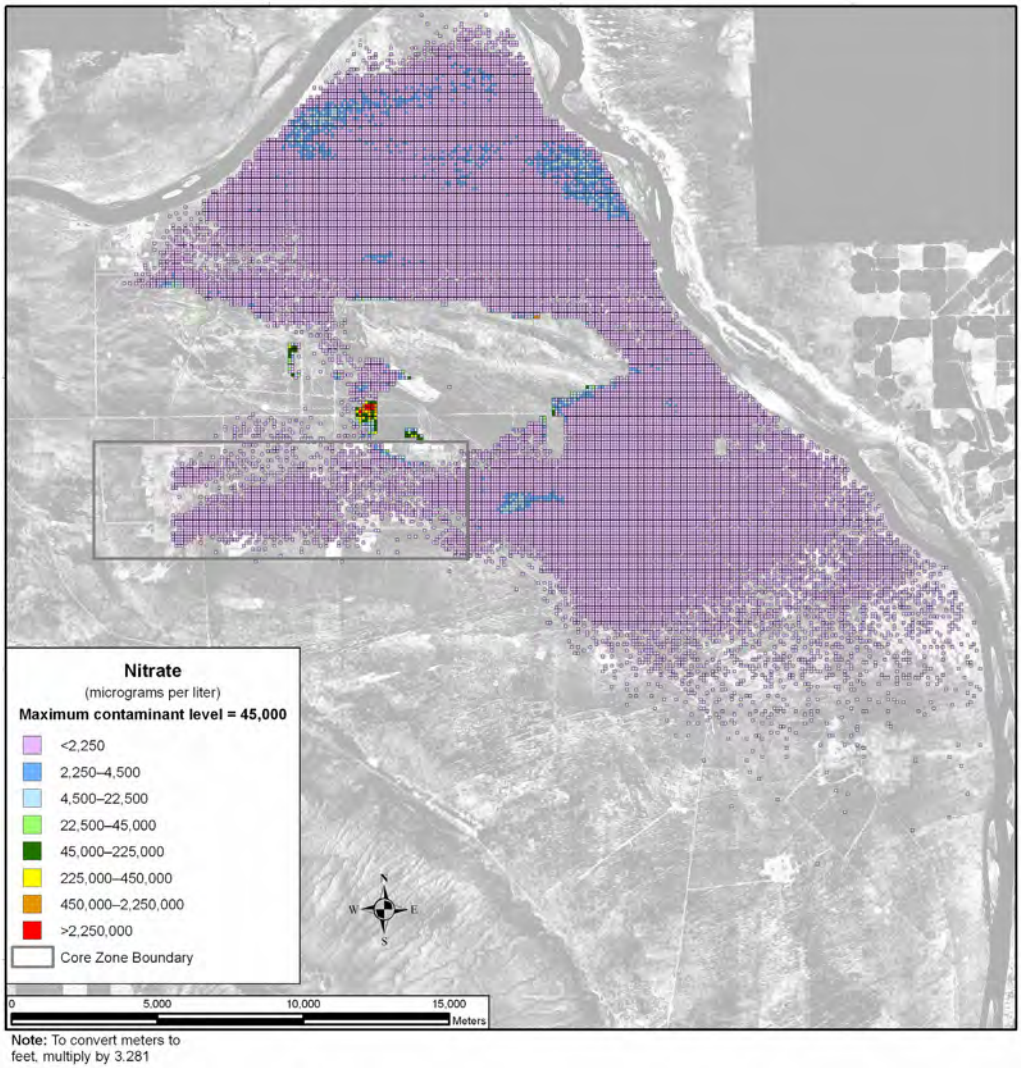
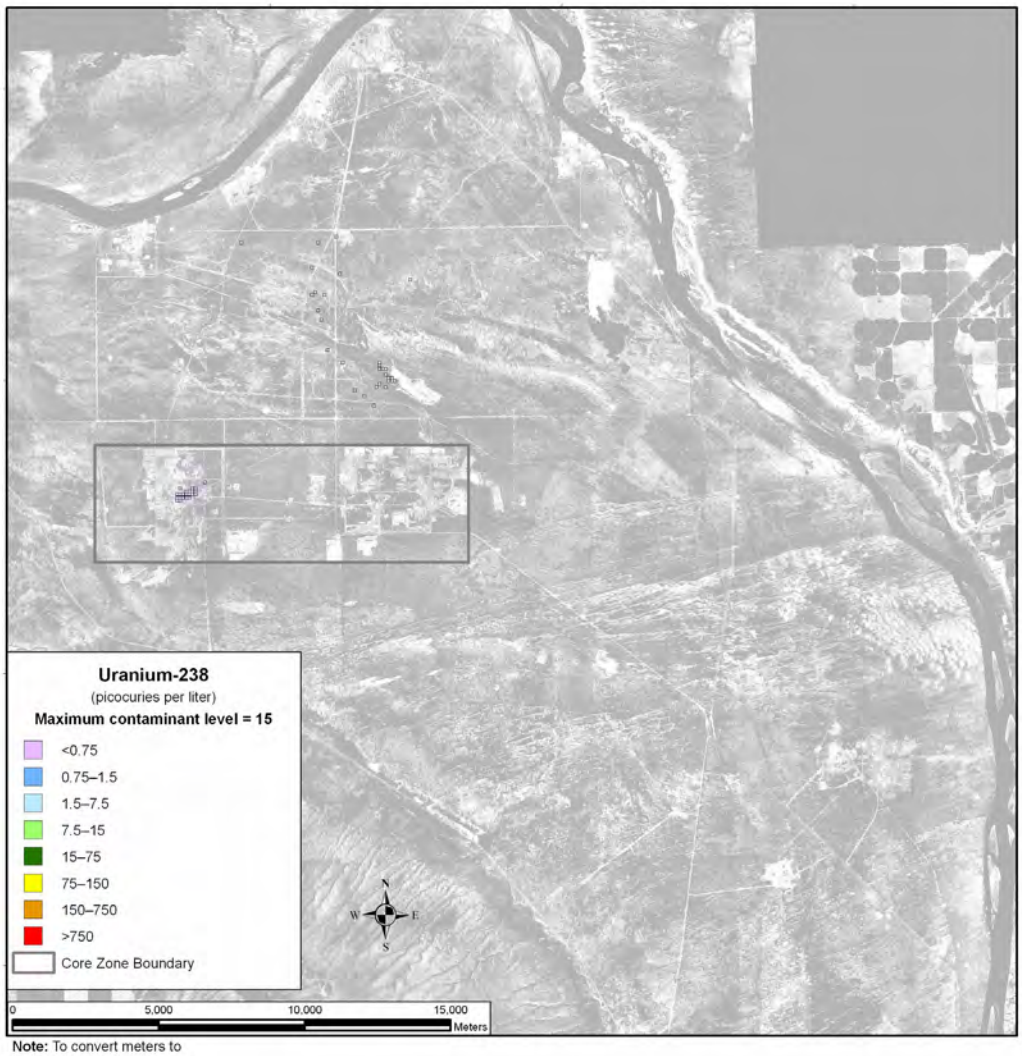


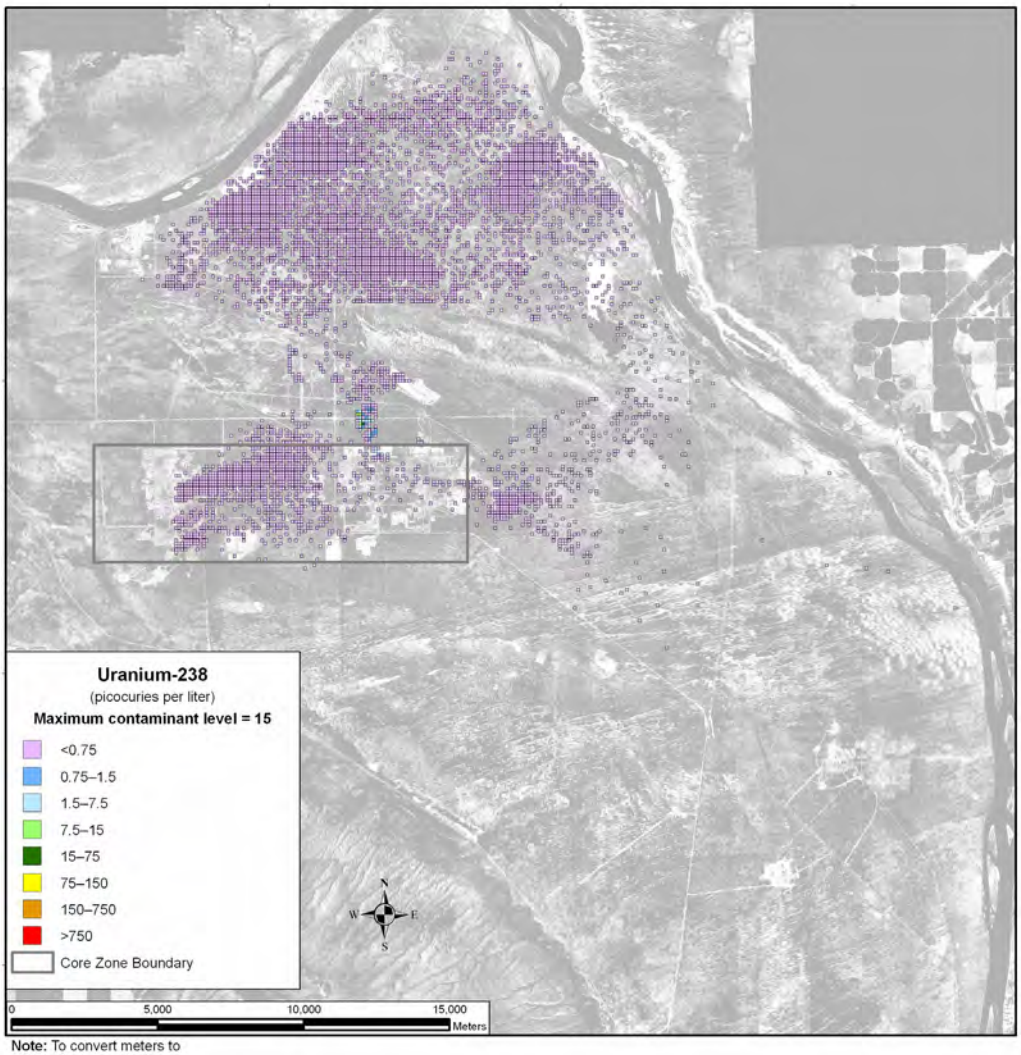
Figure 5–63. Tank Closure Alternative 2A Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890

Uranium-238 and total uranium show a different spatial distribution over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–64 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 3890 (see Figure 5–65), the area of the plume has grown significantly, but there are no significant increases in peak concentration. By CY 7140, an area of high concentration has formed north of the Core Zone Boundary. At CY 11,885 (see Figure 5–66), the greatest development of the plume during the analysis period is seen, with areas north and east of the Core Zone Boundary reaching concentrations above the benchmark concentration. Figures 5–67 through 5–69 show the corresponding results for total uranium, which shows similar spatial distributions at similarly selected times. Concentrations east of the Core Zone Boundary do not exceed the benchmark concentration for total uranium, although the area north of the Core Zone Boundary does have concentrations above the benchmark concentration from CY 7140 to the end of the period of analysis.



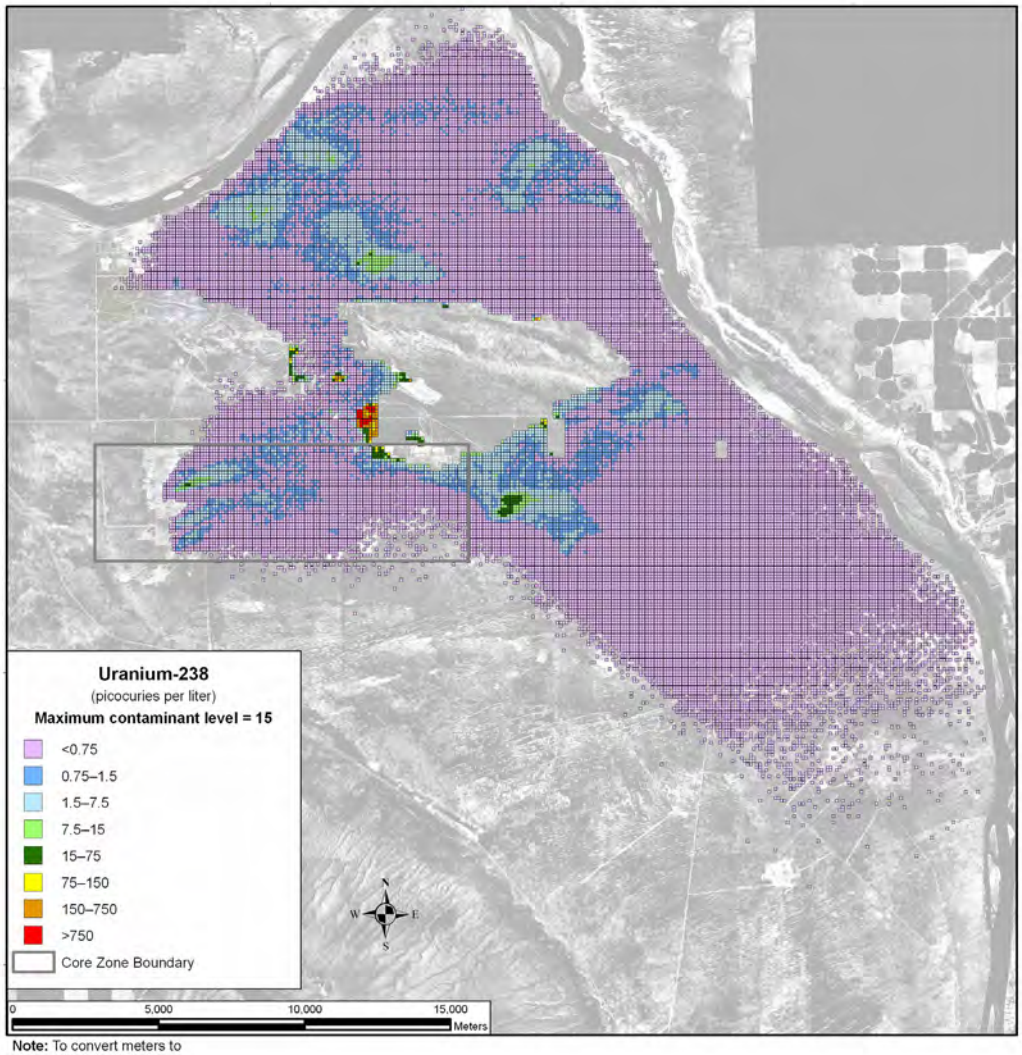
Note: To convert meters to feet, multiply by 3.281

Figure 5–64. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



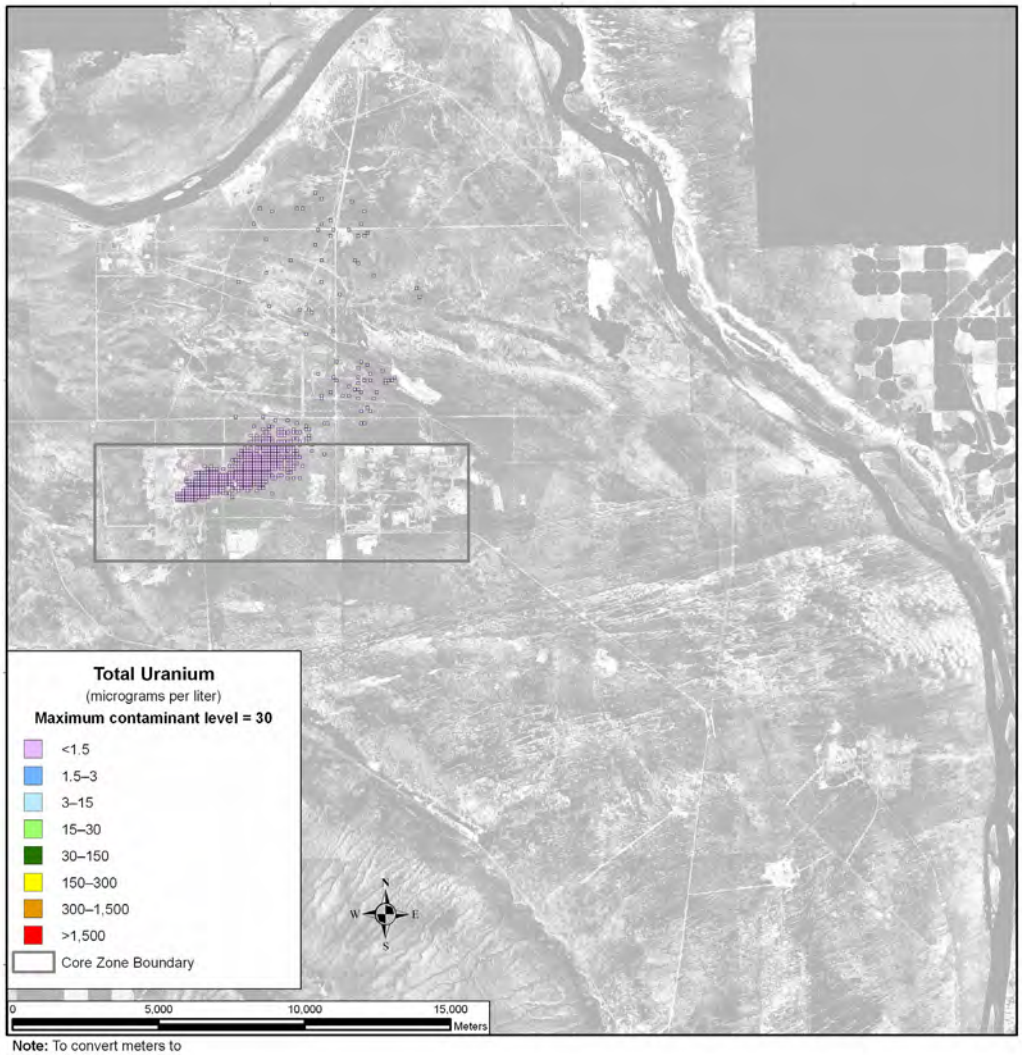
Note: To convert meters to feet, multiply by 3.281

Figure 5–65. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 3890



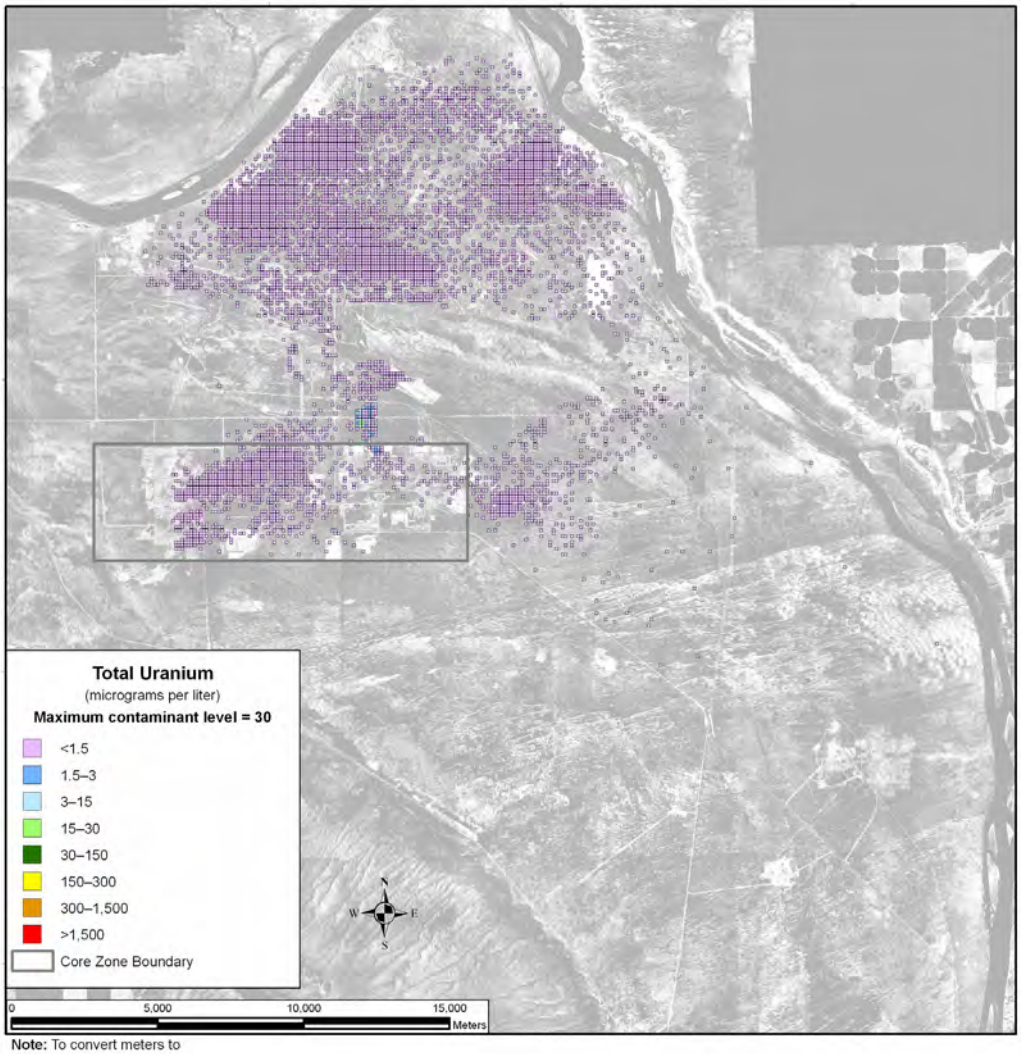
Note: To convert meters to feet, multiply by 3.281

Figure 5–66. Tank Closure Alternative 2A Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–67. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–68. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890

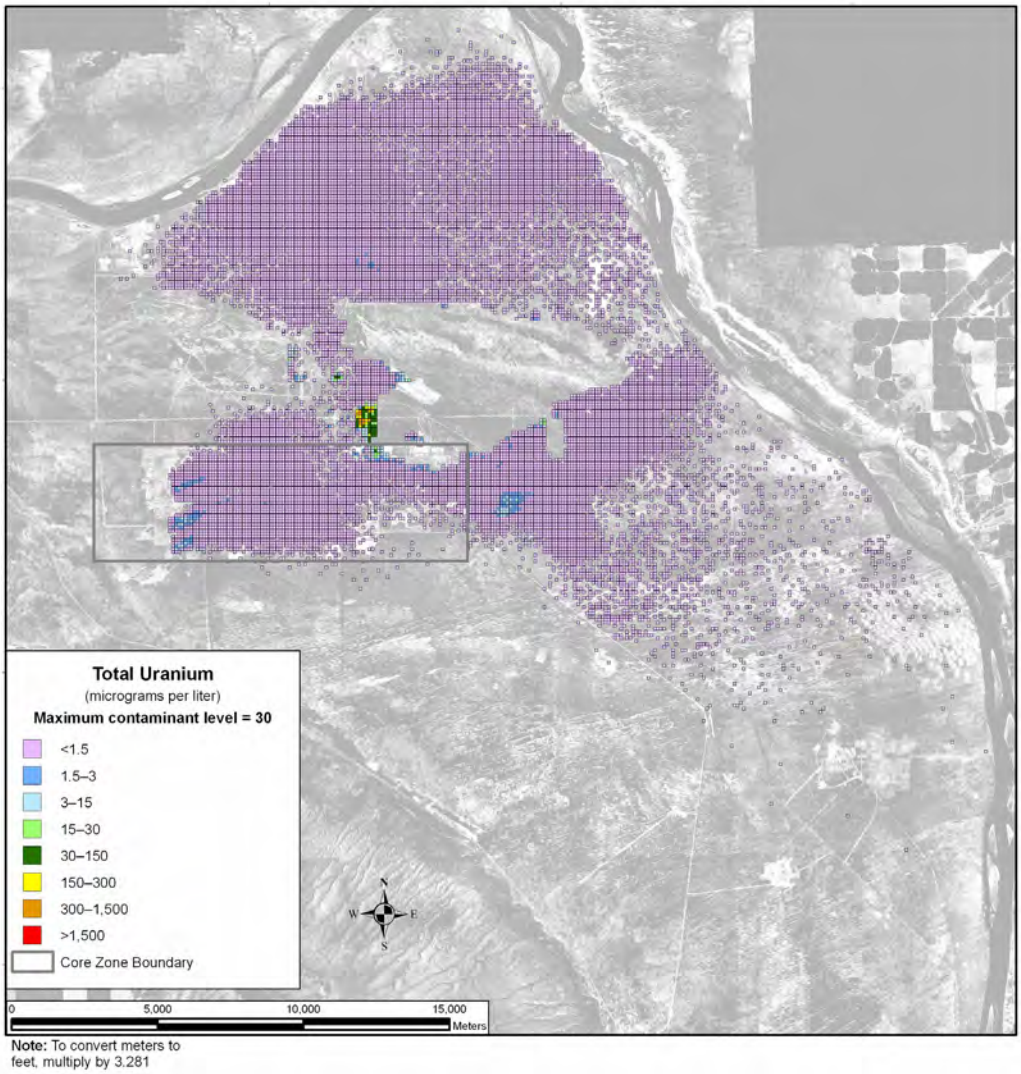


Figure 5–69. Tank Closure Alternative 2A Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140

Figures 5–70 through 5–72 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 9 square kilometers (3.5 square miles) around CY 2070. This area decreases rapidly until CY 2590, when it begins to rise again, peaking at 2.5 square kilometers (0.96 square miles) around CY 3240. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 1 square kilometer (0.38 square miles) around CY 5840, continuing its decline to approximately 0.8 square kilometers (0.3 square miles) by CY 9740 and remaining near that level for the remainder of the simulation. Technetium-99 shows a similar trend, peaking at approximately 5 square kilometers (1.9 square miles) in CY 2135 and reaching 0.5 square kilometers (0.19 square miles) in CY 9740. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 4540. From CY 4540 until the end of the simulation, areas of uranium-238 concentrations above the benchmark slowly increase, never exceeding 2 square kilometers (0.77 square miles) during the simulation.

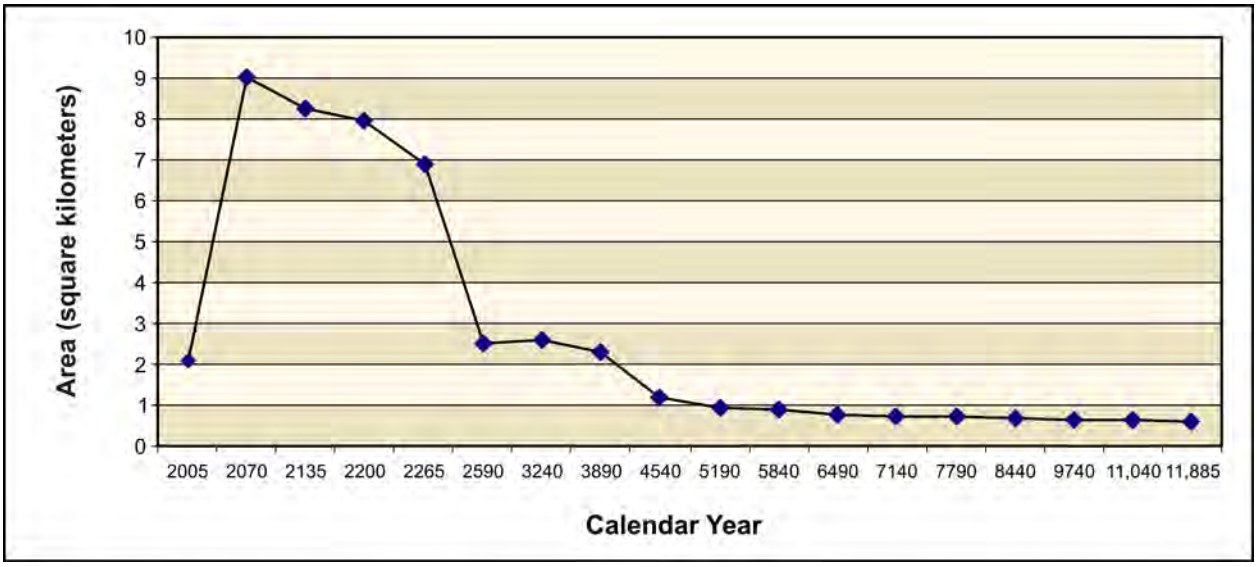


Figure 5–70. Tank Closure Alternative 2A Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

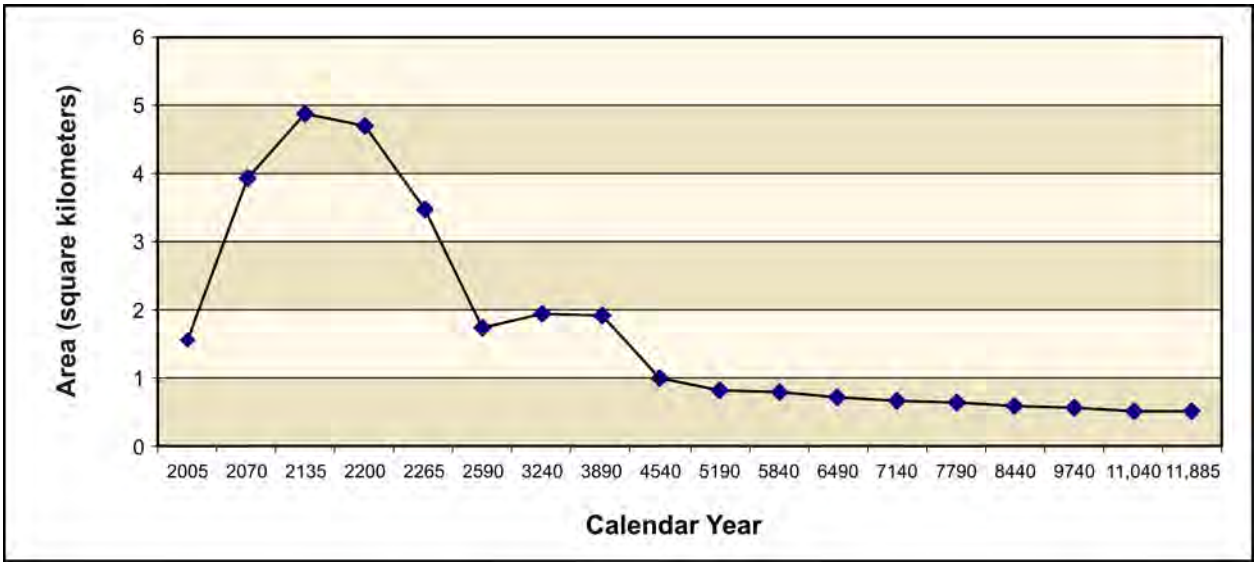


Figure 5–71. Tank Closure Alternative 2A Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

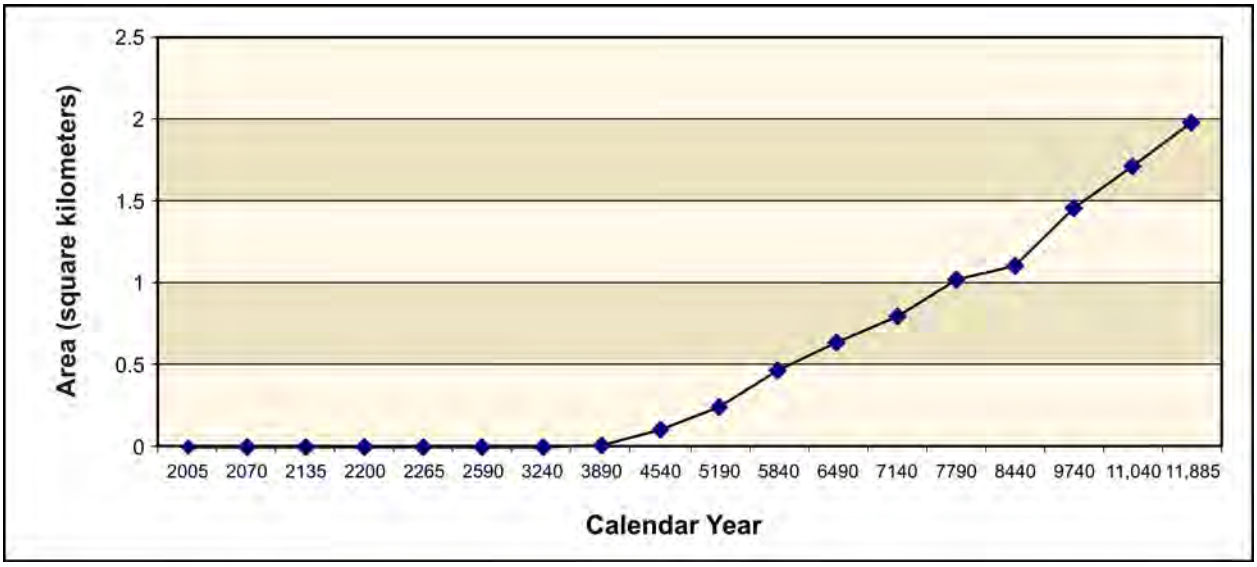


Figure 5–72. Tank Closure Alternative 2A Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.2.6 Summary of Impacts

Under Tank Closure Alternative 2A, releases from cribs and trenches (ditches), past leaks, and other tank farm sources available after the retrieval period are all major contributors in the analysis. The retrieval of waste from the SSTs lowers the contribution of other tank farm sources relative to Tank Closure Alternative 1.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by one to two orders of magnitude early in the analysis, between CY 2100 and 2200. These concentrations fall below the benchmark between 3,000 and 4,000 years into the analysis. Concentrations at the Columbia River remain below the benchmark concentration throughout the period of analysis.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about two orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2040, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. Concentrations at the Core Zone Boundary exceed the benchmark concentration in CY 5900 for uranium-238 and in CY 6900 for total uranium. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, but stay below an order of magnitude less than the benchmark concentration.

5.1.1.3 Tank Closure Alternative 2B: Expanded WTP Vitrification; Landfill Closure

This section describes the groundwater analysis results for Tank Closure Alternative 2B, including long-term groundwater impacts of contaminant sources from within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified Resource Conservation and Recovery Act (RCRA) Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical.

5.1.1.3.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 2B are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 2B, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 2B that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and continue through CY 2145. This period includes retrieval, WTP pretreatment and treatment, landfill closure of the SST farm system, and 100 years of postclosure care. It was assumed that during the retrieval period, 99 percent of waste volume would be retrieved from the tanks. The SST farm system would be landfill-closed with a modified RCRA Subtitle C barrier. A retrieval leakage rate of 15,140 liters (4,000 gallons) per SST (other tank farm sources) was assumed to be released to the vadose zone during the first part of this period. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2146 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice and retrieval periods would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. In addition, the remaining other tank farm sources waste (e.g., residual waste, ancillary equipment) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.3.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 2B. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 2B is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 2B were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become

major contributors toward the end of the period of analysis. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-14}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 2B.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.3.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 2B in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–73 through 5–78). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–73 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–74, the chemical hazard drivers. The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The predominant contributing sources for the remaining COPC drivers are a combination of past leaks and other tank farm sources. This suggests that all three sources are important impact drivers under Tank Closure Alternative 2B.

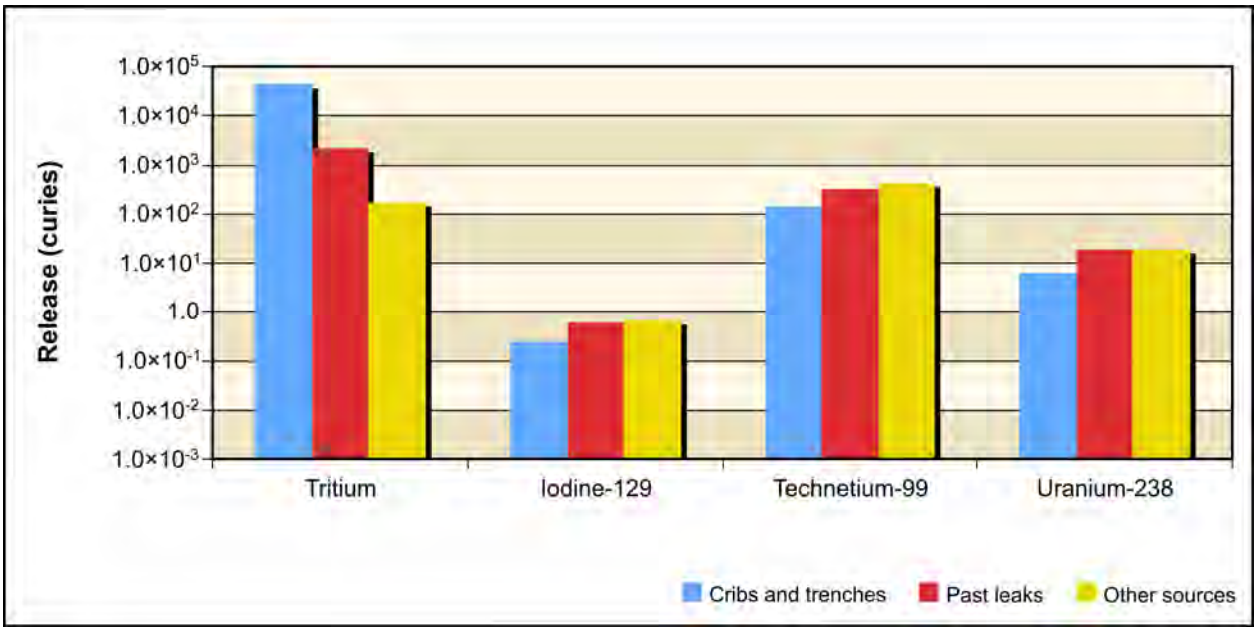


Figure 5–73. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

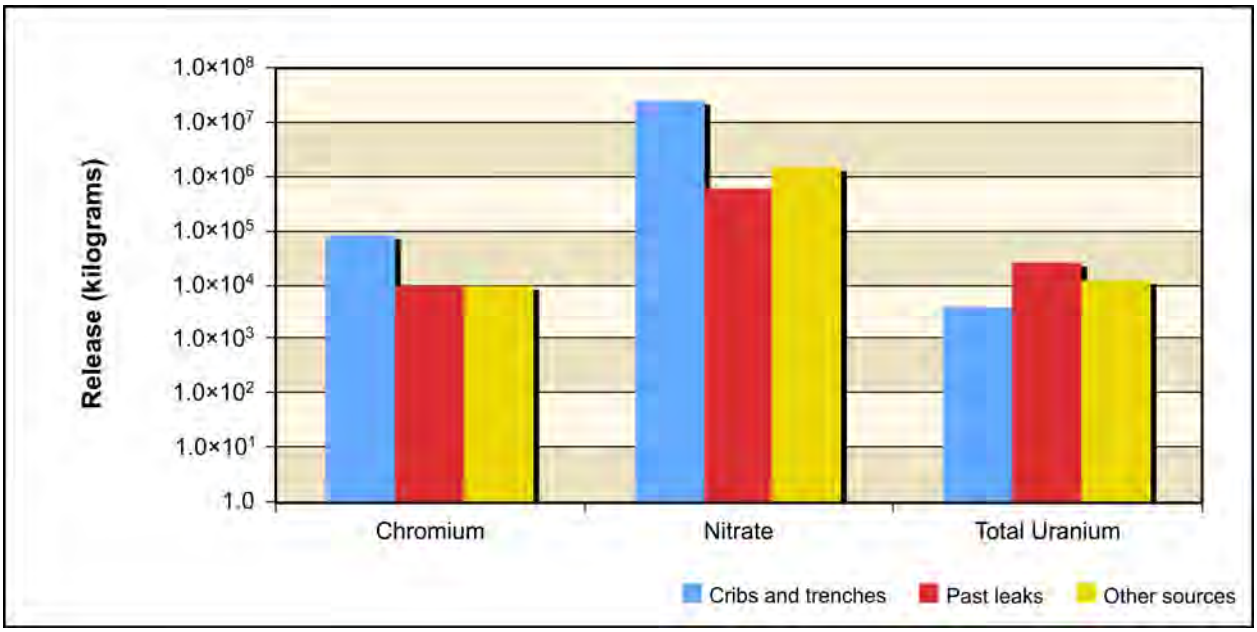


Figure 5–74. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–75 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–76, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

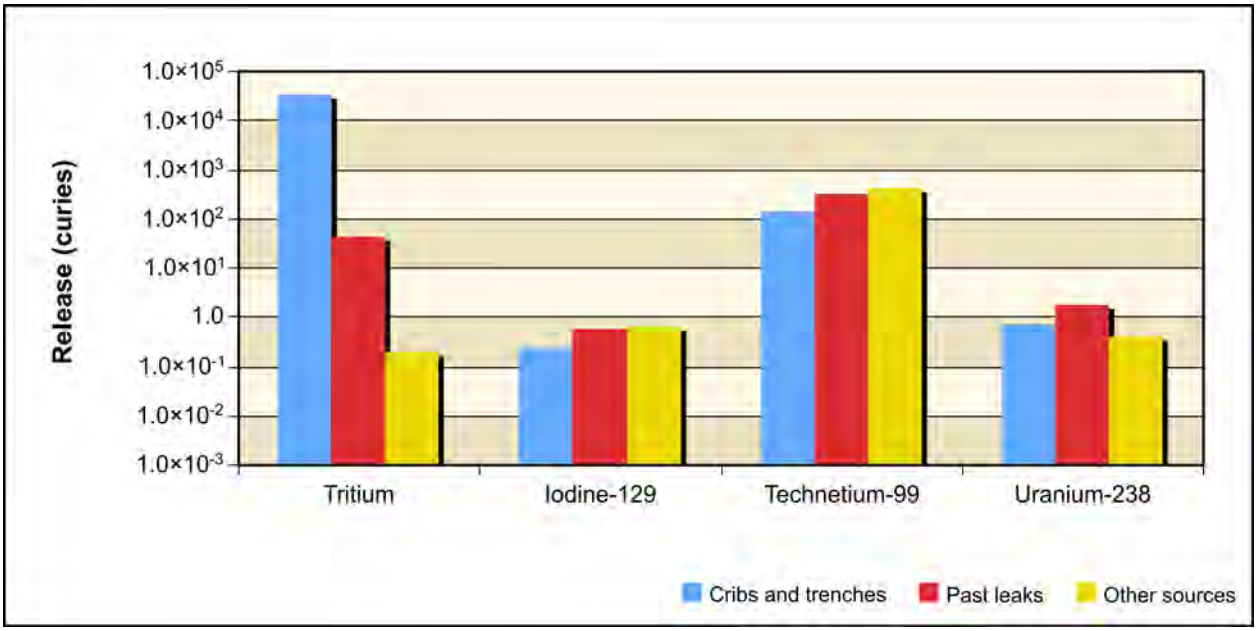


Figure 5–75. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

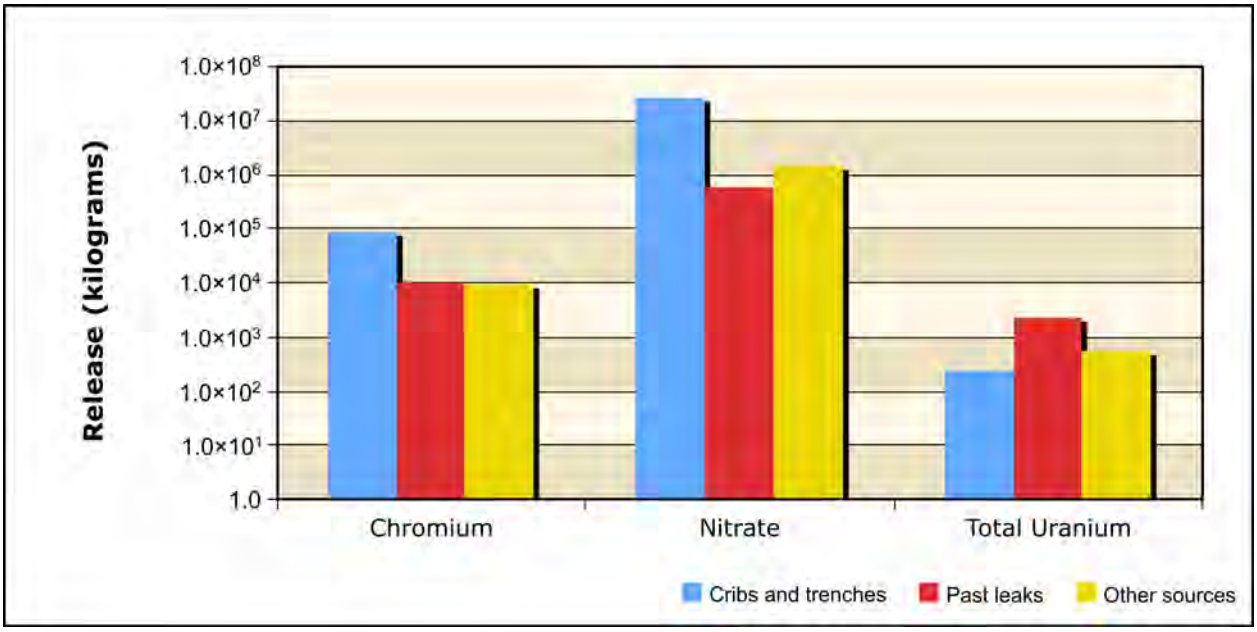


Figure 5–76. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory of uranium-238 and total uranium reached groundwater during the period of analysis; for other tank farm sources, only about 3 percent of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reaches groundwater, for past leaks only about 3 percent, and for other tank farm sources, only about one-tenth of 1 percent of the inventory reached the water table. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–77 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–78, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. Overall, about 25 percent of the uranium-238 and total uranium released to groundwater during the period of analysis reached the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 2 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

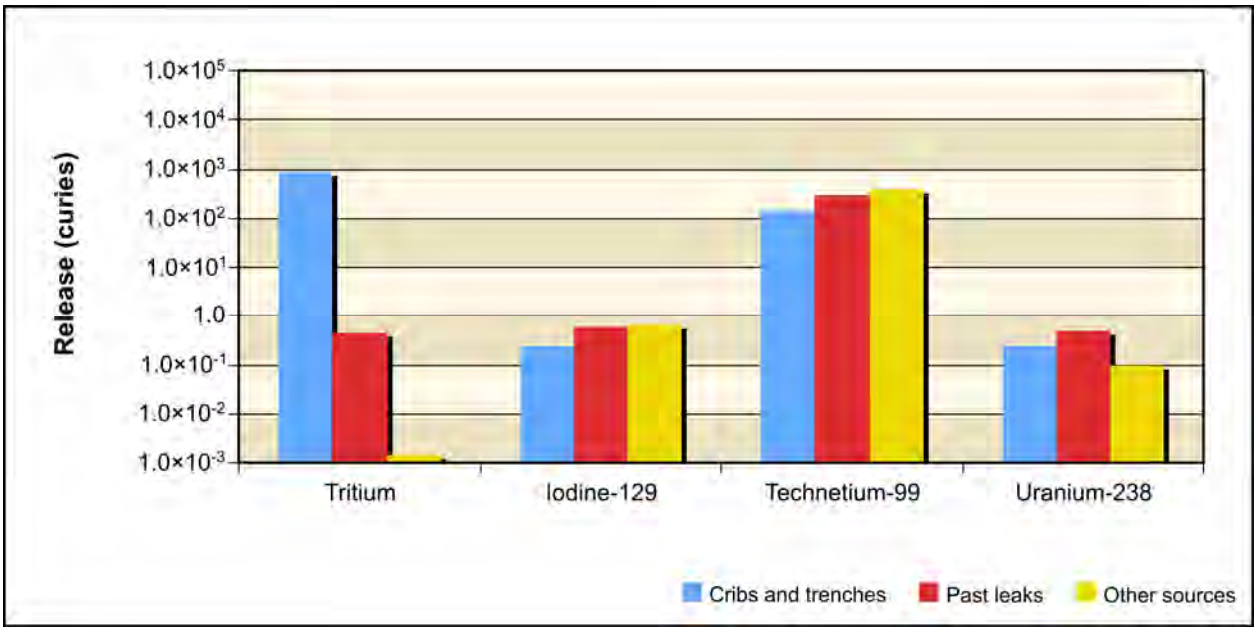


Figure 5–77. Tank Closure Alternative 2B Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

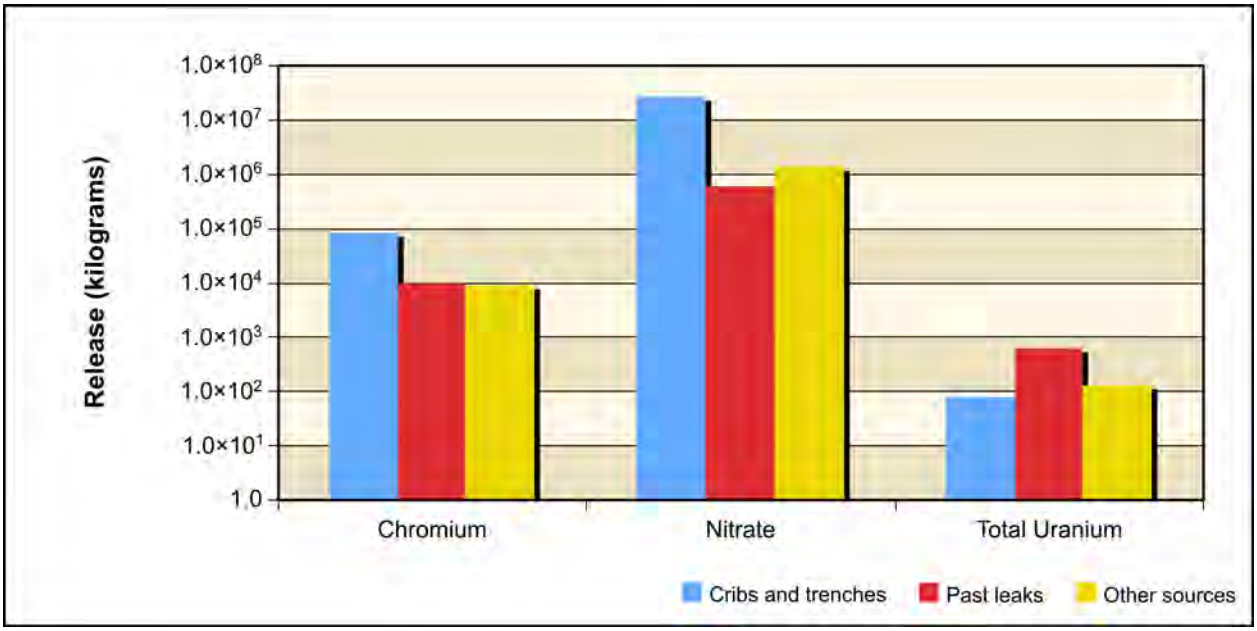


Figure 5–78. Tank Closure Alternative 2B Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.3.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 2B impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–3 and Figures 5–79 through 5–85). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–3 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–79 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations within the Core Zone Boundary to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration but stay about one order of magnitude below it. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium concentrations fall (and stay) below the benchmark concentration at the Core Zone Boundary after CY 2030.

Table 5–3. Tank Closure Alternative 2B Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	28	5,080	52	7,270	13	6,080	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**1,450**	**30,000**	**2,660**	**15,200**	284	**25,900**	205	900
	(2058)	(2050)	(2050)	(2050)	(3499)	(2050)	(2480)	
Iodine-129	**3**	**40**	**5**	**30**	0.4	**34**	0.4	1
	(2053)	(2057)	(2050)	(2050)	(3708)	(2057)	(2876)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	**55**	6	**27**	8	**73**	1	15
	(11,755)	(11,739)	(11,765)	(11,780)	(11,441)	(11,691)	(11,871)	
Chemical in micrograms per liter								
Acetonitrile	1	0	0	0	0	1	0	100
	(3701)	(1940)	(3566)	(1940)	(1940)	(3829)	(4021)	
Chromium	9	**3,230**	**271**	**768**	10	**1,670**	34	100
	(2057)	(2055)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,650	**1,540,000**	8,950	**133,000**	1,380	**1,010,000**	8,580	45,000
	(2057)	(2050)	(2050)	(2054)	(2068)	(2050)	(2450)	
Total uranium	0	**46**	8	11	12	**103**	1	30
	(11,795)	(11,792)	(11,602)	(11,840)	(11,599)	(11,683)	(11,146)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern.

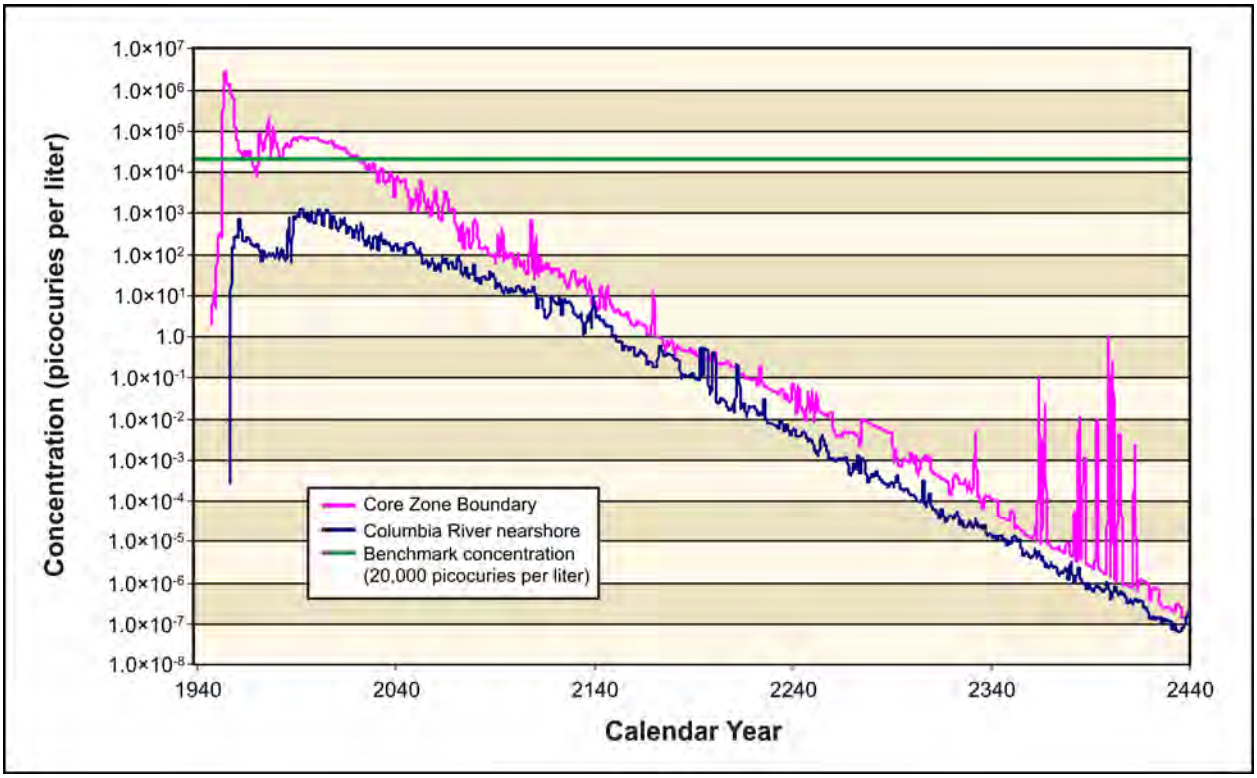


Figure 5–79. Tank Closure Alternative 2B Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–80 through 5–83 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration but remain about one order of magnitude below the benchmark at peak-year conditions. Releases from past leaks and other tank farm sources cause groundwater concentrations to continue to exceed benchmark concentrations in the Core Zone Boundary by about one order of magnitude through about CY 8000 for iodine-129 and CY 5000 for the other conservative tracers. During this time, groundwater concentrations at the Columbia River nearshore are below the benchmark concentration and continue to decline through the end of the period of analysis.

Figures 5–84 and 5–85 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are two to three orders of magnitude lower than benchmark concentrations. Releases from past leaks and other tank farm sources cause groundwater concentrations to rise in the Core Zone Boundary, nearing benchmark concentrations by about CY 8000. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by approximately one-half of an order of magnitude at the end of the period of analysis (CY 11,940). Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis but remain below the benchmark concentration by over one order of magnitude at the end of the period of analysis (CY 11,940).

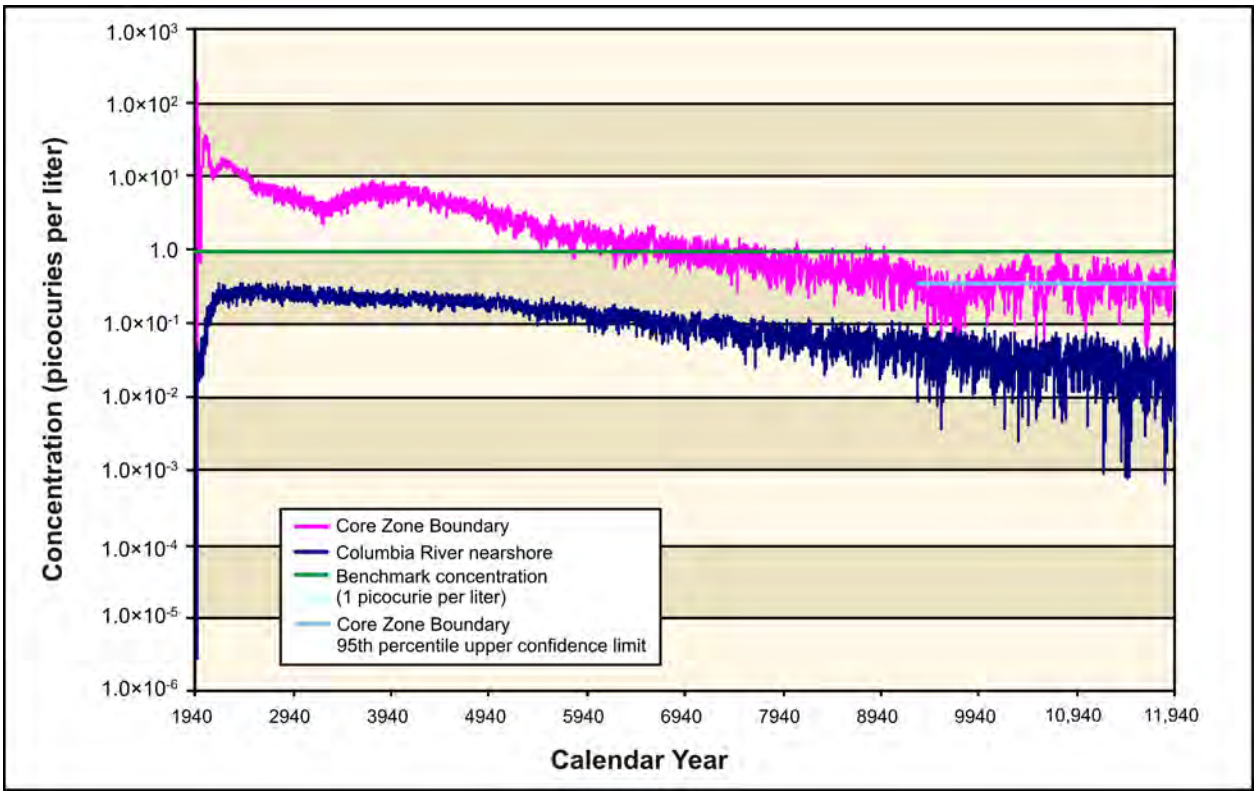


Figure 5–80. Tank Closure Alternative 2B Iodine-129 Concentration Versus Time

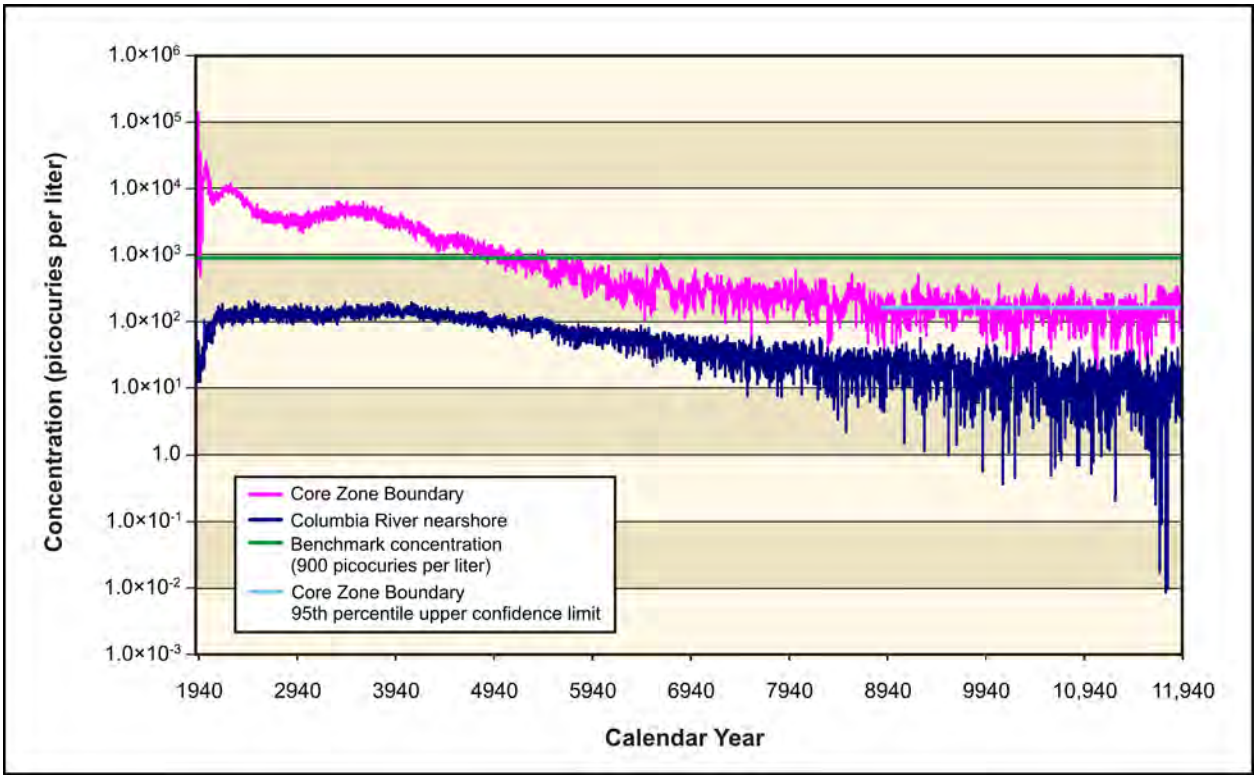


Figure 5–81. Tank Closure Alternative 2B Technetium-99 Concentration Versus Time

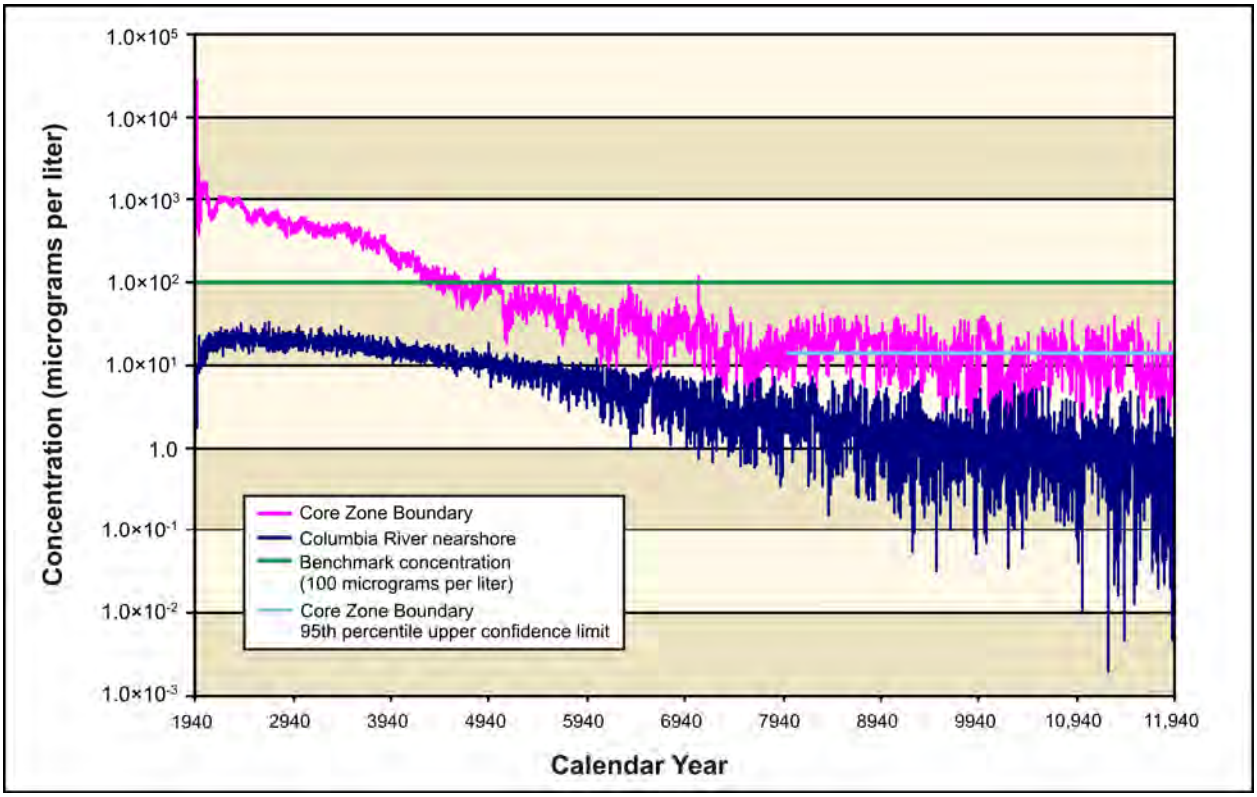


Figure 5–82. Tank Closure Alternative 2B Chromium Concentration Versus Time

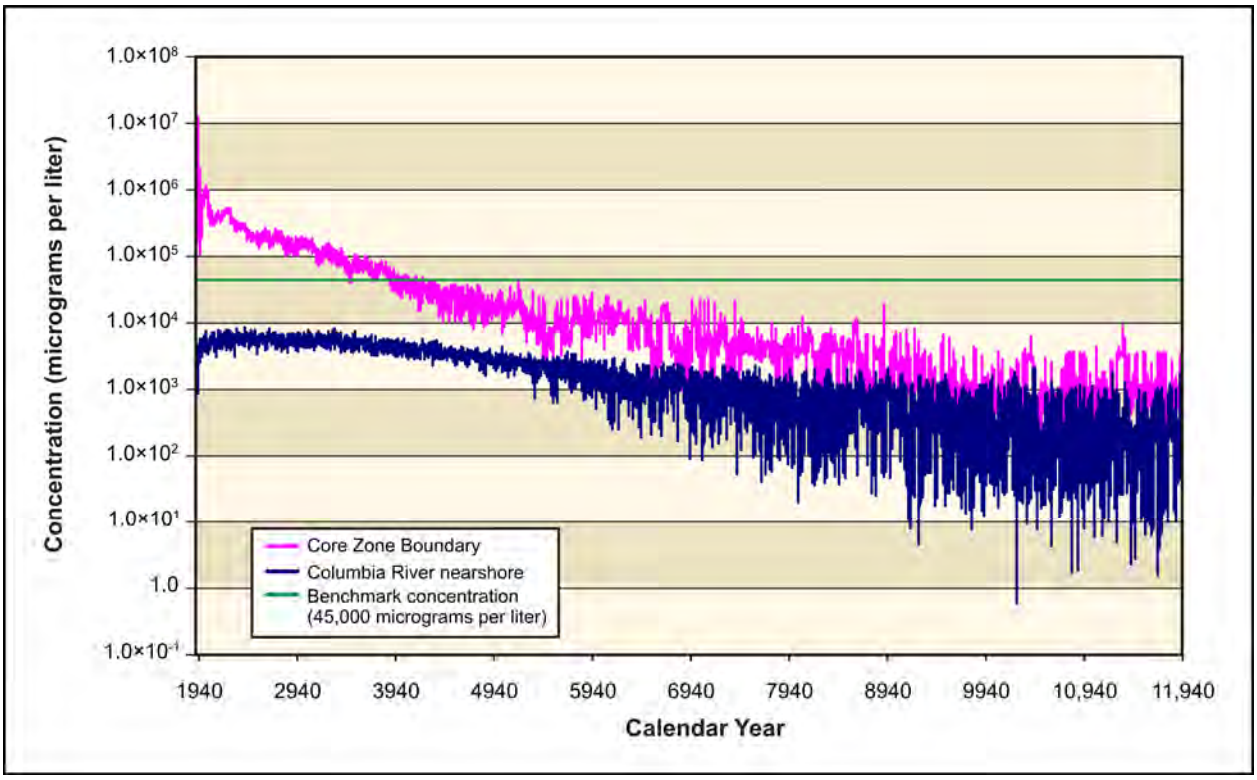


Figure 5–83. Tank Closure Alternative 2B Nitrate Concentration Versus Time

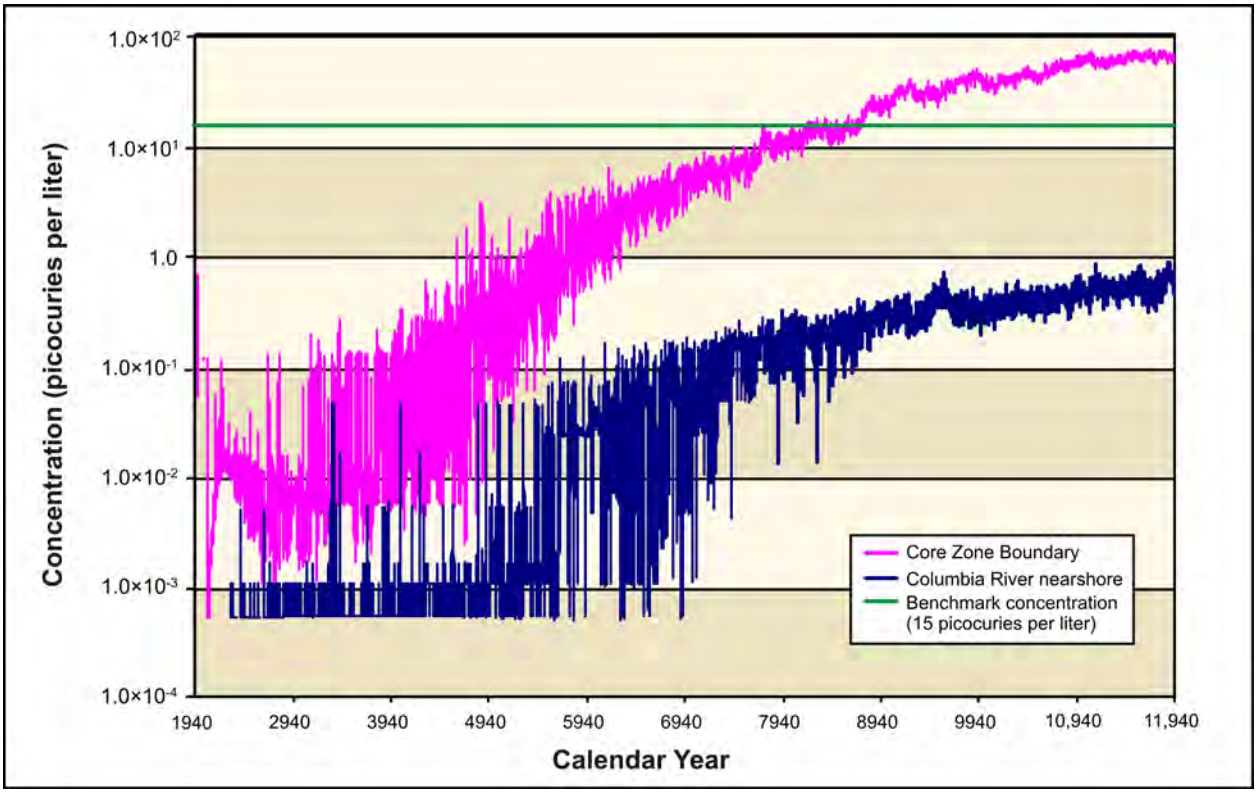


Figure 5–84. Tank Closure Alternative 2B Uranium-238 Concentration Versus Time

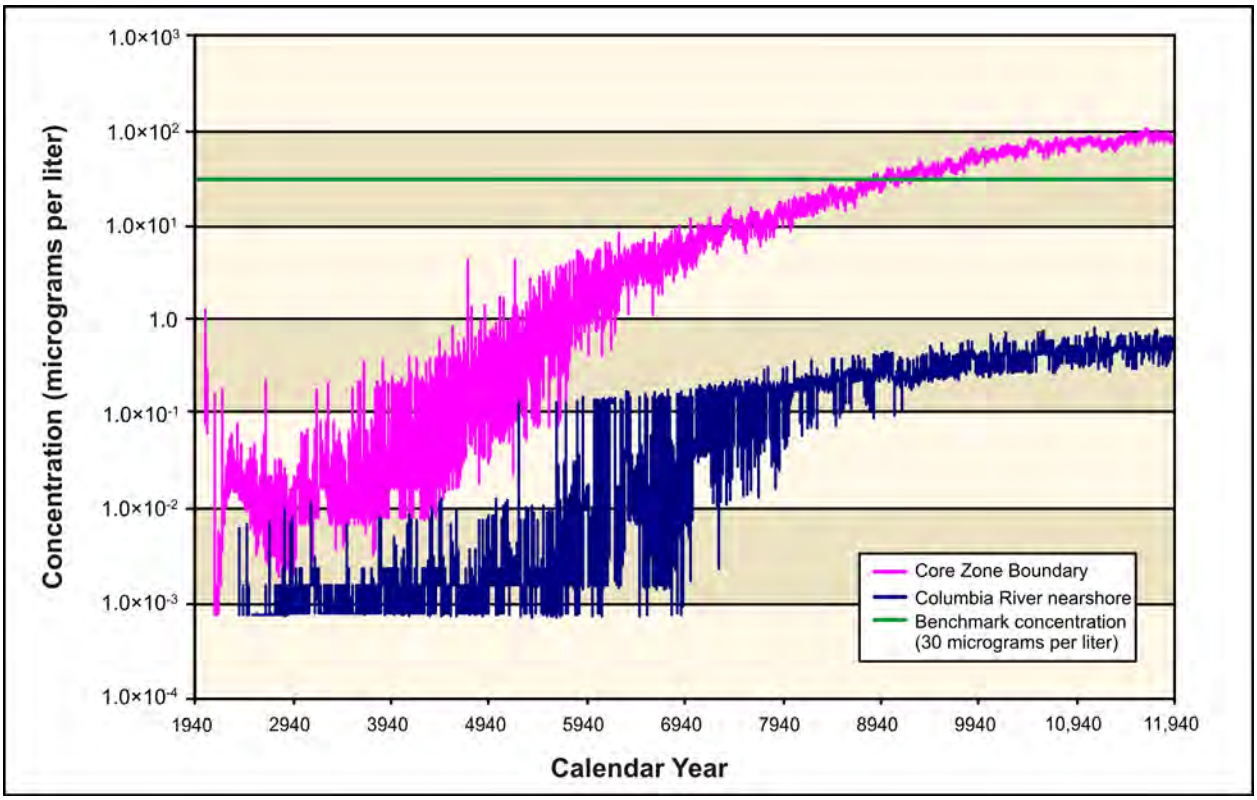
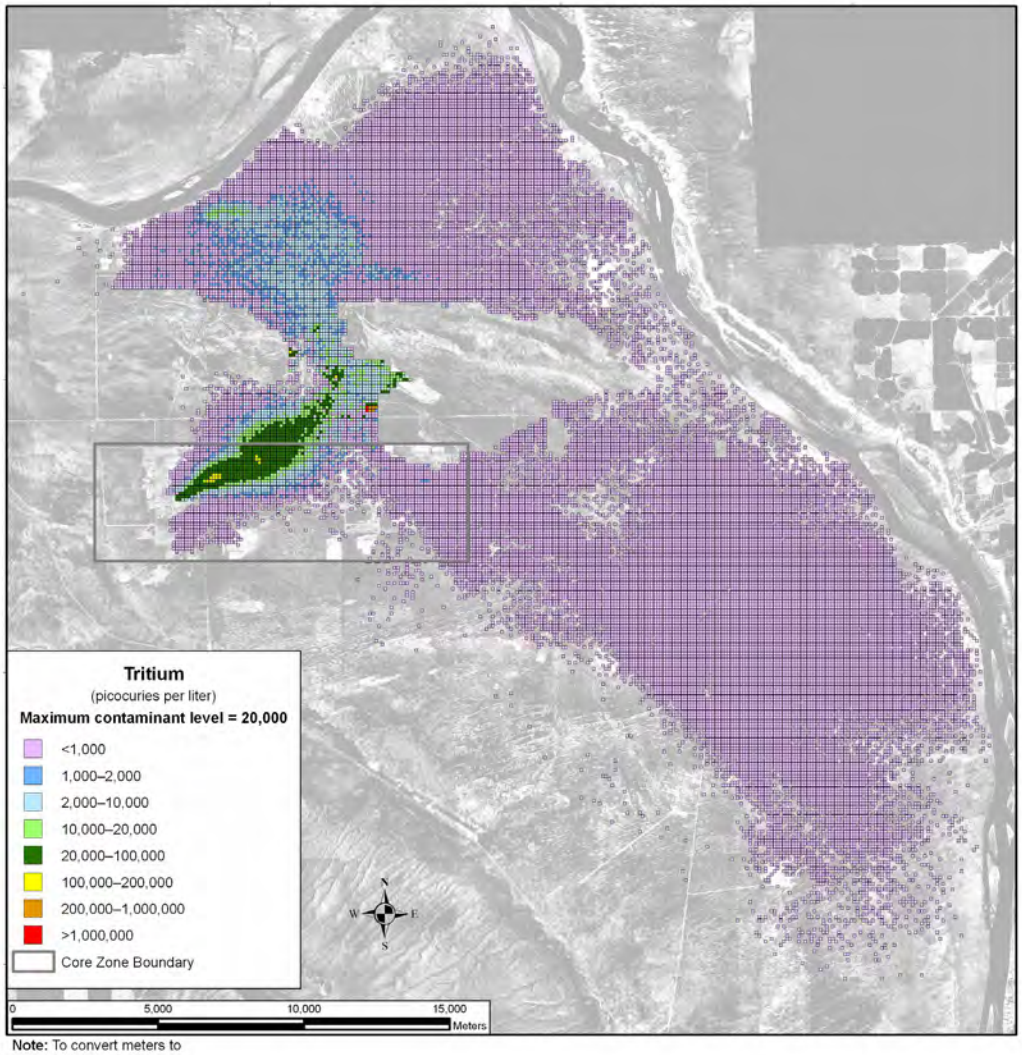


Figure 5–85. Tank Closure Alternative 2B Total Uranium Concentration Versus Time

5.1.1.3.5 Analysis of Spatial Distribution of Concentration

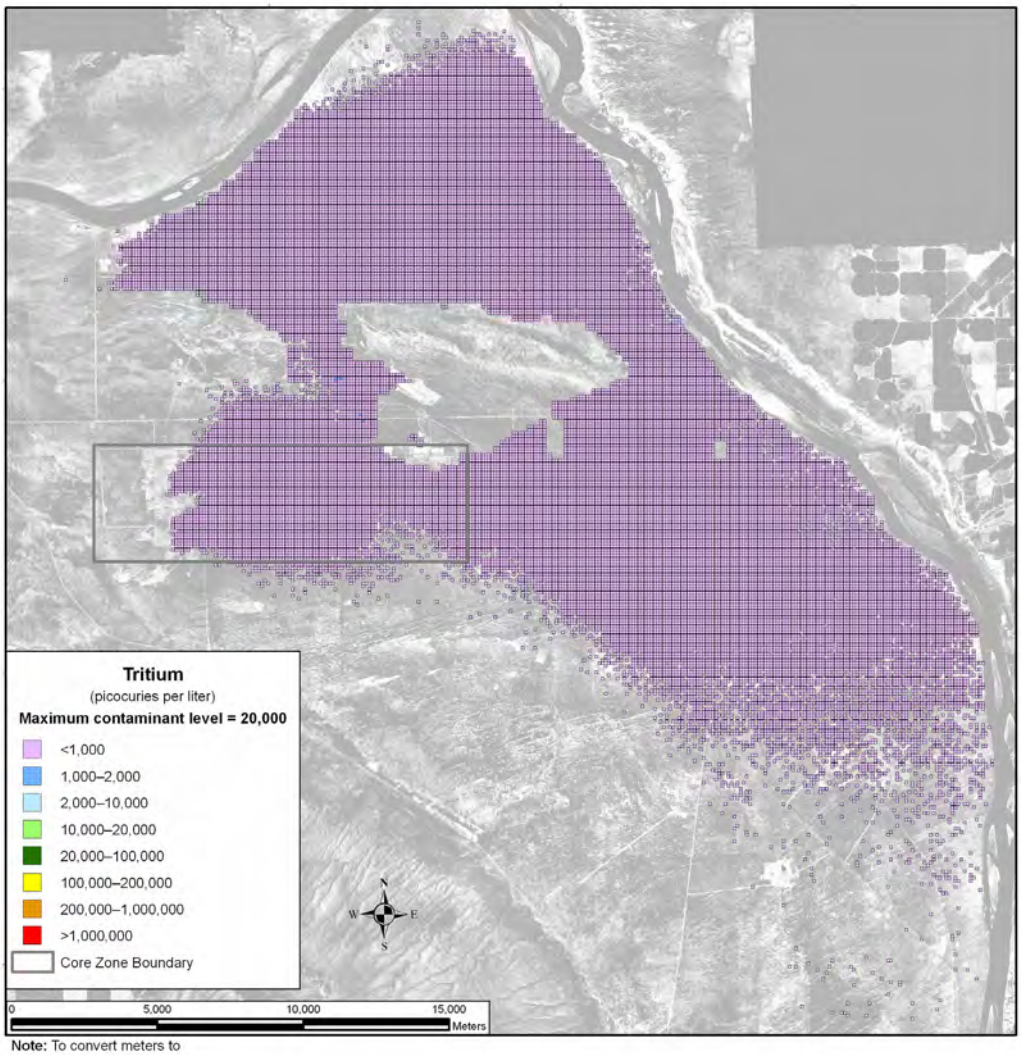
This section presents the impacts of Tank Closure Alternative 2B in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–86 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 5 to 10 times greater than the benchmark, and mostly contained within the Core Zone Boundary. By CY 2135, the tritium plume has diminished to levels less than one-twentieth of the benchmark concentration (see Figure 5–87).



Note: To convert meters to feet, multiply by 3.281

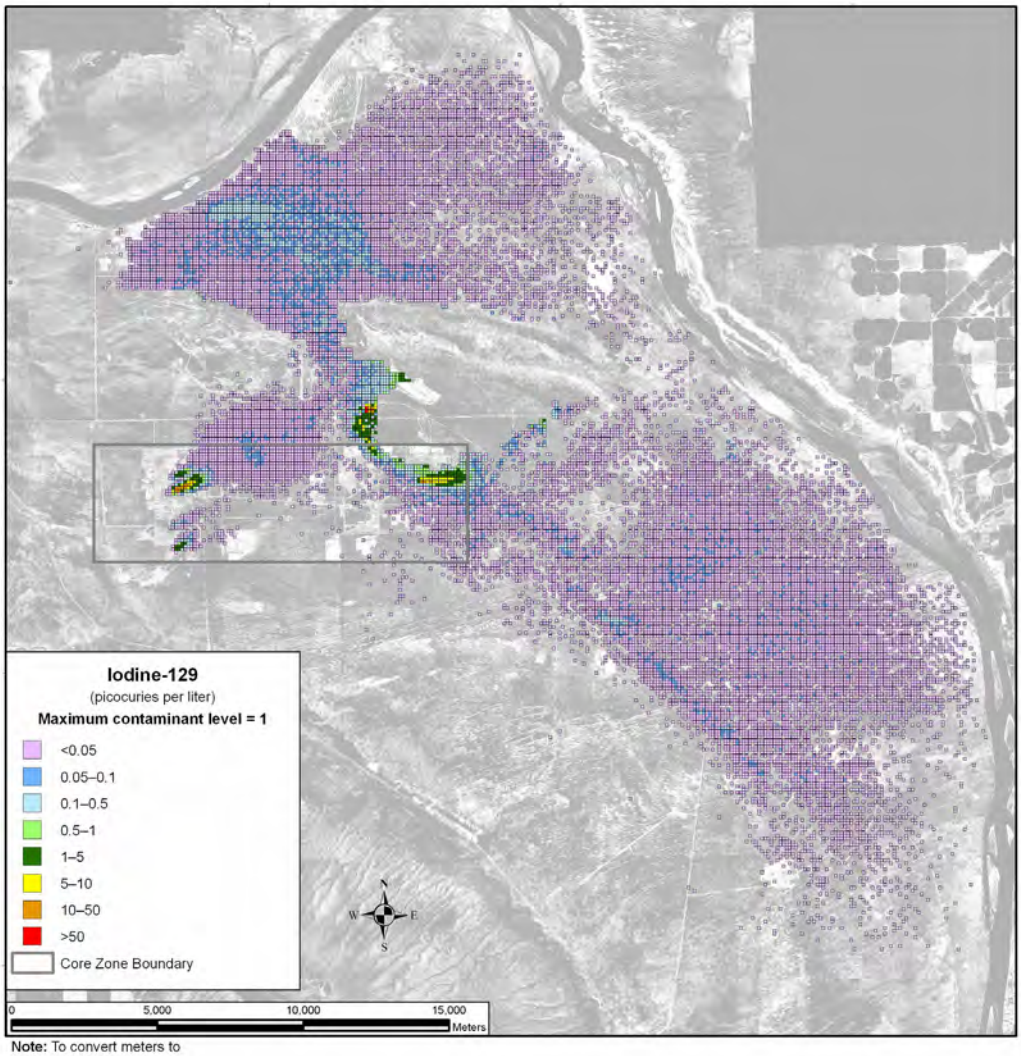
Figure 5–86. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

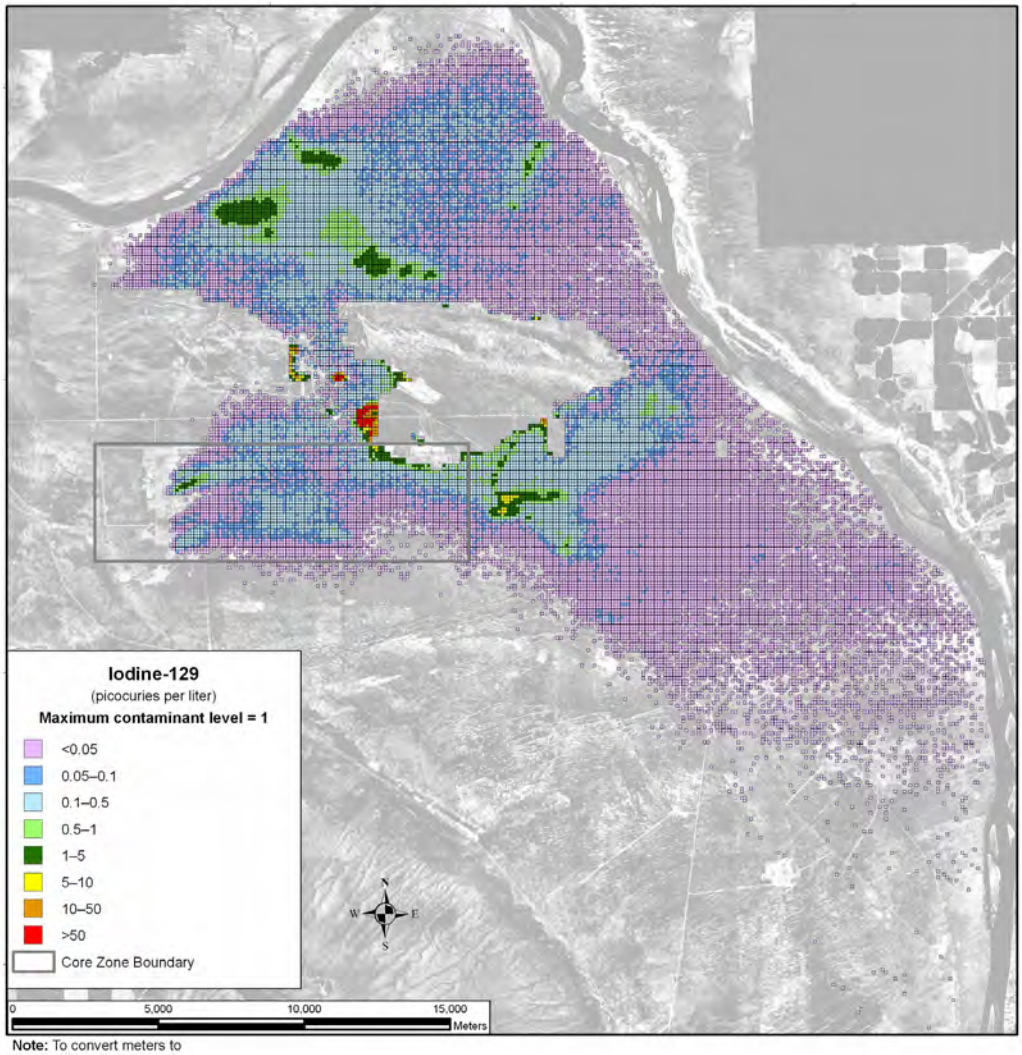
Figure 5–87. Tank Closure Alternative 2B Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

The conservative tracers (iodine-129, technetium-99, chromium, and nitrate) move at the rate of the pore water velocity and are discussed as a group, as they show similar spatial distributions. Figure 5–88 shows the spatial distribution of groundwater concentration of iodine-129 during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 50 times greater than the benchmark, and mostly contained within the Core Zone Boundary. During CY 2135, releases from other tank farm sources create another, less-intense plume (up to 5 to 10 times greater than the benchmark) that extends from the A Barrier toward the Columbia River (see Figure 5–89). By CY 7140, most of the mass in the plumes has reached the Columbia River, with only isolated pockets of high concentrations in Gable Gap (see Figure 5–90). Technetium-99, chromium, and nitrate show a similar spatial distribution at selected times (see Figures 5–91 through 5–99).



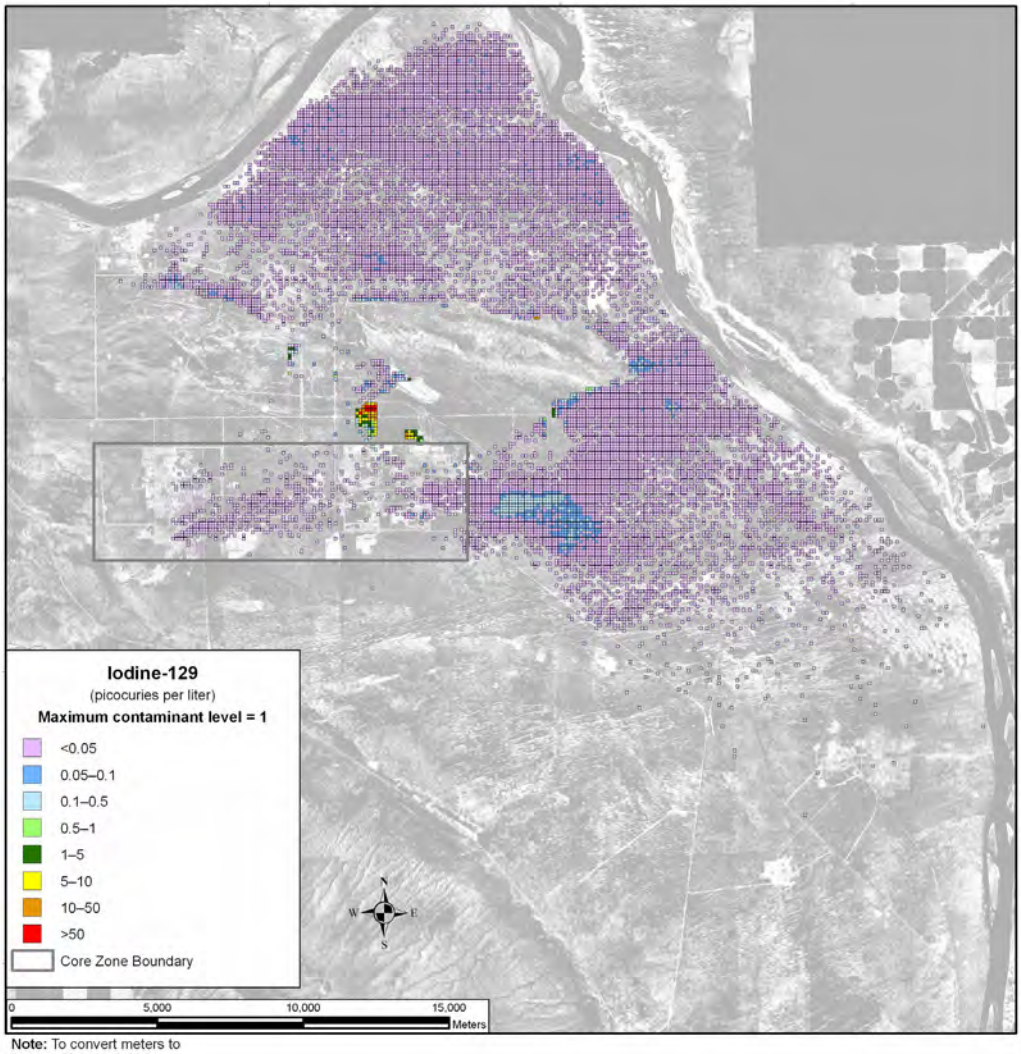
Note: To convert meters to feet, multiply by 3.281

Figure 5–88. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



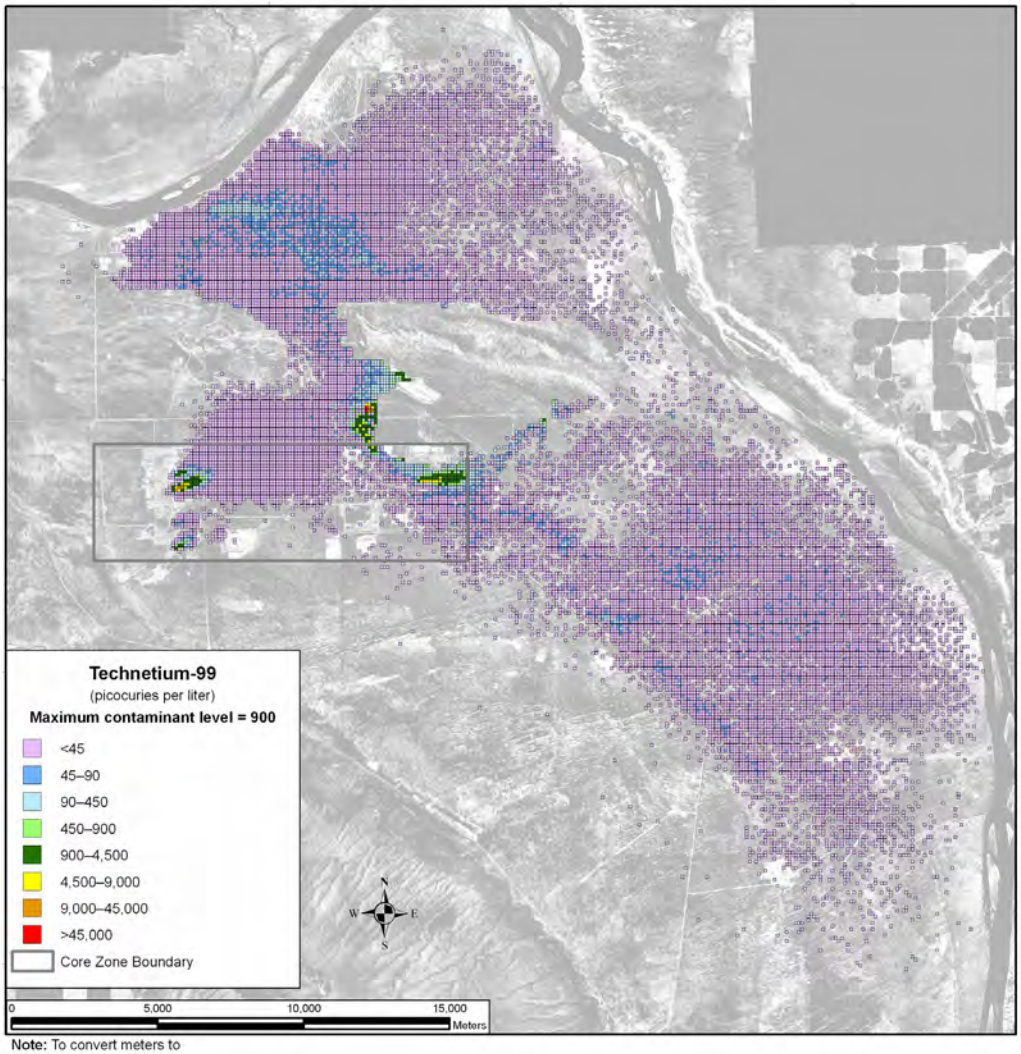
Note: To convert meters to feet, multiply by 3.281

Figure 5–89. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



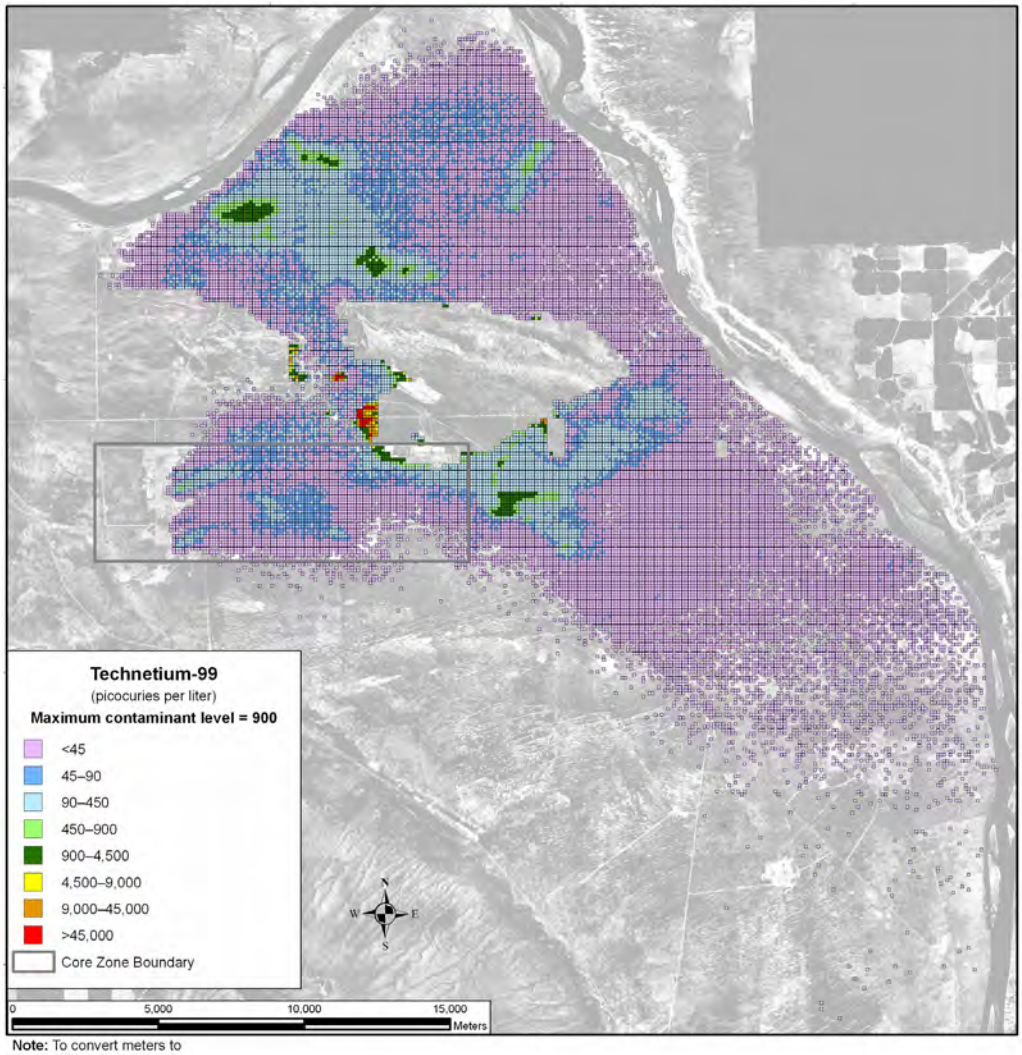
Note: To convert meters to feet, multiply by 3.281

Figure 5–90. Tank Closure Alternative 2B Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



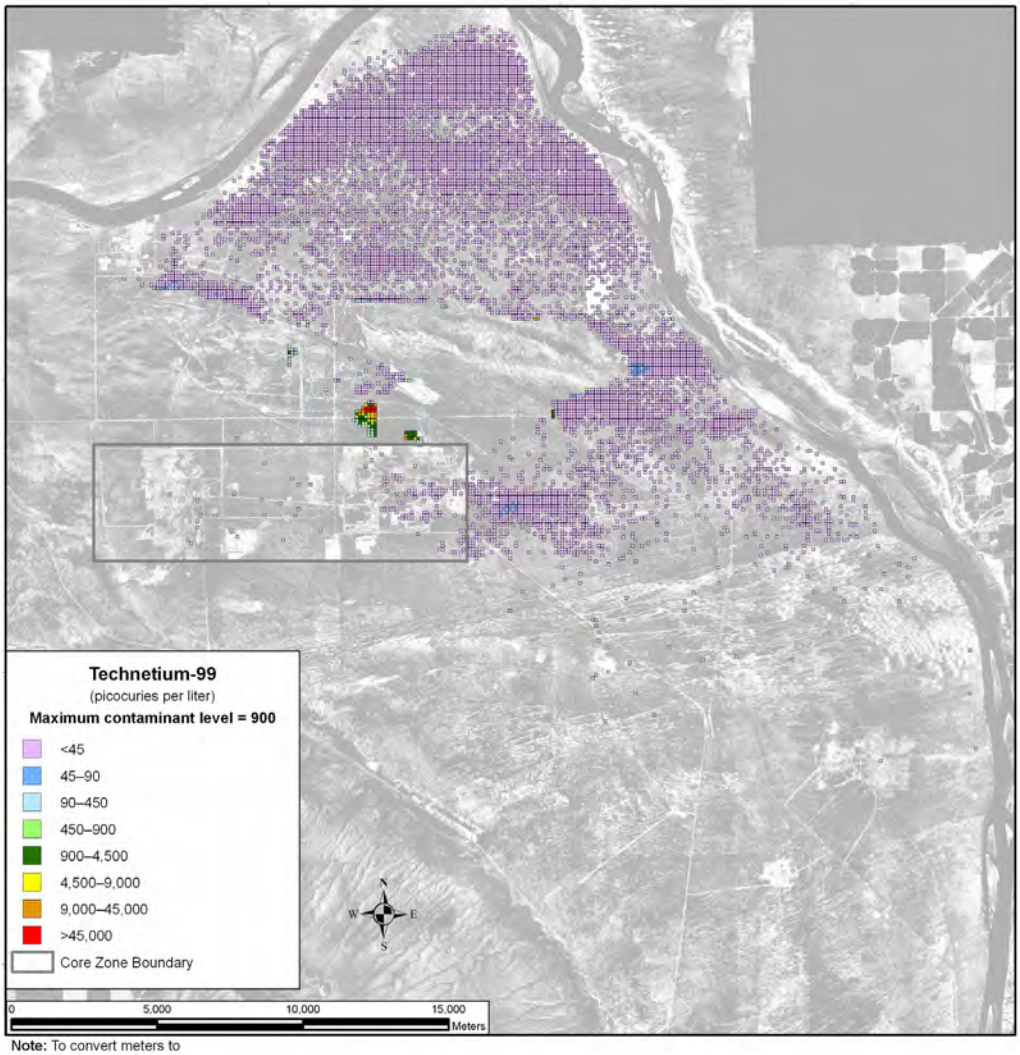
Note: To convert meters to feet, multiply by 3.281

Figure 5–91. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



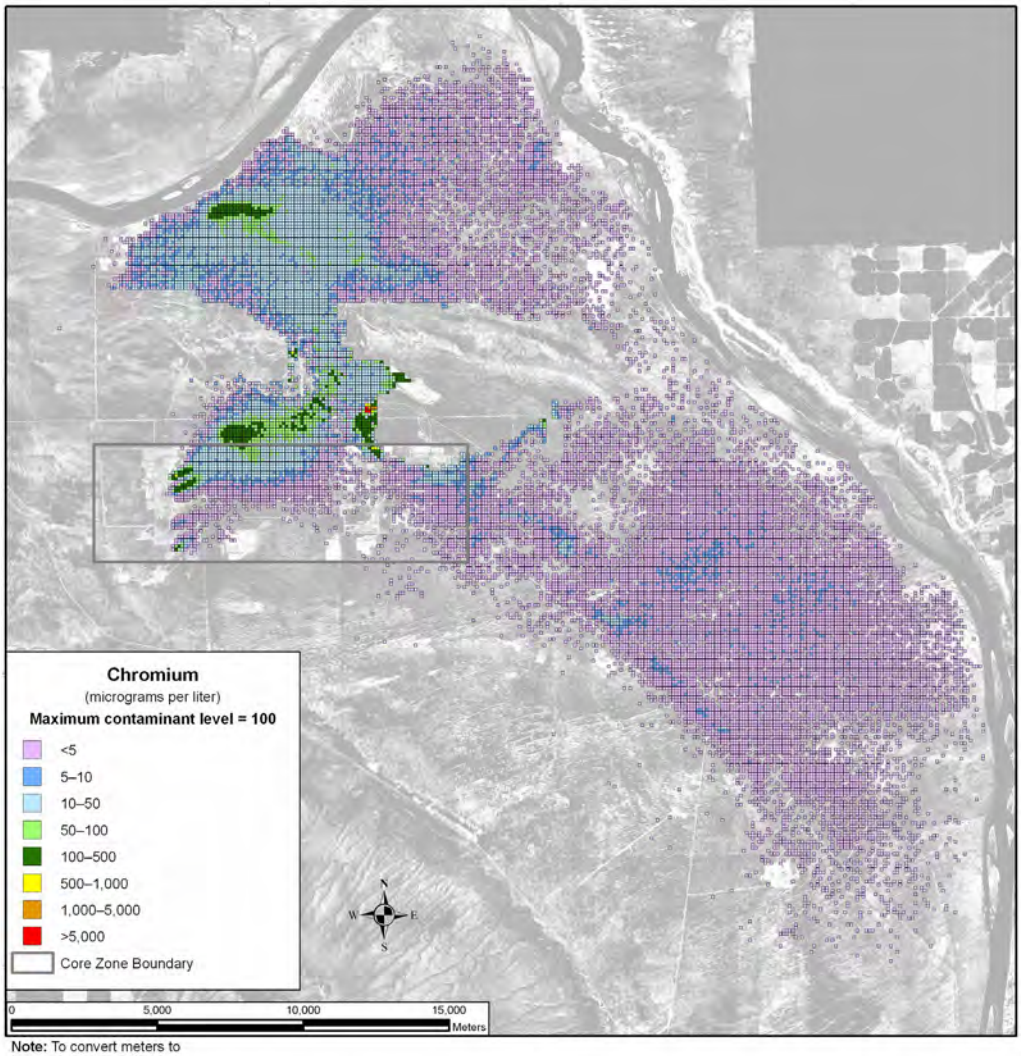
Note: To convert meters to feet, multiply by 3.281

Figure 5–92. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



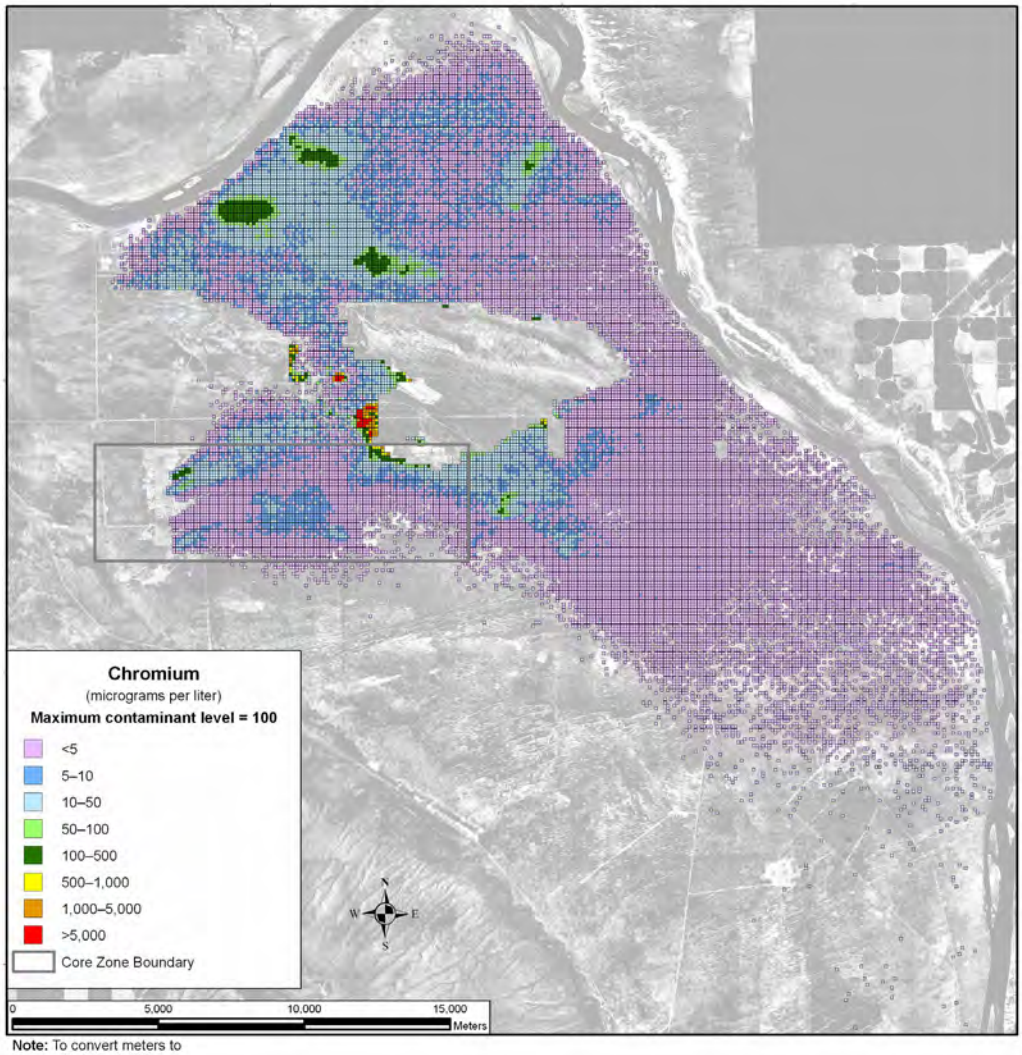
Note: To convert meters to feet, multiply by 3.281

Figure 5–93. Tank Closure Alternative 2B Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



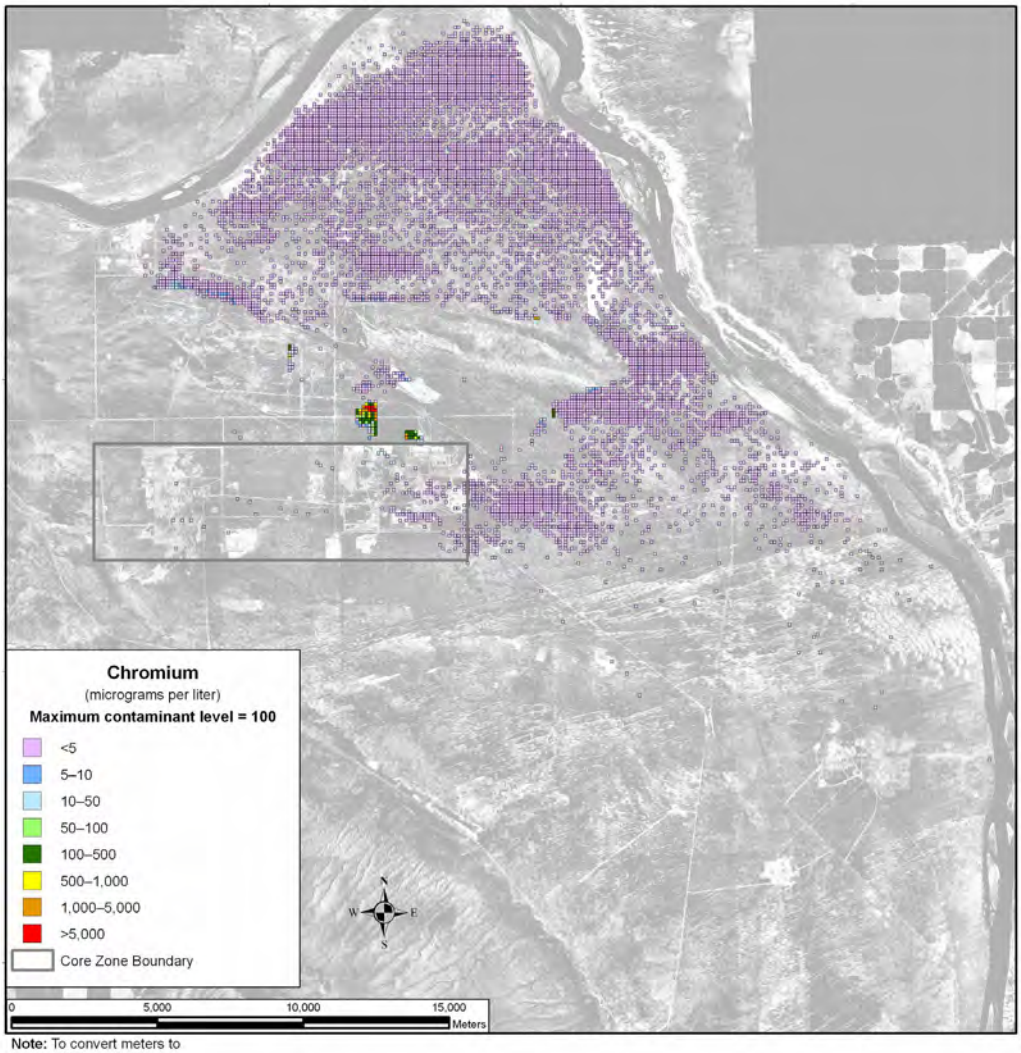
Note: To convert meters to feet, multiply by 3.281

Figure 5–94. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



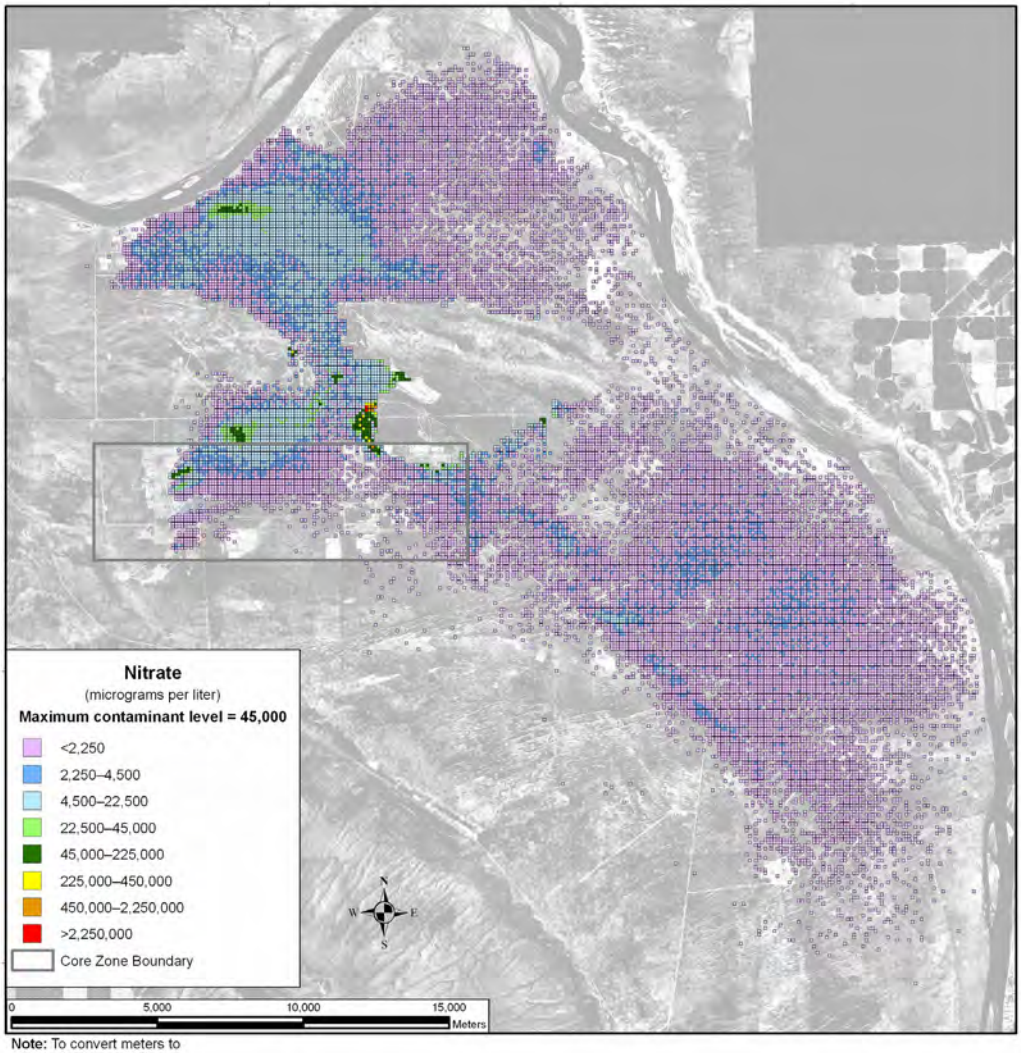
Note: To convert meters to feet, multiply by 3.281

Figure 5–95. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



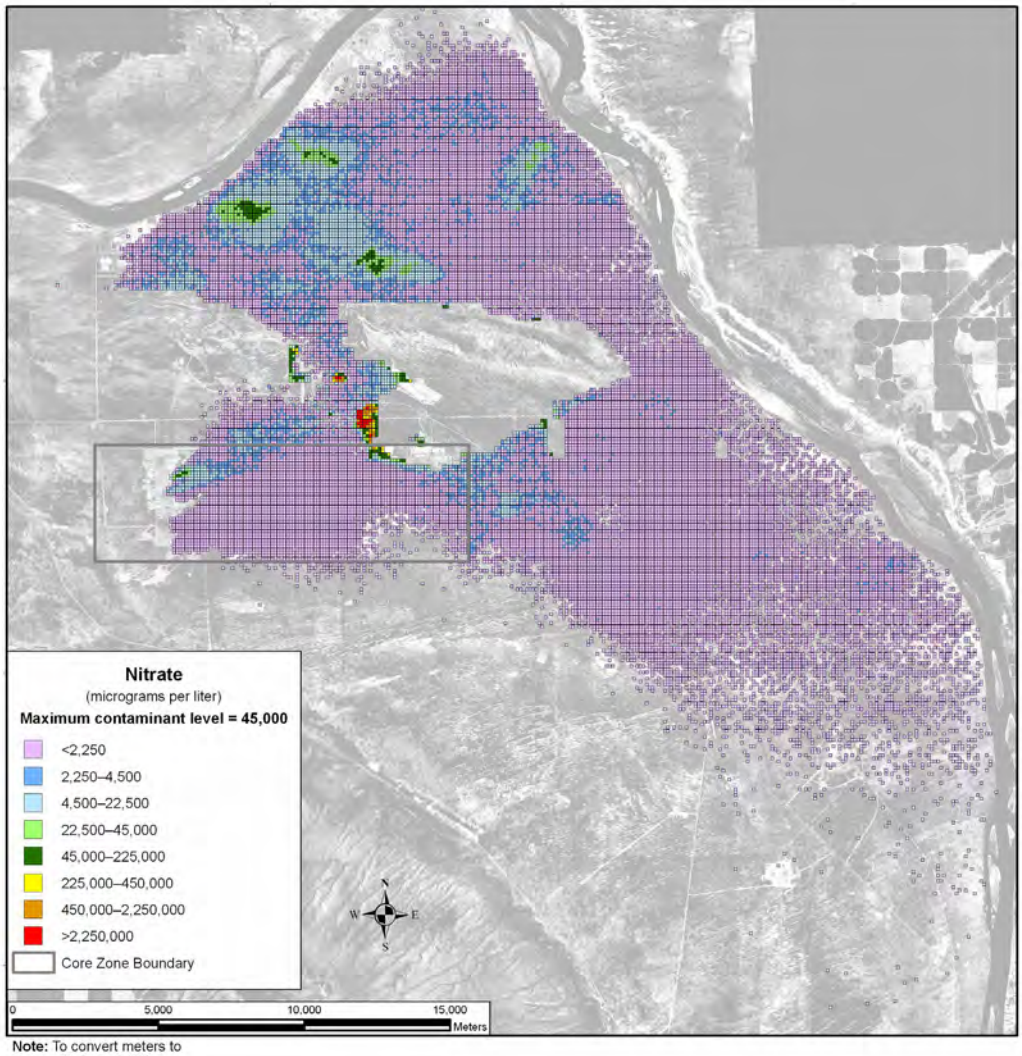
Note: To convert meters to feet, multiply by 3.281

Figure 5–96. Tank Closure Alternative 2B Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



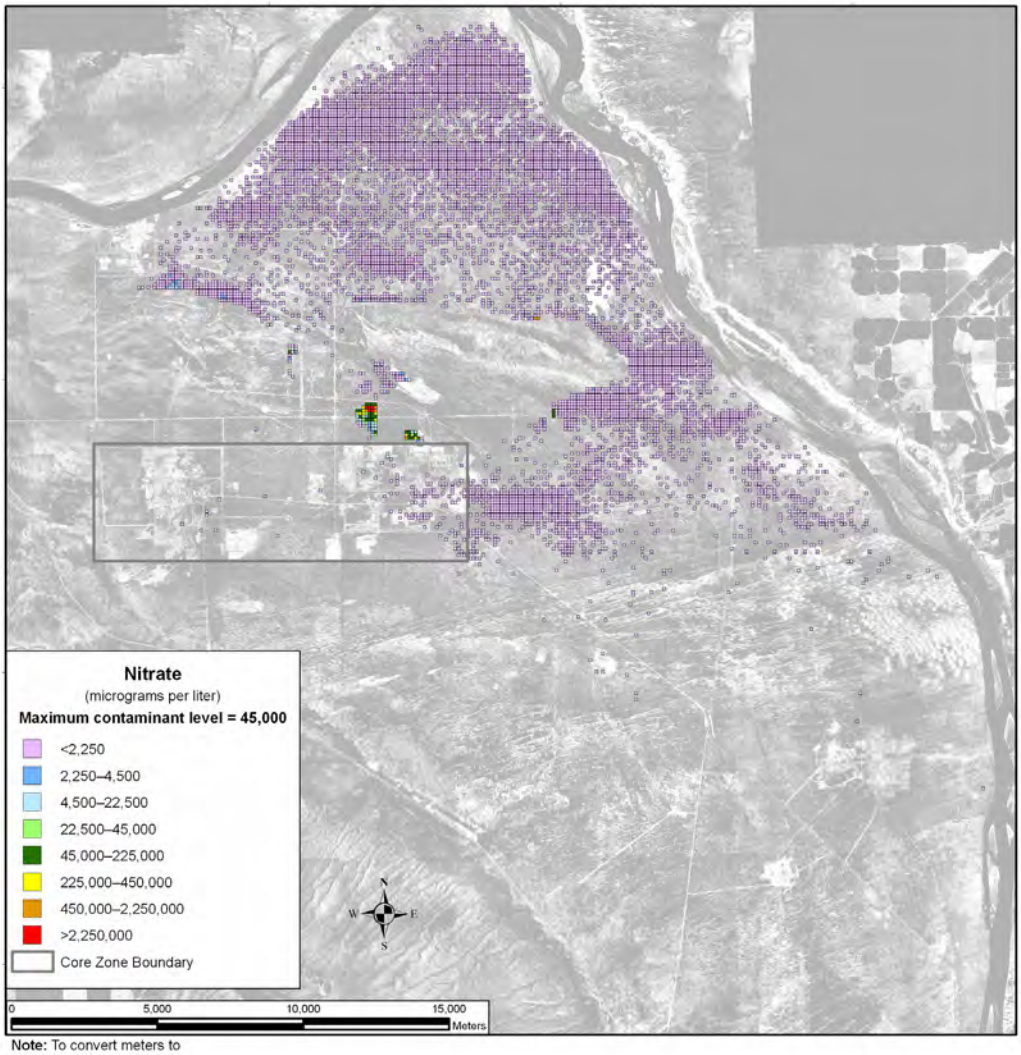
Note: To convert meters to feet, multiply by 3.281

Figure 5–97. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–98. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–99. Tank Closure Alternative 2B Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Figure 5–100 shows the area in square kilometers in which groundwater concentrations of technetium-99 exceed the benchmark concentration in the analysis as a function of time. A peak area of about 4 square kilometers (1.5 square miles) occurs around CY 2135, followed by a fairly sharp decrease. Another peak area of about 2 square kilometers (0.77 square miles) occurs around CY 3890, followed by another decrease. By about CY 6000, the area with a concentration above the benchmark concentration begins to level out to around 0.5 square kilometers (0.2 square miles). Iodine-129 shows a pattern similar to that of technetium-99, as both constituents are conservative tracers (see Figure 5–101).

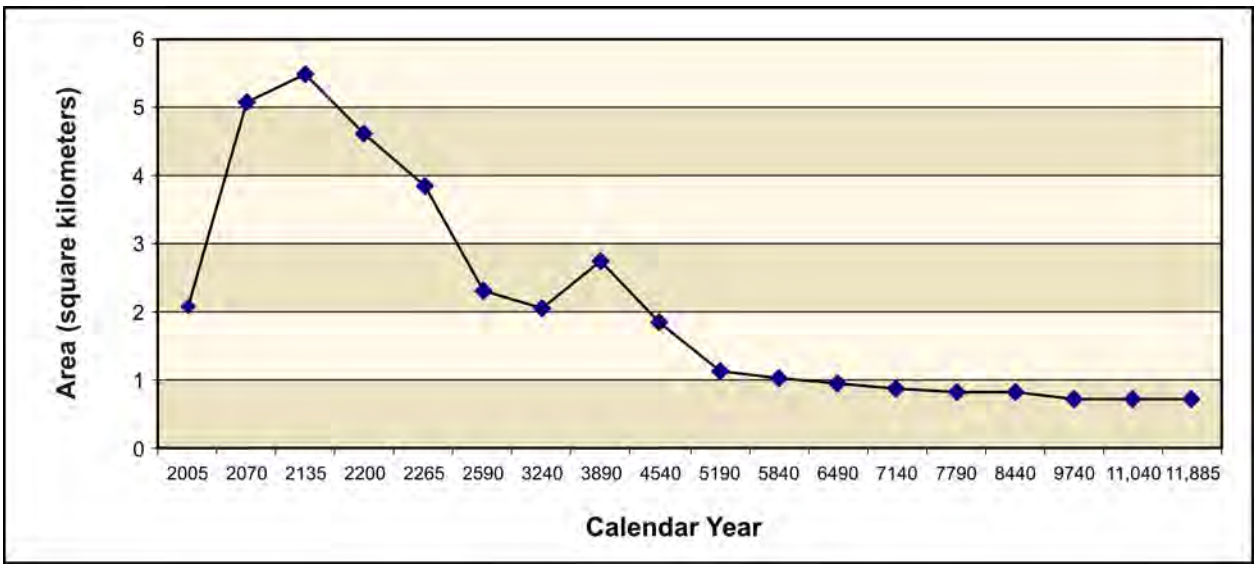


Figure 5–100. Tank Closure Alternative 2B Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

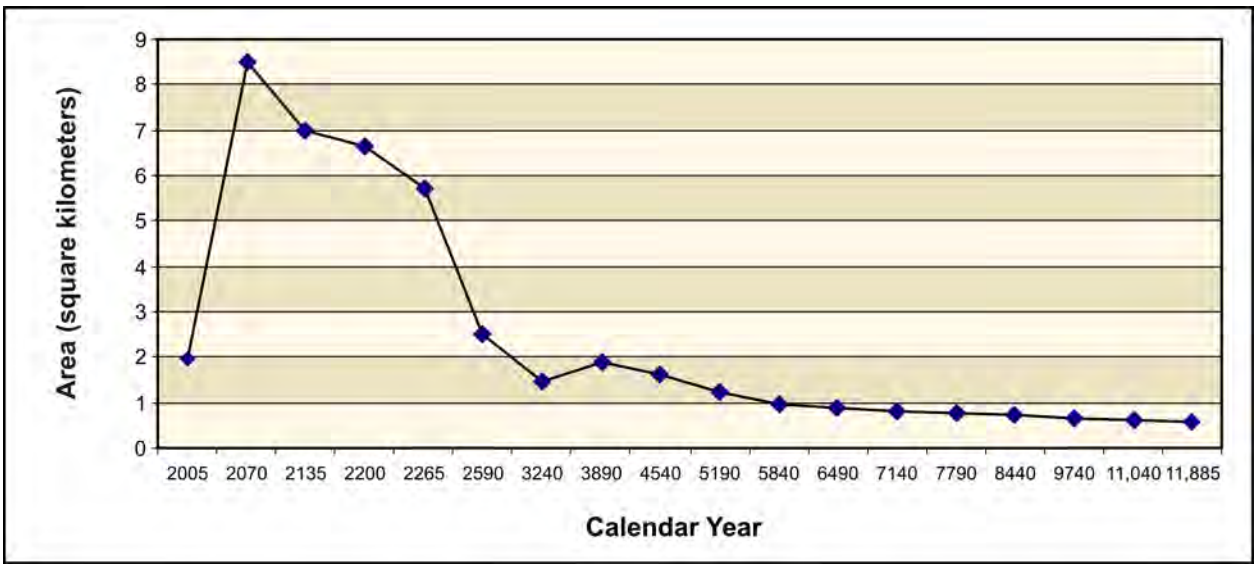
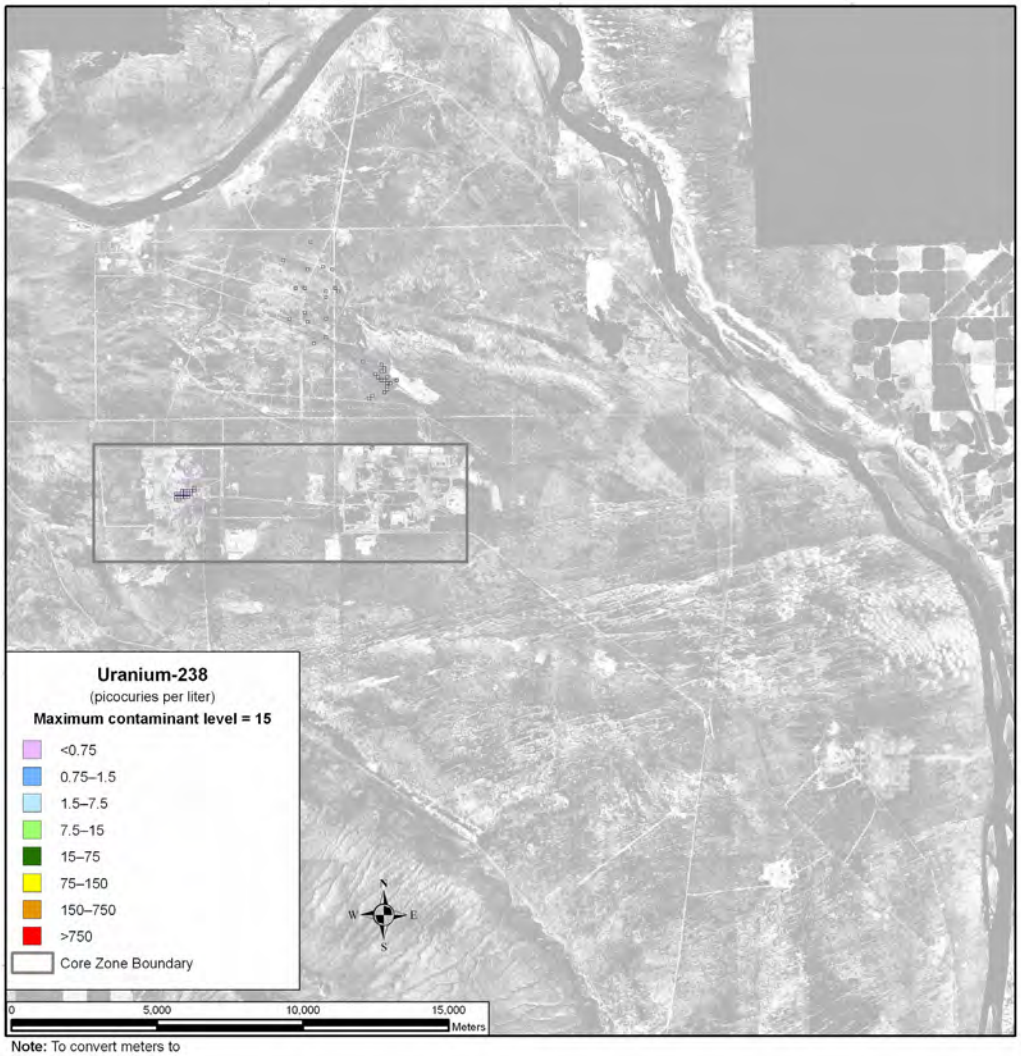


Figure 5–101. Tank Closure Alternative 2B Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–102 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140, the area of the plume has grown and extended to the Columbia River (see Figure 5–103). There is only a small area in Gable Gap that is 5 to 10 times greater in uranium-238 concentration than the benchmark concentration. By CY 11,885, the greatest development of the plume during the analysis period is seen, resulting primarily from past leaks and the release of other tank farm sources at the A Barrier and B Barrier (see Figure 5–104). Figures 5–105 through 5–107 show the corresponding results for total uranium.



Note: To convert meters to feet, multiply by 3.281

Figure 5–102. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005

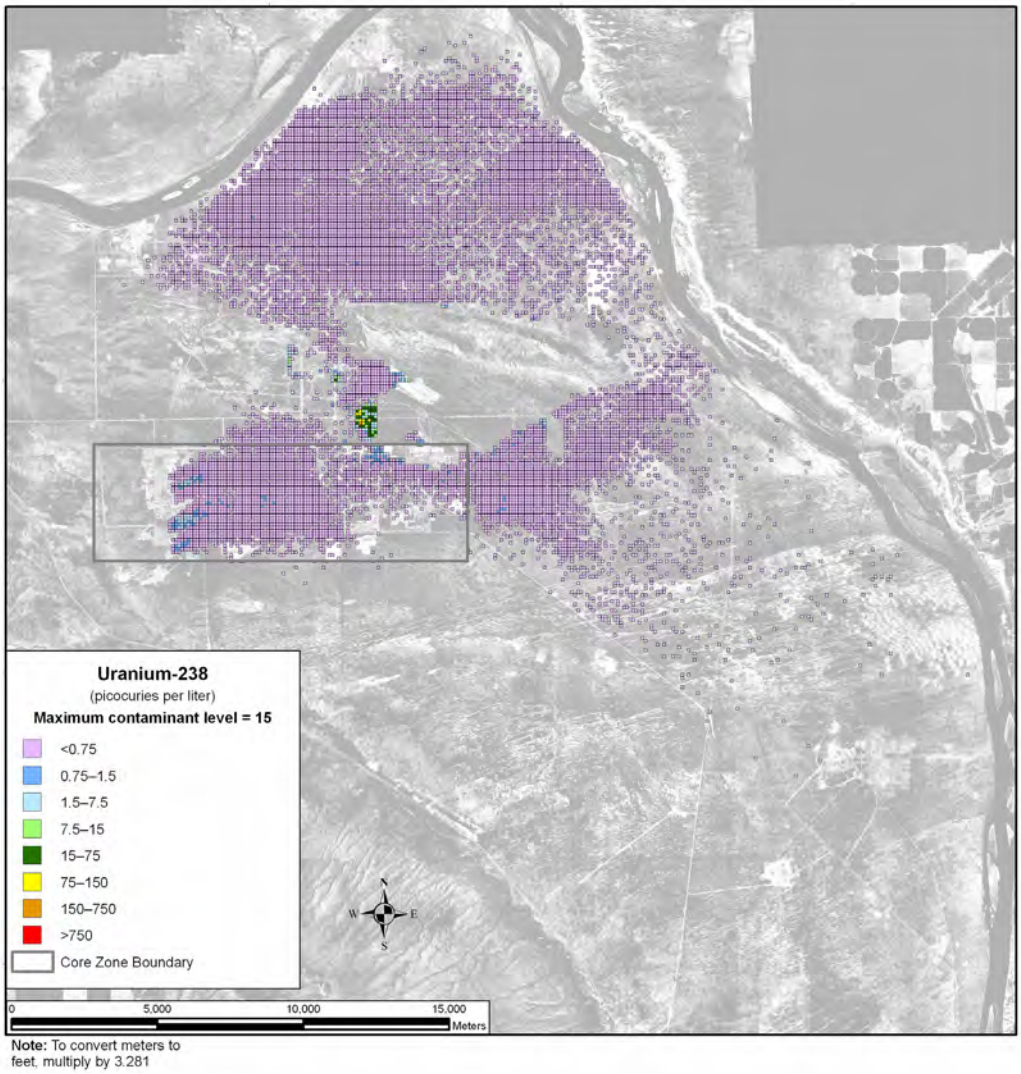
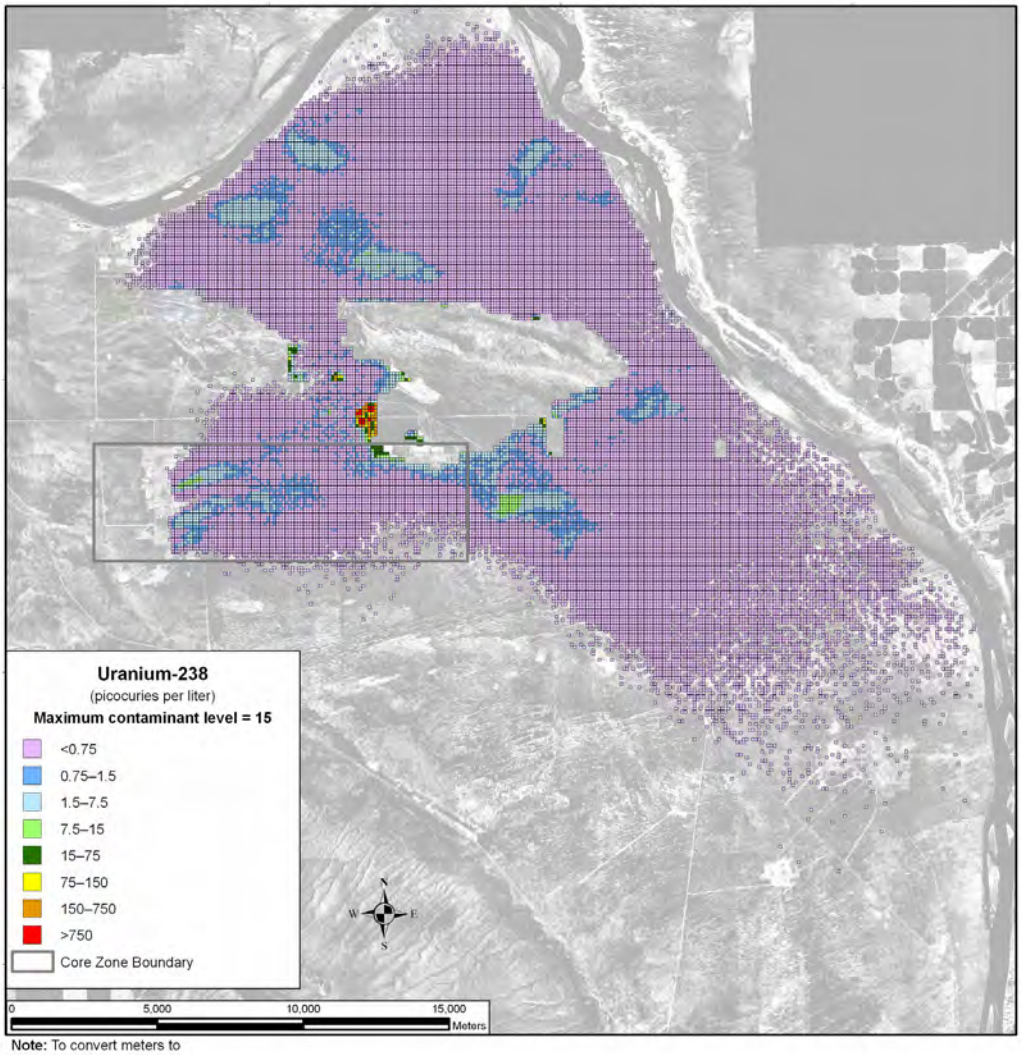
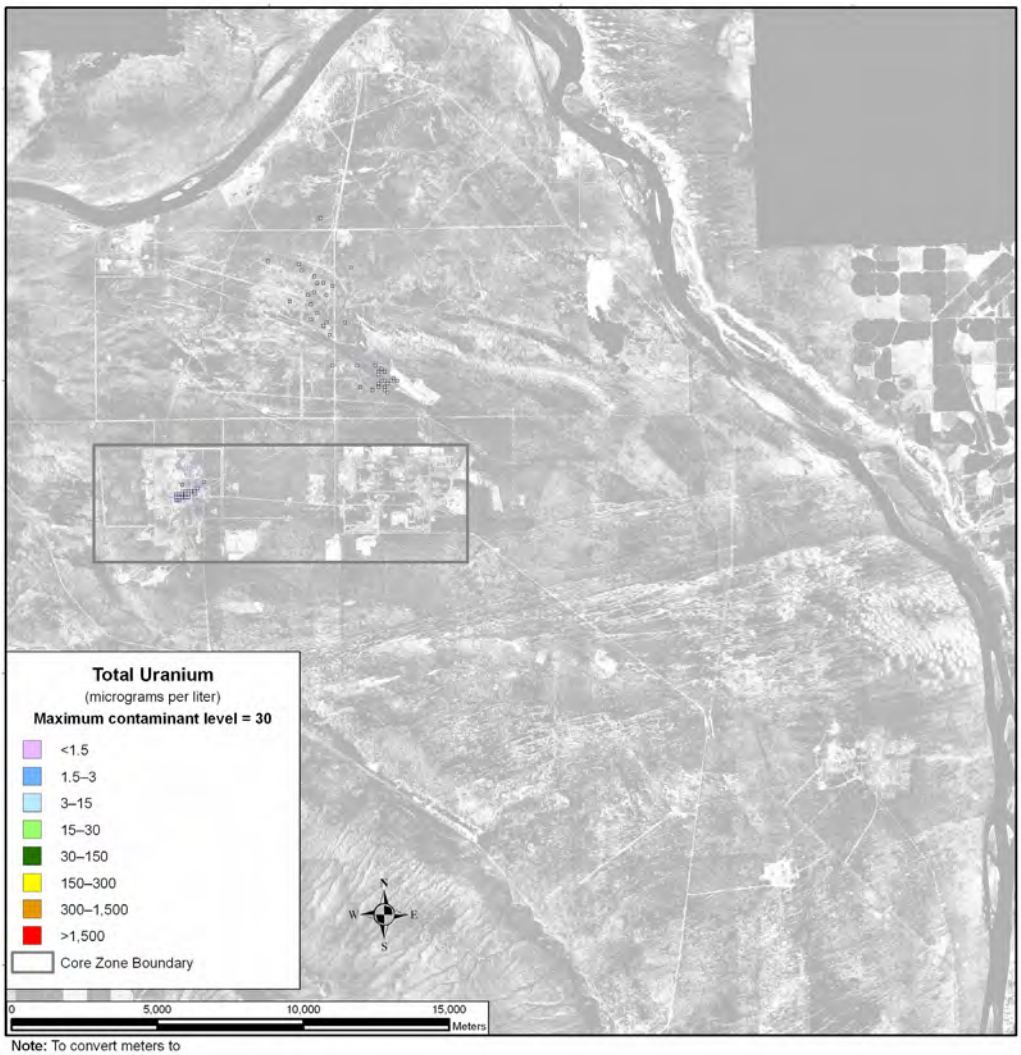


Figure 5–103. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



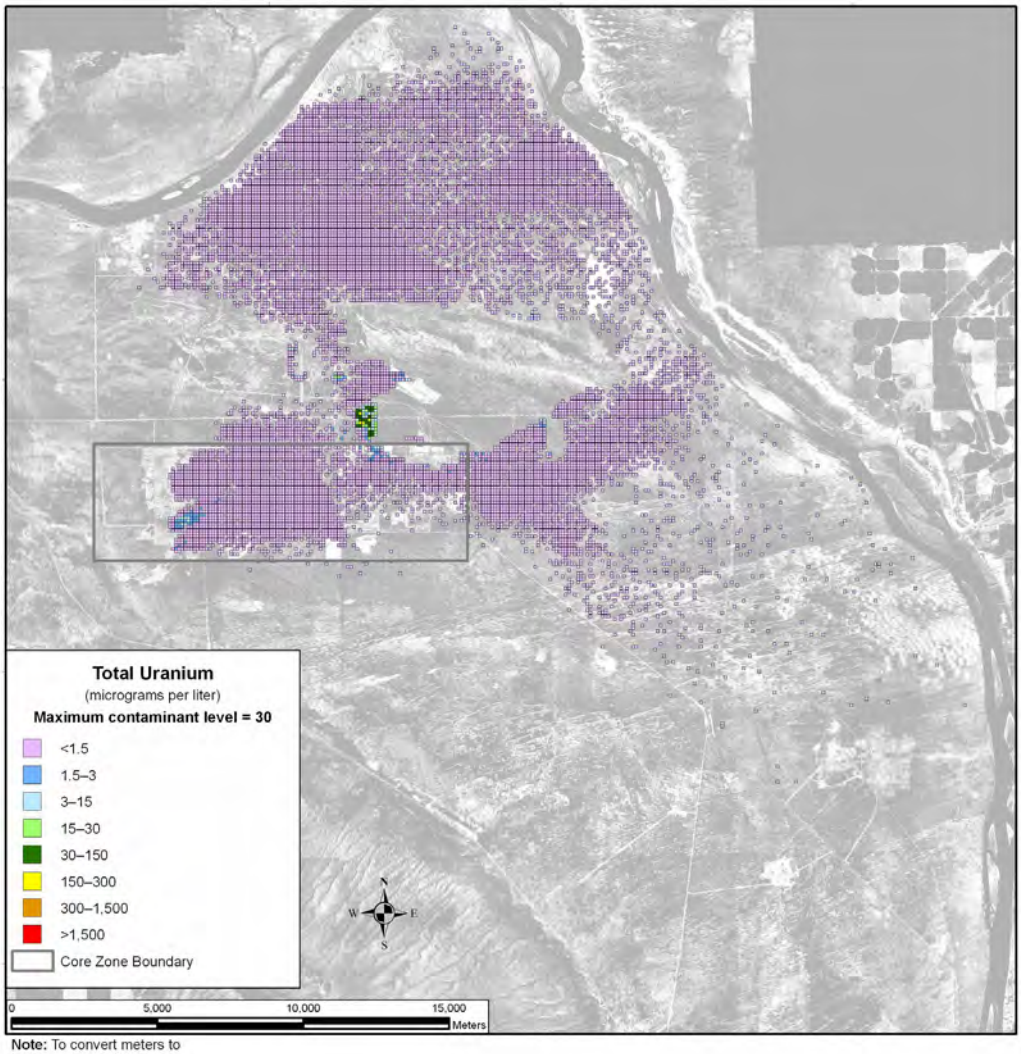
Note: To convert meters to feet, multiply by 3.281

Figure 5–104. Tank Closure Alternative 2B Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–105. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–106. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140

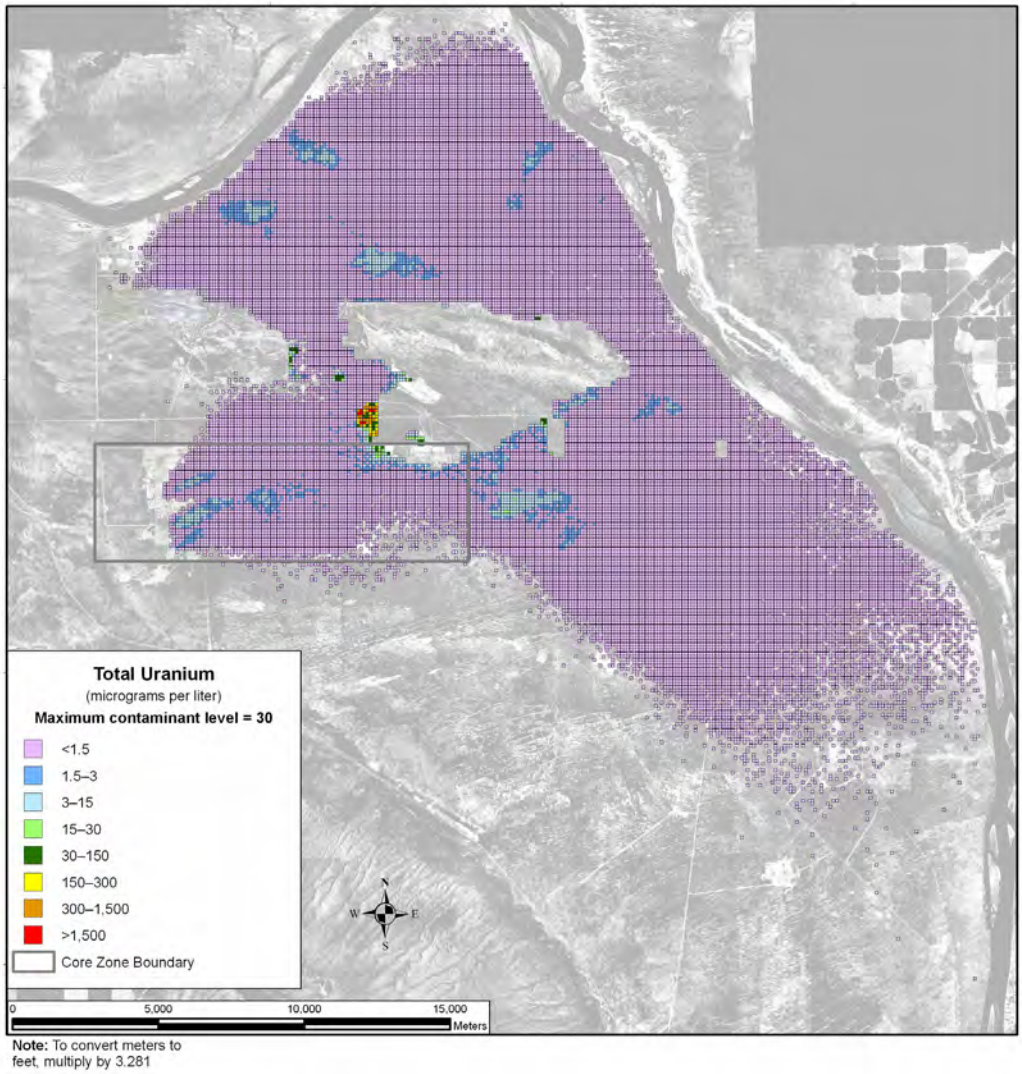


Figure 5–107. Tank Closure Alternative 2B Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Uranium-238 does not exceed the benchmark concentration in any area until after CY 5190 (see Figure 5–108). A sharp increase in area with concentrations above the maximum contaminant level is seen after this time and continues to rise to over 1.25 square kilometers (0.48 square miles) through the end of the period of analysis (CY 11,940). It is expected that the majority of the uranium-238 would continue to migrate through the vadose zone after the period of analysis is over.

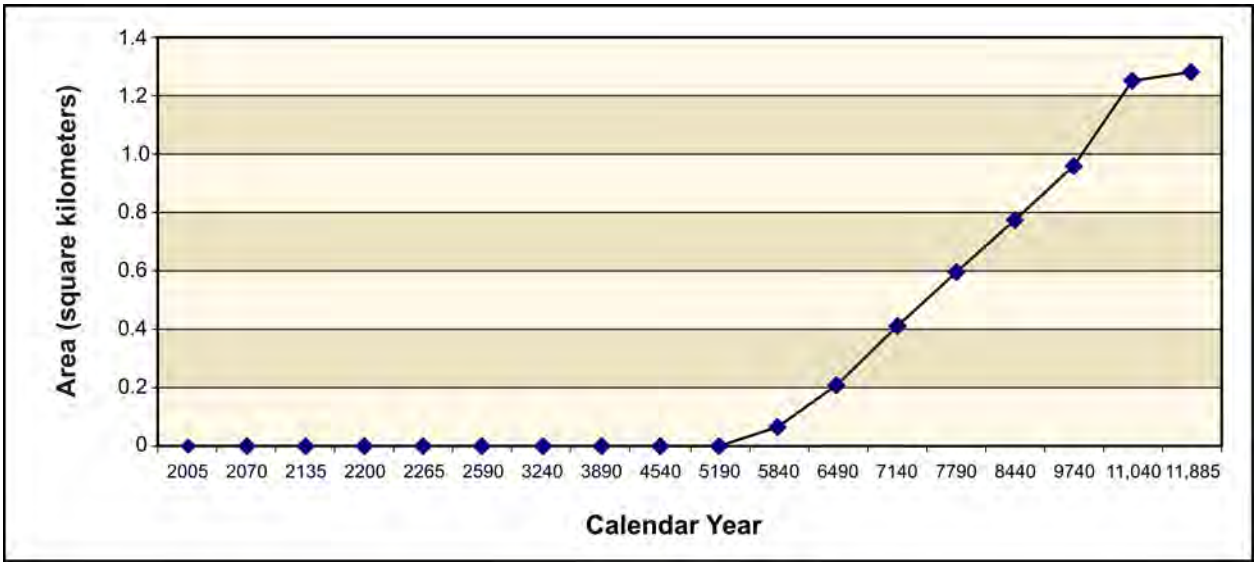


Figure 5–108. Tank Closure Alternative 2B Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.3.6 Summary of Impacts

Under Tank Closure Alternative 2B, concentrations of tritium at the Core Zone Boundary exceed the benchmark concentration by about two orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River nearshore approach but do not exceed the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during the early part of the period of analysis and then gradually decline to around one order of magnitude below the benchmark, where they remain throughout the period of analysis. Concentrations at the Columbia River nearshore remain below the benchmark throughout the period of analysis.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark at the Core Zone Boundary beyond about CY 8000. Concentrations at the Columbia River nearshore rise throughout the period of analysis but remain below the benchmark by around one order of magnitude. The peak intensity and area of the contamination plume is at the end of the period of analysis.

5.1.1.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); Landfill Closure

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical. Refer to Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.1 Actions and Timeframes Influencing Groundwater Impacts

Refer to Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.2 COPC Drivers

Refer to Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.3 Analysis of Release and Mass Balance

Refer to Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.4 Analysis of Concentration Versus Time

Refer to Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.5 Analysis of Spatial Distribution of Concentration

Refer to Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.4.6 Summary of Impacts

Refer to Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3A.

5.1.1.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); Landfill Closure

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical. Refer to Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.1 Actions and Timeframes Influencing Groundwater Impacts

Refer to Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.2 COPC Drivers

Refer to Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.3 Analysis of Release and Mass Balance

Refer to Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.4 Analysis of Concentration Versus Time

Refer to Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.5 Analysis of Spatial Distribution of Concentration

Refer to Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.5.6 Summary of Impacts

Refer to Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3B.

5.1.1.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); Landfill Closure

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical. Refer to Section 5.1.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.1 Actions and Timeframes Influencing Groundwater Impacts

Refer to Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.2 COPC Drivers

Refer to Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.3 Analysis of Release and Mass Balance

Refer to Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.4 Analysis of Concentration Versus Time

Refer to Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.5 Analysis of Spatial Distribution of Concentration

Refer to Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.6.6 Summary of Impacts

Refer to Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 3C.

5.1.1.7 Tank Closure Alternative 4: Existing WTP Vitrification with Supplemental Treatment Technologies; Selective Clean Closure/Landfill Closure

This section describes the groundwater analysis results for Tank Closure Alternative 4, including long-term groundwater impacts of contaminant sources from within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

5.1.1.7.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 4 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 4, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 4 presented in this section would be common to all the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2144. During this period, 99.9 percent of the waste would be retrieved from the tanks. A retrieval loss of 15,140 liters (4,000 gallons) per tank was assumed for all SSTs. Most tank farms would be landfill-closed with a modified RCRA Subtitle C barrier. The exceptions are the BX and SX tank farms, which would undergo clean closure.

- The post–administrative control period was assumed to start in CY 2145 and continue through the 10,000-year period of analysis until CY 11,940. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system during the post–administrative control period. All remaining waste would be available for release into the vadose zone at the start of the post–administrative control period.

5.1.1.7.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 4. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 4 is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 4 were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become major contributors toward the end of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. There would be no chemical risk. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 4.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.7.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 4 in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–109 through 5–114). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–109 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–110, the chemical hazard drivers. For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are past leaks. This suggests that activities during the past-practice period are an important impact driver under Tank Closure Alternative 4.

Figure 5–111 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–112, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

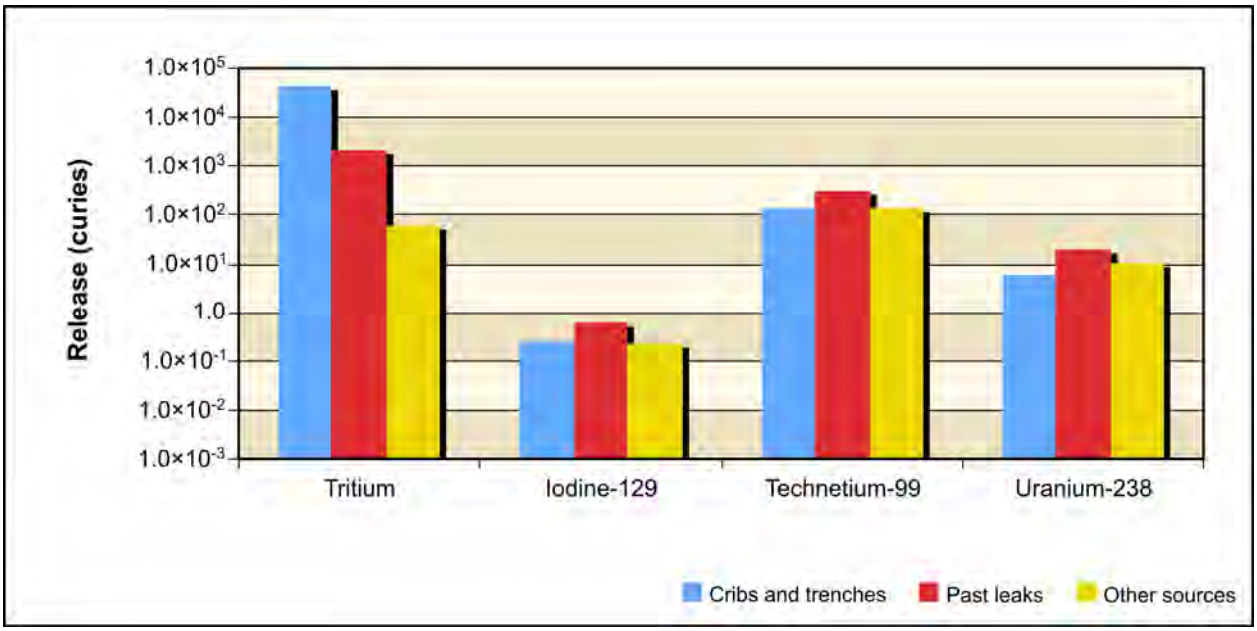


Figure 5–109. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

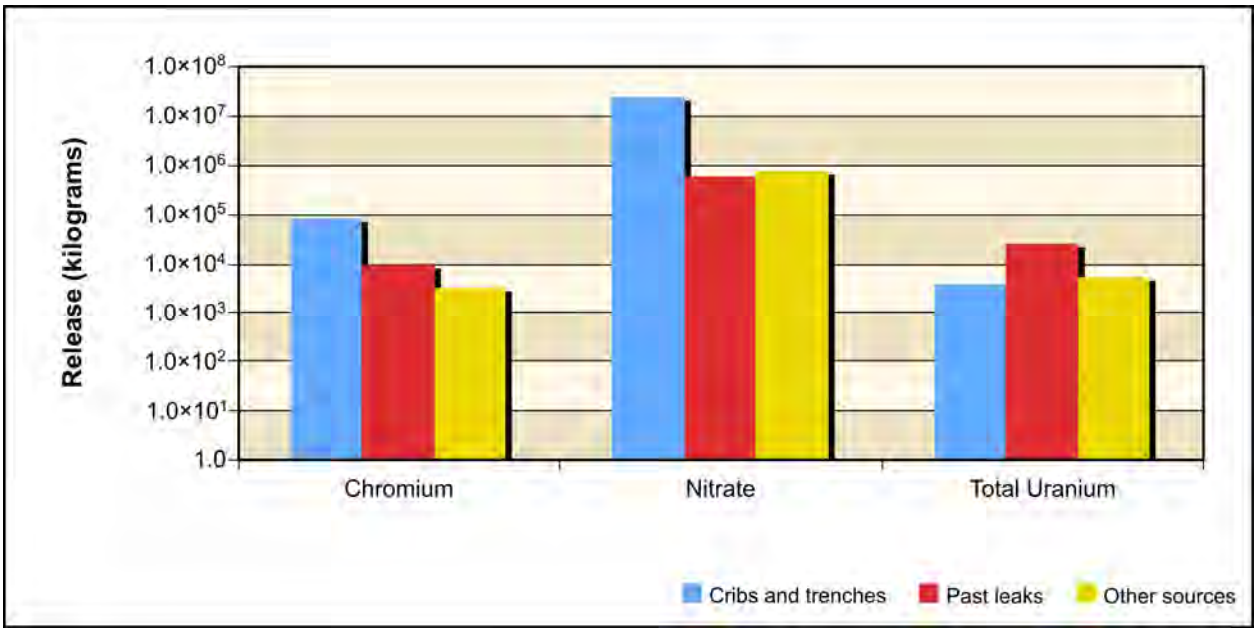


Figure 5–110. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

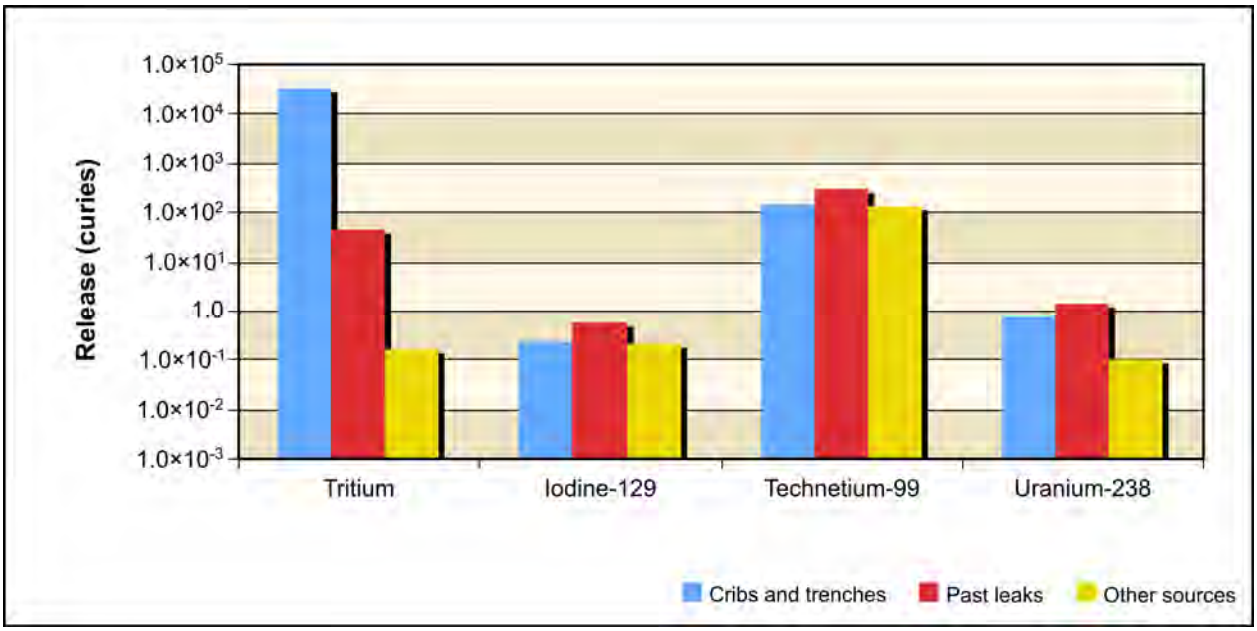


Figure 5–111. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

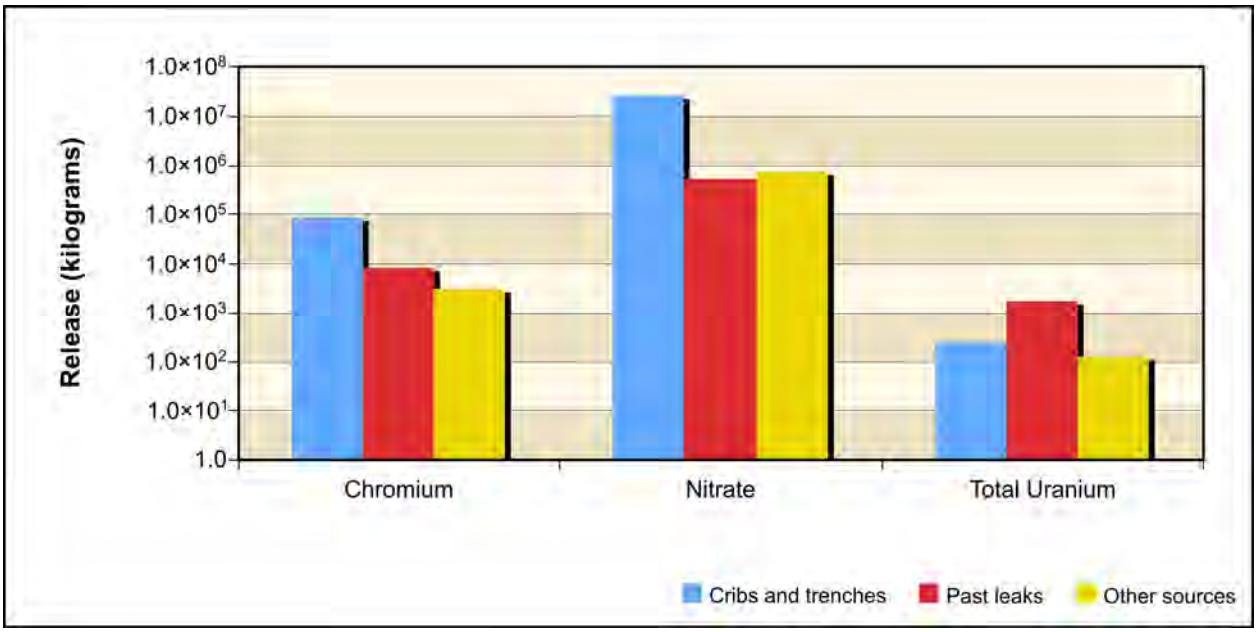


Figure 5–112. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory reached groundwater during the period of analysis; for other tank farm sources, only about 2 percent of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent reached the water table. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post-remediation period because of the long travel times in the vadose zone for these COPCs.

Figure 5–113 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–114, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. Overall, about 25 percent of the amount released to groundwater during the period of analysis reached the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post-remediation period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

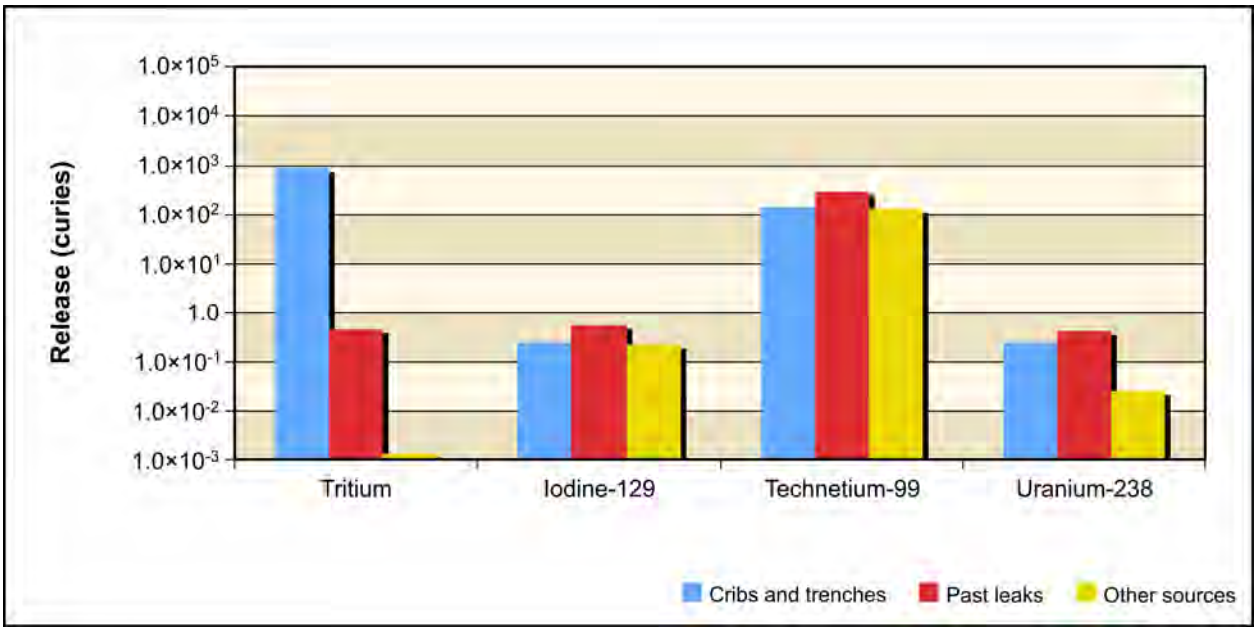


Figure 5–113. Tank Closure Alternative 4 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

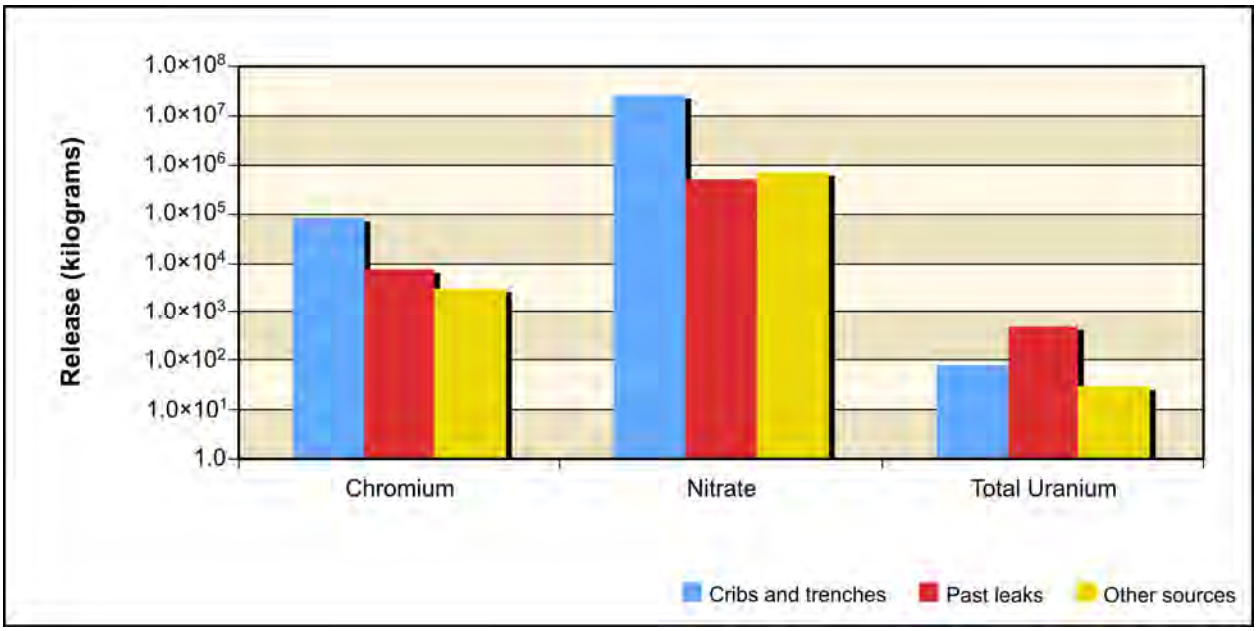


Figure 5–114. Tank Closure Alternative 4 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.7.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 4 impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–4 and Figures 5–115 through 5–121). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–4 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–115 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore remain over an order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2050.

Table 5–4. Tank Closure Alternative 4 Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	28	5,060	4	7,270	13	6,060	178	20,000
	(2051)	(2054)	(2062)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**1,460**	**28,200**	214	**15,200**	180	**24,100**	191	900
	(2058)	(2050)	(2060)	(2050)	(2060)	(2050)	(2480)	
Iodine-129	**3**	**38**	0.4	**30**	0.3	**31**	0.3	1
	(2053)	(2057)	(2052)	(2050)	(2052)	(2057)	(2181)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**36**	1	**26**	8	**48**	1	15
	(11,814)	(11,742)	(11,795)	(11,780)	(11,441)	(11,529)	(11,891)	
Chemical in micrograms per liter								
Chromium	9	**3,220**	36	**768**	10	**1,650**	34	100
	(2057)	(2055)	(2057)	(2050)	(2050)	(2050)	(2695)	
Nitrate	5,530	**1,540,000**	1,400	**133,000**	1,230	**1,010,000**	8,490	45,000
	(2056)	(2050)	(2059)	(2054)	(2067)	(2050)	(2450)	
Total uranium	0	14	1	11	12	**63**	1	30
	(11,819)	(11,678)	(11,828)	(11,840)	(11,599)	(11,690)	(11,577)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

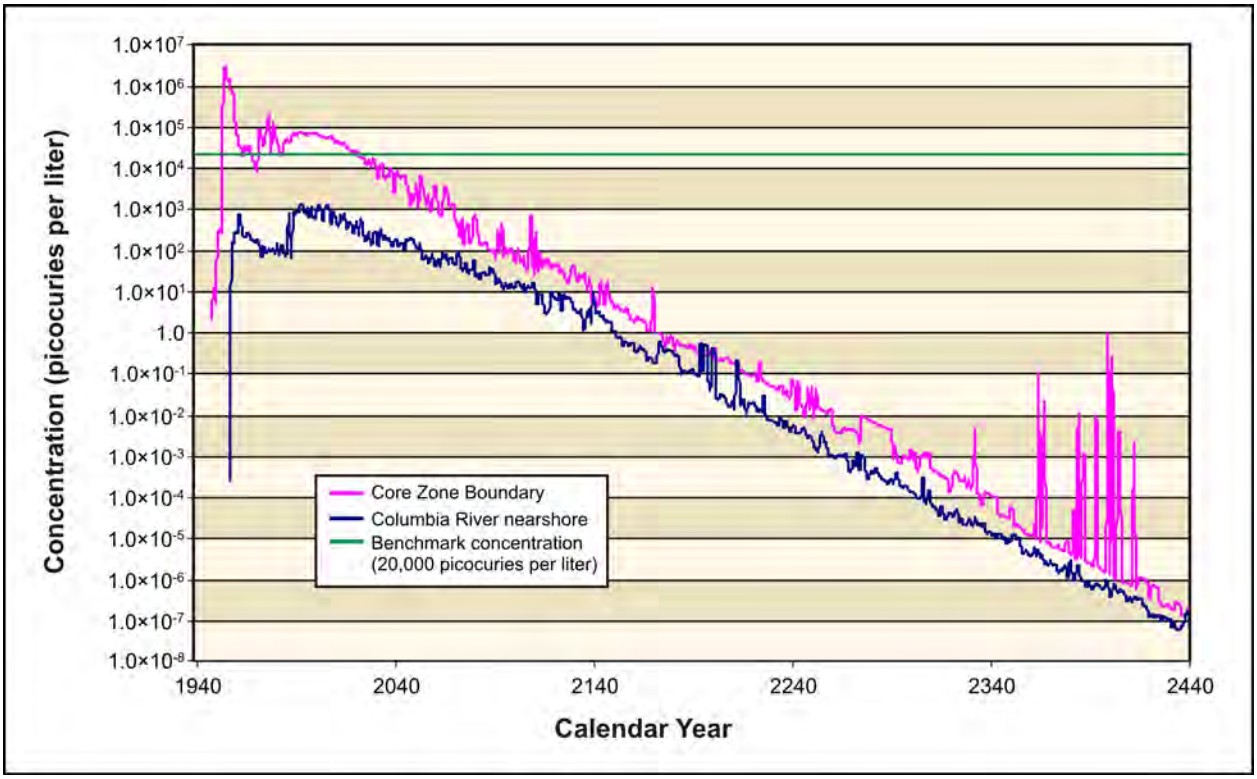


Figure 5–115. Tank Closure Alternative 4 Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–116 through 5–119 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis at the Core Zone Boundary. During this time, groundwater concentrations at the Columbia River nearshore approach but do not exceed the benchmark concentration. Technetium-99 and nitrate concentrations fall below the benchmark concentration at the Core Zone Boundary around CY 4000, while iodine-129 and chromium fall below the benchmark around CY 5000. Concentrations for all four conservative tracers decline over the remainder of the period of analysis.

Figures 5–120 and 5–121 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. These concentrations continue to rise throughout the duration of the period of analysis. Uranium-238 concentrations exceed the benchmark concentration around CY 8000, while total uranium concentrations exceed the benchmark around CY 9500. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis but remain over an order of magnitude below the benchmark concentration for the duration of the simulation.

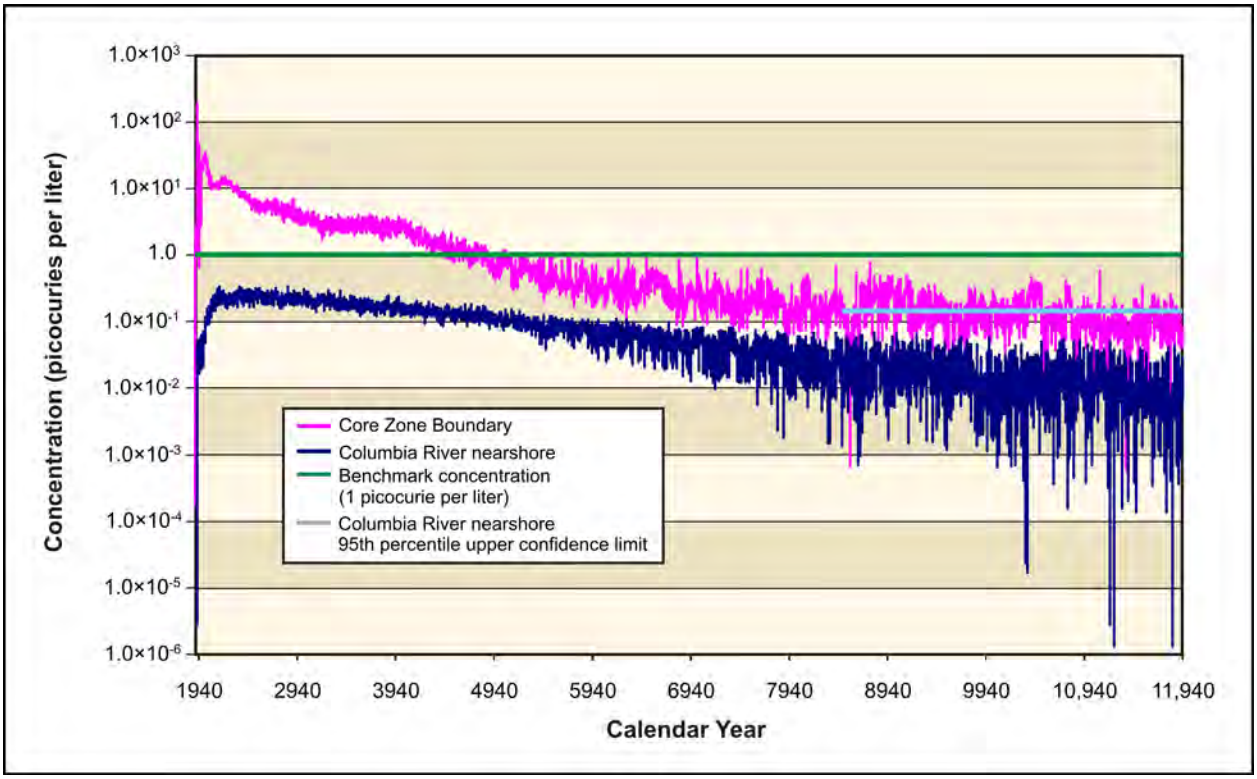


Figure 5–116. Tank Closure Alternative 4 Iodine-129 Concentration Versus Time

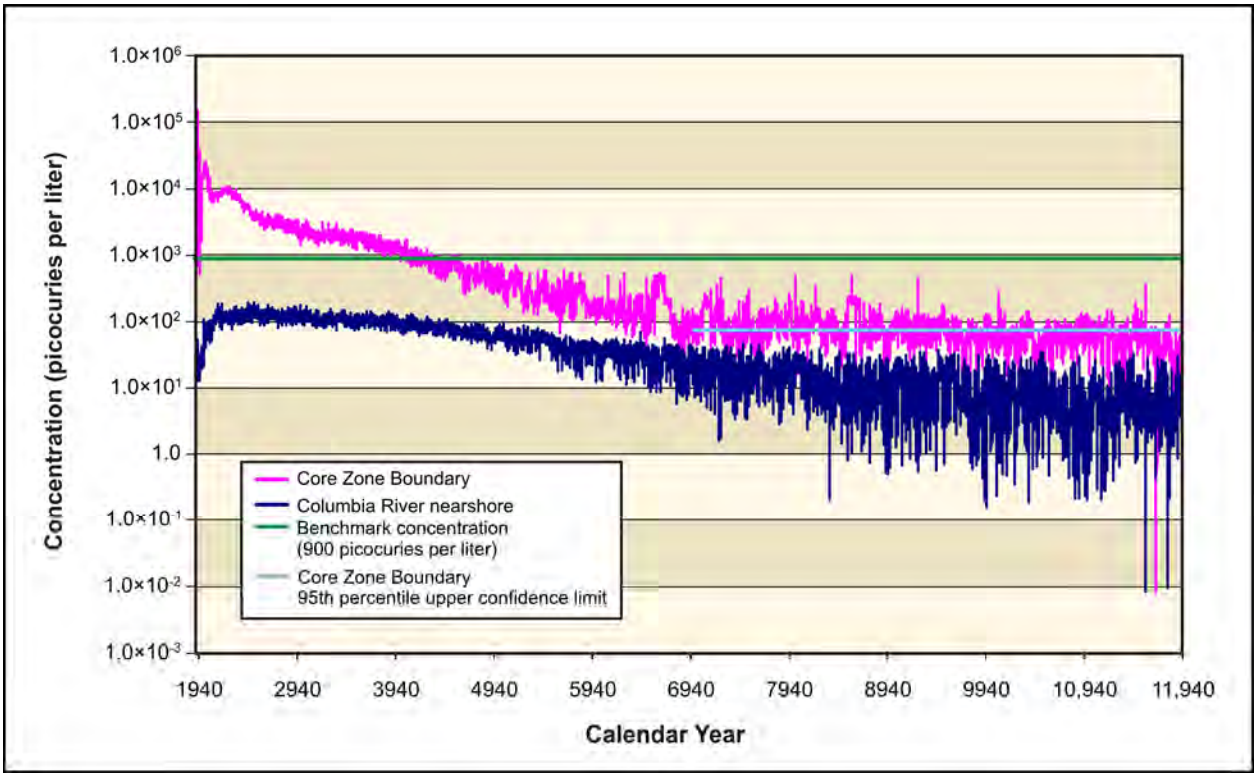


Figure 5–117. Tank Closure Alternative 4 Technetium-99 Concentration Versus Time

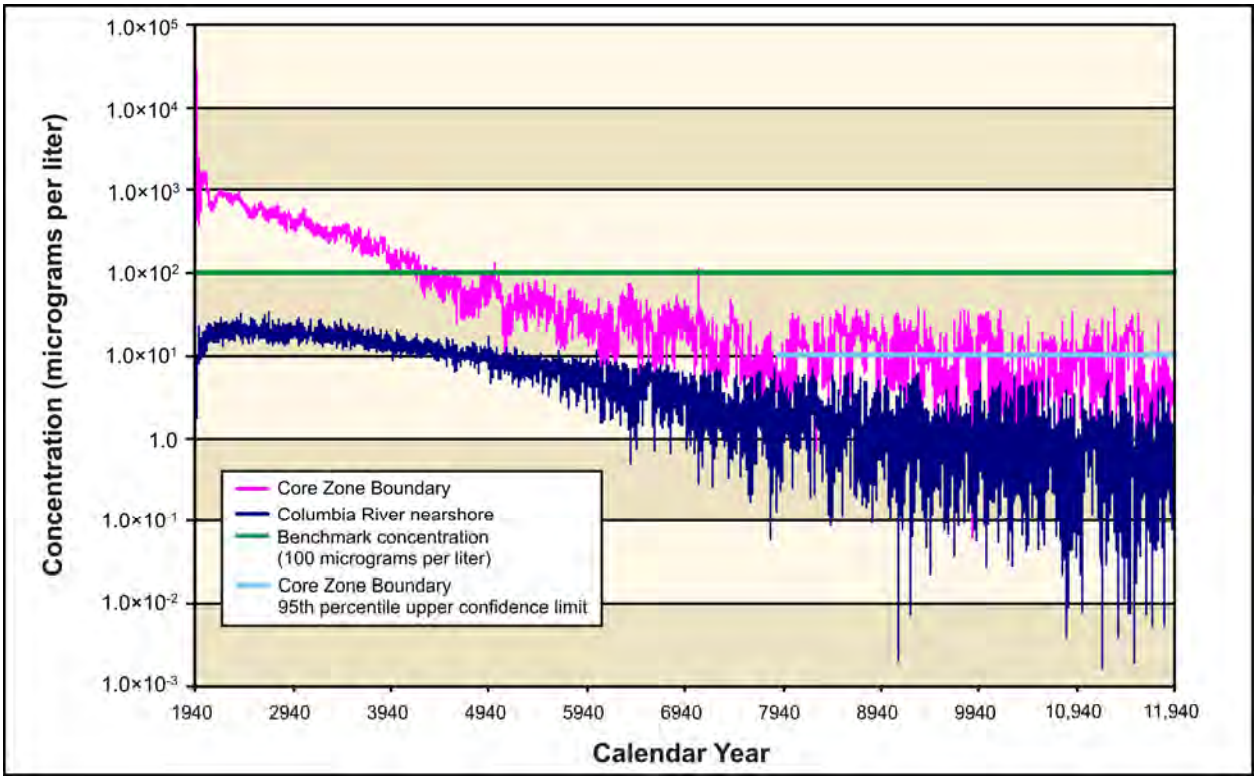


Figure 5–118. Tank Closure Alternative 4 Chromium Concentration Versus Time

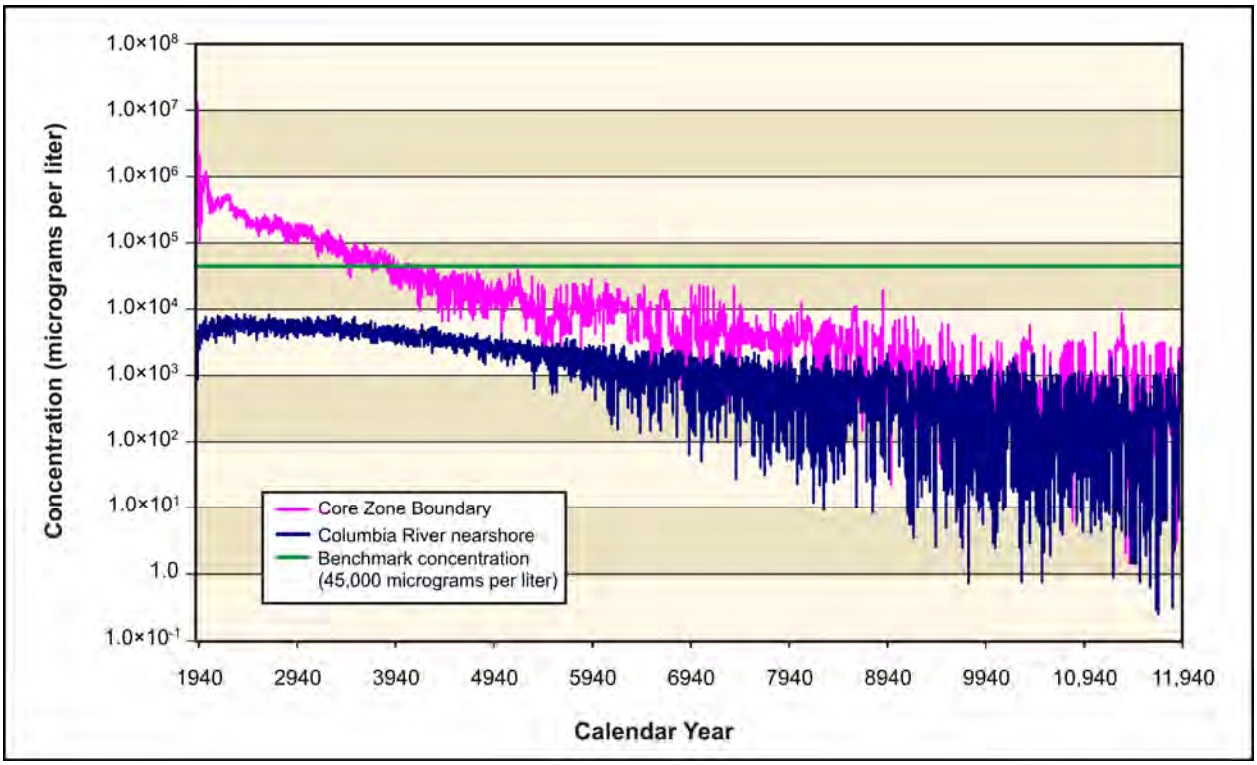


Figure 5–119. Tank Closure Alternative 4 Nitrate Concentration Versus Time

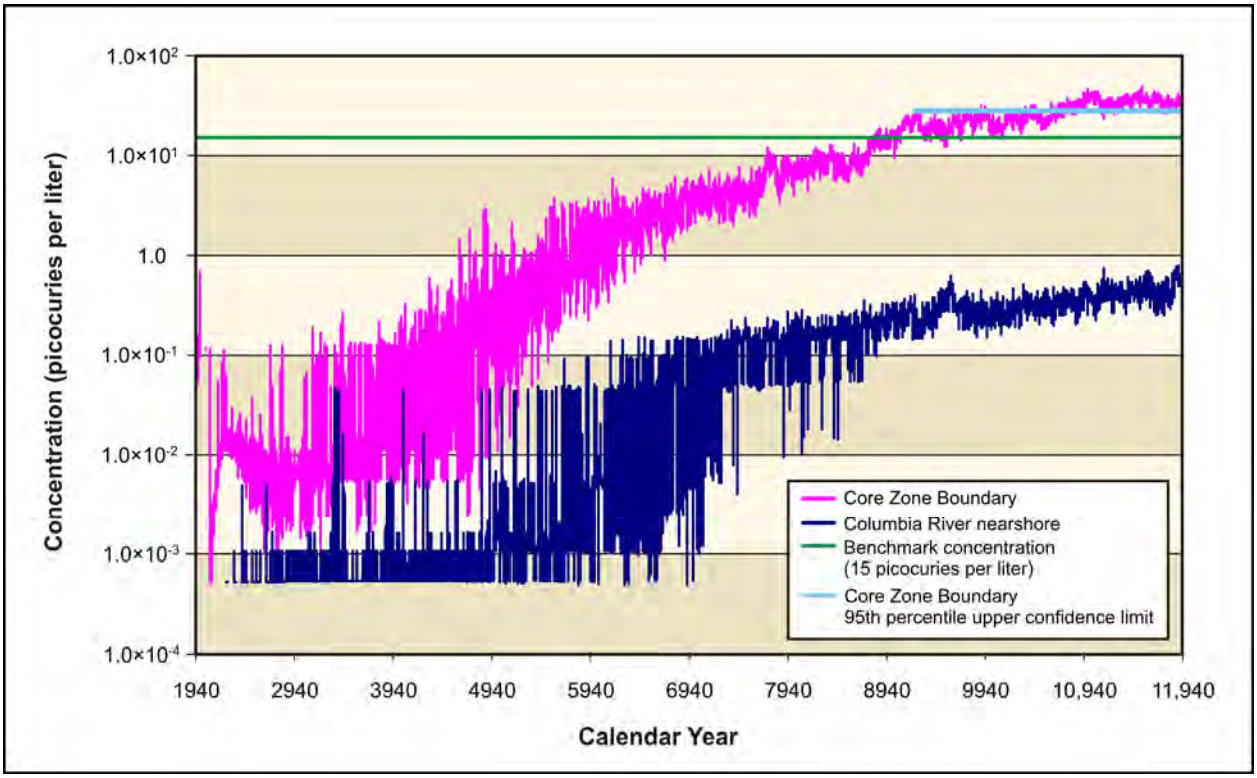


Figure 5–120. Tank Closure Alternative 4 Uranium-238 Concentration Versus Time

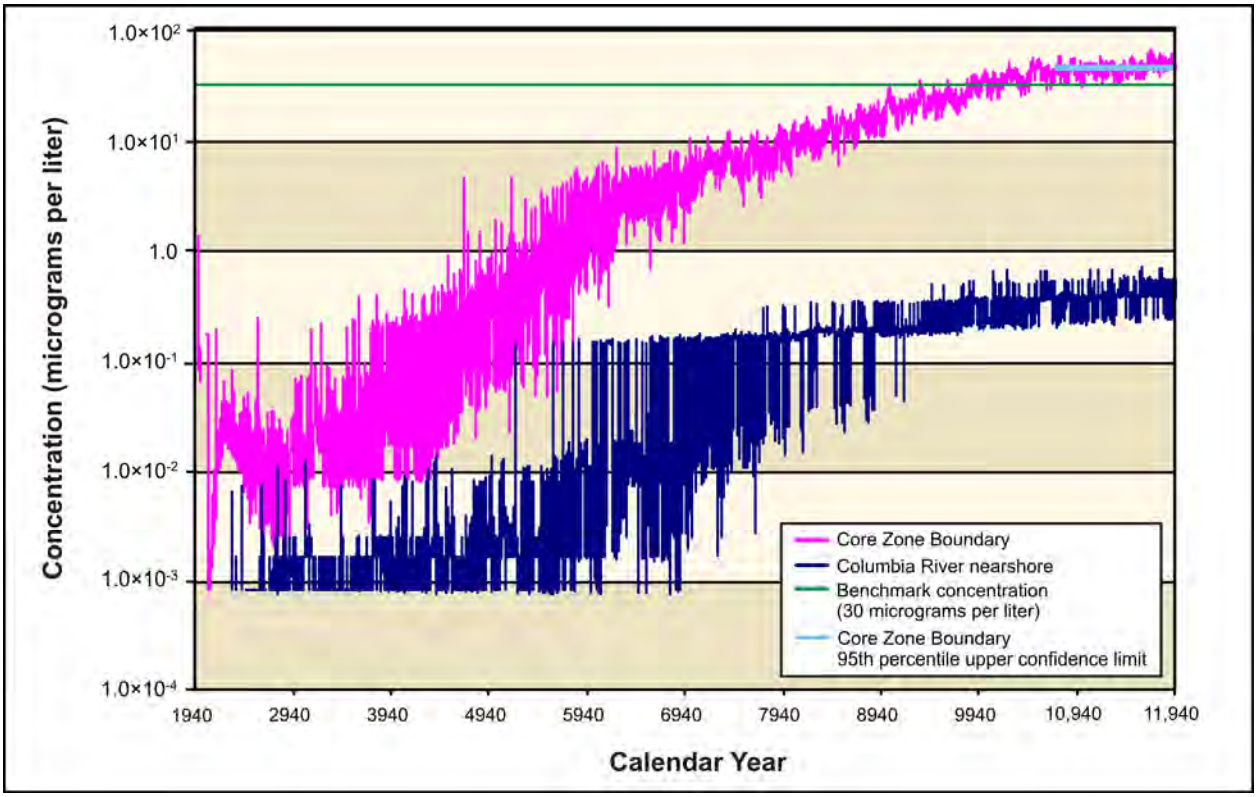
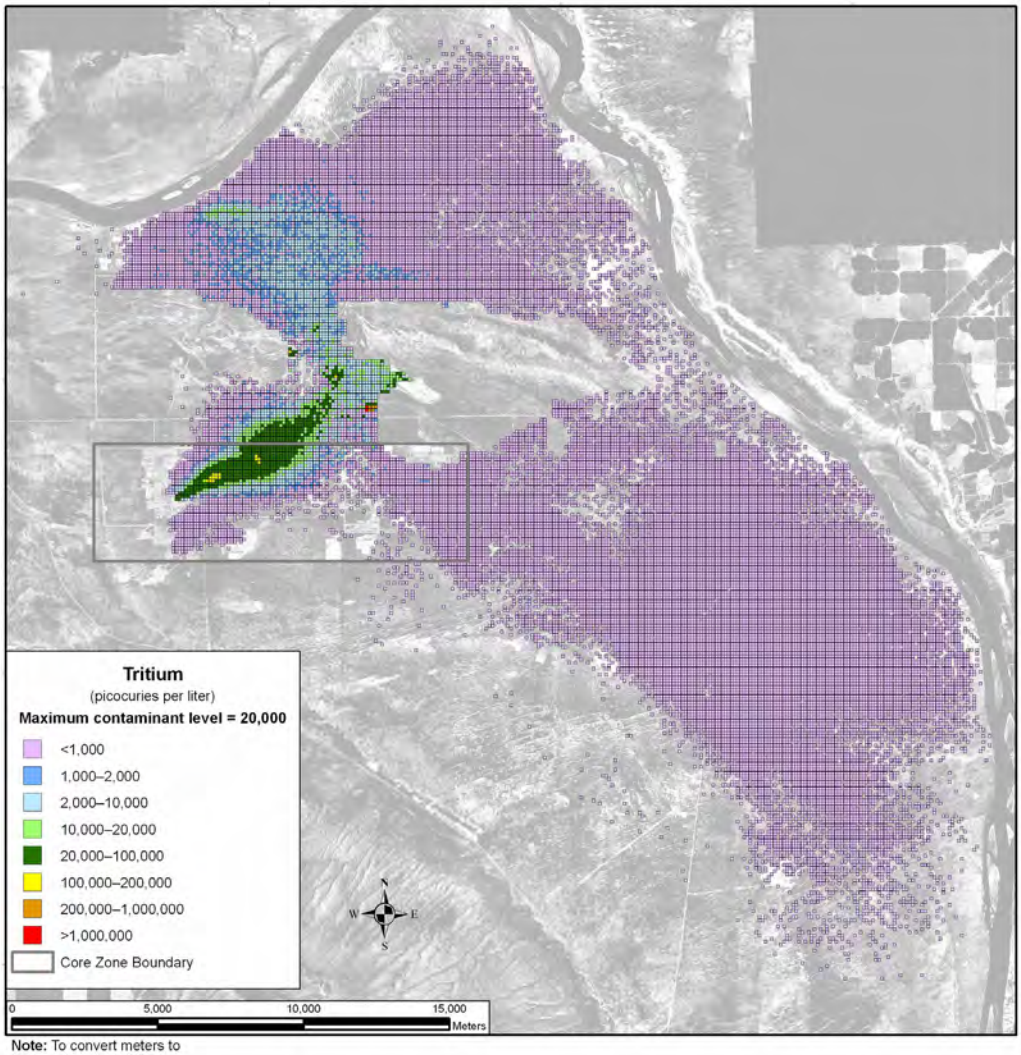


Figure 5–121. Tank Closure Alternative 4 Total Uranium Concentration Versus Time

5.1.1.7.5 Analysis of Spatial Distribution of Concentration

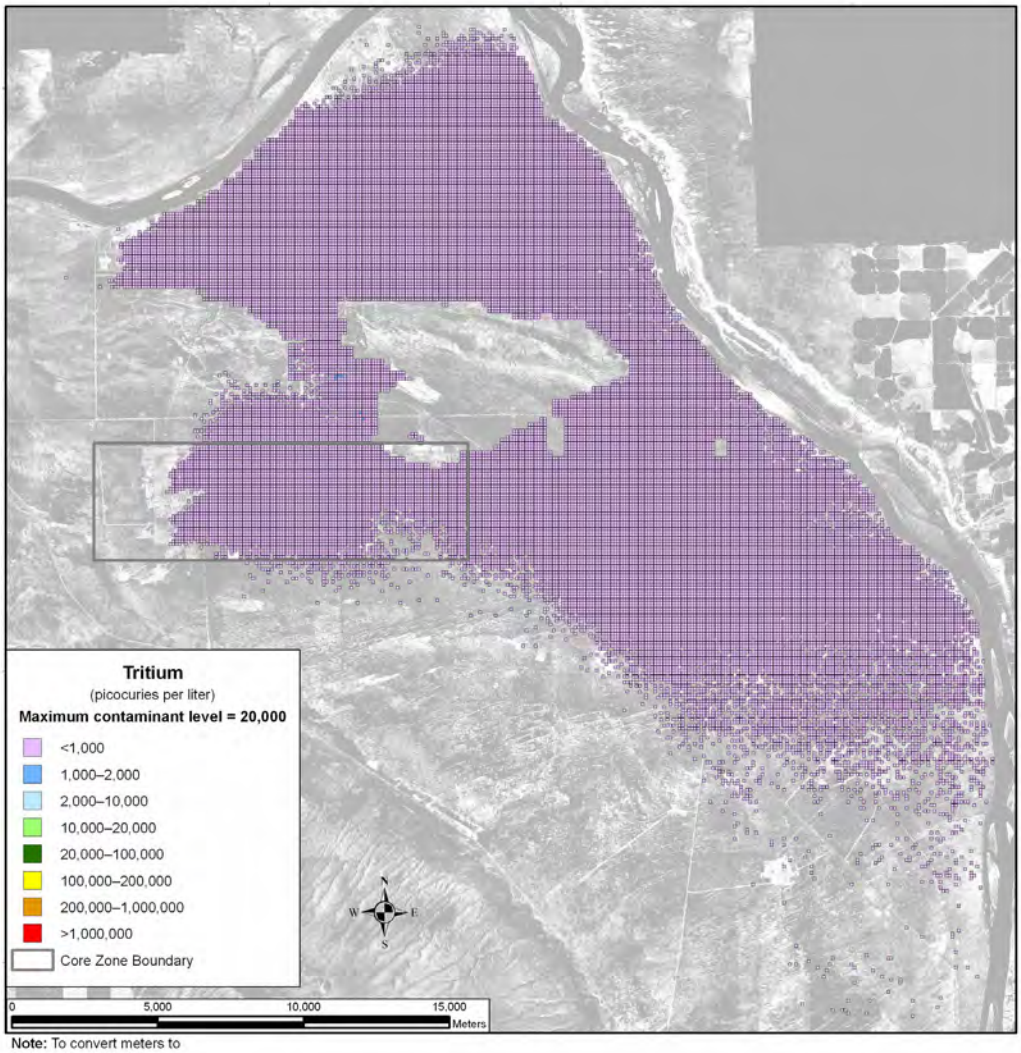
This section presents the impacts of Tank Closure Alternative 4 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–122 through 5–146). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–122 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–123).



Note: To convert meters to feet, multiply by 3.281

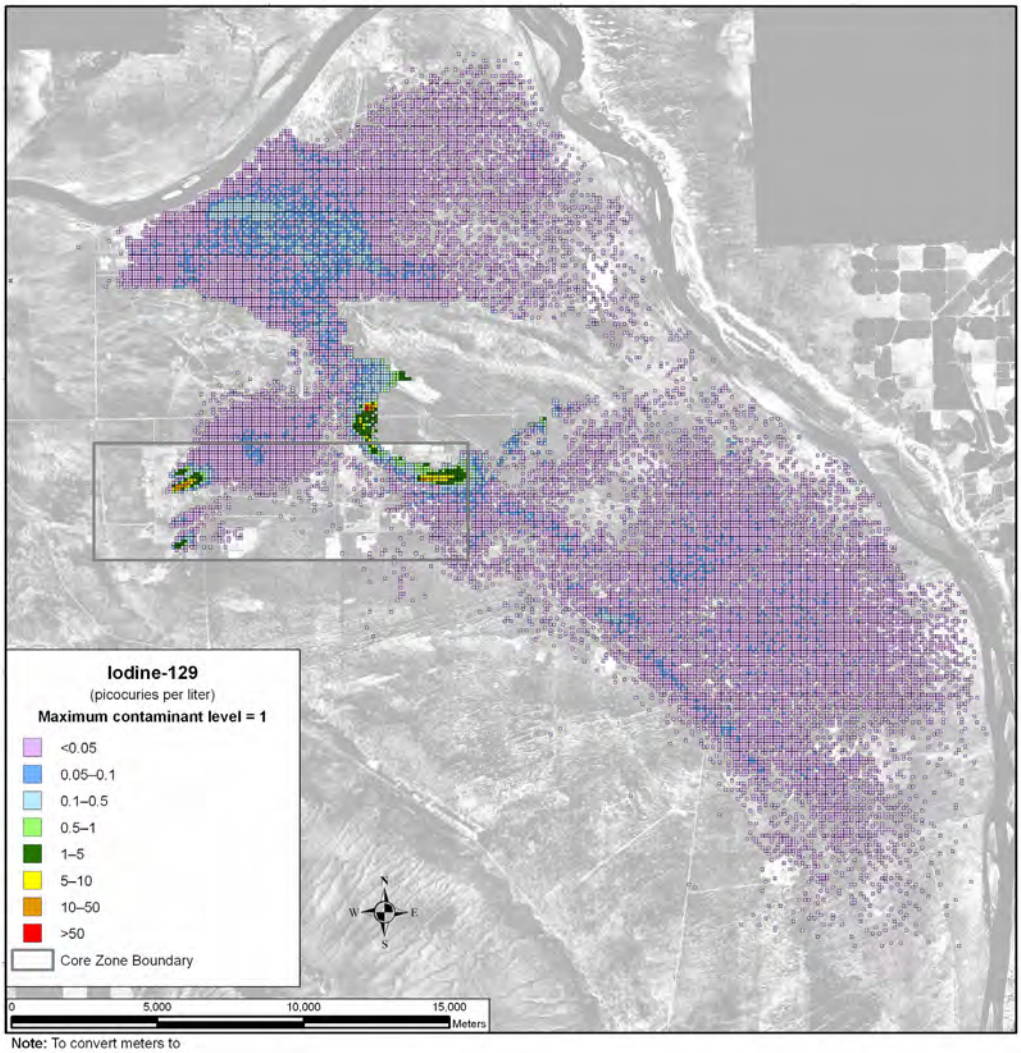
Figure 5–122. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

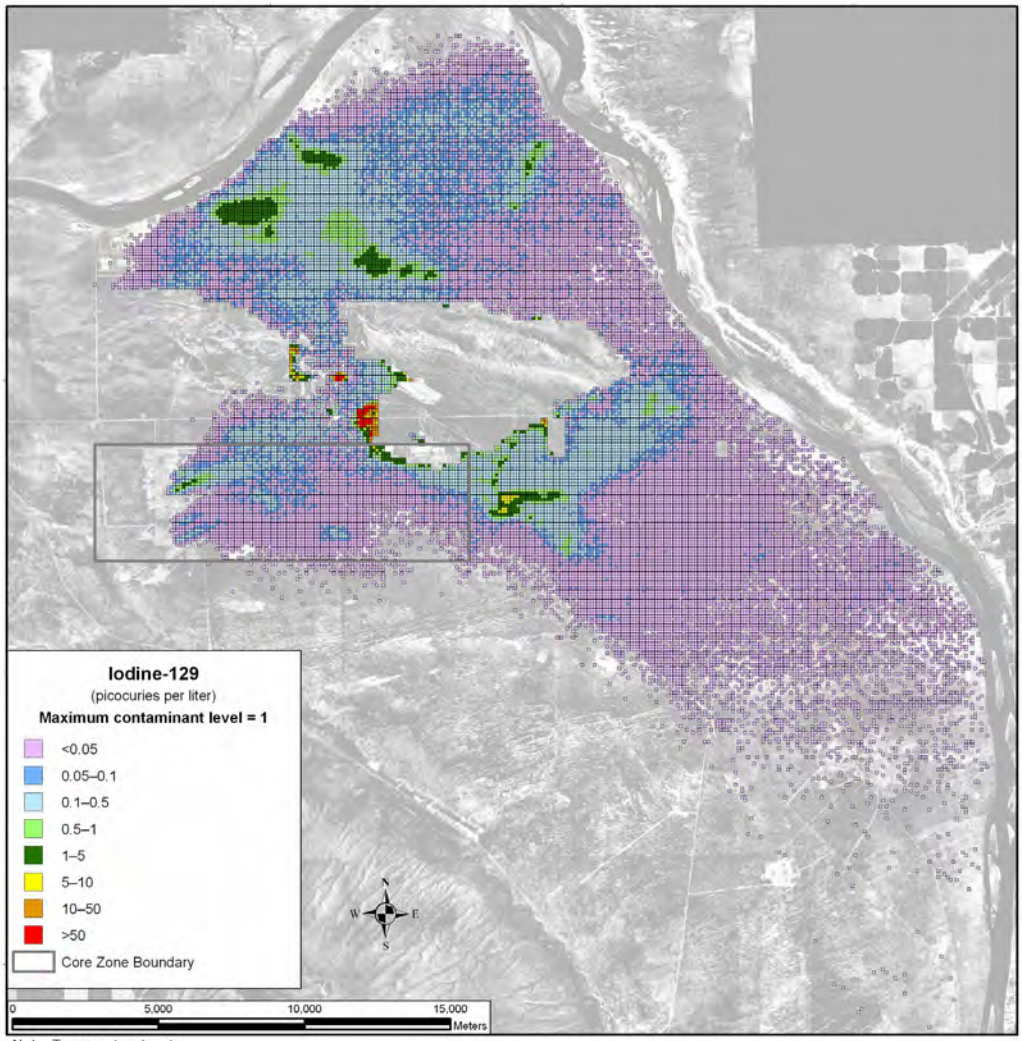
Figure 5–123. Tank Closure Alternative 4 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Plume distribution for iodine-129 during CY 2005 is shown in Figure 5–124. By CY 2135 (see Figure 5–125), areas of concentrations above the benchmark concentration exist east of the Core Zone Boundary, north of the 200-East Area, and in three separate areas north of Gable Gap. By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–126). Technetium-99 (see Figures 5–127 through 5–129), chromium (see Figures 5–130 through 5–132), and nitrate (see Figures 5–133 through 5–135) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



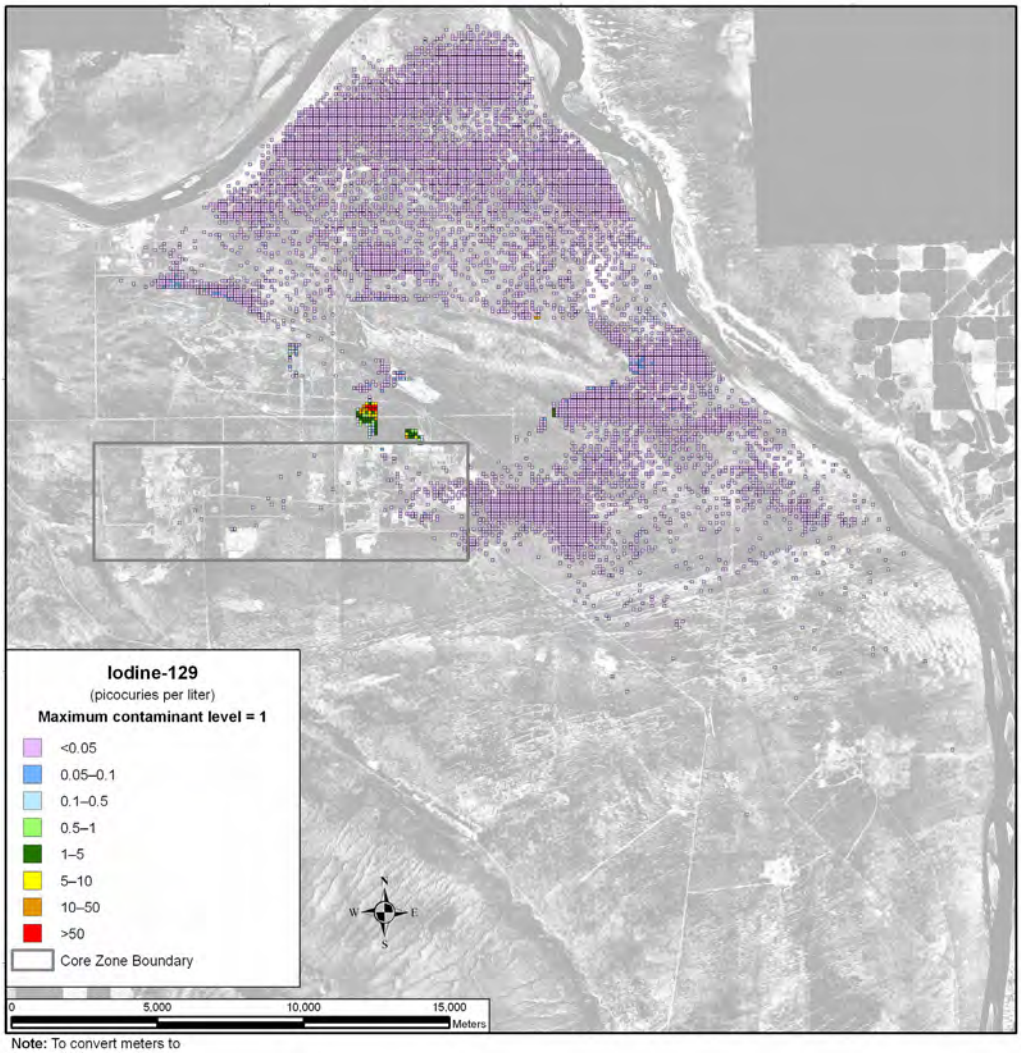
Note: To convert meters to feet, multiply by 3.281

Figure 5–124. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



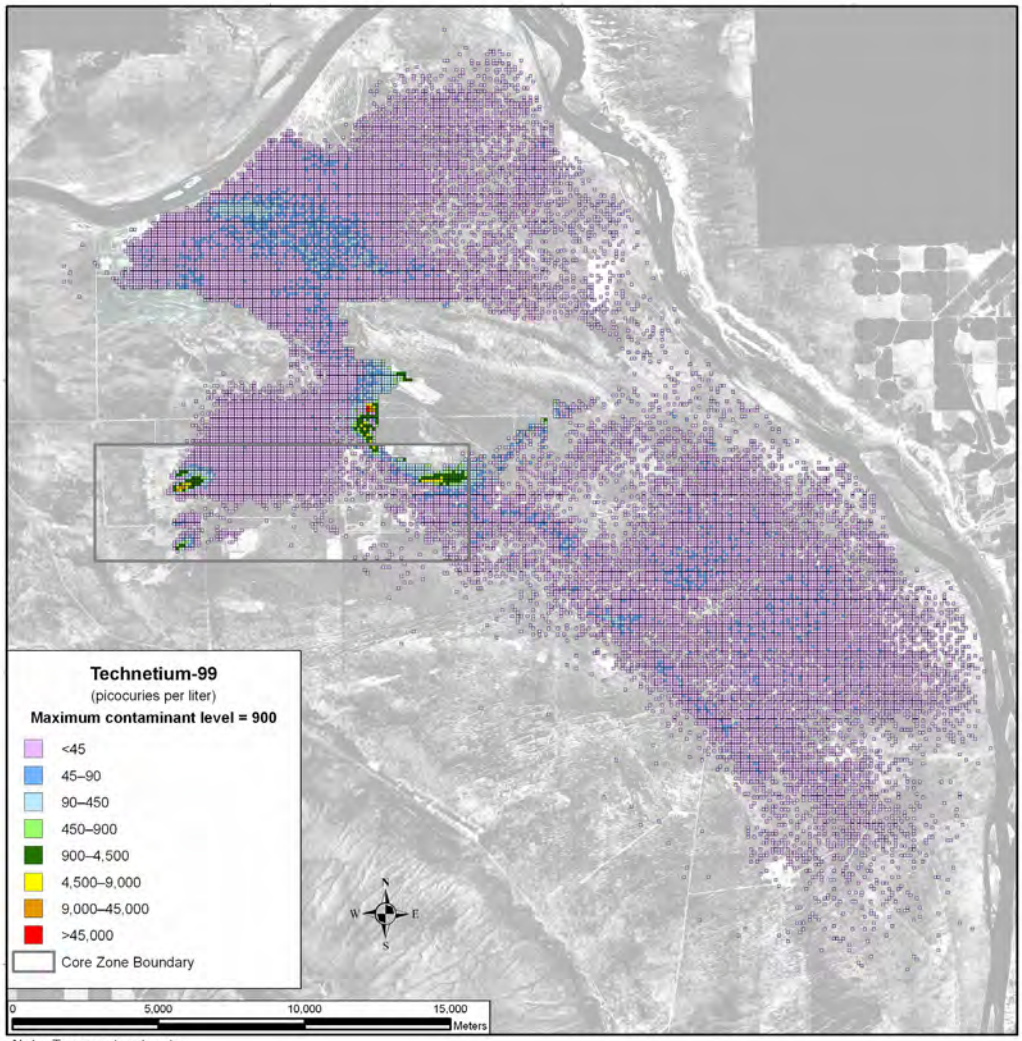
Note: To convert meters to feet, multiply by 3.281

Figure 5–125. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



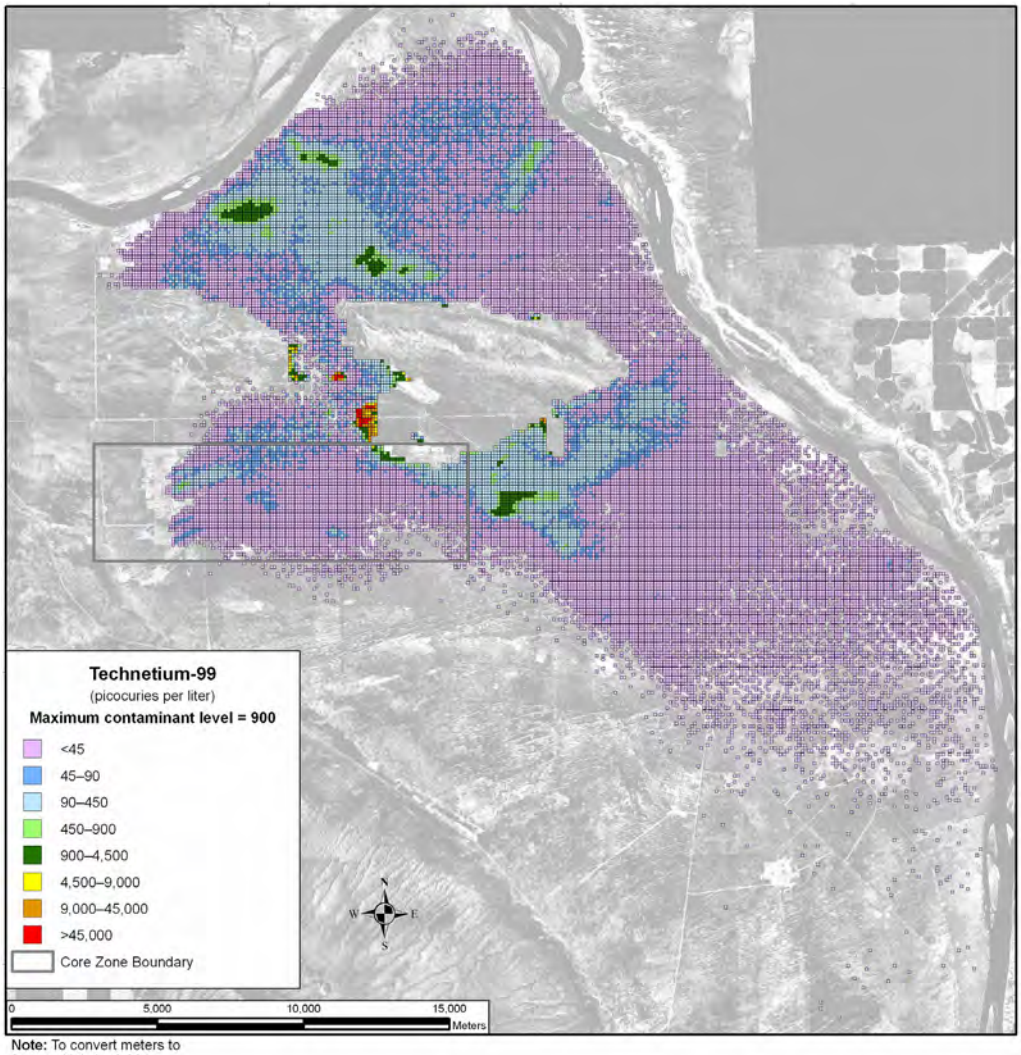
Note: To convert meters to feet, multiply by 3.281

Figure 5–126. Tank Closure Alternative 4 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



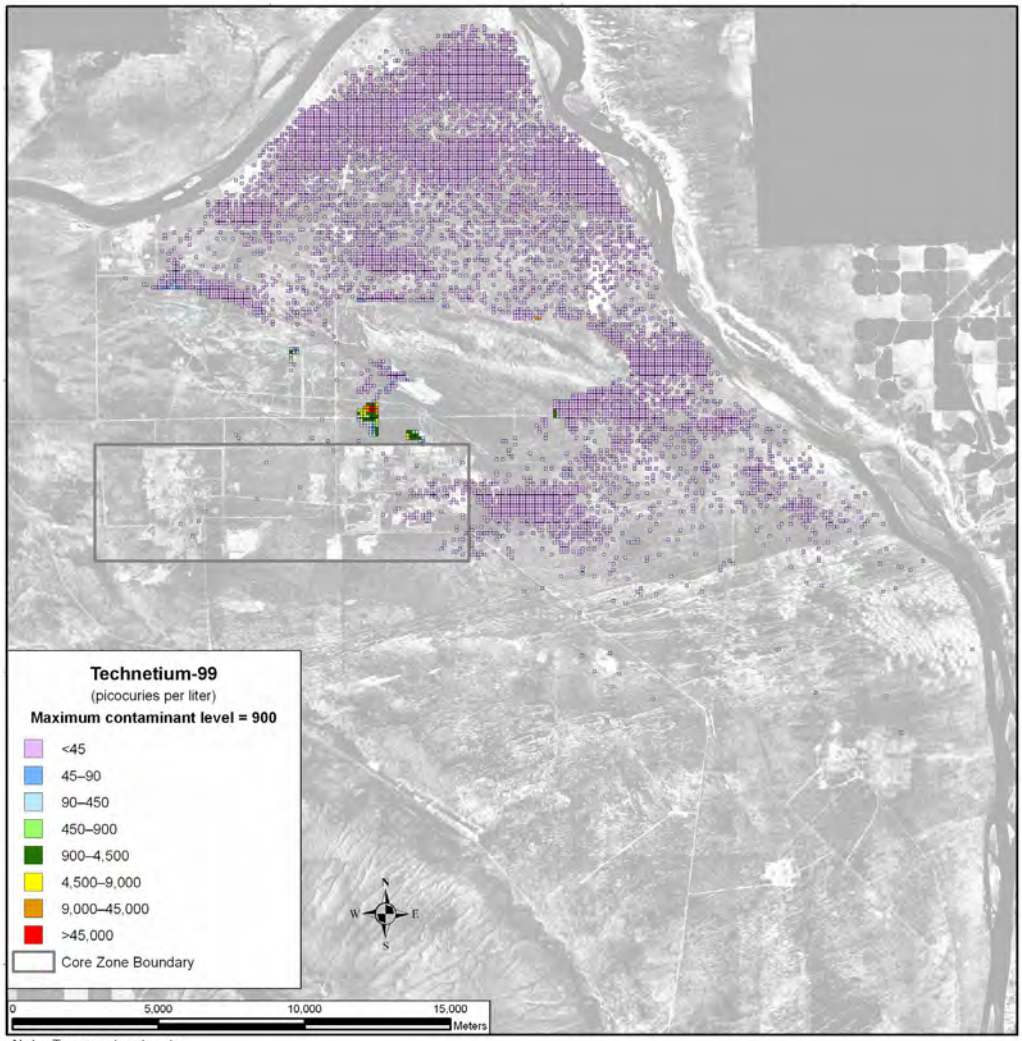
Note: To convert meters to feet, multiply by 3.281

Figure 5–127. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



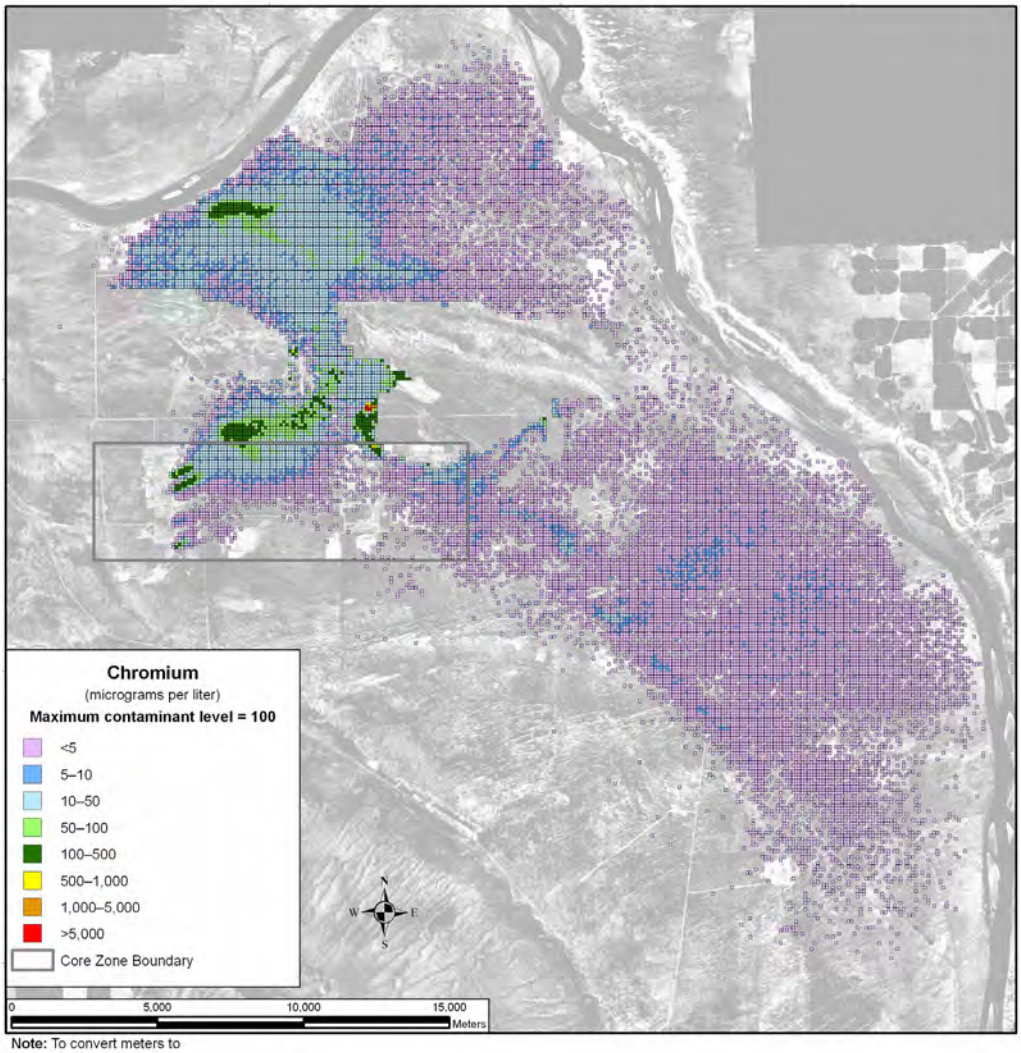
Note: To convert meters to feet, multiply by 3.281

Figure 5–128. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



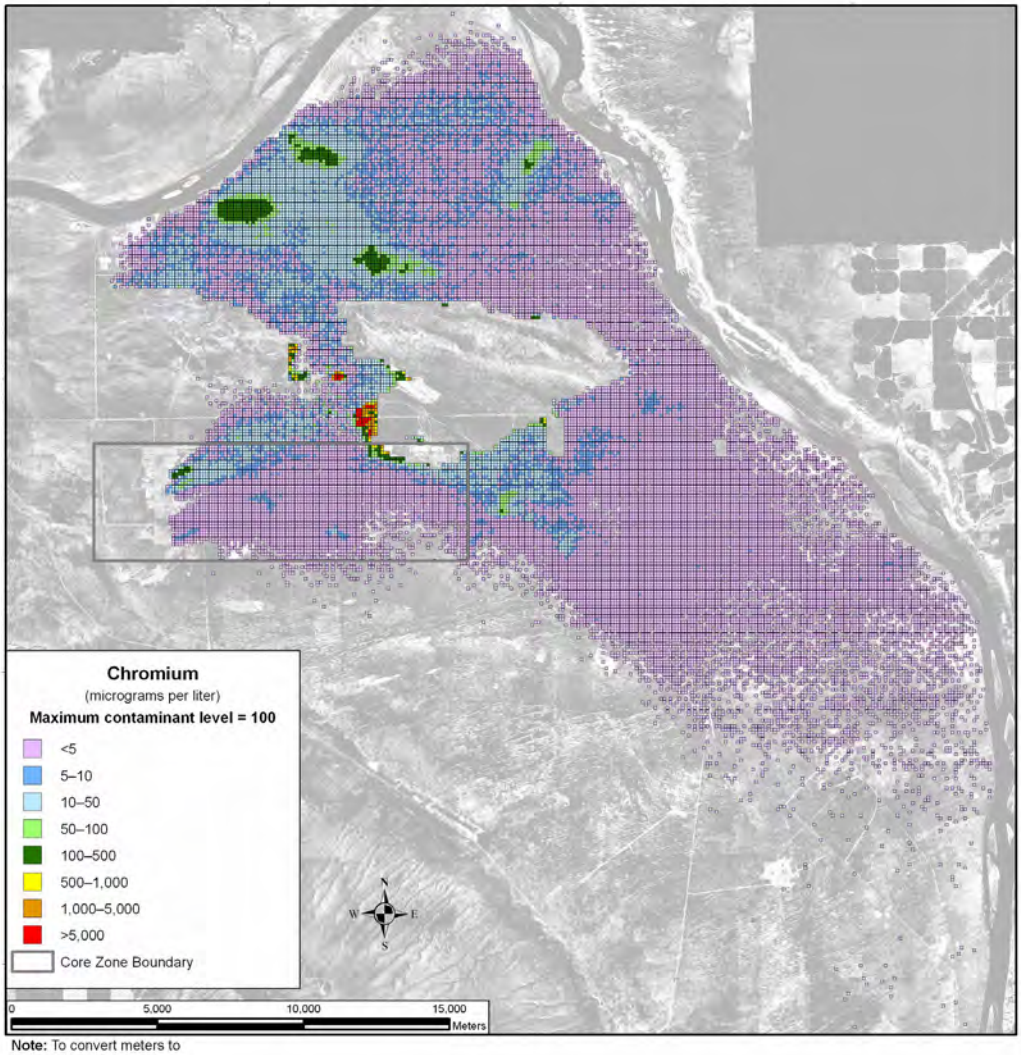
Note: To convert meters to feet, multiply by 3.281

Figure 5–129. Tank Closure Alternative 4 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



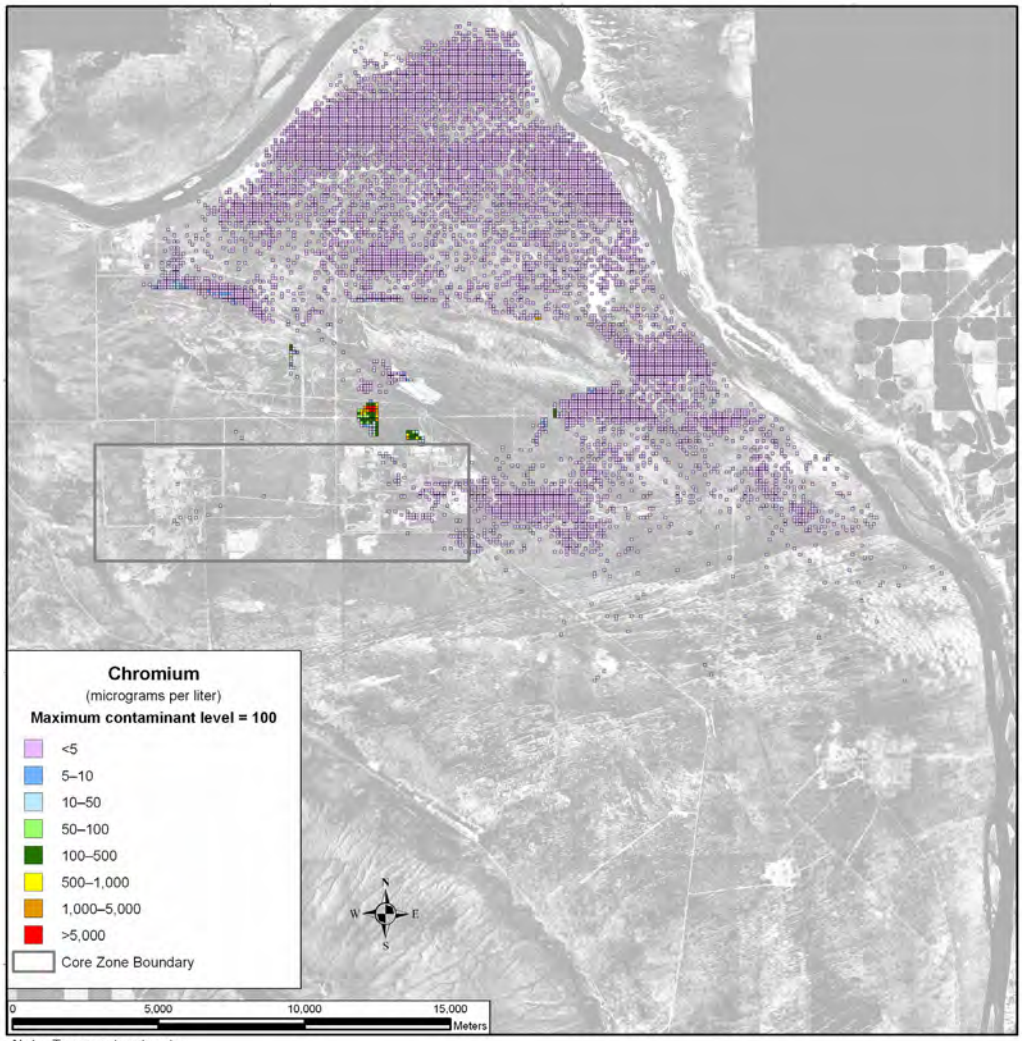
Note: To convert meters to feet, multiply by 3.281

Figure 5–130. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



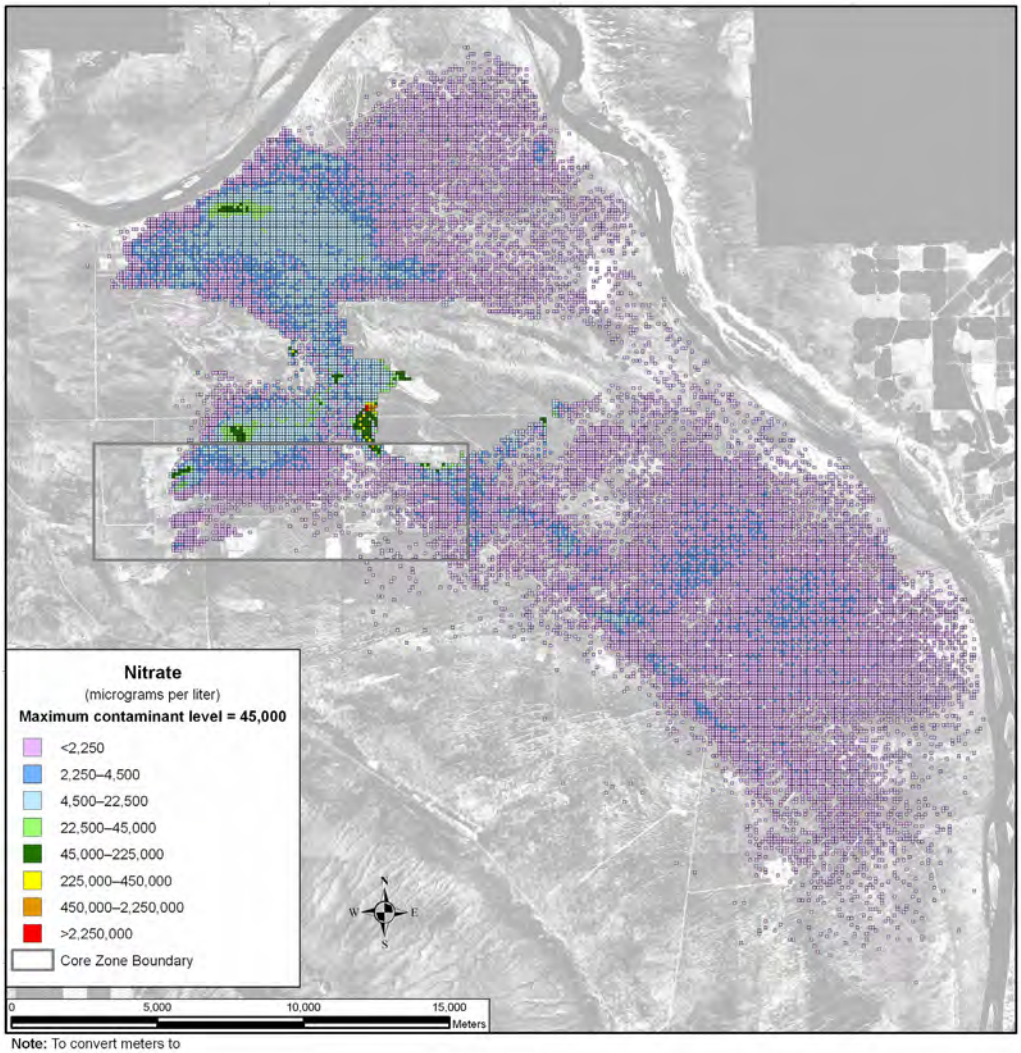
Note: To convert meters to feet, multiply by 3.281

Figure 5–131. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



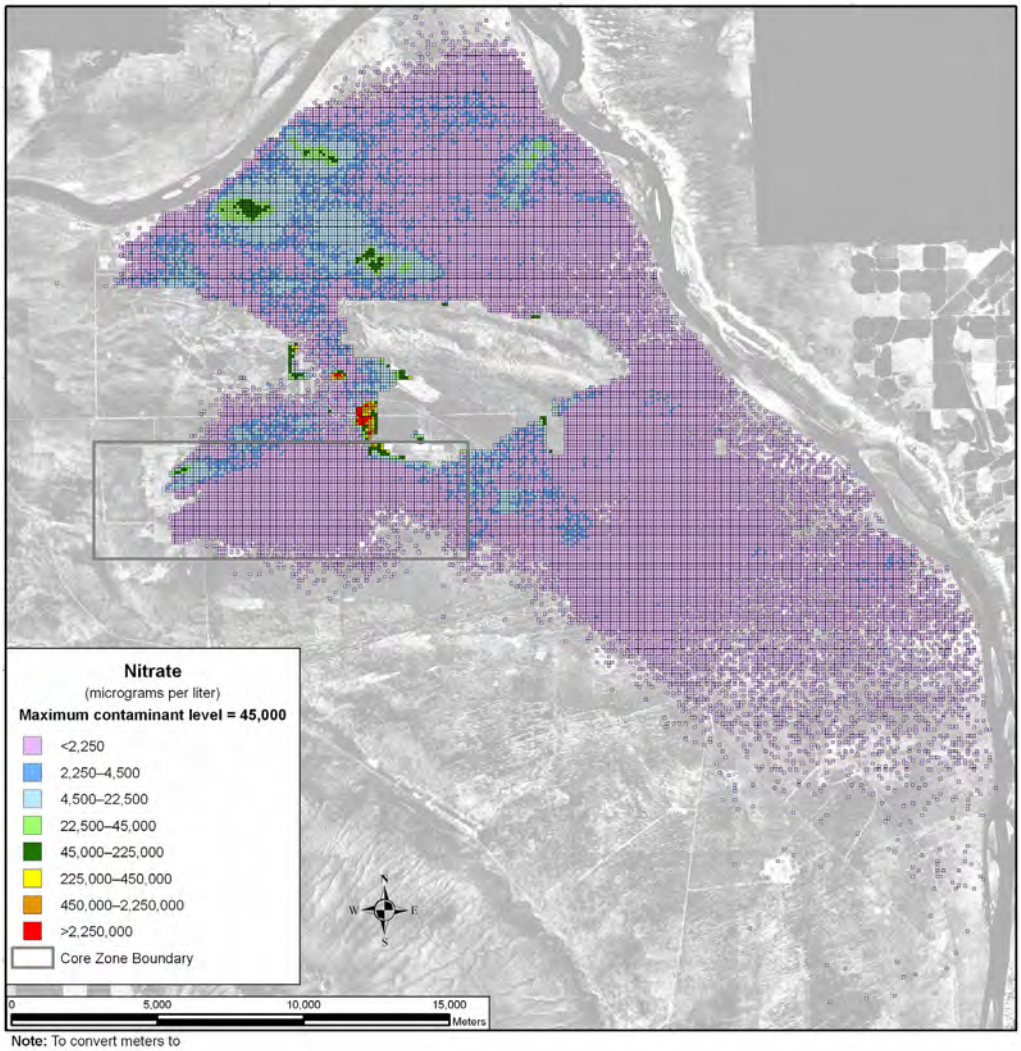
Note: To convert meters to feet, multiply by 3.281

Figure 5–132. Tank Closure Alternative 4 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



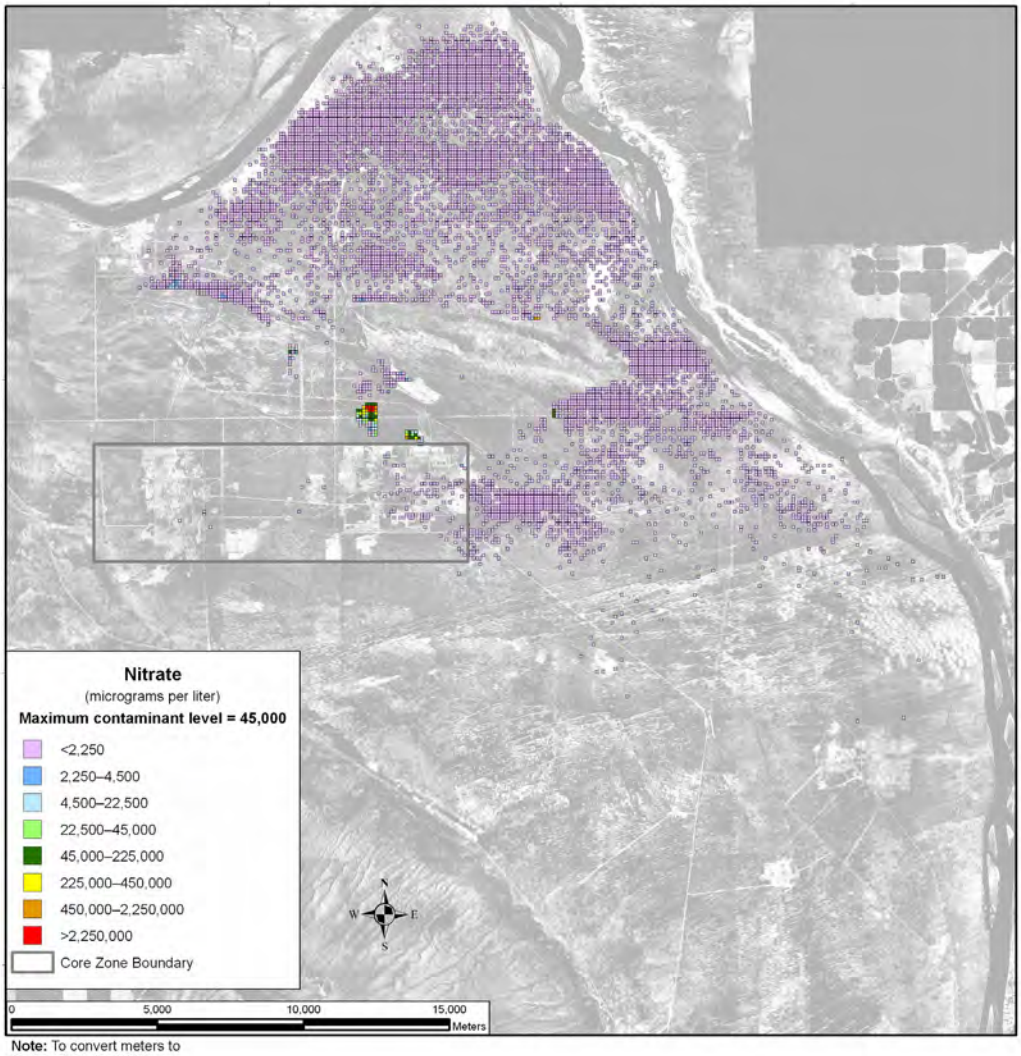
Note: To convert meters to feet, multiply by 3.281

Figure 5–133. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

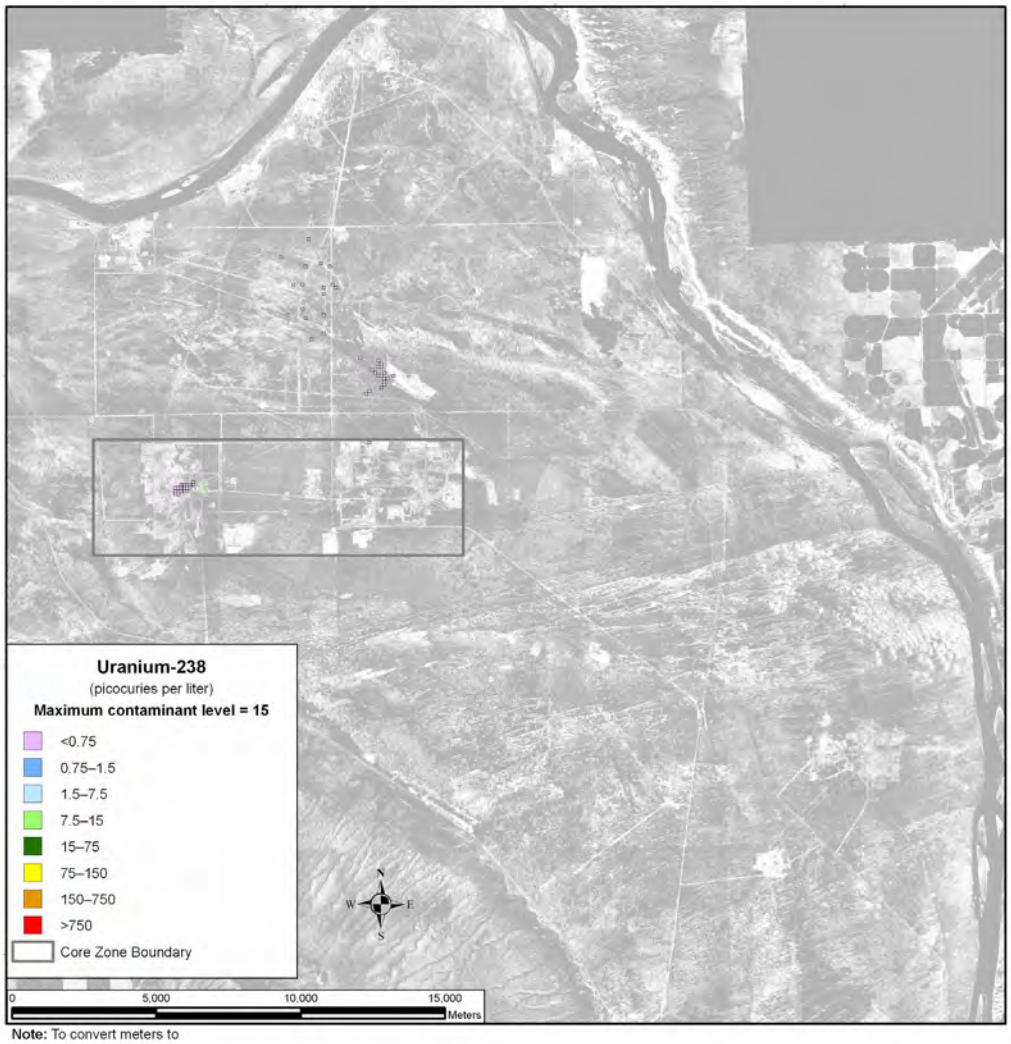
Figure 5–134. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

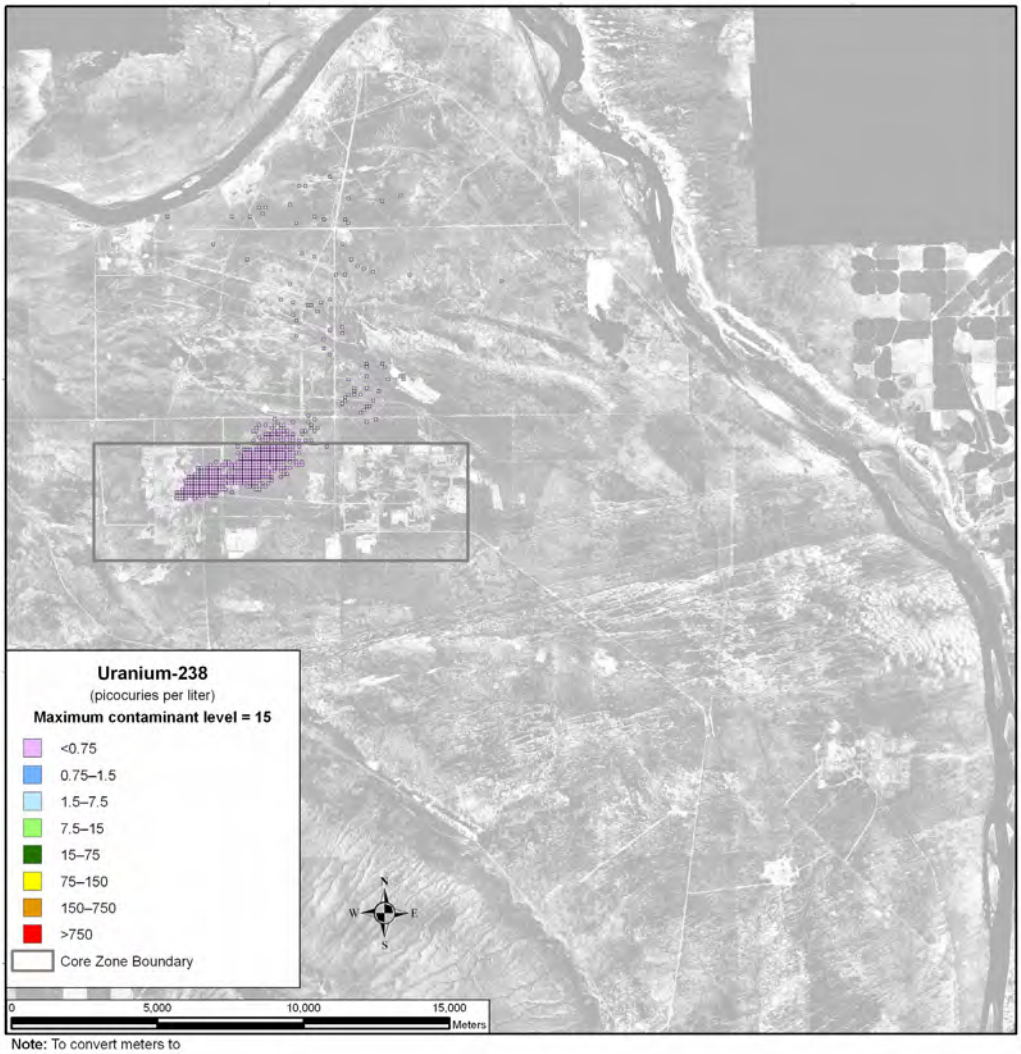
Figure 5–135. Tank Closure Alternative 4 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. The distribution of uranium-238 during CY 2005 is shown in Figure 5–136. By CY 2135 (see Figure 5–137), the area of the plume has grown, but there are no significant increases in peak concentration. By CY 7140 (see Figure 5–138), some areas of higher concentration begin to appear in the western part of the Core Zone Boundary and in the area north of the Core Zone Boundary. At CY 11,885 (see Figure 5–139), the greatest development of the plume during the analysis period is seen, resulting primarily from releases during the past-practice period. At this point, a small area of high concentrations has developed just north of the 200-East Area. Figures 5–140 through 5–143 show the corresponding results for total uranium, which has a similar distribution.



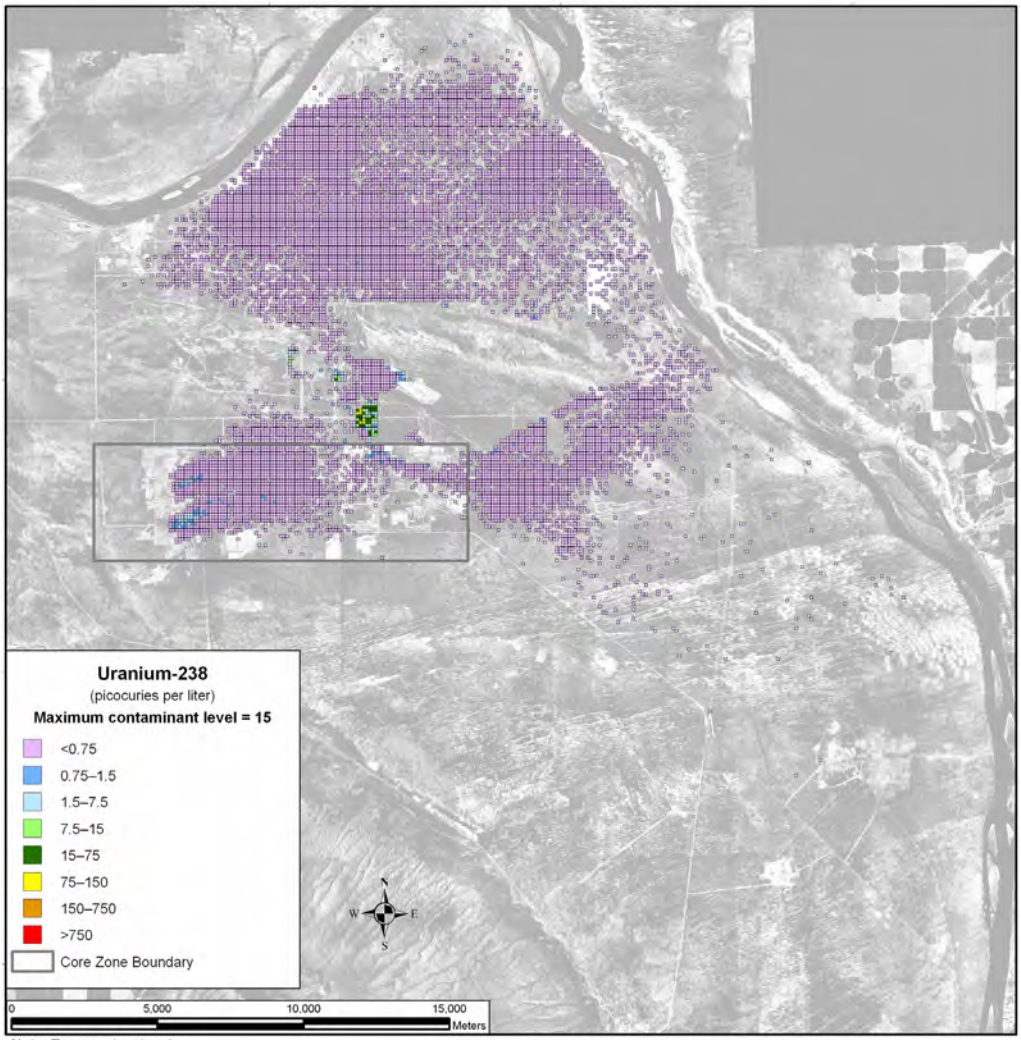
Note: To convert meters to feet, multiply by 3.281

Figure 5–136. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



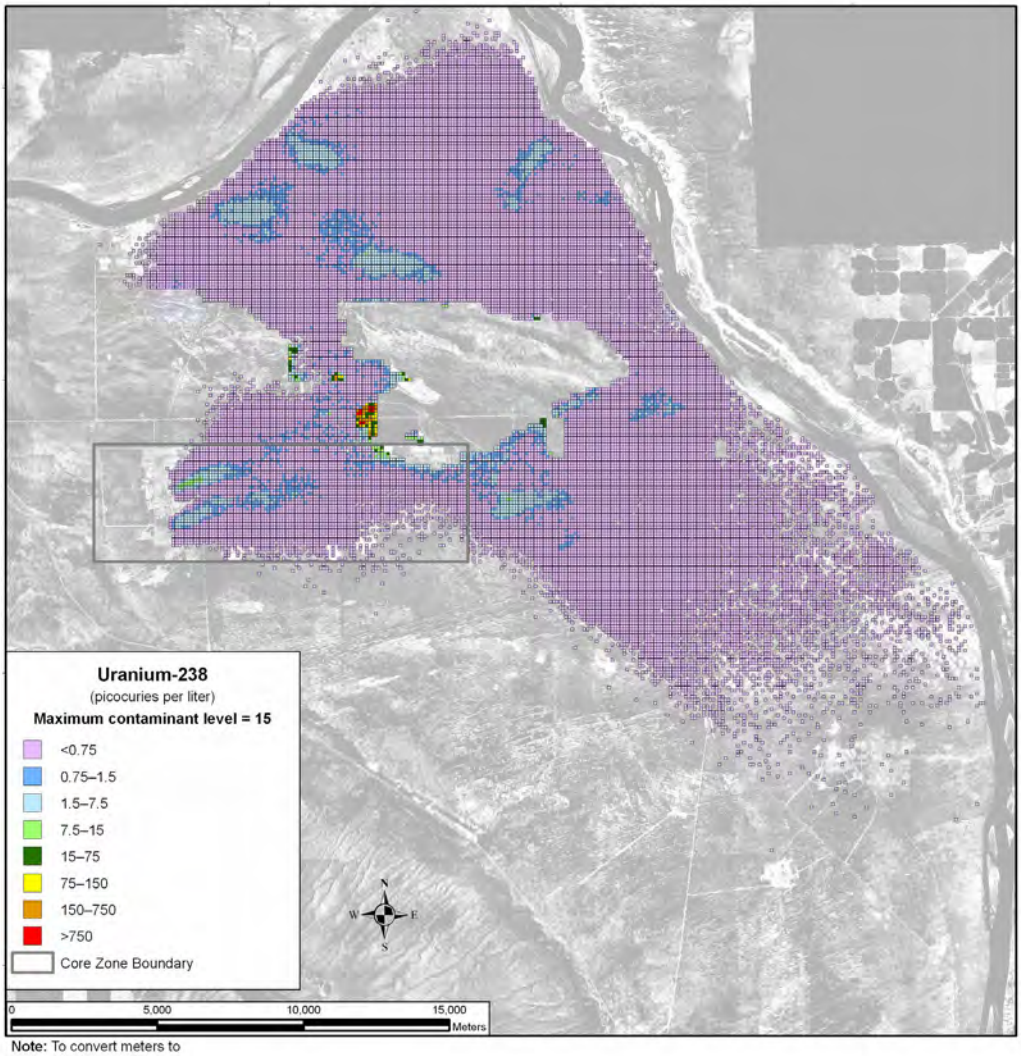
Note: To convert meters to feet, multiply by 3.281

Figure 5–137. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



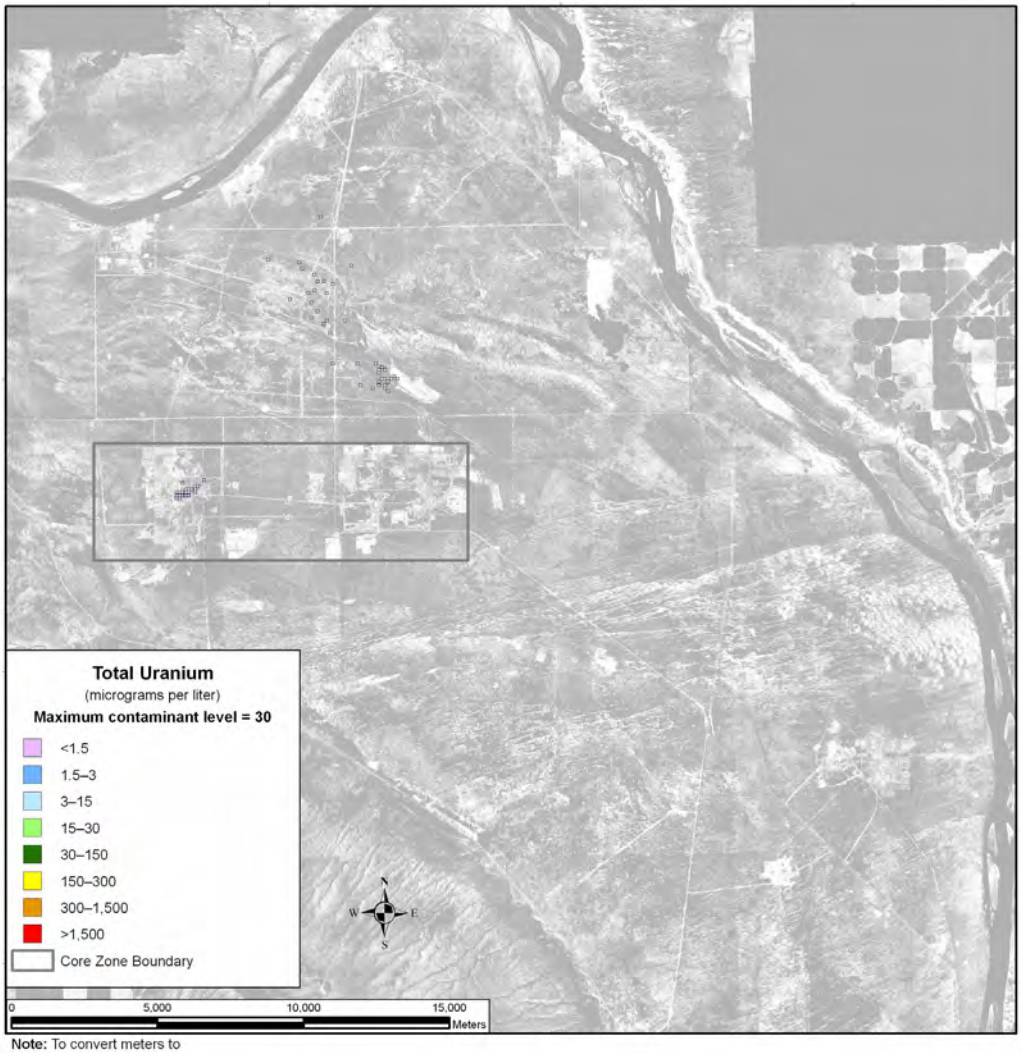
Note: To convert meters to feet, multiply by 3.281

Figure 5–138. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



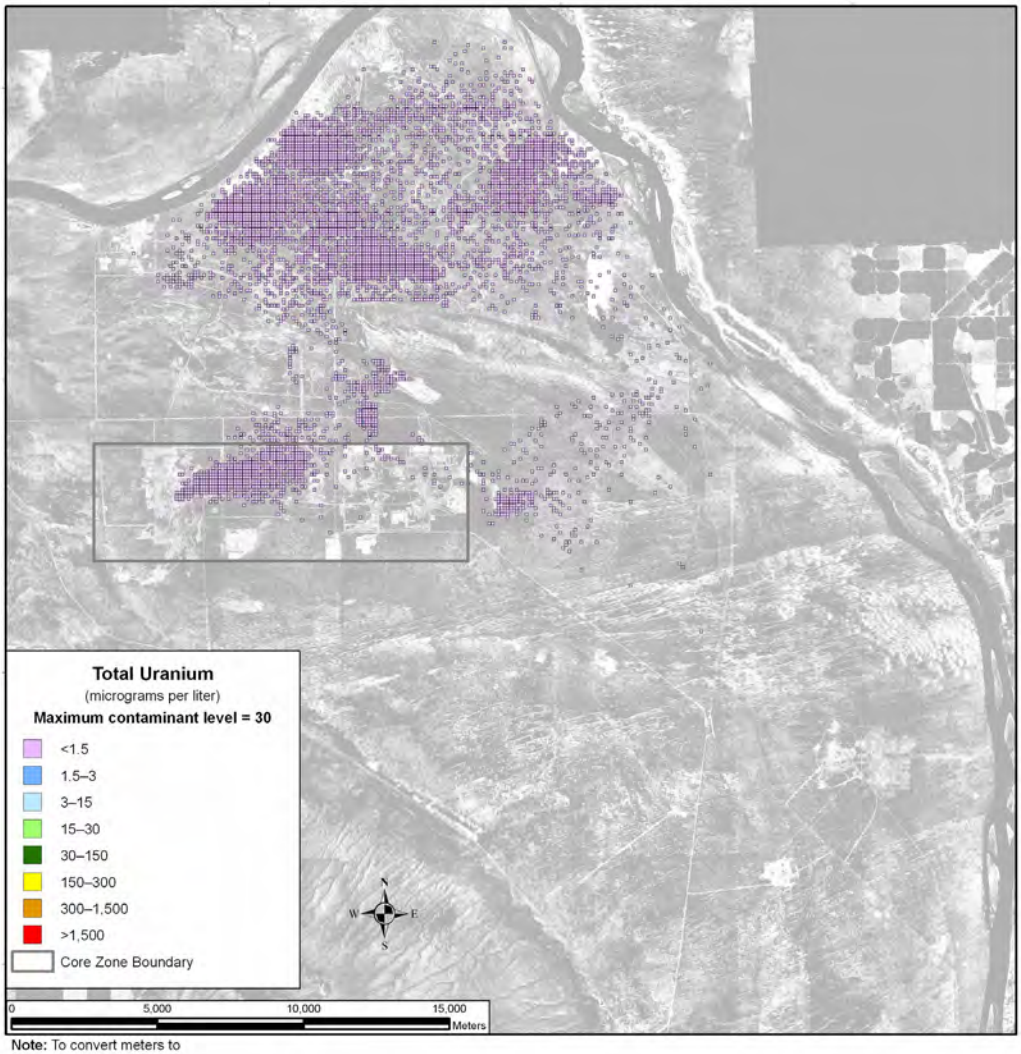
Note: To convert meters to feet, multiply by 3.281

Figure 5–139. Tank Closure Alternative 4 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



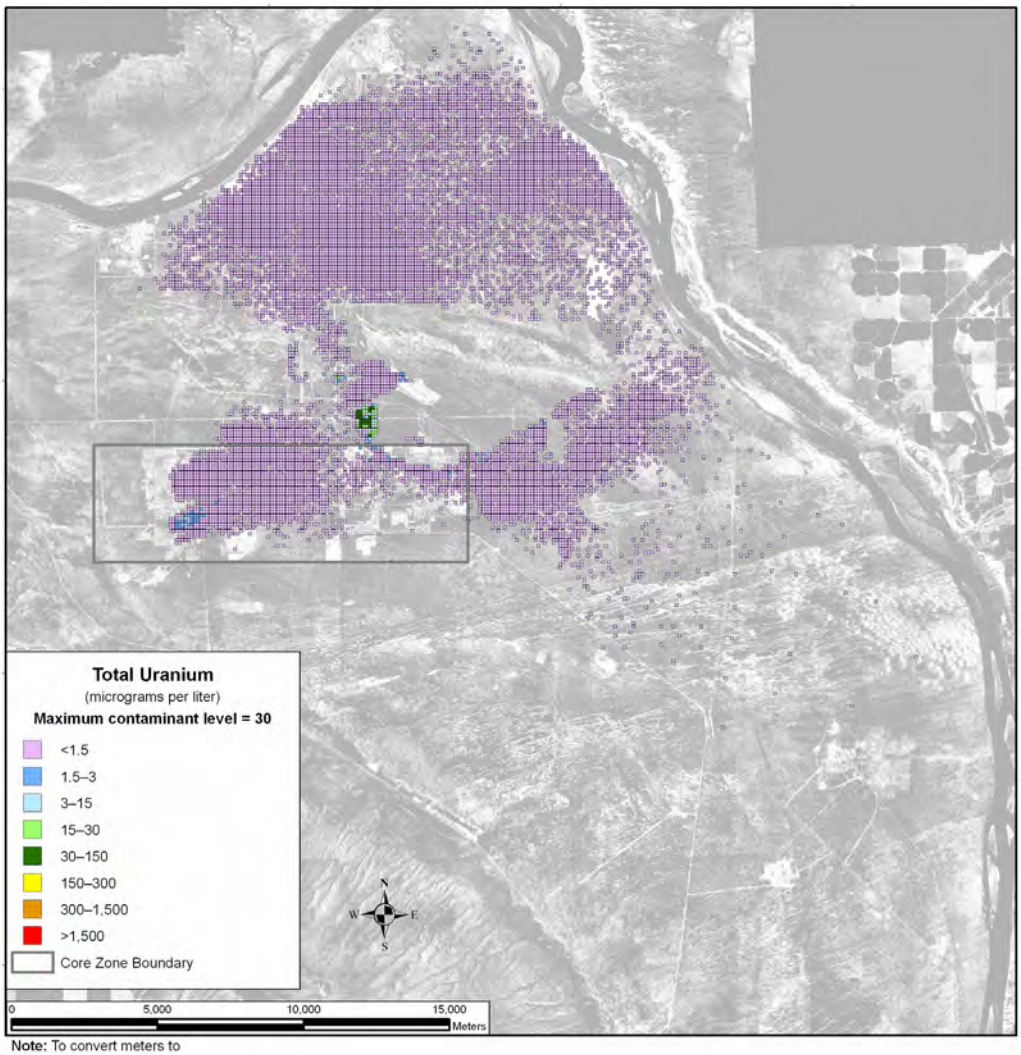
Note: To convert meters to feet, multiply by 3.281

Figure 5–140. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



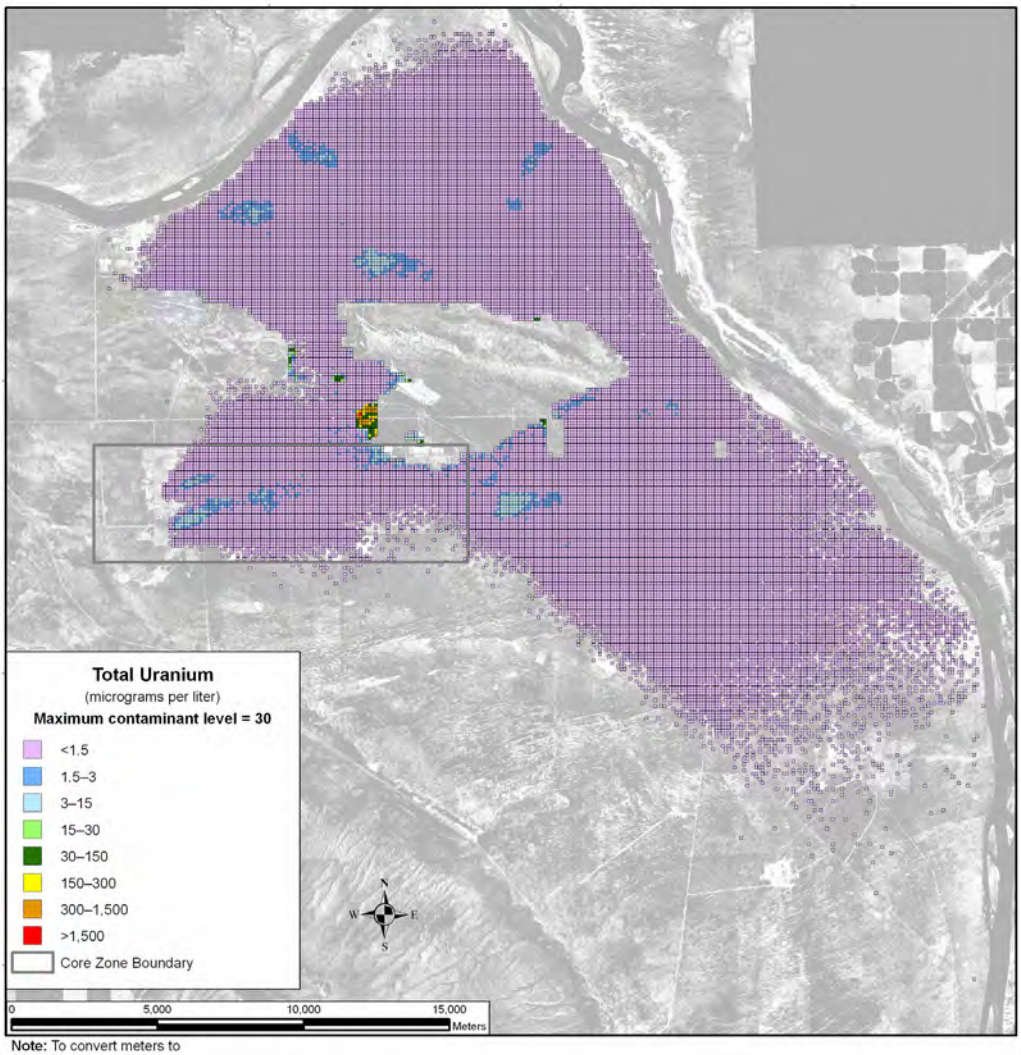
Note: To convert meters to feet, multiply by 3.281

Figure 5–141. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–142. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–143. Tank Closure Alternative 4 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figures 5–144 through 5–146 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 4 square kilometers (1.5 square miles) around CY 2135. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 1.1 square kilometers (0.4 square miles) around CY 3890, continuing its decline to 0.5 square kilometers (0.2 square miles) by CY 9740 and remaining near that level for the remainder of the simulation. Technetium-99 shows a similar trend, peaking at just over 8 square kilometers (3 square miles) in CY 2070 and reaching 0.5 square kilometers (0.2 square miles) in CY 7790. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 5840. From CY 5840 until the end of the simulation, areas of uranium-238 concentrations above the benchmark concentration slowly increase, never exceeding 1.1 square kilometers (0.4 square miles).

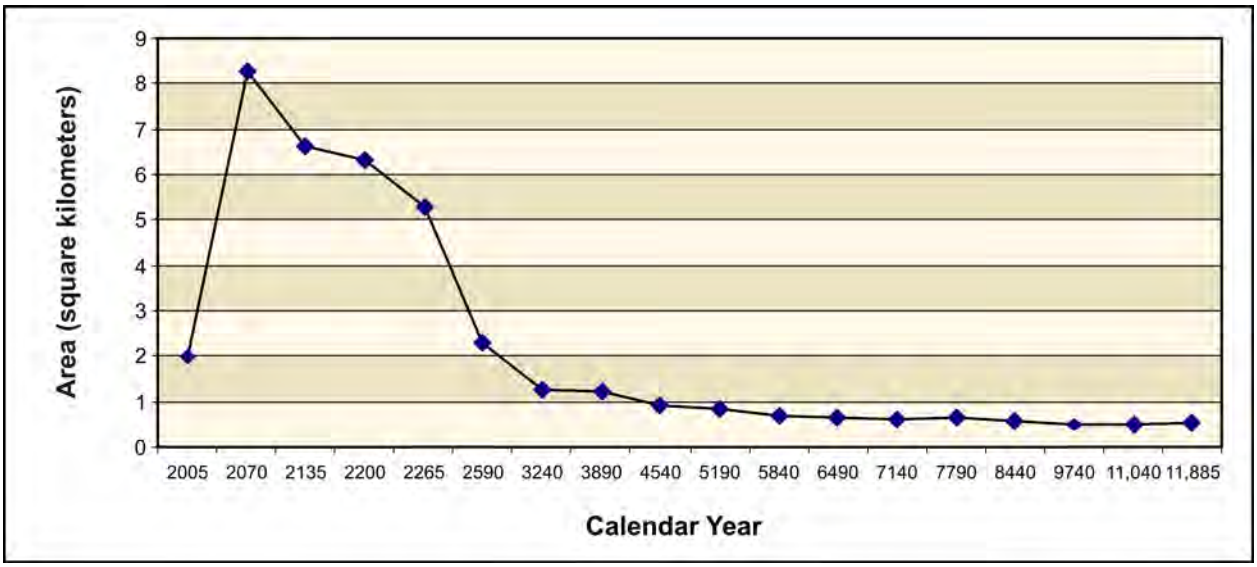


Figure 5–144. Tank Closure Alternative 4 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

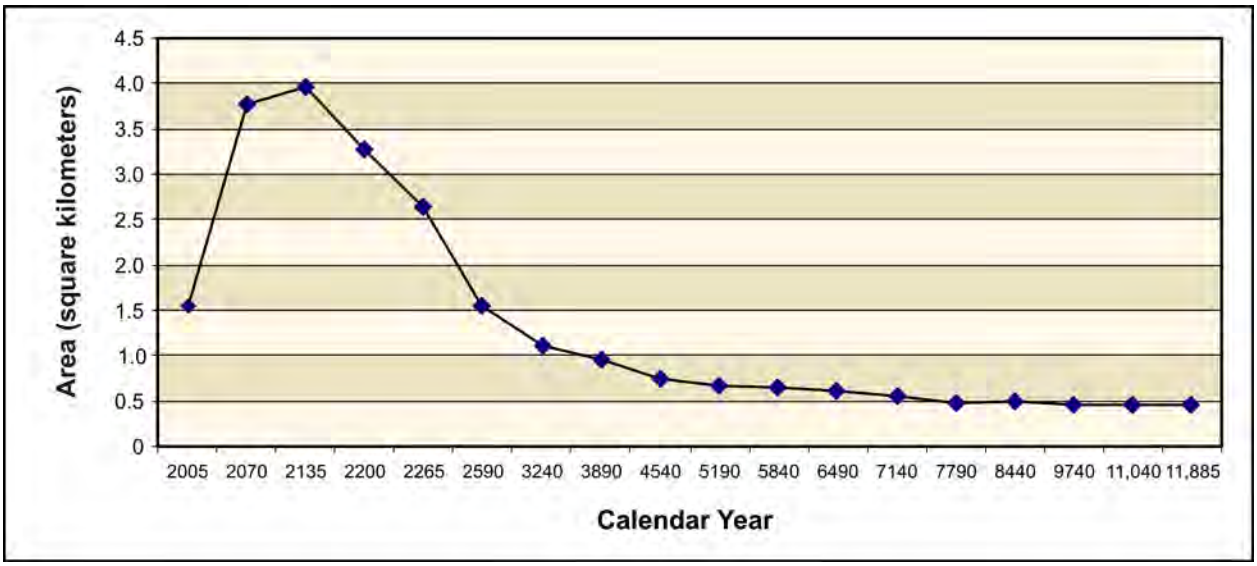


Figure 5–145. Tank Closure Alternative 4 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

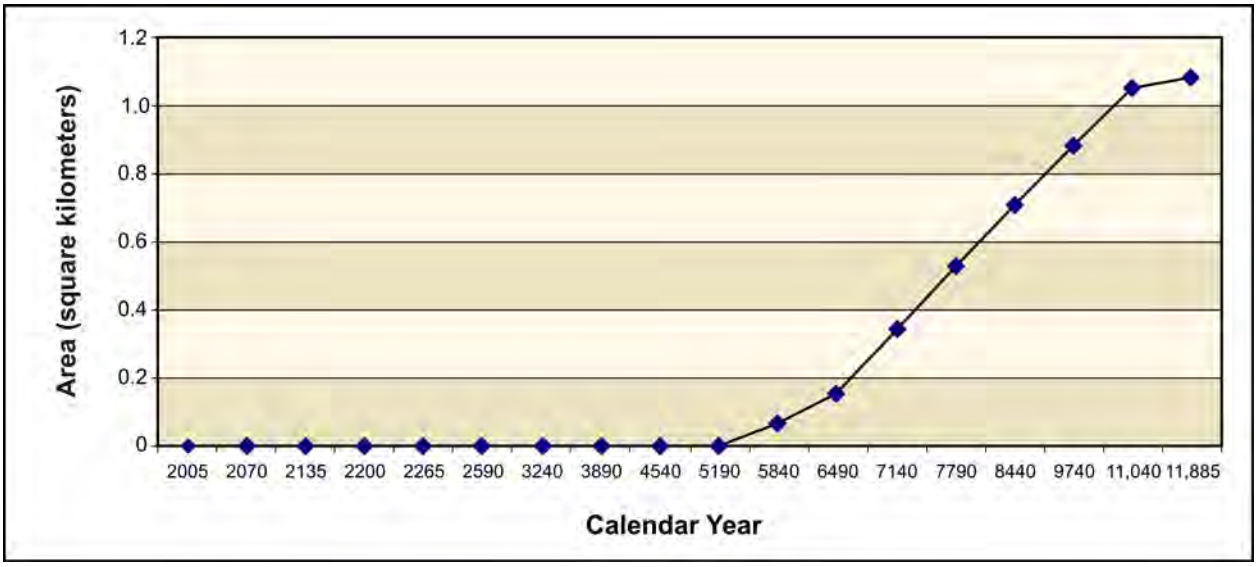


Figure 5–146. Tank Closure Alternative 4 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.7.6 Summary of Impacts

Under Tank Closure Alternative 4, discharges to cribs and trenches (ditches) and past leaks are the predominant contributors. Other tank farm sources, available after the remediation period, are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by about one order of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two to three orders of magnitude smaller. The intensities and areas of these groundwater plumes peak around CY 2070.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2050, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark concentration at the Core Zone Boundary beyond CY 8000, and remain below the benchmark concentration at the Columbia River nearshore. The intensity and area of the contamination plume continue to increase until the end of the analysis period.

5.1.1.8 Tank Closure Alternative 5: Expanded WTP Vitrification with Supplemental Treatment Technologies; Landfill Closure

This section describes the groundwater analysis results for Tank Closure Alternative 5, including long-term groundwater impacts of sources from within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

5.1.1.8.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 5 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 5, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades would be complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. Refer to Tank Closure Alternative 1 (see Section 5.1.1) for groundwater impacts during the past-practice period.

- The retrieval period was assumed to start in 2008 and end in CY 2139. During this period, 90 percent of the waste would be retrieved from the tanks. A retrieval loss of 15,140 liters (4,000 gallons) per tank was assumed for all SSTs, with no leakage from DSTs or miscellaneous underground storage tanks. The SST farm system would be landfill-closed with a Hanford barrier. Releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system.

- The post–administrative control period was assumed to start in CY 2140 and continue through the 10,000-year period of analysis until CY 11,940. During this post–administrative control period, releases that occurred during the past-practice period would continue to migrate through the vadose zone and groundwater system. In addition, all remaining waste at the SST farms (other tank farm sources) would be released to the vadose zone at the start of the post–administrative control period.

5.1.1.8.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 5. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 5 is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 5 were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become major contributors toward the end of the period of analysis. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-13}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 5.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers.

Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.8.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 5 in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–147 through 5–152). Three subtotals are plotted representing releases from cribs and trenches (ditches), past leaks, and other tank farm sources. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–147 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–148, the chemical hazard drivers. For all three types of sources, the release to the vadose zone is controlled by the inventory (i.e., 90 percent of the inventory was removed during the period of analysis by supplemental treatment technologies). The predominant sources for tritium are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are other tank farm sources. This suggests that other tank farm sources, which are released in the analysis during the post–administrative control period, are an important impact driver under Tank Closure Alternative 5.

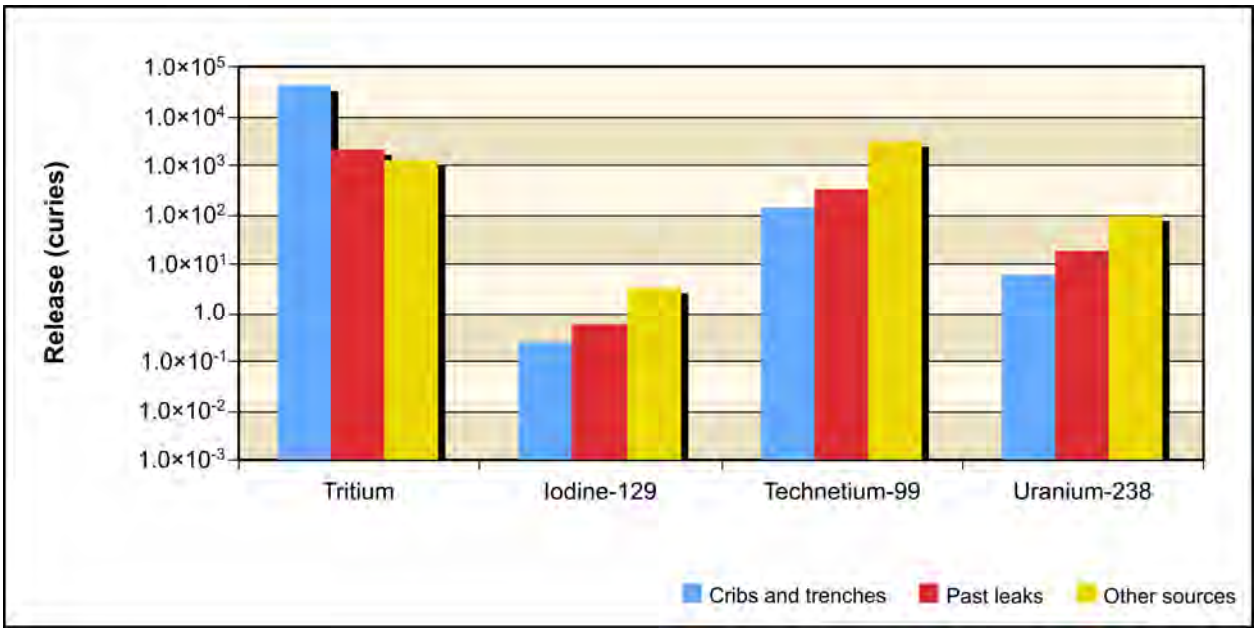


Figure 5–147. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

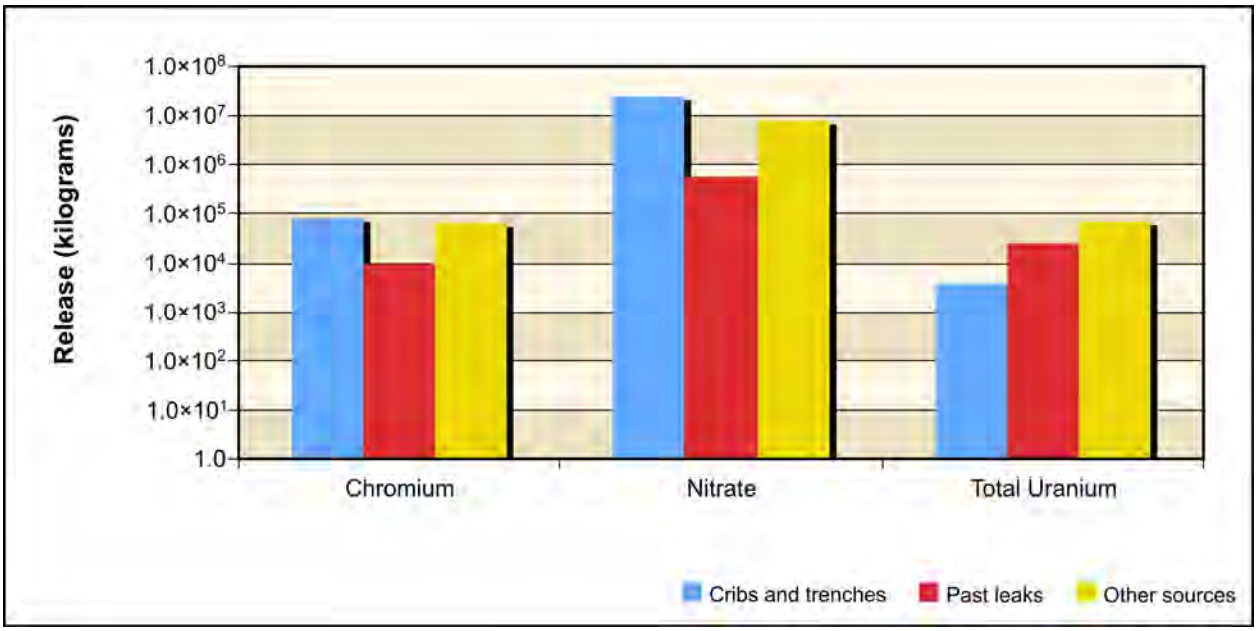


Figure 5–148. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–149 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–150, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

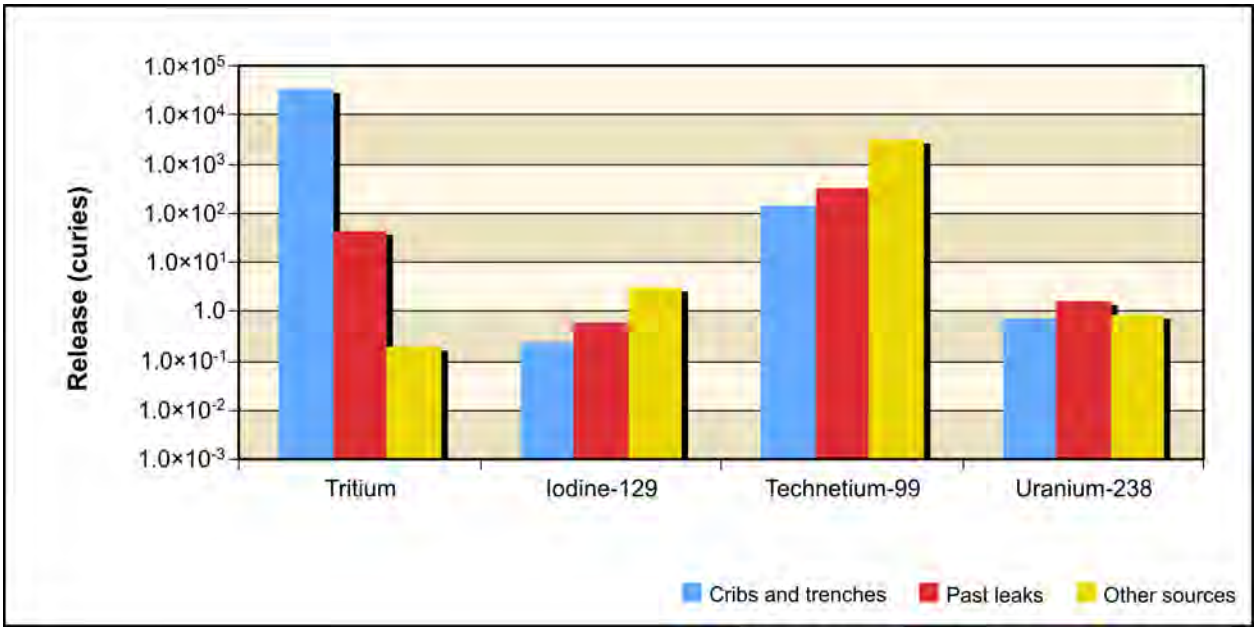


Figure 5–149. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

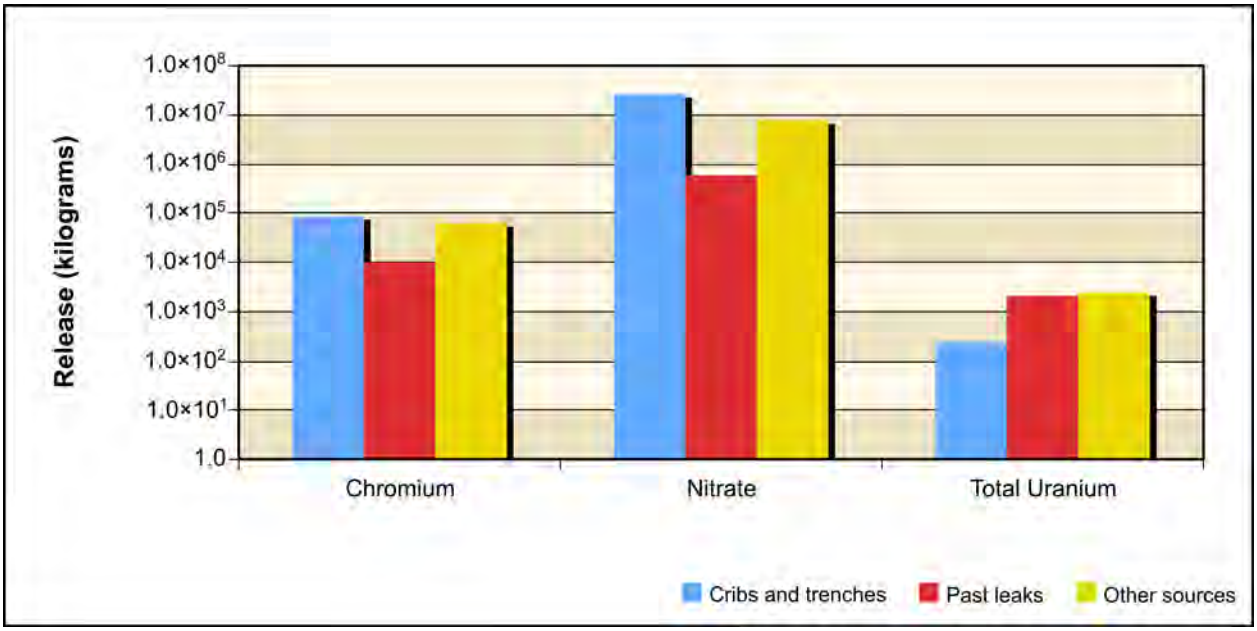


Figure 5–150. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches) and past leaks, where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory reached groundwater during the period of analysis; for other tank farm sources, only about 2 percent reached groundwater.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 70 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent; and for other tank farm sources, only one-third of 1 percent reached the water table. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–151 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–152, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. Overall, about 25 percent of the amount released to groundwater during the period of analysis reached the Columbia River. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. Overall, only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

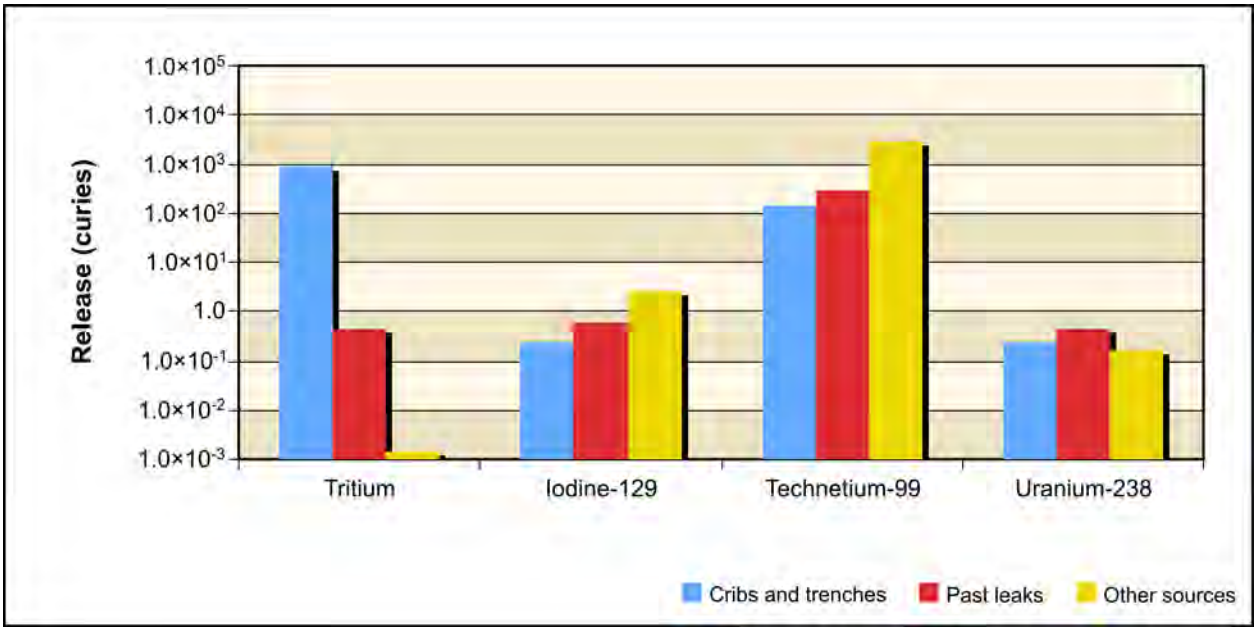


Figure 5–151. Tank Closure Alternative 5 Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

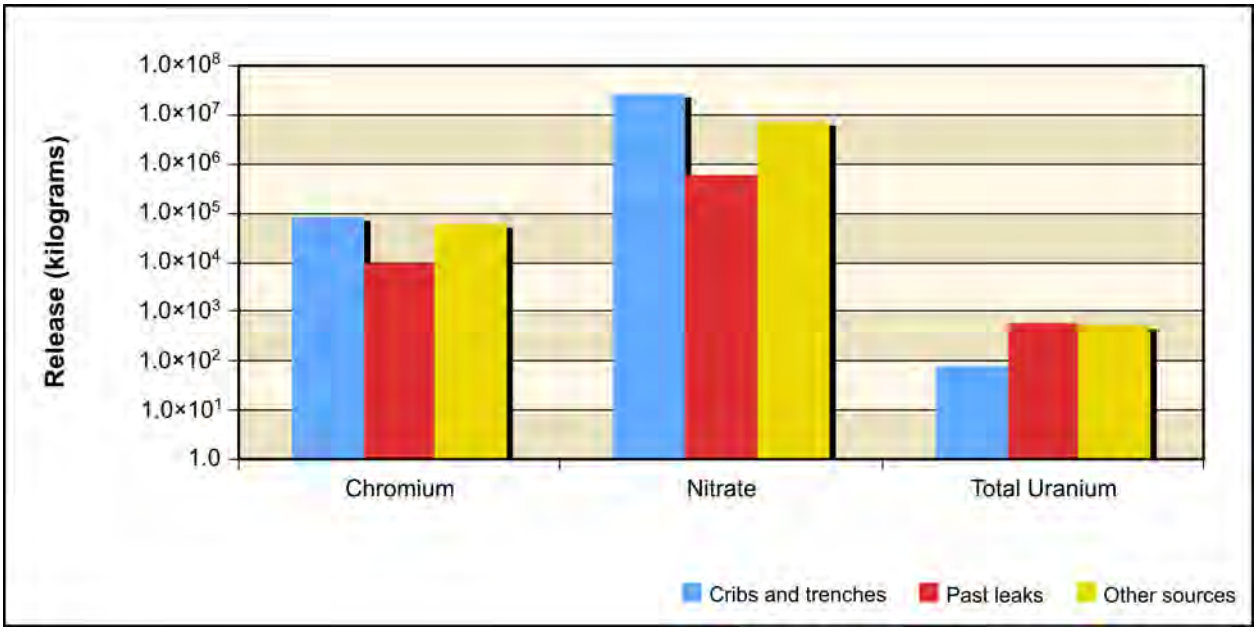


Figure 5–152. Tank Closure Alternative 5 Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.8.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 5 impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Table 5–5 and Figures 5–153 through 5–159). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–5 lists the maximum concentrations of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–153 shows concentration versus time for tritium. Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration, and tritium is essentially not a factor at times later than CY 2100.

Figures 5–154 through 5–157 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from cribs and trenches (ditches) cause groundwater concentrations to exceed benchmark concentrations by about two to three orders of magnitude during the early part of the period of analysis. During this time, groundwater concentrations at the Columbia River nearshore approach but do not exceed the benchmark concentration. Releases from other tank farm sources cause groundwater concentrations at the Core Zone Boundary to exceed benchmark concentrations by about one order of magnitude during the middle and latter parts of the period of analysis (around CY 3000 to 5000). During this time, groundwater concentrations at the Columbia River nearshore do not approach the benchmark concentration.

Table 5–5. Tank Closure Alternative 5 Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	28	5,070	52	7,270	13	6,070	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2050)	(2054)	(2050)	
Technetium-99	**3,040**	**22,500**	**3,340**	**15,300**	**1,780**	**35,700**	724	900
	(4338)	(2050)	(3931)	(2050)	(4022)	(4326)	(5017)	
Iodine-129	**3**	**42**	**5**	**19**	0.8	**34**	0.5	1
	(2059)	(2057)	(2050)	(2051)	(4694)	(2057)	(7030)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	1	**67**	**15**	**25**	9	**102**	1	15
	(11,845)	(11,739)	(11,727)	(11,780)	(11,750)	(11,735)	(11,594)	
Chemical in micrograms per liter								
Acetonitrile	8	0	2	0	0	12	1	100
	(4221)	(1940)	(4208)	(1940)	(1940)	(4510)	(4297)	
Chromium	29	**3,210**	**289**	**782**	36	**1,730**	35	100
	(4094)	(2055)	(2050)	(2050)	(3847)	(3891)	(2695)	
Nitrate	6,510	**1,540,000**	13,200	**133,000**	4,510	**1,010,000**	8,750	45,000
	(4099)	(2050)	(3586)	(2054)	(3794)	(2050)	(2450)	
Total uranium	0	**83**	**33**	15	15	**204**	1	30
	(11,795)	(11,798)	(11,473)	(11,815)	(11,821)	(11,805)	(11,935)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

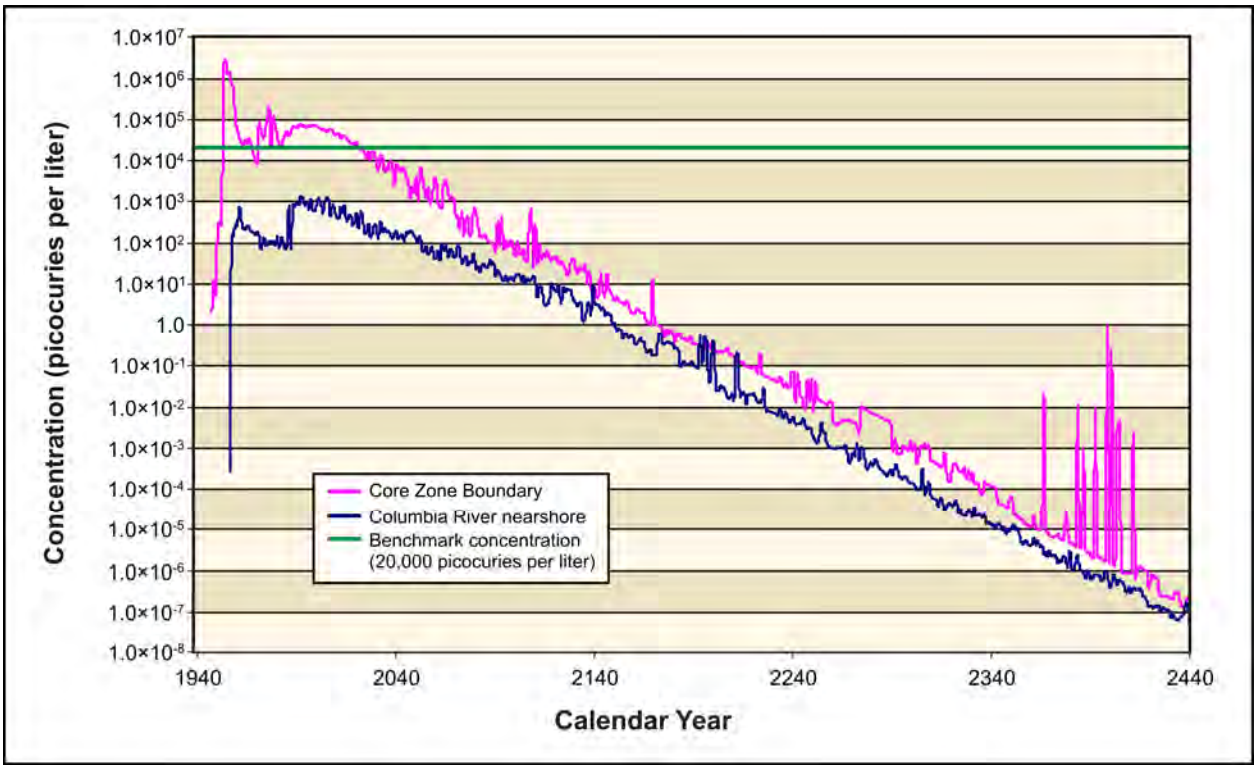


Figure 5–153. Tank Closure Alternative 5 Hydrogen-3 (Tritium) Concentration Versus Time

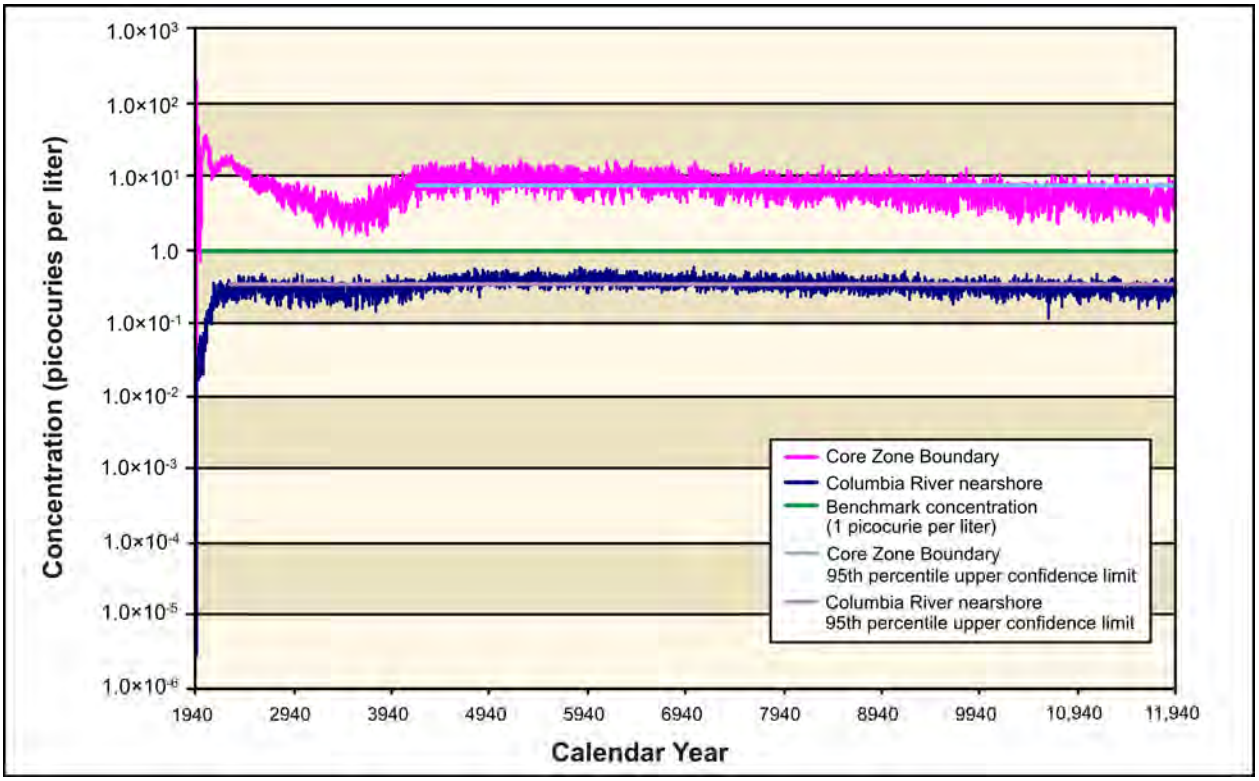


Figure 5–154. Tank Closure Alternative 5 Iodine-129 Concentration Versus Time

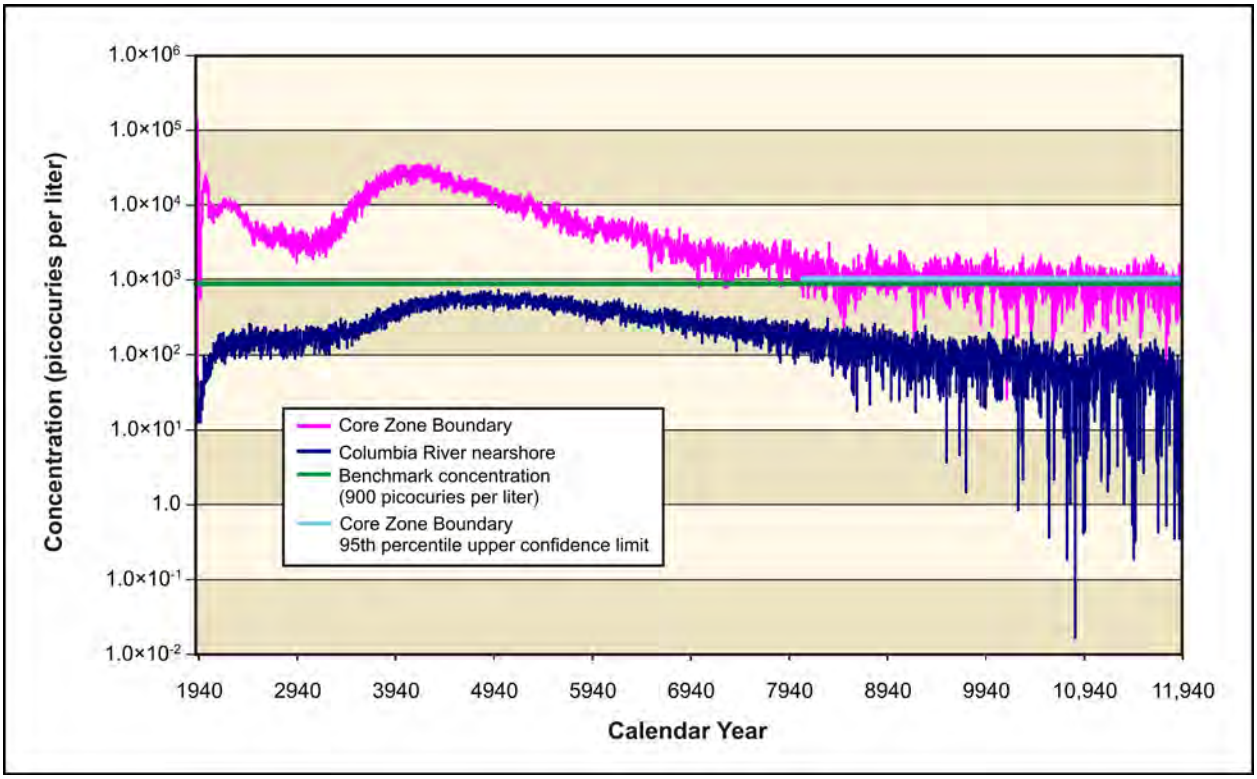


Figure 5–155. Tank Closure Alternative 5 Technetium-99 Concentration Versus Time

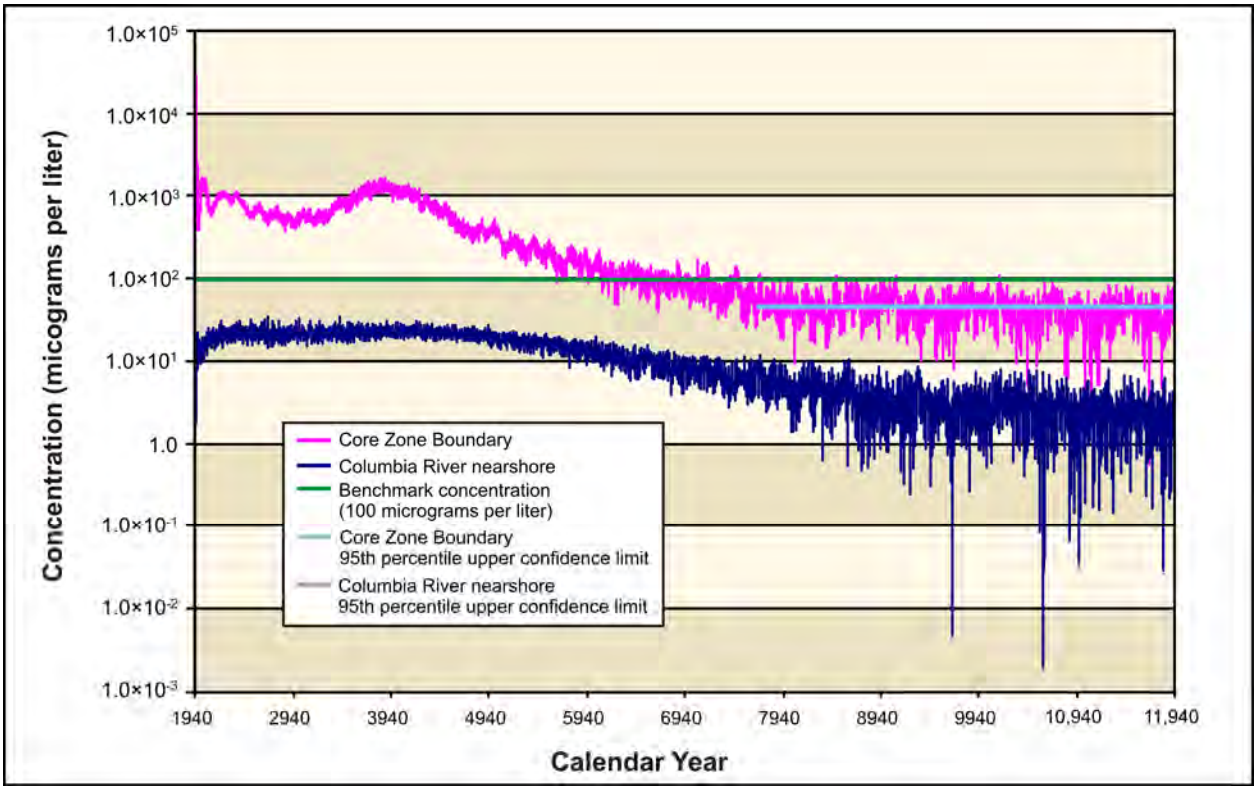


Figure 5–156. Tank Closure Alternative 5 Chromium Concentration Versus Time

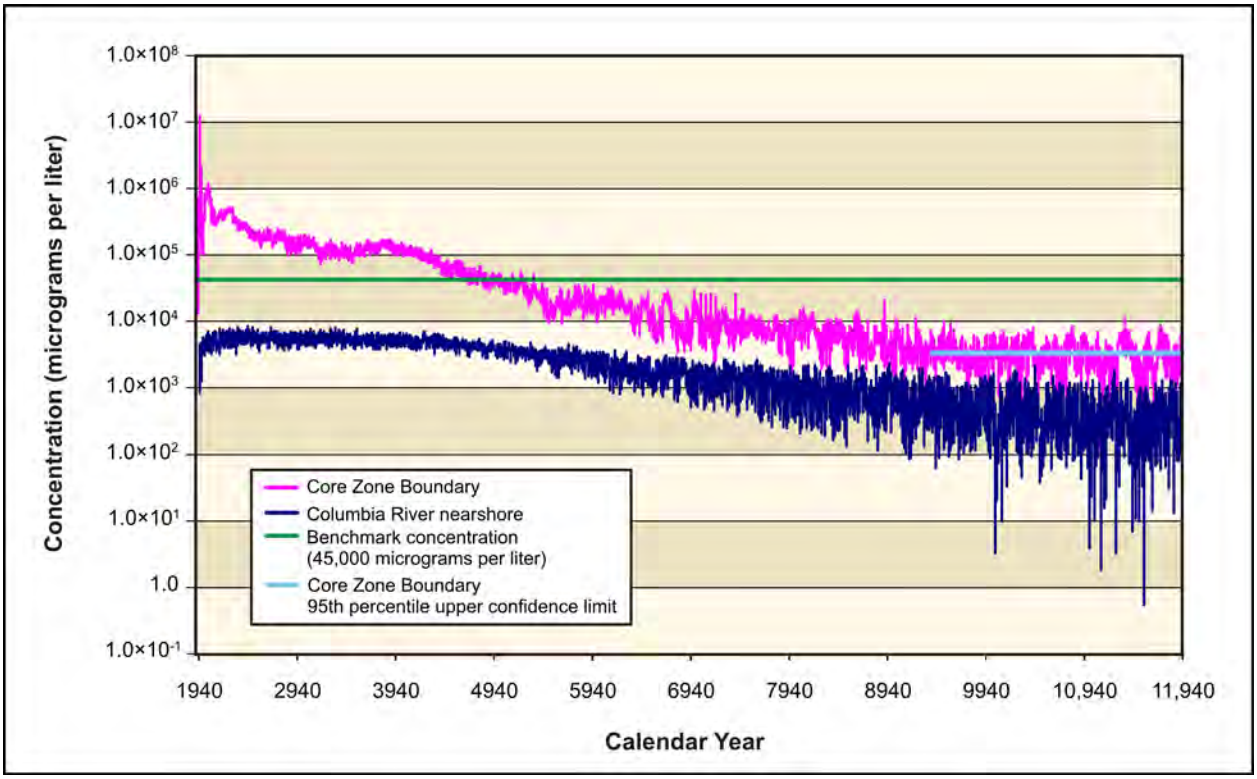


Figure 5–157. Tank Closure Alternative 5 Nitrate Concentration Versus Time

Figures 5–158 and 5–159 show concentration versus time for uranium-238 and total uranium. Early releases from cribs and trenches (ditches) result in groundwater concentrations that are one to two orders of magnitude lower than benchmark concentrations. Releases from other tank farm sources cause groundwater concentrations to rise, nearing benchmark concentrations by CY 8200 for uranium-238 and by CY 8400 for total uranium. Concentrations continue to rise throughout the duration of the period of analysis, exceeding benchmark concentrations by about one order of magnitude at the end of the period of analysis. Groundwater concentrations at the Columbia River nearshore rise throughout the period of analysis, nearing an order of magnitude less than the benchmark concentration by CY 11,940.

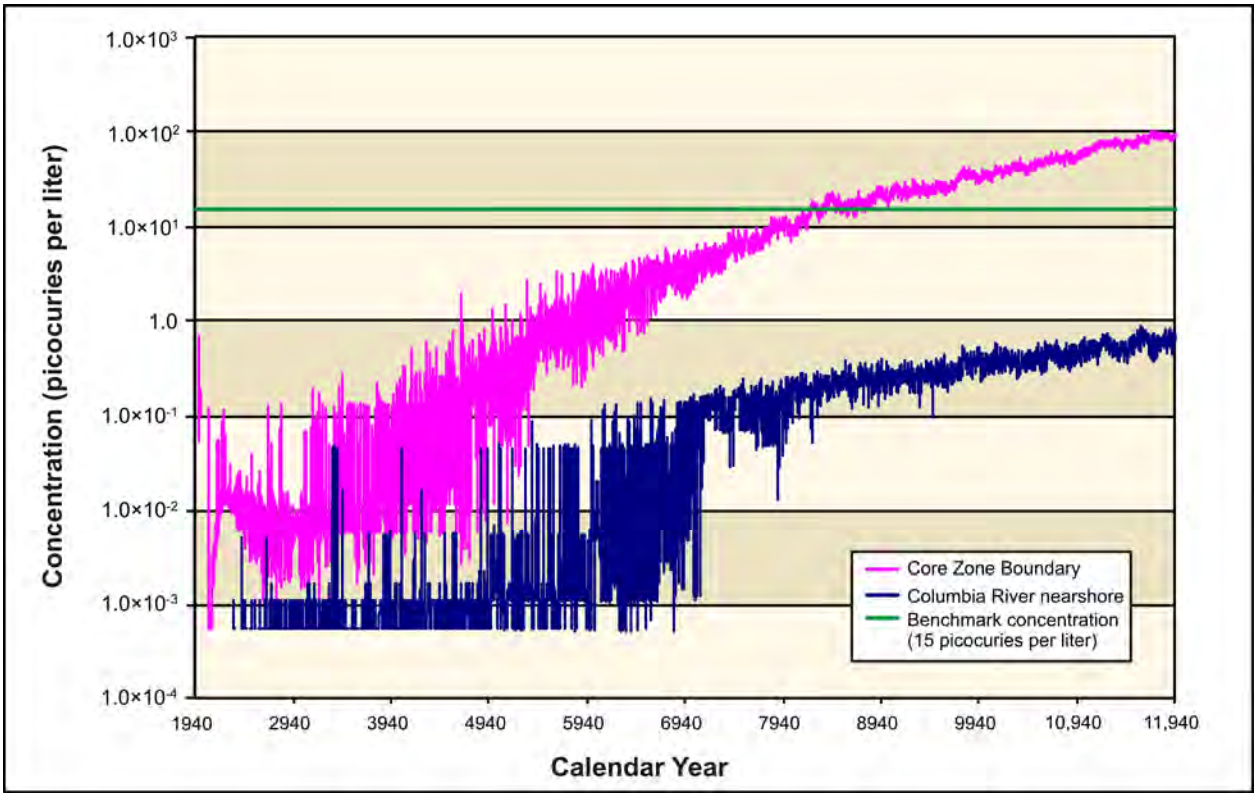


Figure 5–158. Tank Closure Alternative 5 Uranium-238 Concentration Versus Time

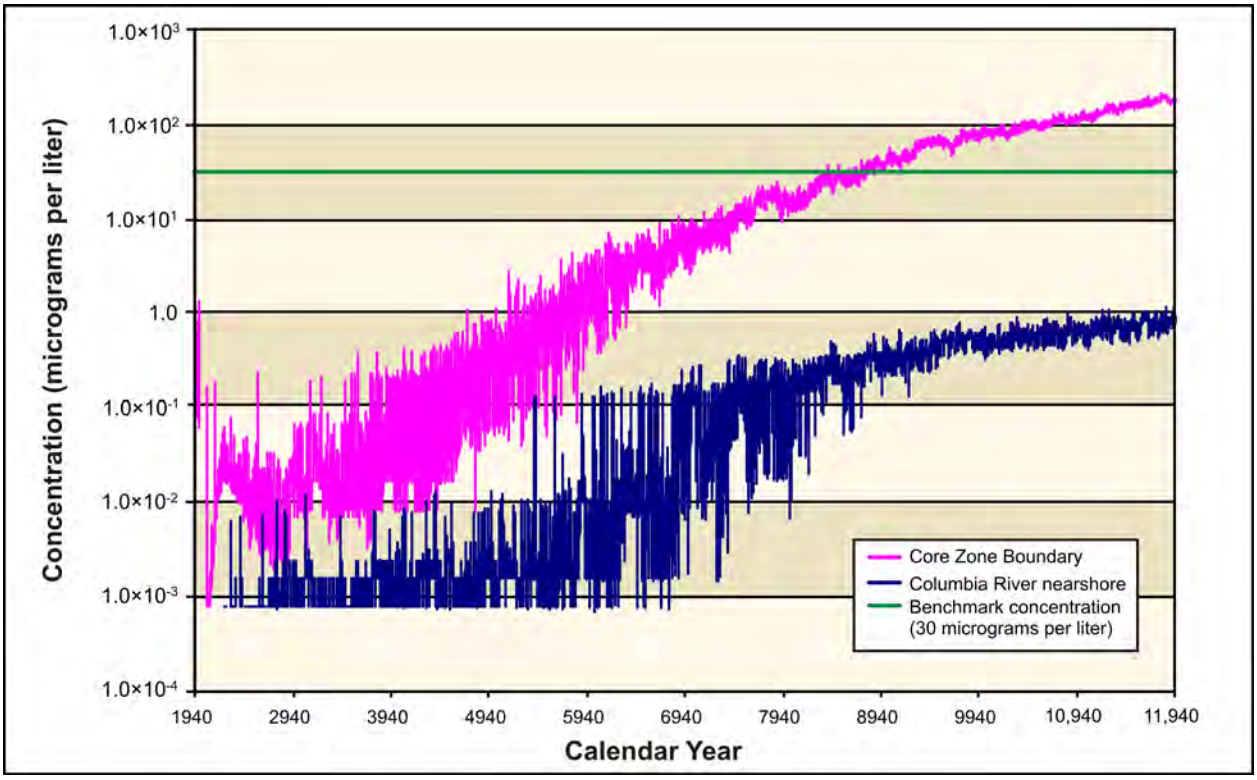
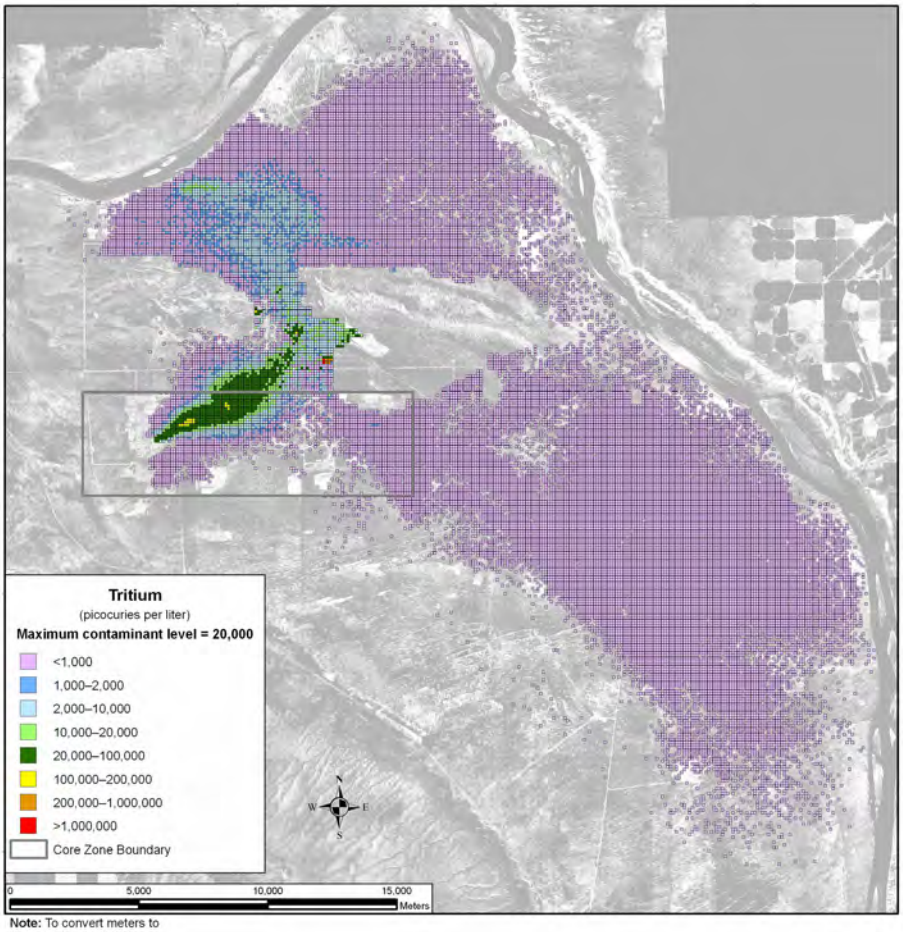


Figure 5–159. Tank Closure Alternative 5 Total Uranium Concentration Versus Time

5.1.1.8.5 Analysis of Spatial Distribution of Concentration

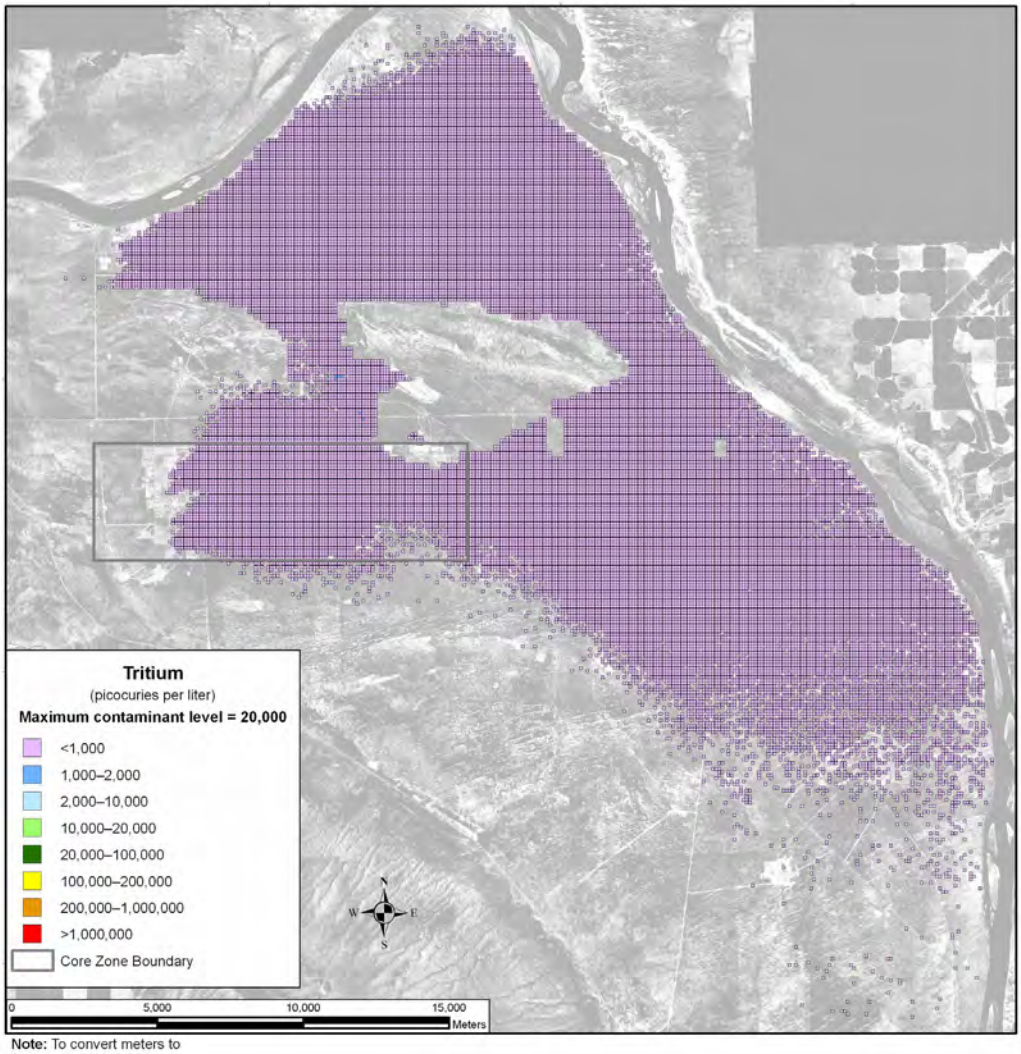
This section presents the impacts of Tank Closure Alternative 5 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–160 through 5–182). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–160 shows the spatial distribution of groundwater concentration for tritium during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 10 to 20 times greater than the benchmark, and mostly contained within the Core Zone Boundary. Tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135 (see Figure 5–161).



Note: To convert meters to feet, multiply by 3.281

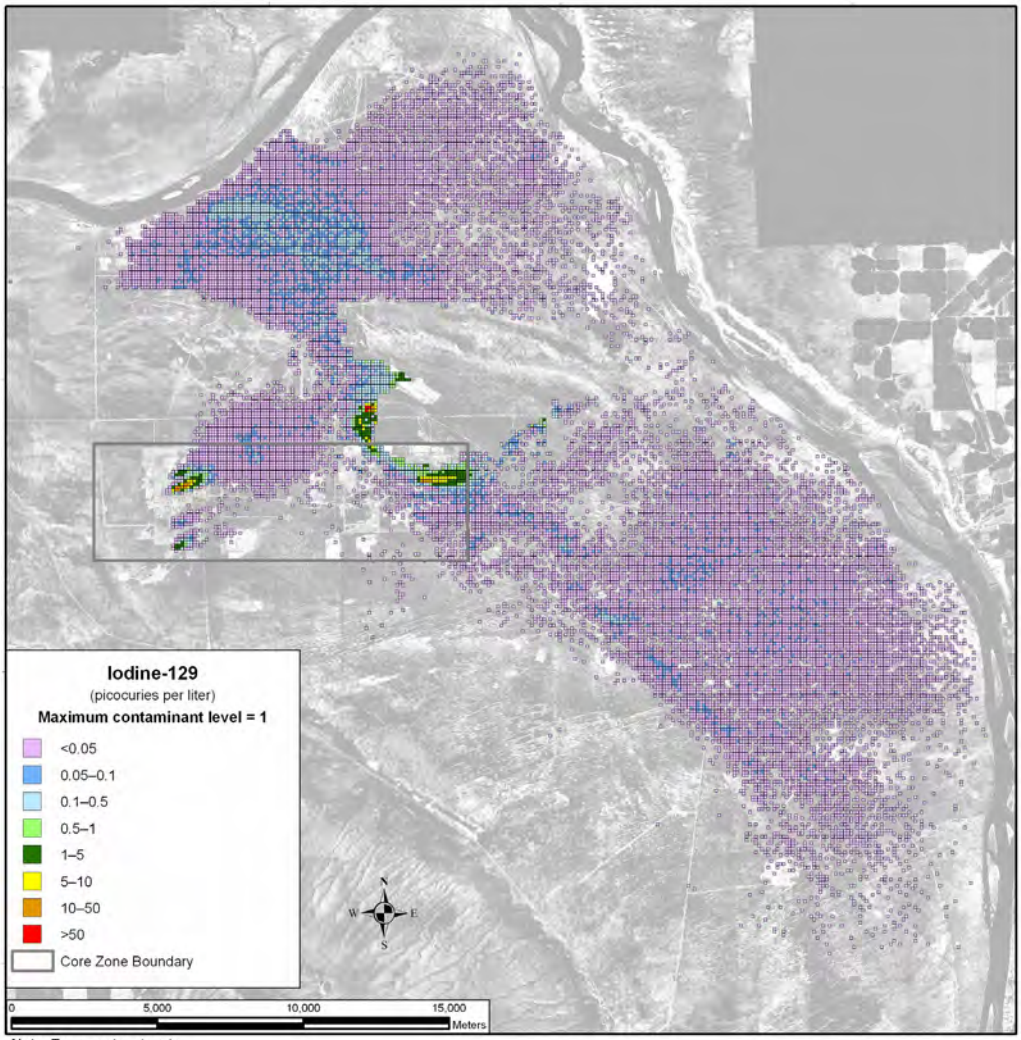
Figure 5–160. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

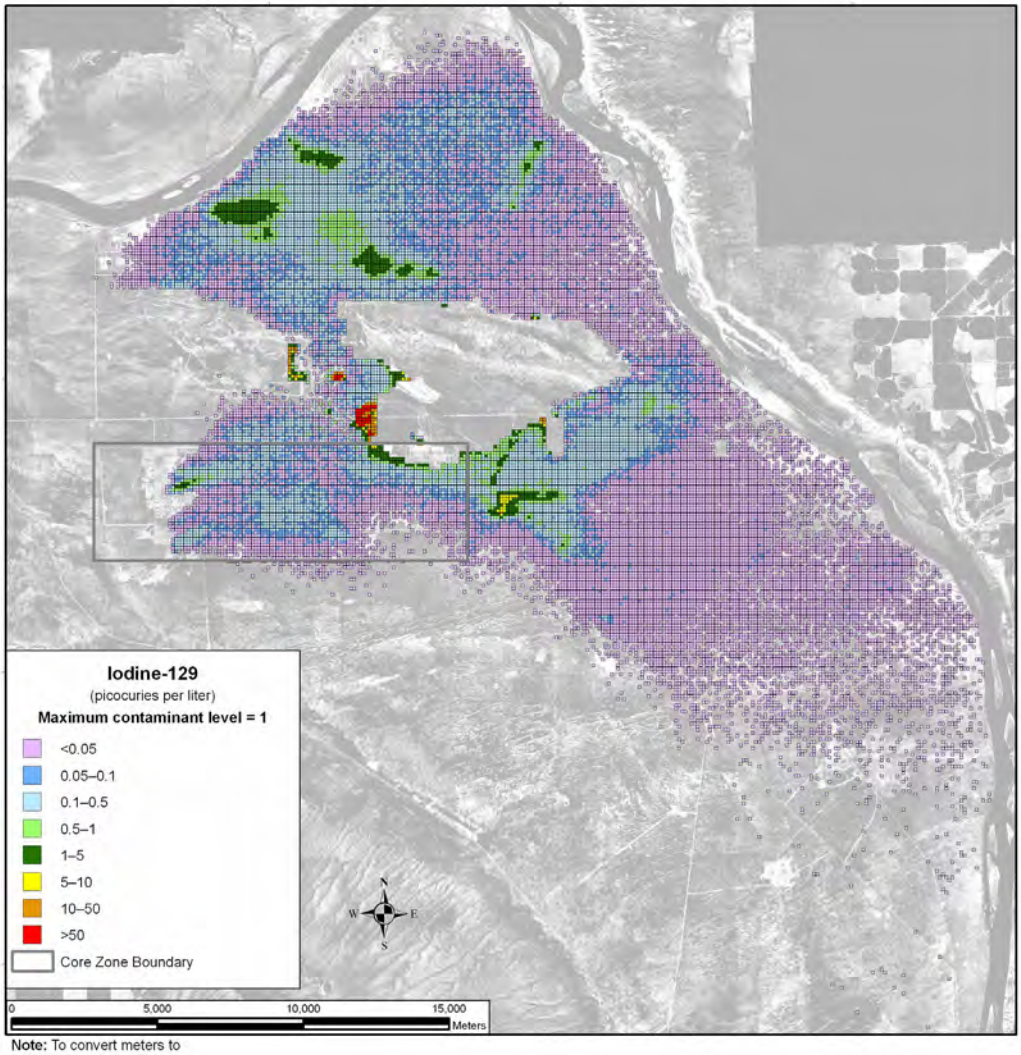
Figure 5–161. Tank Closure Alternative 5 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–162 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, S Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 30 times greater than the benchmark, and mostly contained within the Core Zone Boundary. During CY 2135, releases from other tank farm sources create a large plume exceeding the benchmark concentration, extending from the A Barrier to the Columbia River (see Figure 5–163). By CY 7140, most of the mass in the plume has reached the Columbia River, with only isolated pockets of high-concentration areas where the groundwater flow velocities are extremely small (see Figure 5–164). Technetium-99 (see Figures 5–165 through 5–167), chromium (see Figures 5–168 through 5–170), and nitrate (see Figure 5–171 through 5–173) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



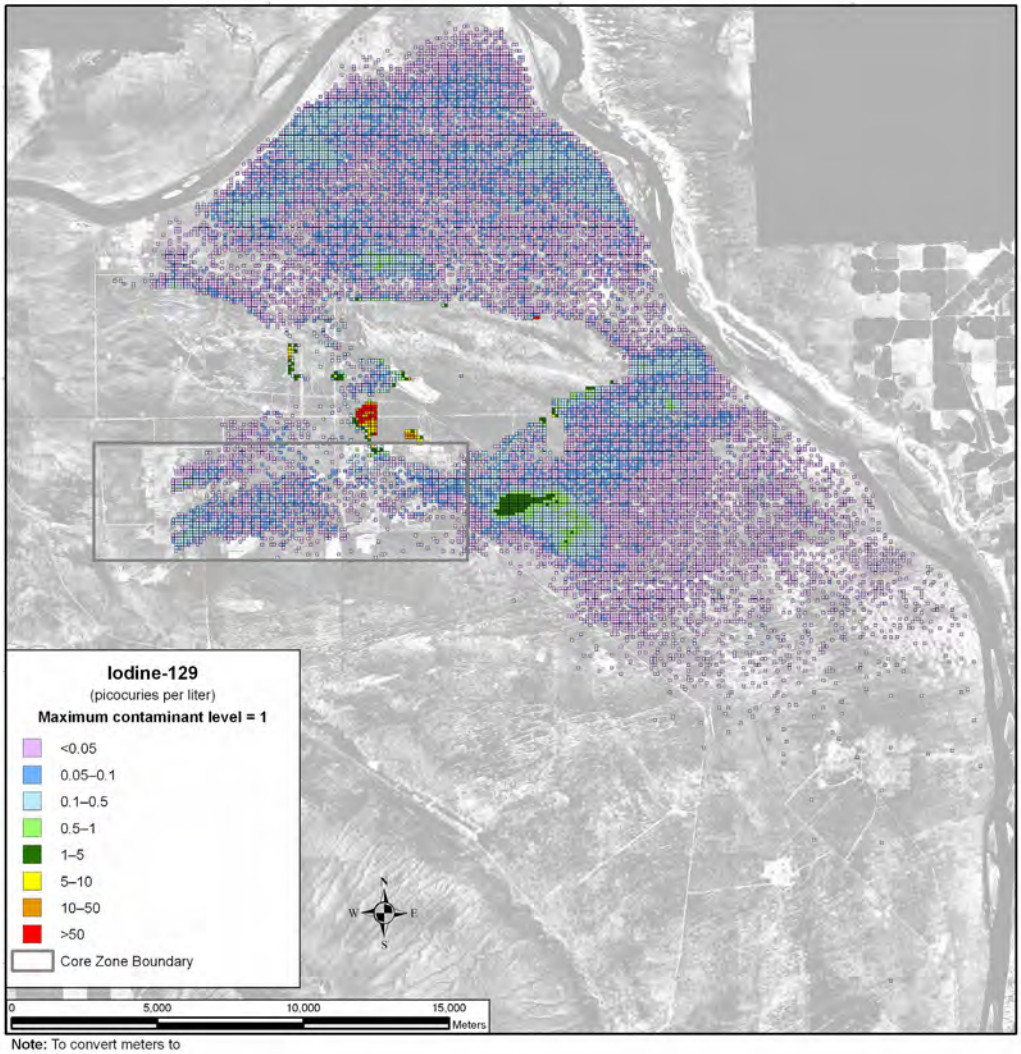
Note: To convert meters to feet, multiply by 3.281

Figure 5–162. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



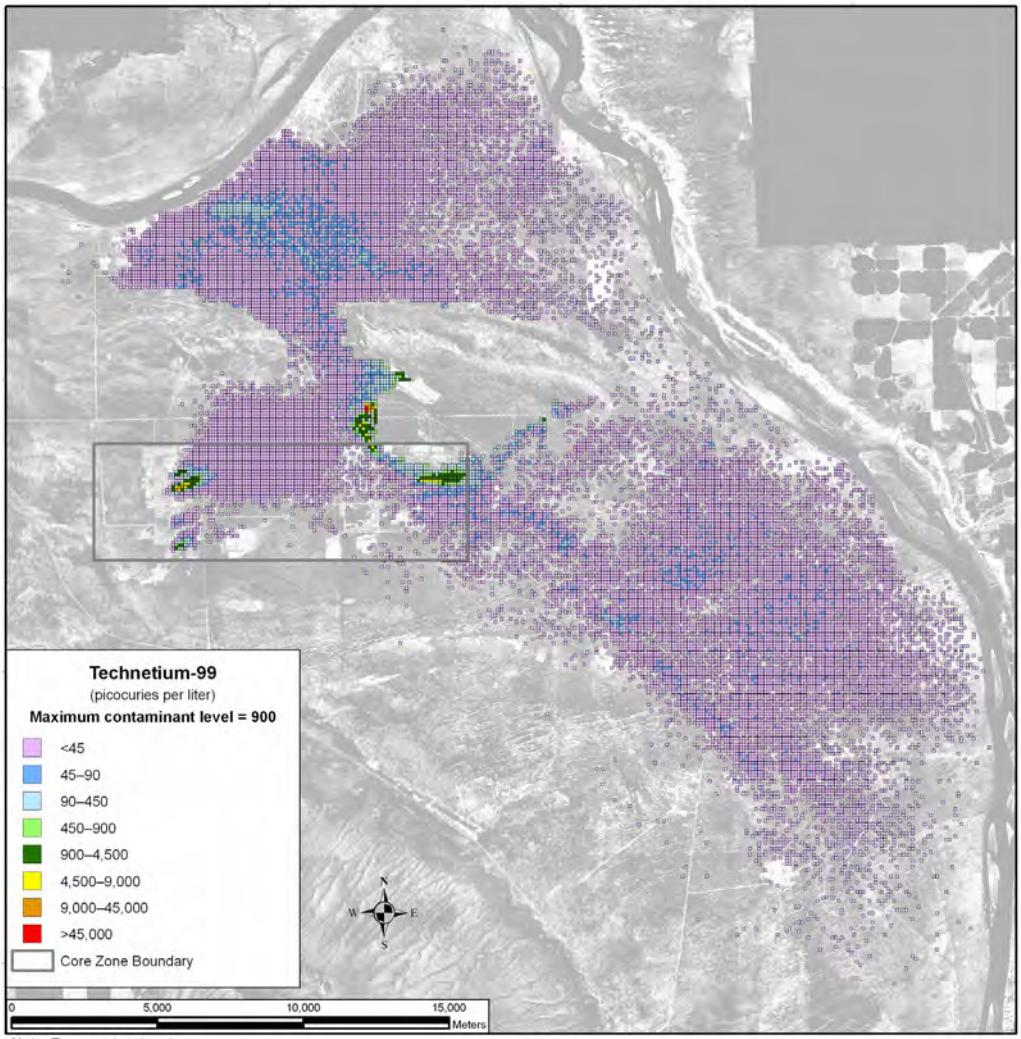
Note: To convert meters to feet, multiply by 3.281

Figure 5–163. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



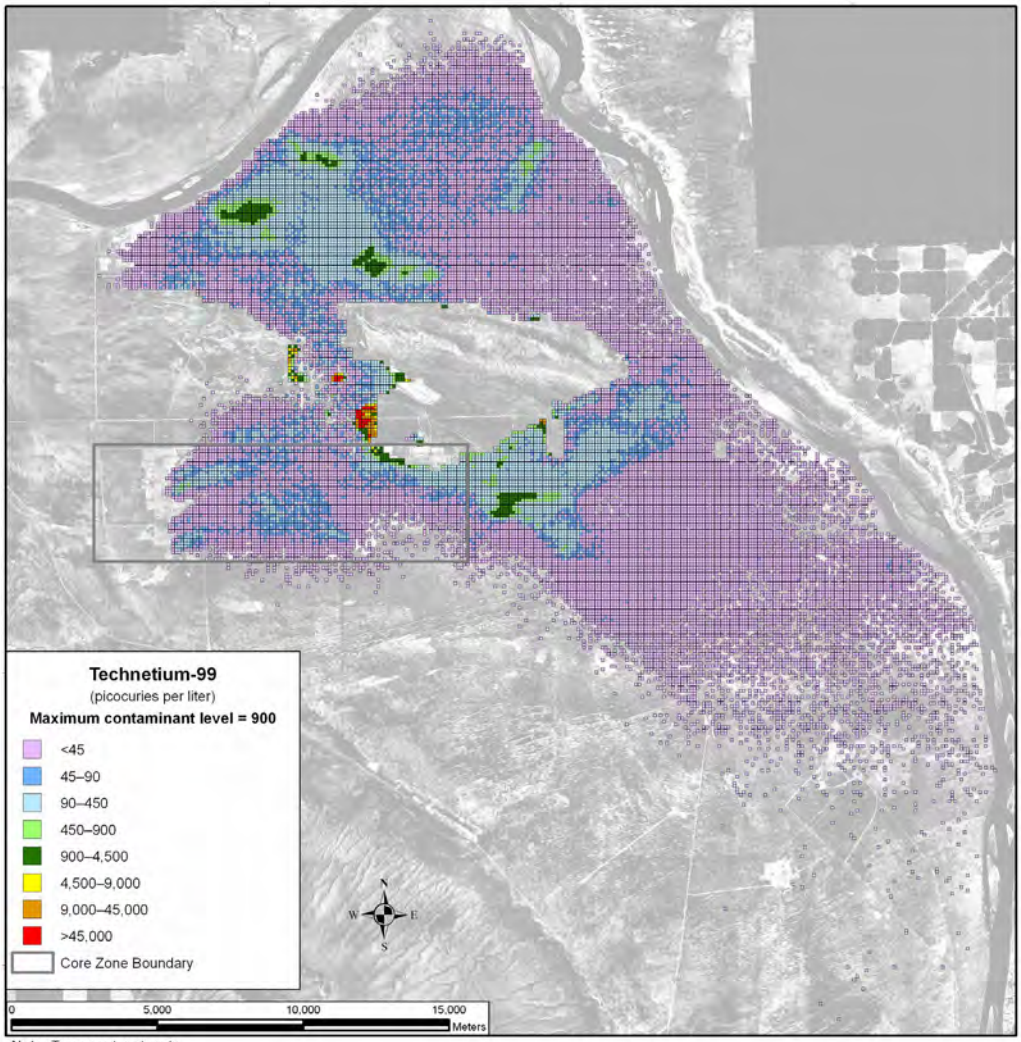
Note: To convert meters to feet, multiply by 3.281

Figure 5–164. Tank Closure Alternative 5 Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



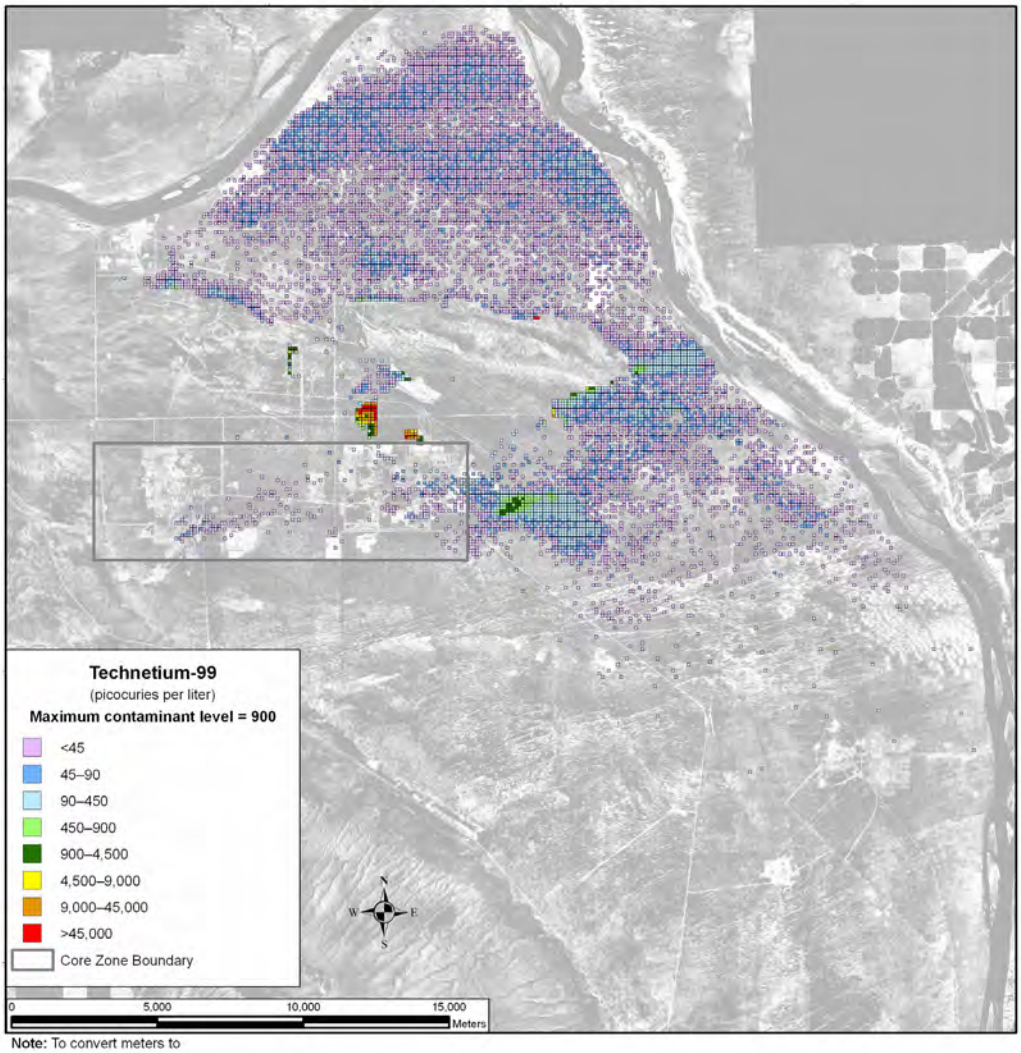
Note: To convert meters to feet, multiply by 3.281

Figure 5–165. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



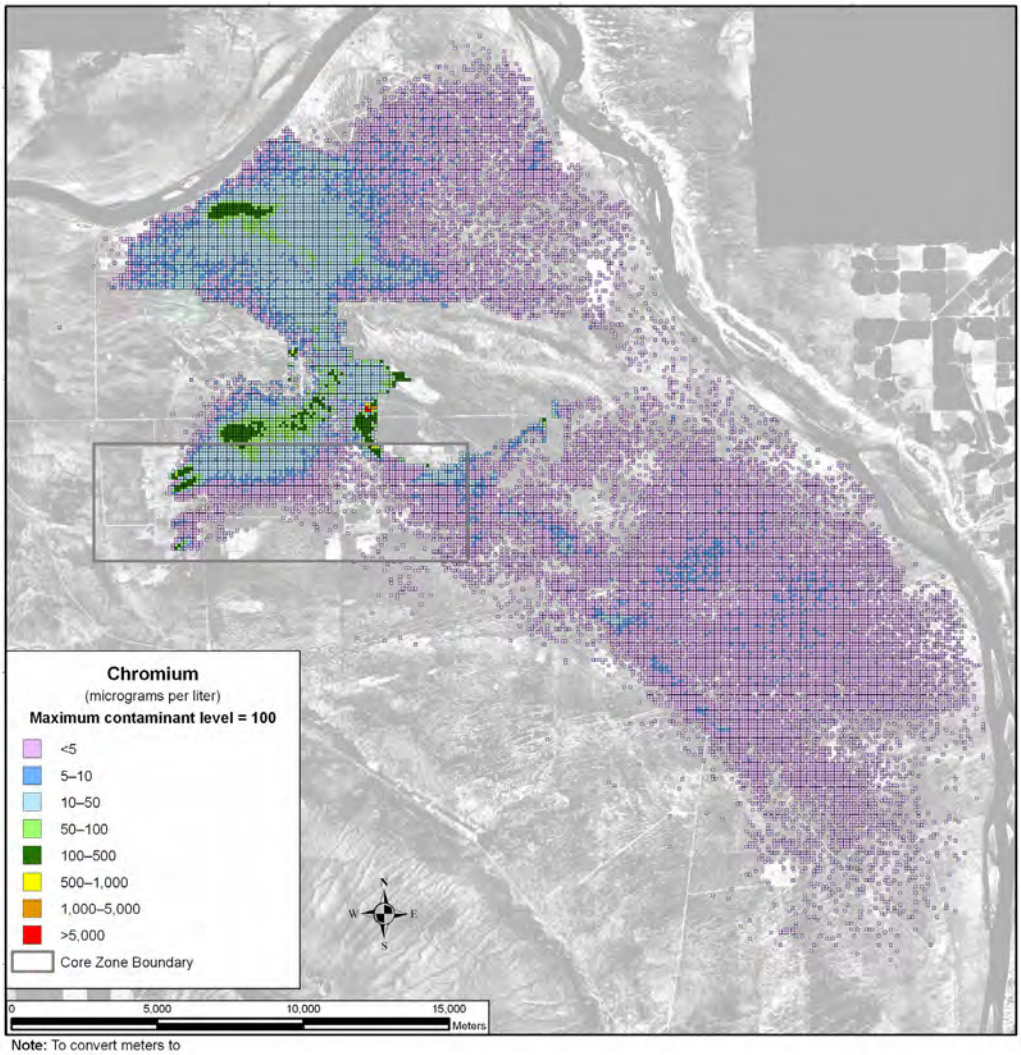
Note: To convert meters to feet, multiply by 3.281

Figure 5–166. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



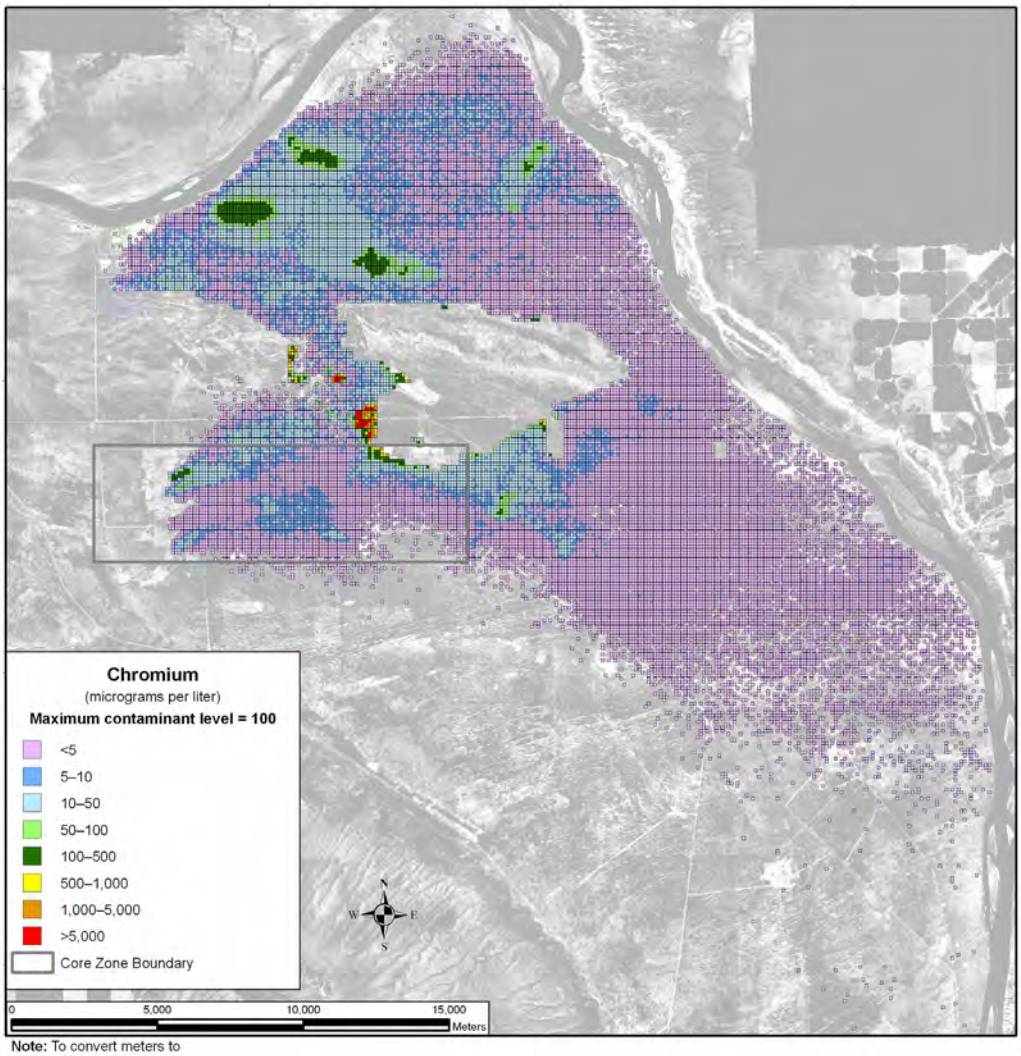
Note: To convert meters to feet, multiply by 3.281

Figure 5–167. Tank Closure Alternative 5 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



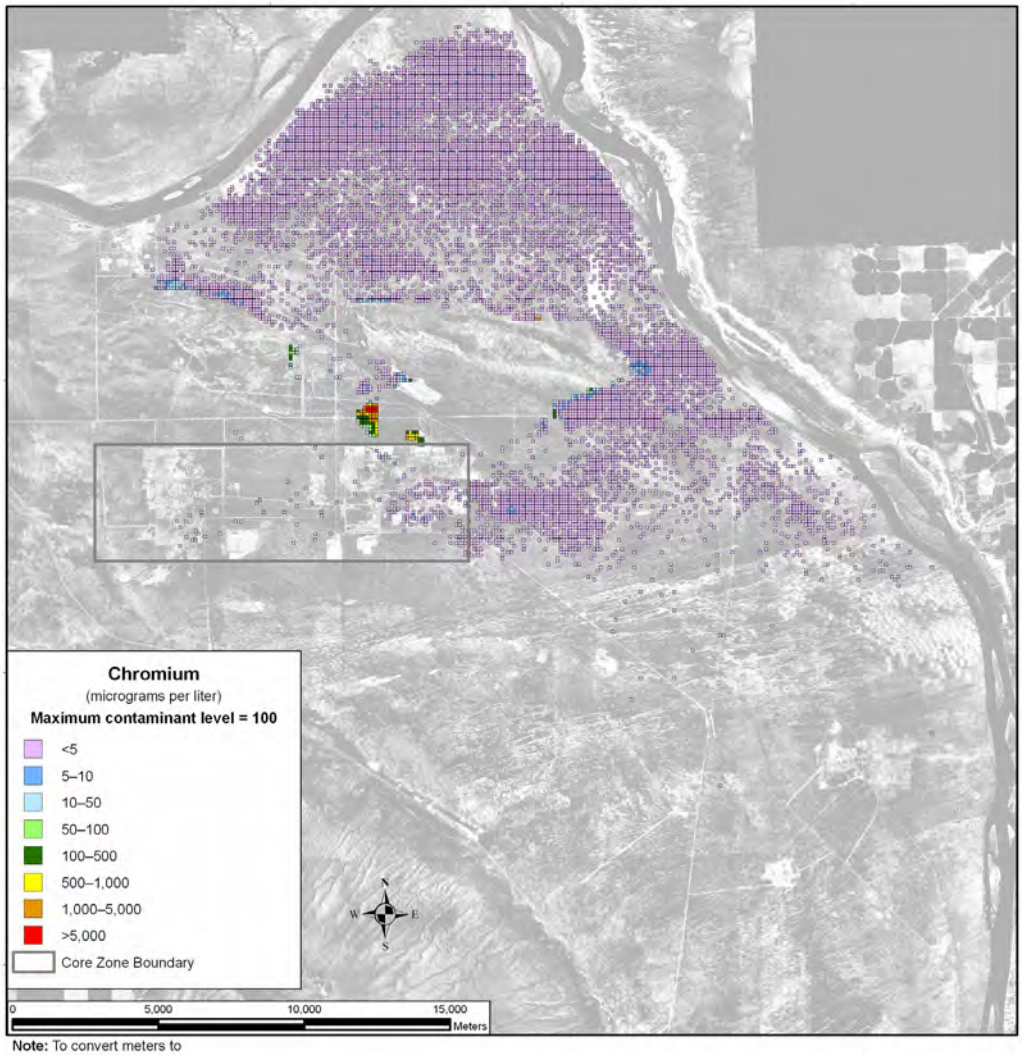
Note: To convert meters to feet, multiply by 3.281

Figure 5–168. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



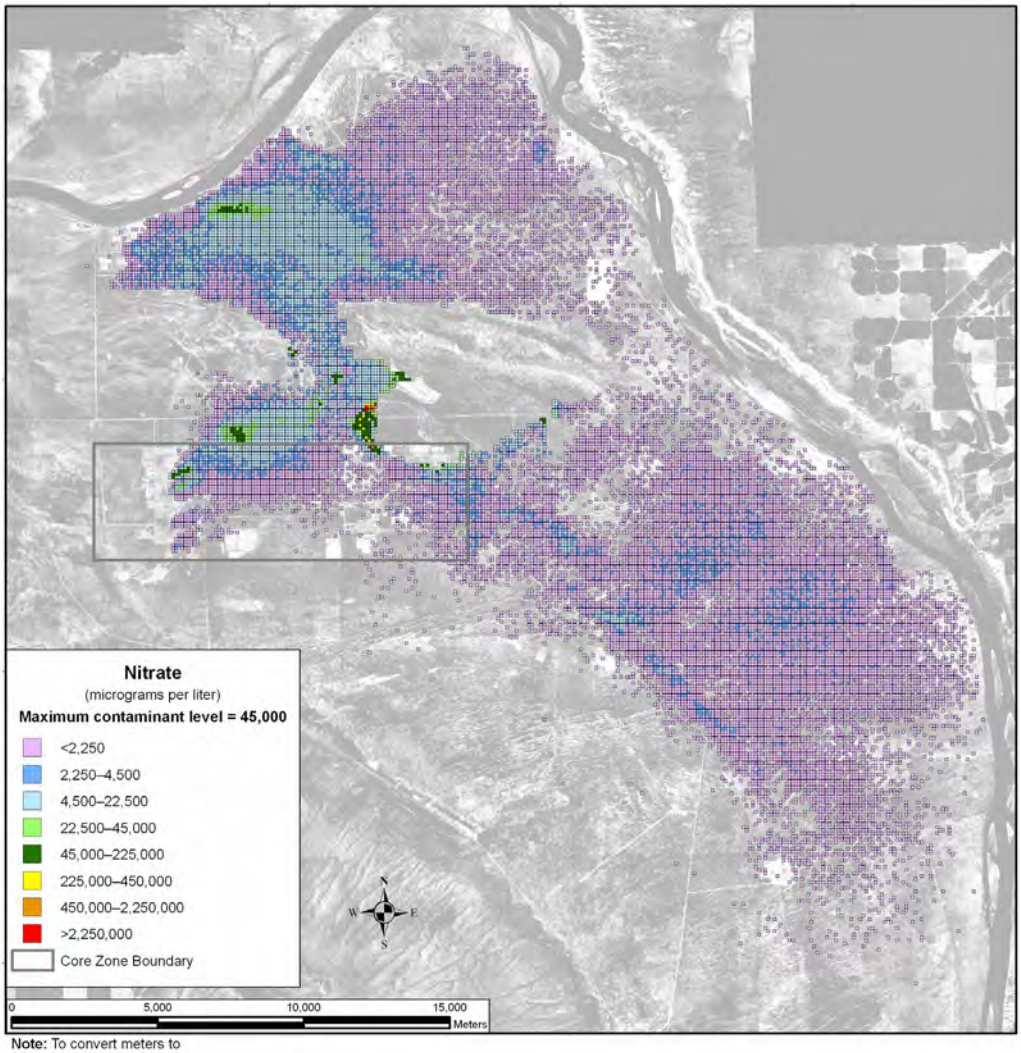
Note: To convert meters to feet, multiply by 3.281

Figure 5–169. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



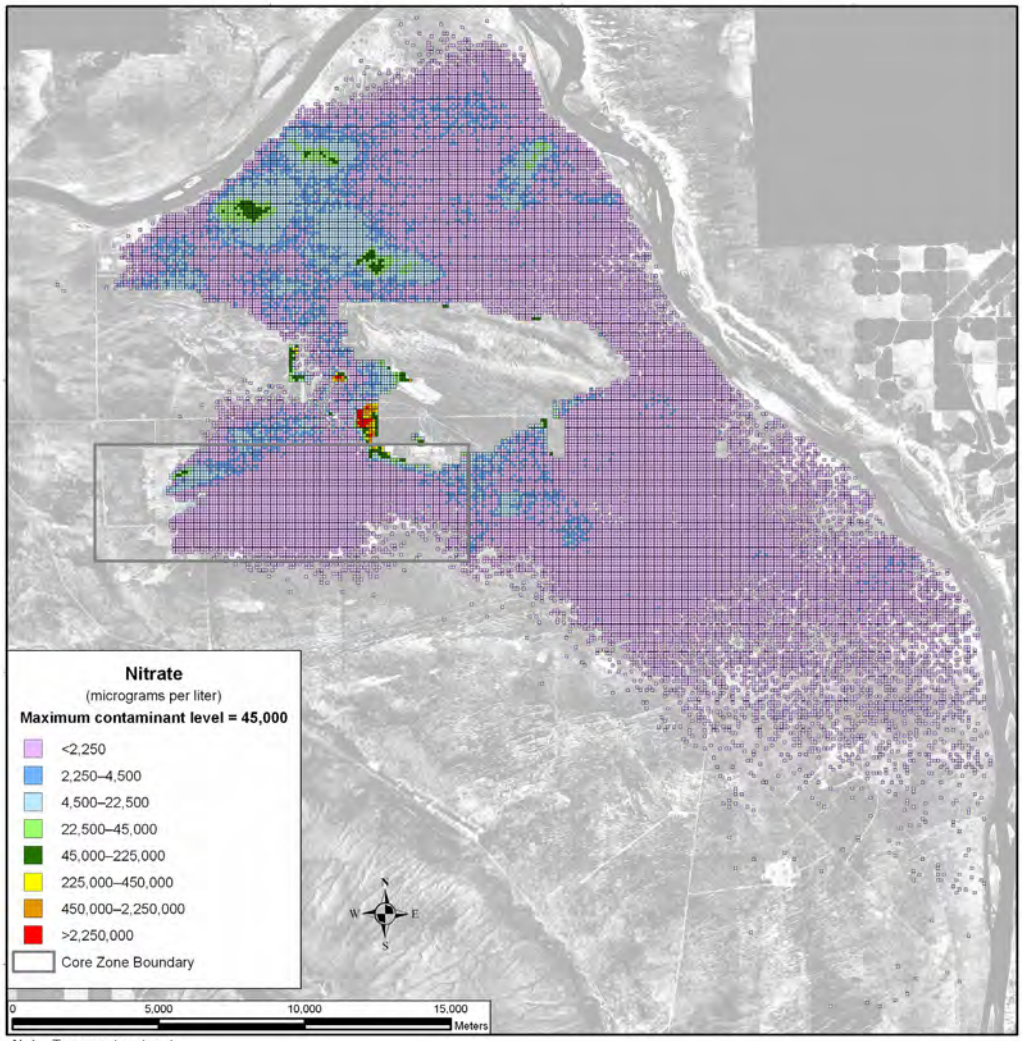
Note: To convert meters to feet, multiply by 3.281

Figure 5–170. Tank Closure Alternative 5 Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



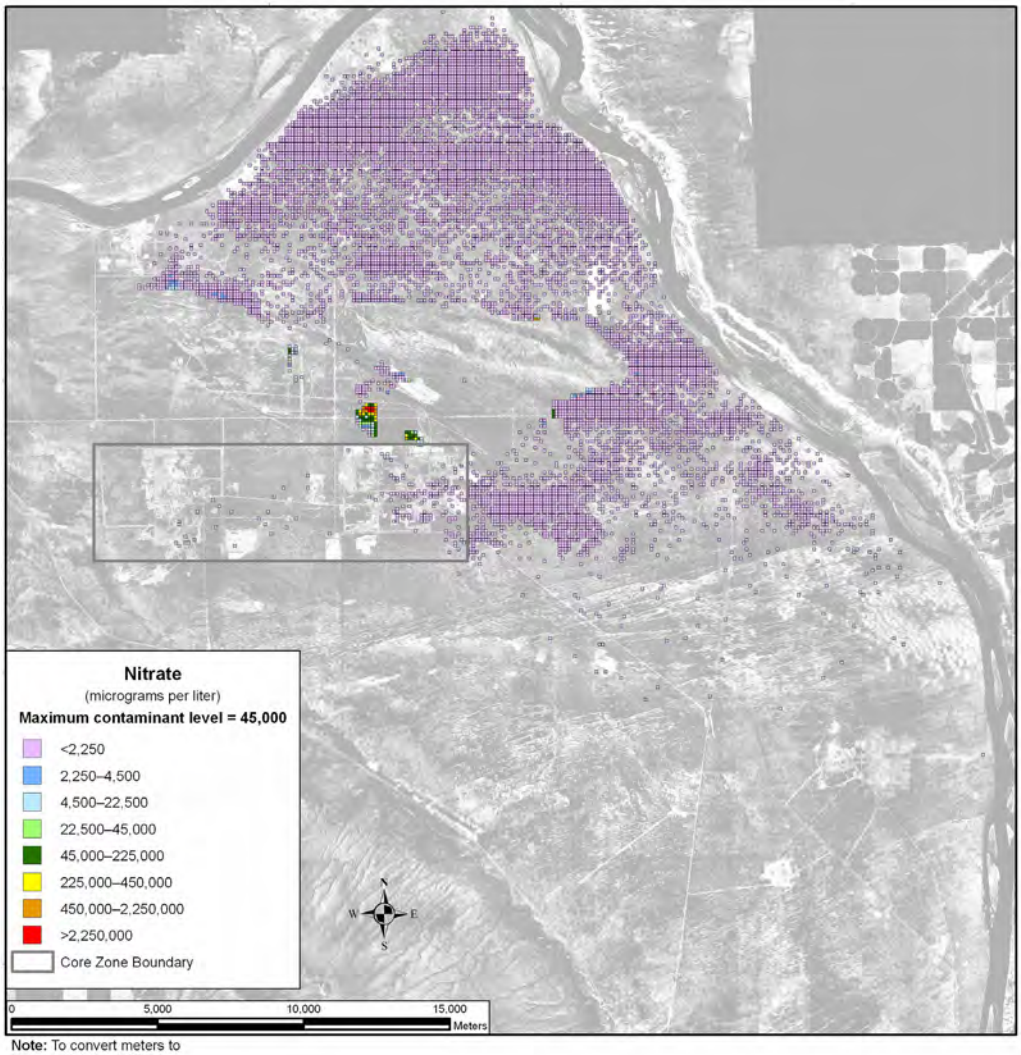
Note: To convert meters to feet, multiply by 3.281

Figure 5–171. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

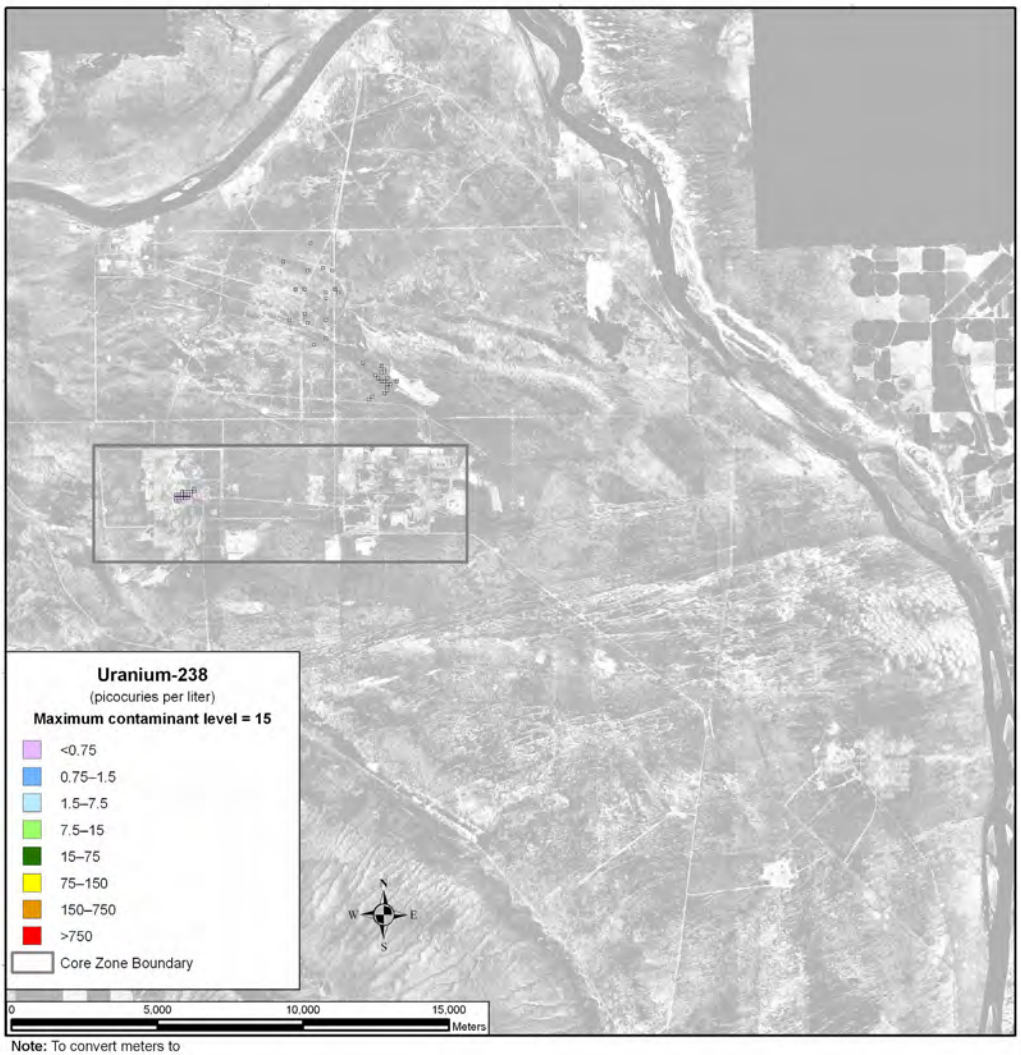
Figure 5–172. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

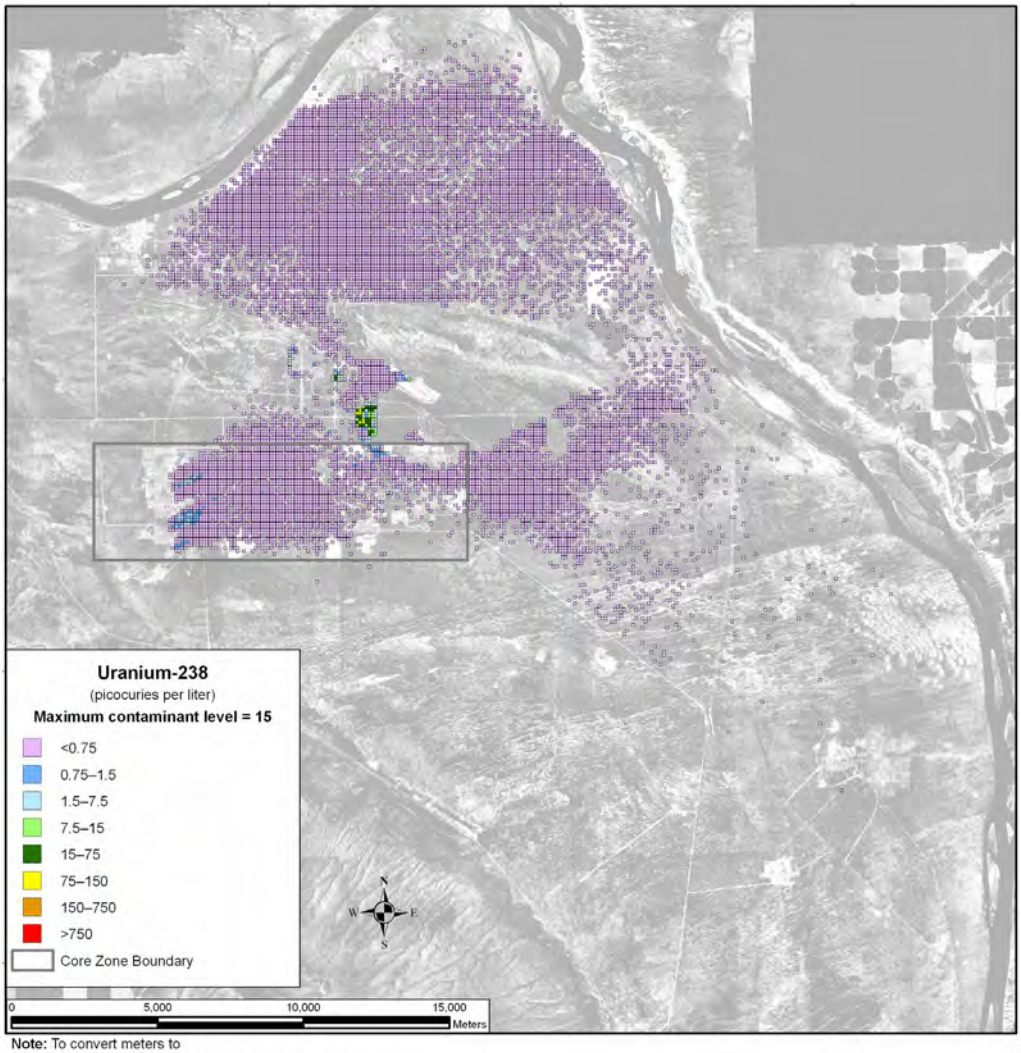
Figure 5–173. Tank Closure Alternative 5 Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium show a different spatial distribution in the analysis over time. These COPCs are not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–174 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140 (see Figure 5–175), the area of the plume has grown, but there are no significant increases in peak concentration. At CY 11,885 (see Figure 5–176), the greatest development of the plume during the analysis period is seen, resulting primarily from the release of other tank farm sources at the A and B Barriers. Figures 5–177 through 5–179 show the corresponding results for total uranium.



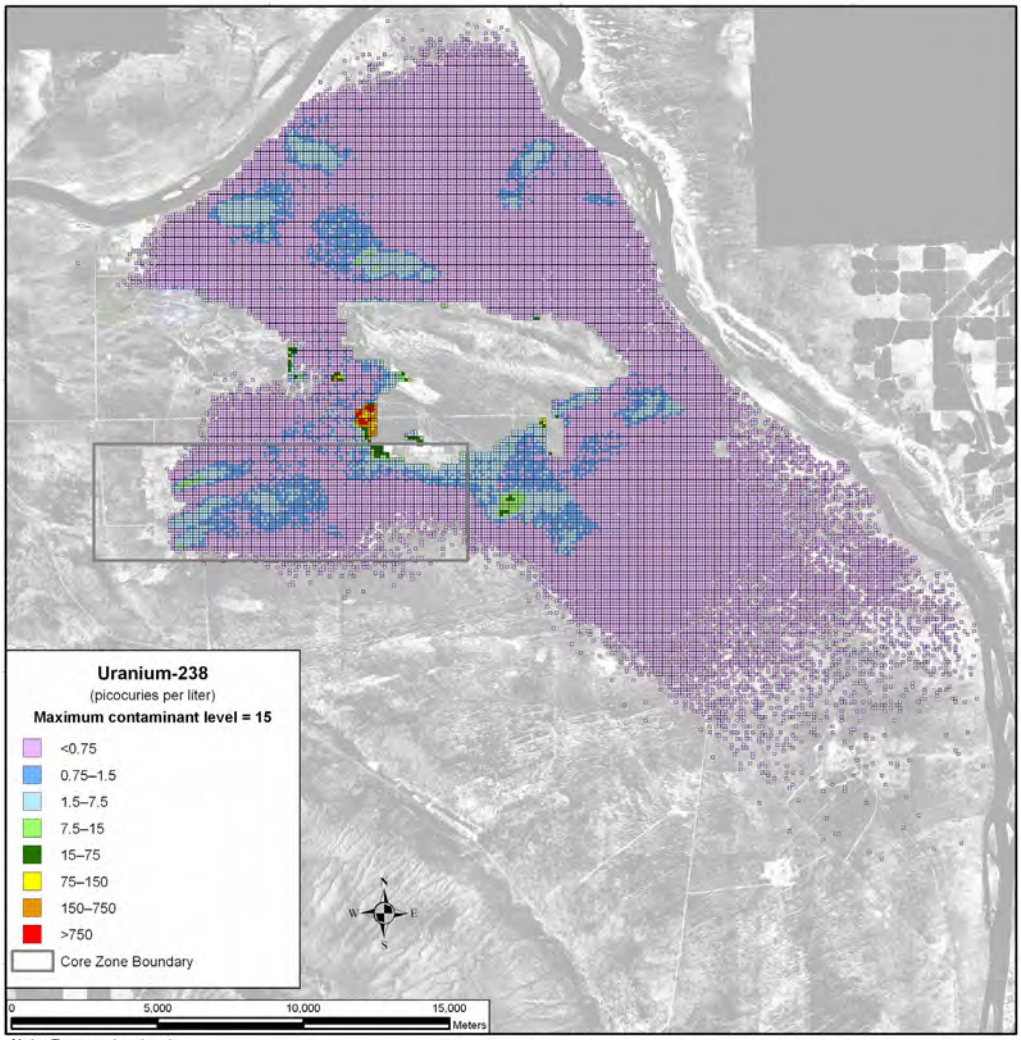
Note: To convert meters to feet, multiply by 3.281

Figure 5–174. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



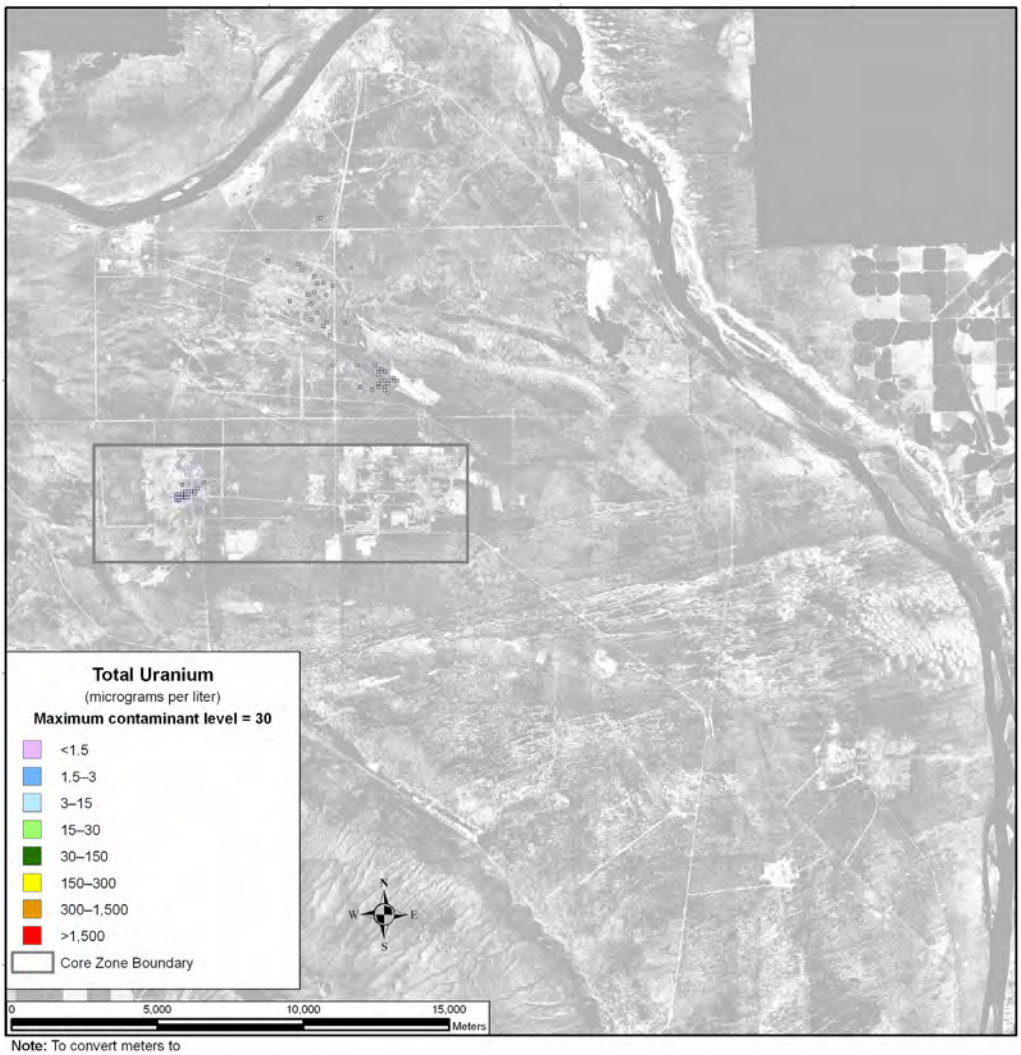
Note: To convert meters to feet, multiply by 3.281

Figure 5–175. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



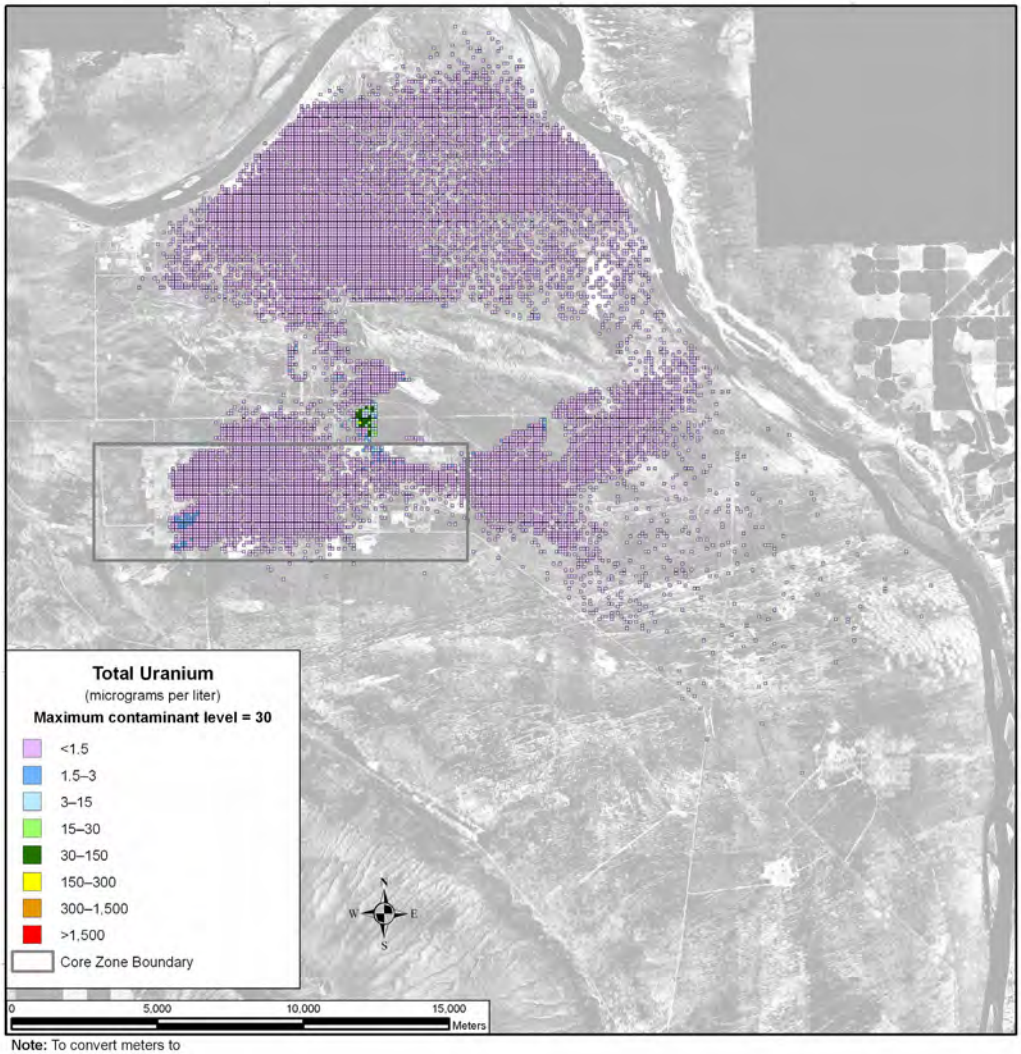
Note: To convert meters to feet, multiply by 3.281

Figure 5–176. Tank Closure Alternative 5 Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–177. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–178. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140

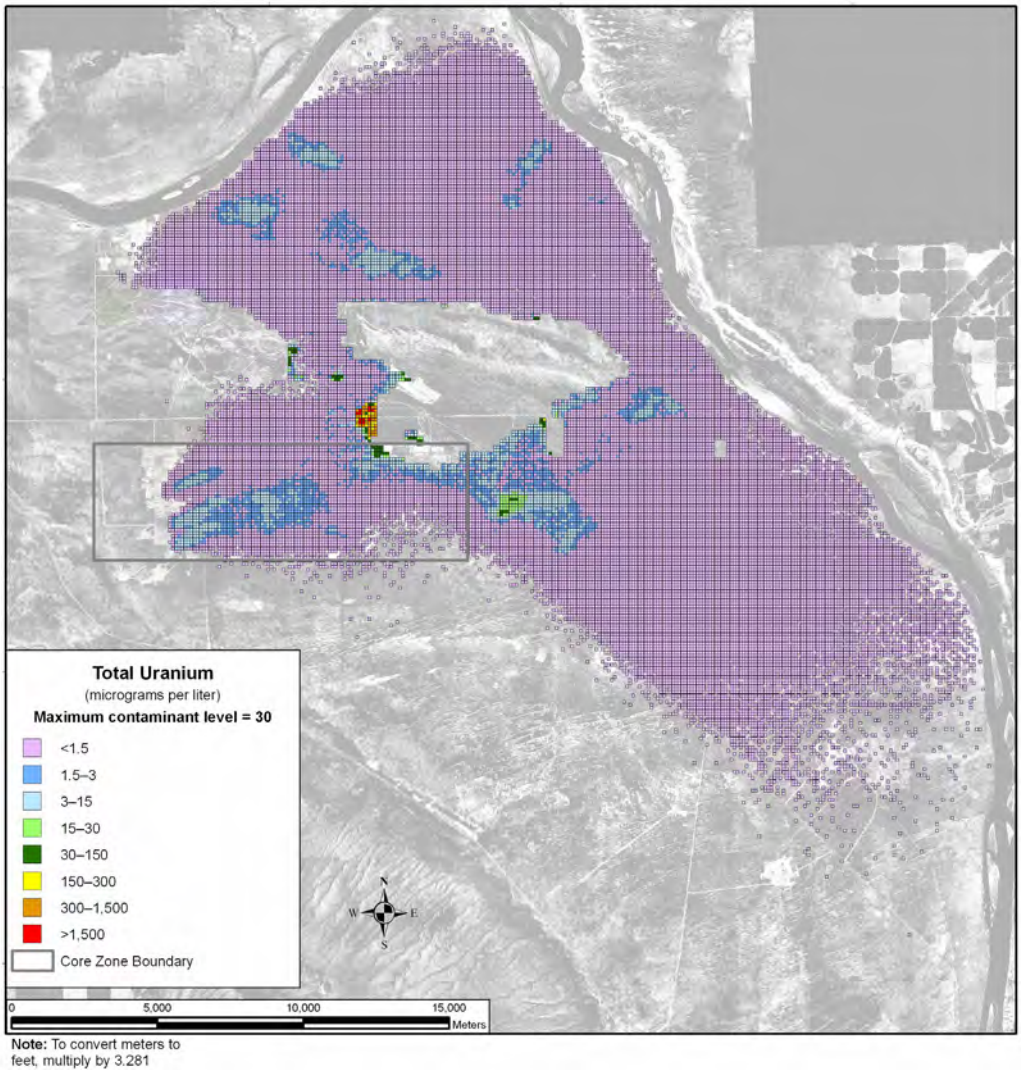


Figure 5–179. Tank Closure Alternative 5 Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figures 5–180 through 5–182 show the area covered by concentrations above the benchmark concentration for iodine-129, technetium-99, and uranium-238. Iodine-129 spikes early in the simulation, covering a peak area of just over 8 square kilometers (3 square miles) around CY 2070. The total area covered by the iodine-129 plume that is above the benchmark concentration drops below 2 square kilometers (0.77 square miles) by CY 3240. The plume then rises to almost 3 square kilometers (1.2 square miles) in CY 5190, after which it declines to less than 2 square kilometers (0.77 square miles) by CY 11,885. Technetium-99 shows a similar, more-gradual trend, peaking at over 4 square kilometers (1.5 square miles) in CY 2135, and decreasing to less than 2 square kilometers (0.77 square miles) in CY 3240. The plume then increases to greater than 10 square kilometers (3.8 square miles) in CY 4540, then declines rapidly to around 2 square kilometers (0.77 square miles), and then it levels off around 1 square kilometer (0.38 square miles) by CY 11,885. Uranium-238 shows a distinctly different pattern, without any area above the benchmark concentration until CY 5840. From CY 5840 until the end of the simulation, areas of uranium-238 concentrations above the benchmark concentration slowly increase, exceeding 1.4 square kilometers (0.54 square miles) at the end of the simulation.

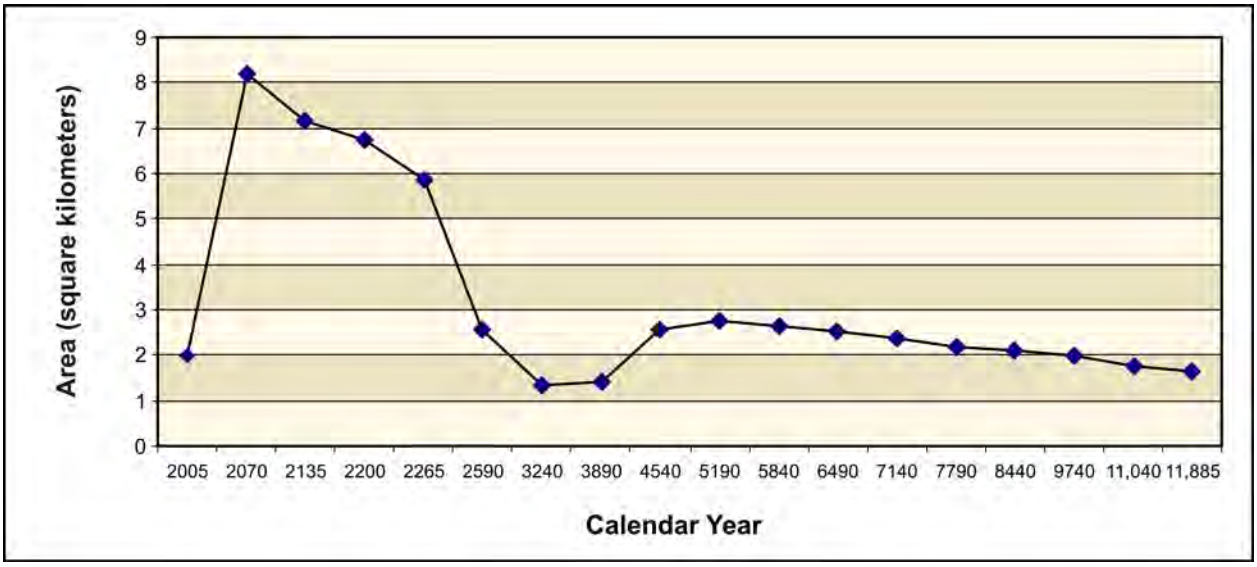


Figure 5–180. Tank Closure Alternative 5 Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

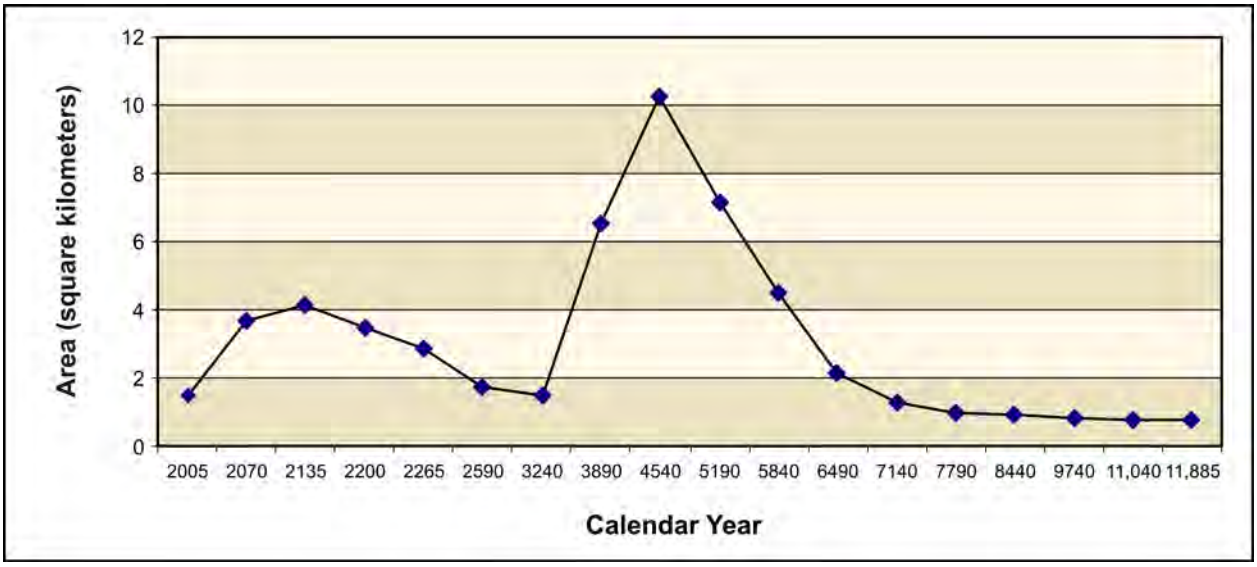


Figure 5–181. Tank Closure Alternative 5 Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

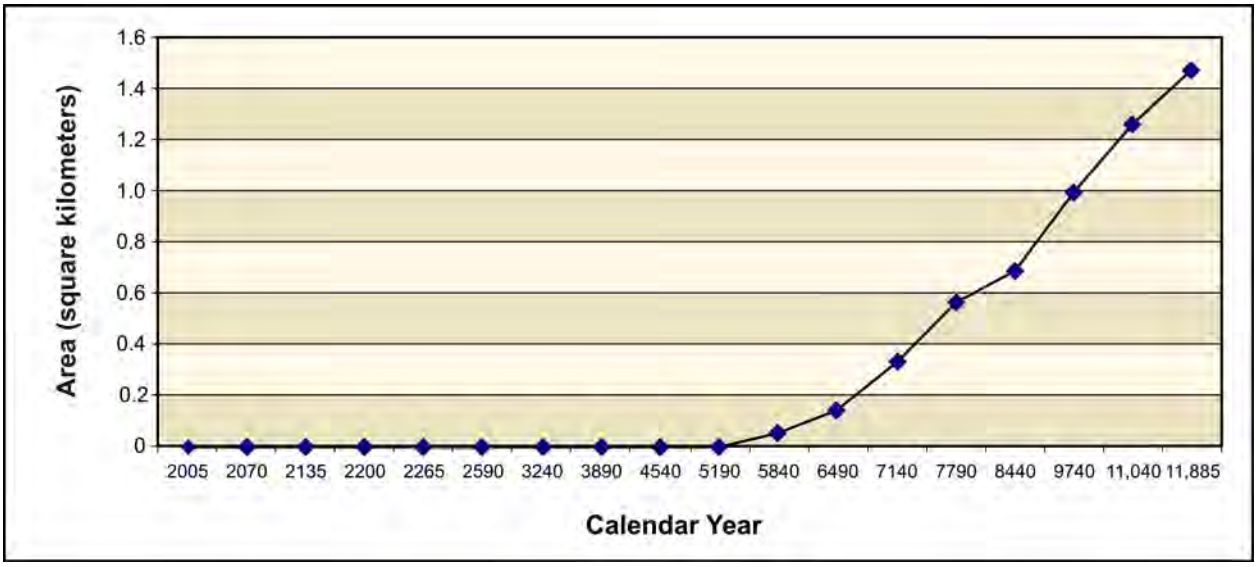


Figure 5–182. Tank Closure Alternative 5 Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.8.6 Summary of Impacts

Under Tank Closure Alternative 5, in general, the inventory remaining in the tank farms, available for release to the environment at the start of the post–administrative control period, is the predominant contributor in the analysis. Discharges to cribs and trenches (ditches) and past leaks are a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary exceed benchmark standards by two to three orders of magnitude during most of the period of analysis. Concentrations at the Columbia River are about two orders of magnitude smaller. The intensities and areas of these groundwater plumes peak around CY 4540.

For tritium, concentrations at the Core Zone Boundary exceed the benchmark by about three orders of magnitude during the first 100 years of the period of analysis. Concentrations at the Columbia River approach the benchmark during this time. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium. After CY 2100, tritium impacts are essentially negligible.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species exceed the benchmark concentration at the Core Zone Boundary beyond CY 8200, and approach the benchmark concentration at the Columbia River after CY 11,885. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

5.1.1.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure, Base and Option Cases

This section describes the groundwater analysis results for Tank Closure Alternative 6A, including long-term groundwater impacts of sources within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

Under Tank Closure Alternative 6A, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier.

Under Tank Closure Alternative 6A, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed.

5.1.1.9.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 6A are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 6A, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 6A that are presented in this section would be common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2250. During this period, 99.9 percent of the waste would be retrieved from the tanks and all tank farms would be clean-closed.

- The post–administrative control period was assumed to start in CY 2251 and continue through the 10,000-year period of analysis until CY 11,940.

5.1.1.9.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 6A. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 6A is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 6A were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers, although their contribution to risk and hazard are not dominant during the year of peak risk or hazard. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-11}, which is negligible for

purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 6A.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.9.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 6A in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–183 through 5–194). Two subtotals are plotted representing releases from cribs and trenches (ditches) and past leaks. Amounts released from other tank farm sources are negligible for the purposes of this discussion. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–183 shows the estimated release to the vadose zone for the radiological risk drivers under the Base Case, which would include use of a modified RCRA Subtitle C barrier, and Figure 5–184, the chemical hazard drivers. The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are from past leaks. This suggests that past leaks, which were released during the past-practice period, as well as the cribs and trenches (ditches), are both important impact drivers under Tank Closure Alternative 6A, Base Case.

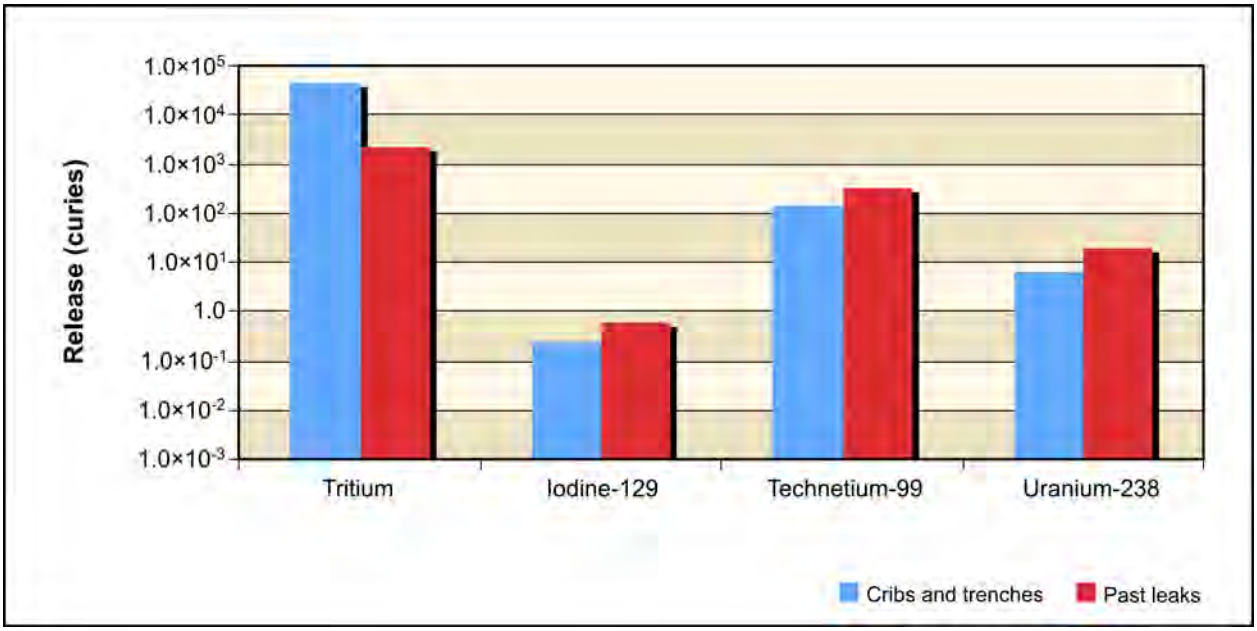


Figure 5–183. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

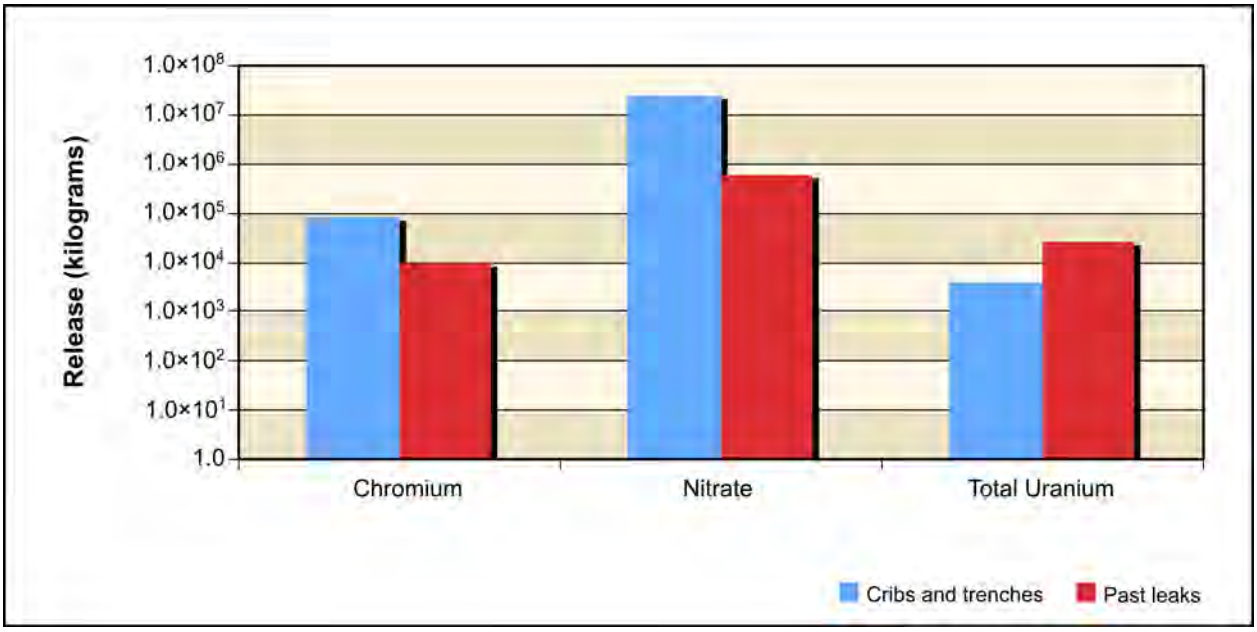


Figure 5–184. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–185 shows the estimated release to the vadose zone for the radiological risk drivers under the Option Case, which would include clean closure of cribs and trenches (ditches), and Figure 5–186, the chemical hazard drivers. The predominant sources for tritium, the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), uranium-238, and total uranium are similar to those in the vadose zone under the Base Case.

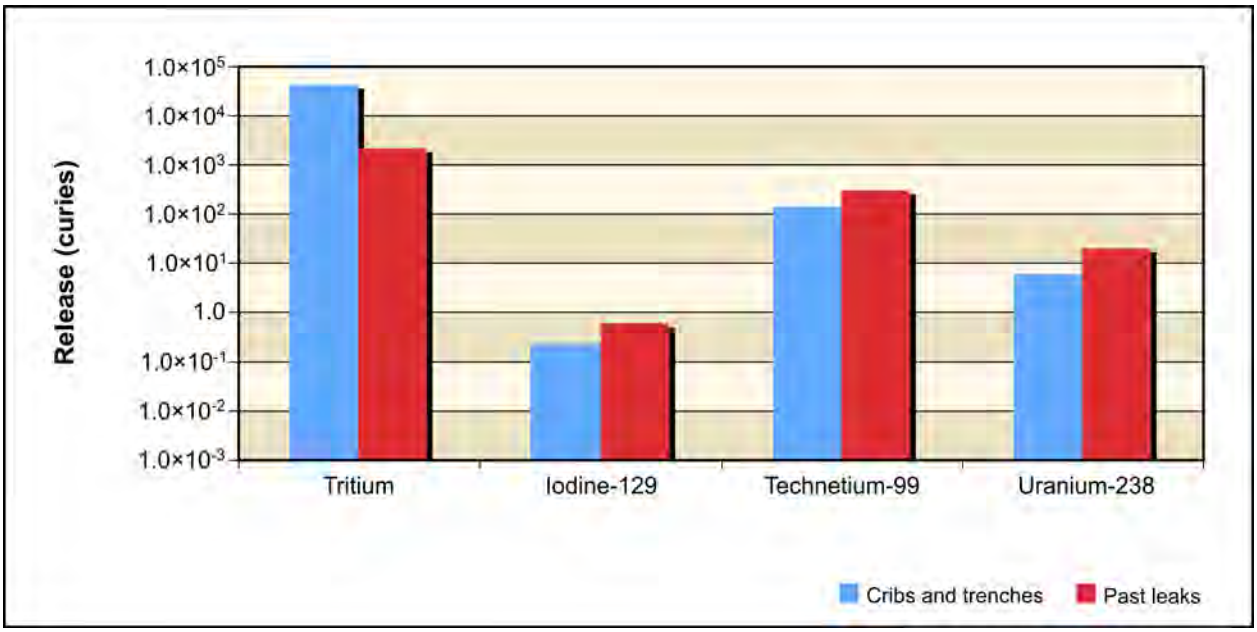


Figure 5–185. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

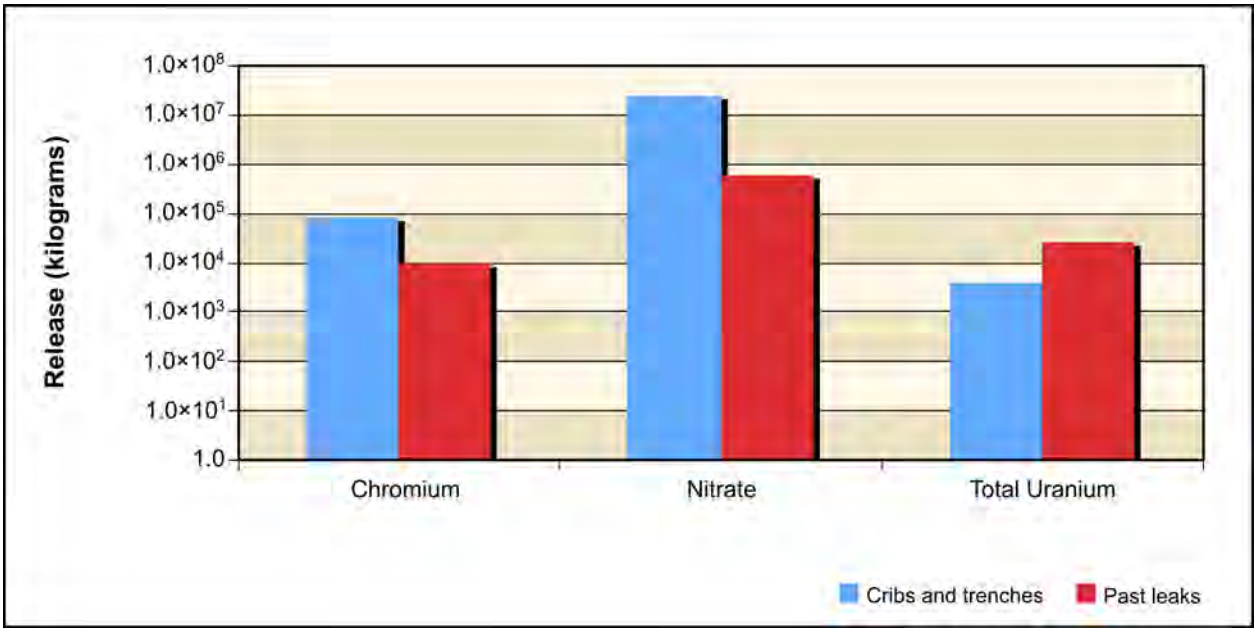


Figure 5–186. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

Figure 5–187 shows the estimated release to groundwater for the radiological risk drivers under the Base Case and Figure 5–188, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

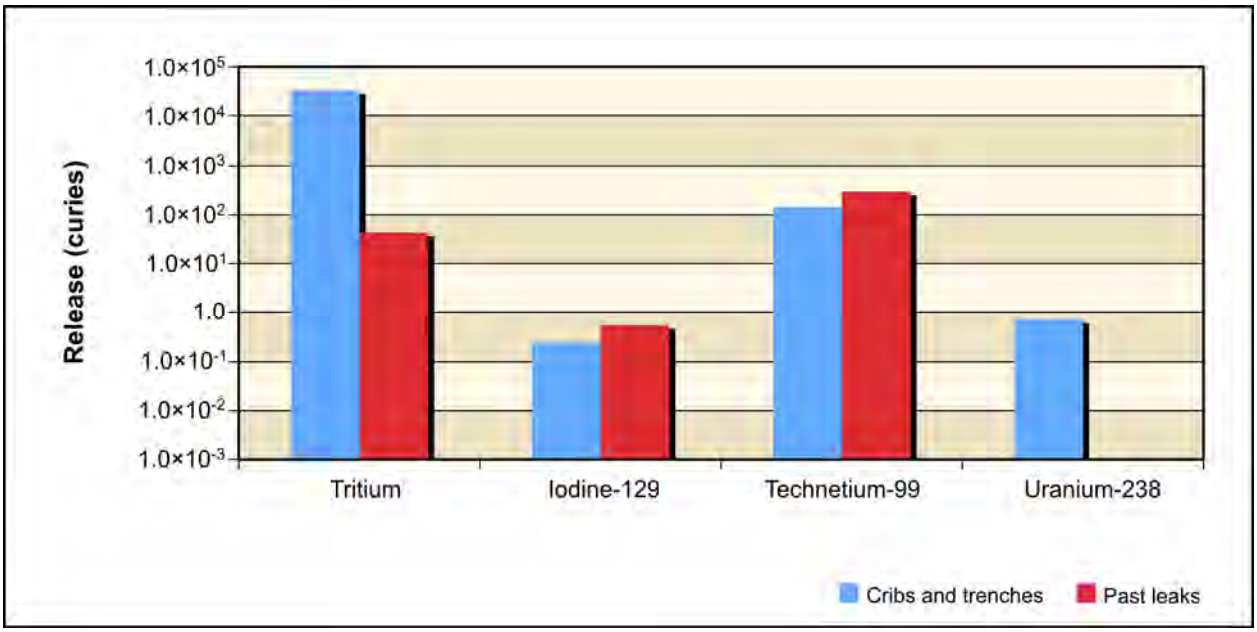


Figure 5–187. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

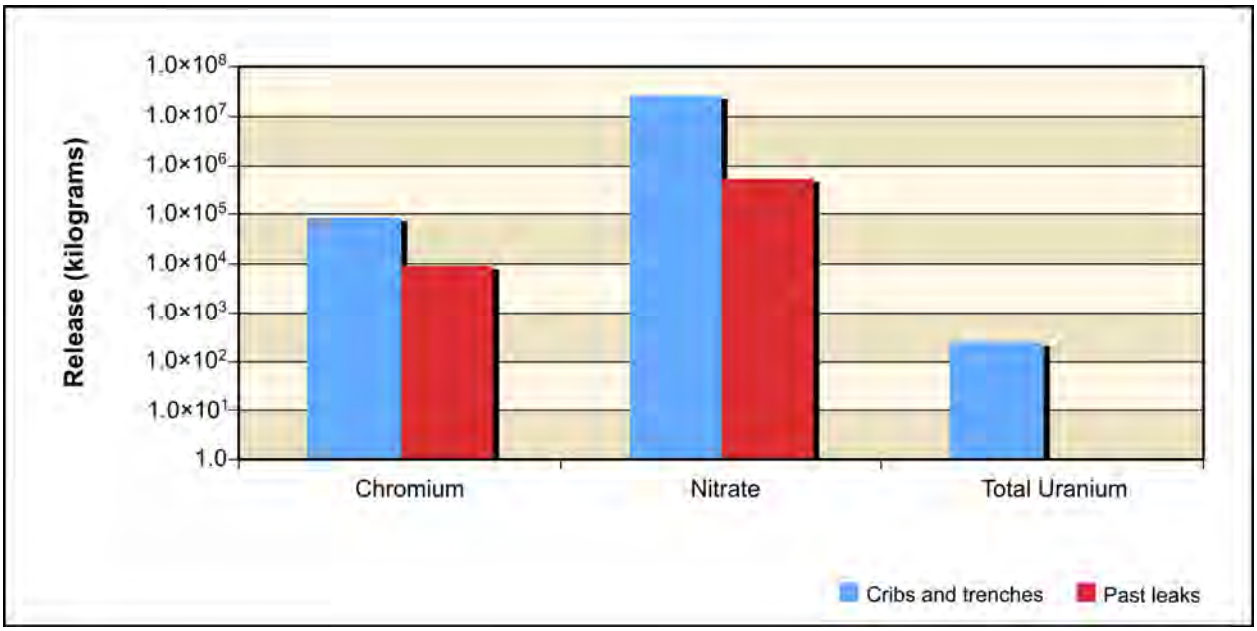


Figure 5–188. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of retardation. The amount of attenuation depends on the rate of moisture movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), about 10 percent of the total inventory reached groundwater during the period of analysis; for past leaks, essentially none of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 74 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–189 shows the estimated release to groundwater for the radiological risk drivers under the Option Case and Figure 5–190, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is about 7 percent less than the amount released to the vadose zone.

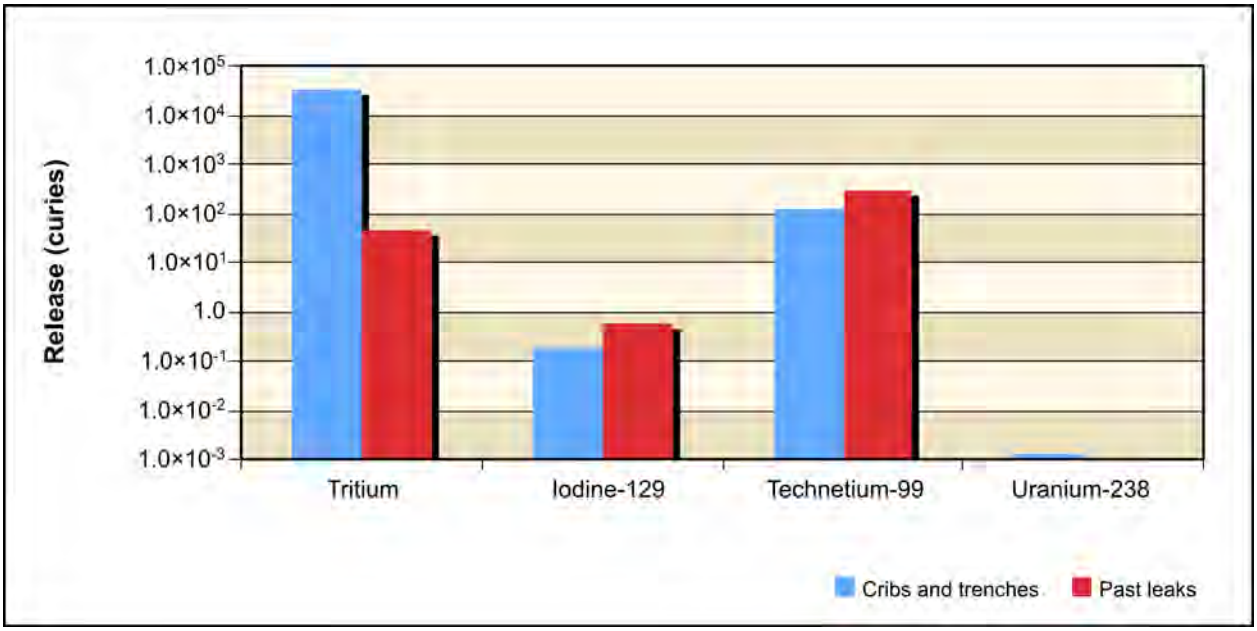


Figure 5–189. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

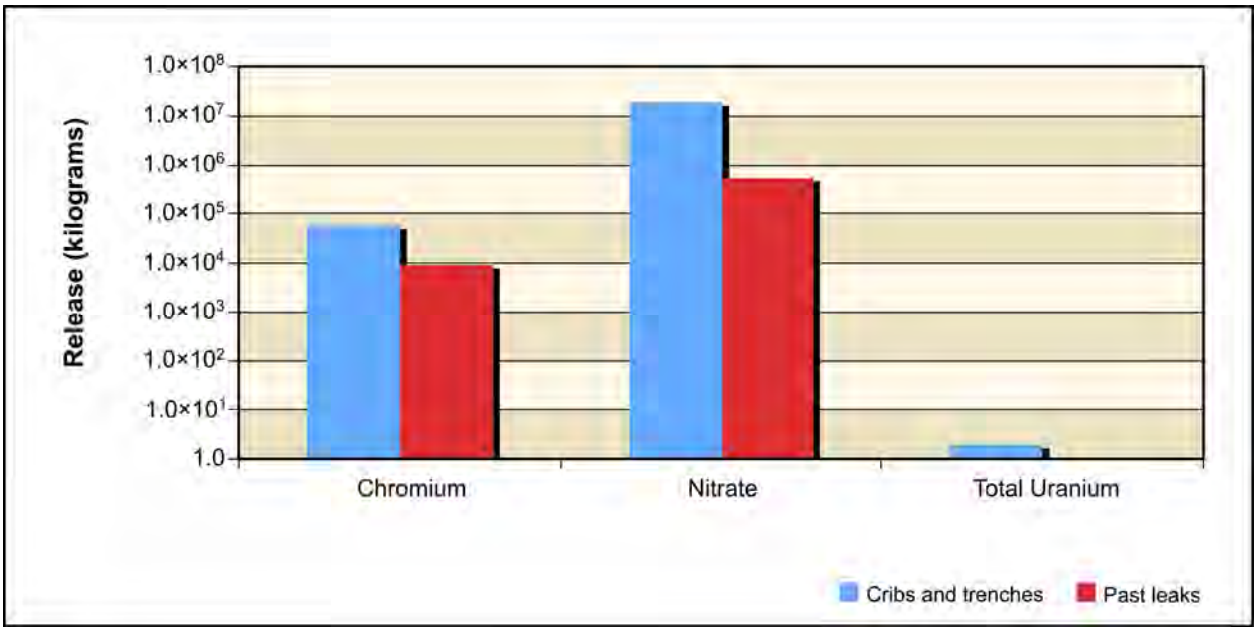


Figure 5–190. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), essentially none of the total inventory reached groundwater during the period of analysis. For past leaks, essentially none of the total inventory reached groundwater during the period of analysis.

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 85 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would decrease over time because the long travel times in the vadose zone for these COPCs allow much of what was released to be collected and treated when the cribs and trenches (ditches) are removed and their deep plumes remediated.

Figure 5–191 shows the estimated release to the Columbia River for the radiological risk drivers under the Base Case and Figure 5–192, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

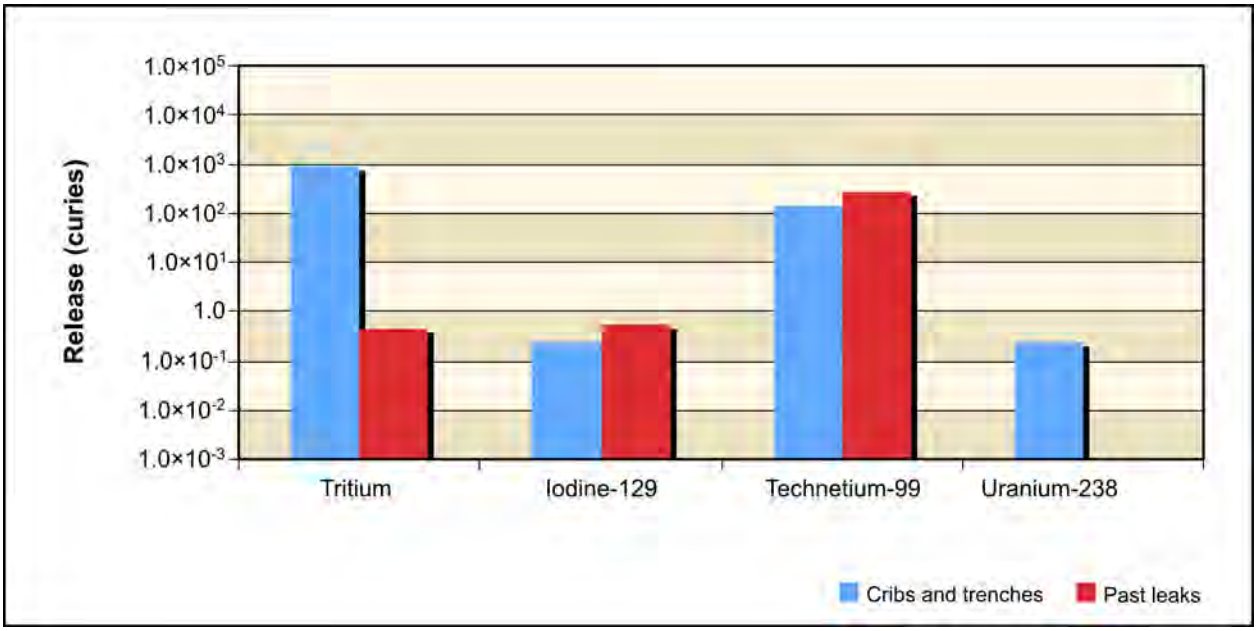


Figure 5–191. Tank Closure Alternative 6A, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

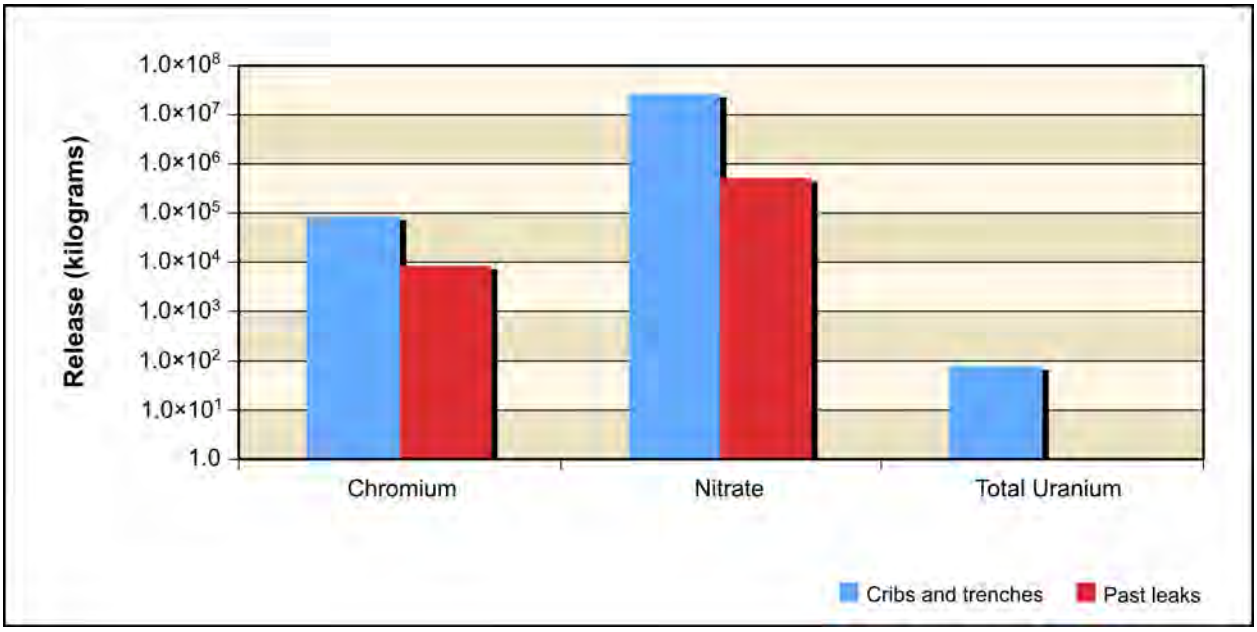


Figure 5–192. Tank Closure Alternative 6A, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. For cribs and trenches (ditches), about 40 percent of the amount released to groundwater during the period of analysis reached the Columbia River.

For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

Figure 5–193 shows the estimated release to the Columbia River for the radiological risk drivers under the Option Case and Figure 5–194, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. For uranium-238 and total uranium, the amount released to the Columbia River from the groundwater is effectively zero, as essentially no uranium reached the groundwater from the vadose zone in the analysis. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River in the analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River in the analysis. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium would not impact the Columbia River, as much of what was released would be collected when the cribs and trenches (ditches) are removed and their deep plumes remediated.

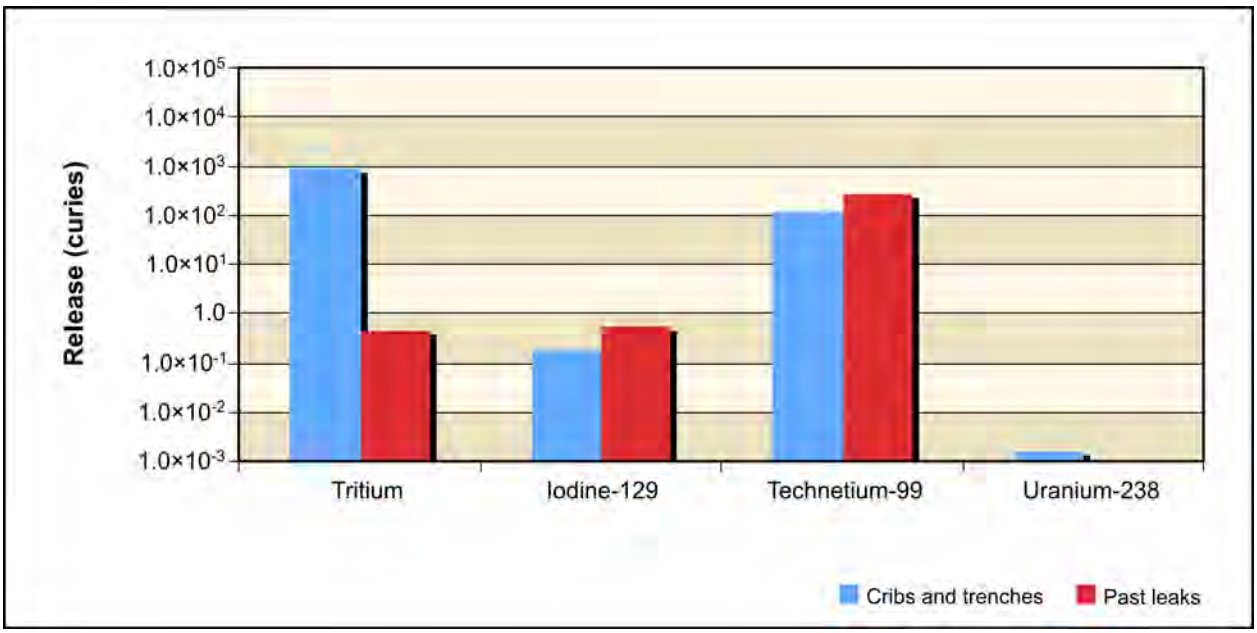


Figure 5–193. Tank Closure Alternative 6A, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

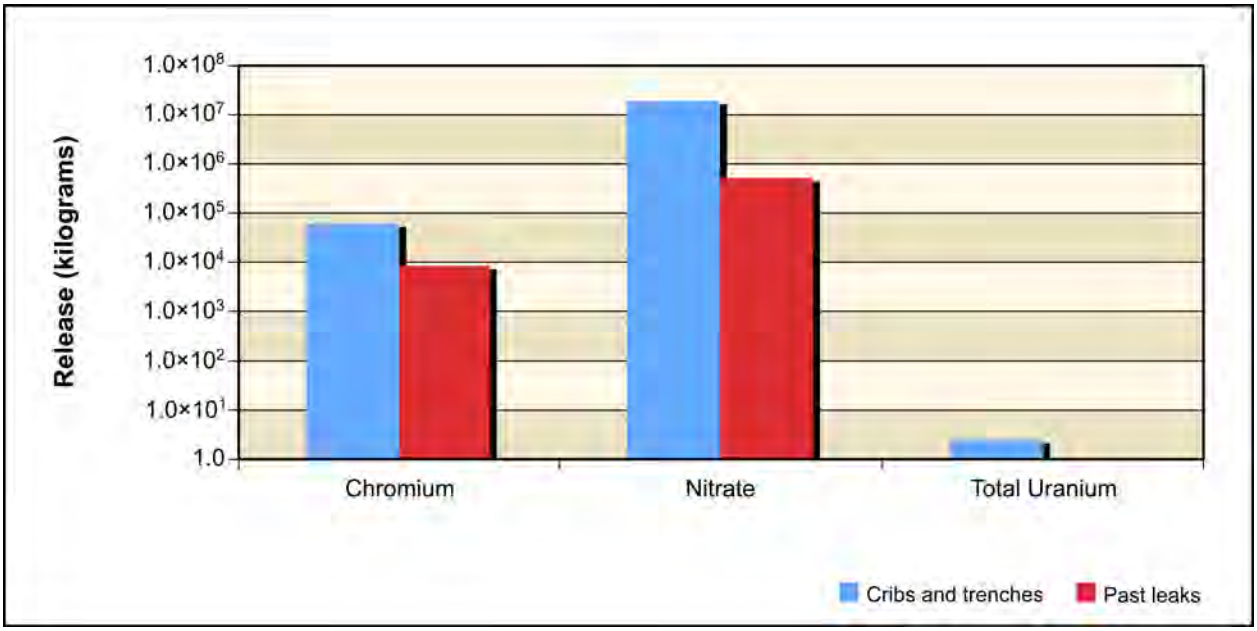


Figure 5–194. Tank Closure Alternative 6A, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

5.1.1.9.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 6A impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Tables 5–6 and 5–7 and Figures 5–195 through 5–208). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–6 and 5–7 list the maximum concentrations under the Base and Option Cases for the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–195 shows the concentration versus time for tritium under the Base Case. Releases from cribs and trenches (ditches) causes the groundwater concentrations at the Core Zone Boundary to exceed the benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration.

Table 5–6. Tank Closure Alternative 6A, Base Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	26	5,000	51	7,310	13	6,000	178	20,000
	(2052)	(2054)	(2050)	(2055)	(2052)	(2054)	(2050)	
Technetium-99	**1,350**	**29,100**	**2,680**	**15,200**	150	**24,700**	169	900
	(2056)	(2050)	(2050)	(2051)	(2064)	(2050)	(2515)	
Iodine-129	**3**	**41**	**5**	**31**	0.3	**31**	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2579)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**34**	0	13	0	10	0	15
	(1940)	(11,742)	(2166)	(11,780)	(1940)	(11,758)	(11,844)	
Chemical in micrograms per liter								
Chromium	8	**3,180**	**289**	**761**	10	**1,660**	33	100
	(2050)	(2050)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	475	**1,540,000**	8,550	**133,000**	667	**1,010,000**	8,410	45,000
	(2051)	(2050)	(2050)	(2054)	(2054)	(2050)	(2450)	
Total uranium	0	10	0	4	0	7	0	30
	(2160)	(11,678)	(2166)	(11,755)	(2167)	(11,678)	(11,508)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

Table 5–7. Tank Closure Alternative 6A, Option Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	26	5,140	51	5,190	13	6,990	170	20,000
	(2052)	(2050)	(2050)	(2050)	(2052)	(2050)	(2057)	
Technetium-99	**1,350**	**25,000**	**2,680**	**15,200**	150	**21,000**	181	900
	(2056)	(2055)	(2050)	(2051)	(2064)	(2056)	(2502)	
Iodine-129	**3**	**45**	**5**	**31**	0.3	**35**	0.3	1
	(2053)	(2057)	(2050)	(2050)	(2070)	(2057)	(2308)	
Chemical in micrograms per liter								
Chromium	8	**3,790**	**289**	**772**	10	**1,660**	29	100
	(2050)	(2088)	(2050)	(2051)	(2050)	(2051)	(2256)	
Nitrate	475	**1,670,000**	8,550	**154,000**	667	**1,180,000**	7,930	45,000
	(2051)	(2056)	(2050)	(2102)	(2054)	(2056)	(2460)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

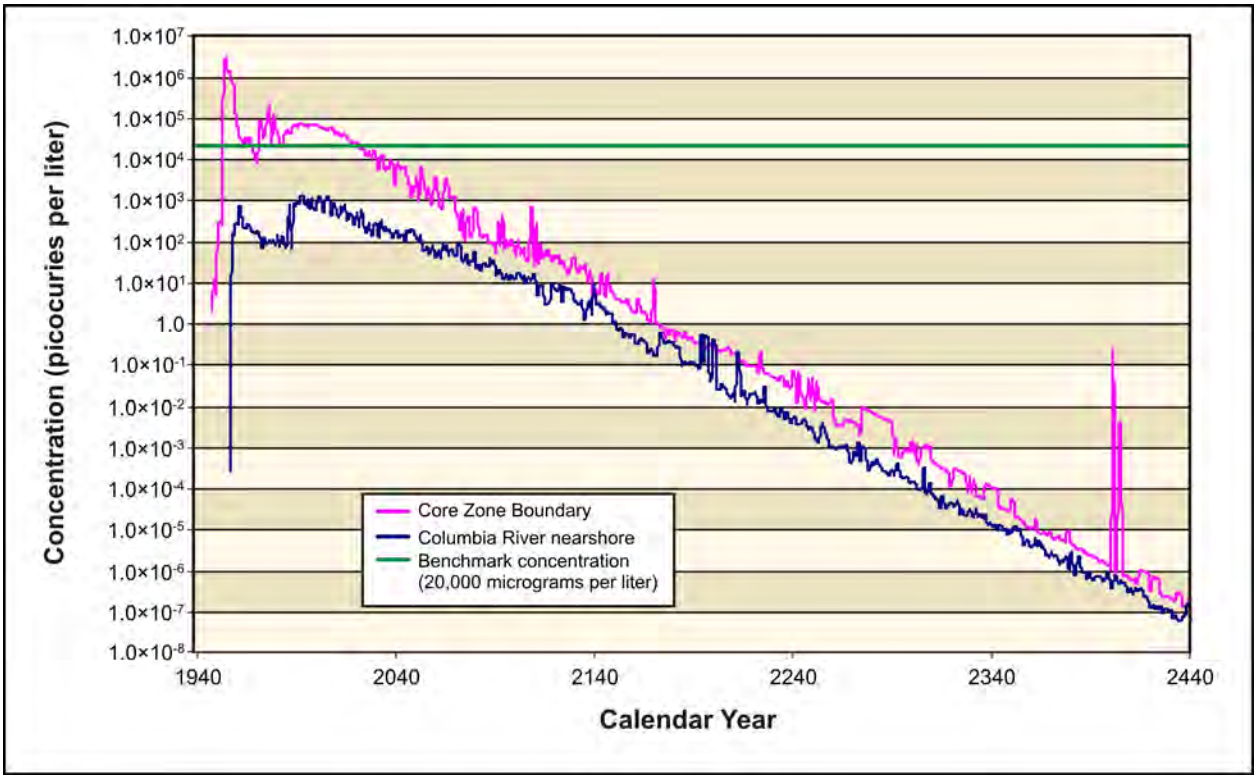


Figure 5–195. Tank Closure Alternative 6A, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

The concentration versus time for tritium under the Option Case is essentially identical to that of the Base Case (see Figure 5–196).

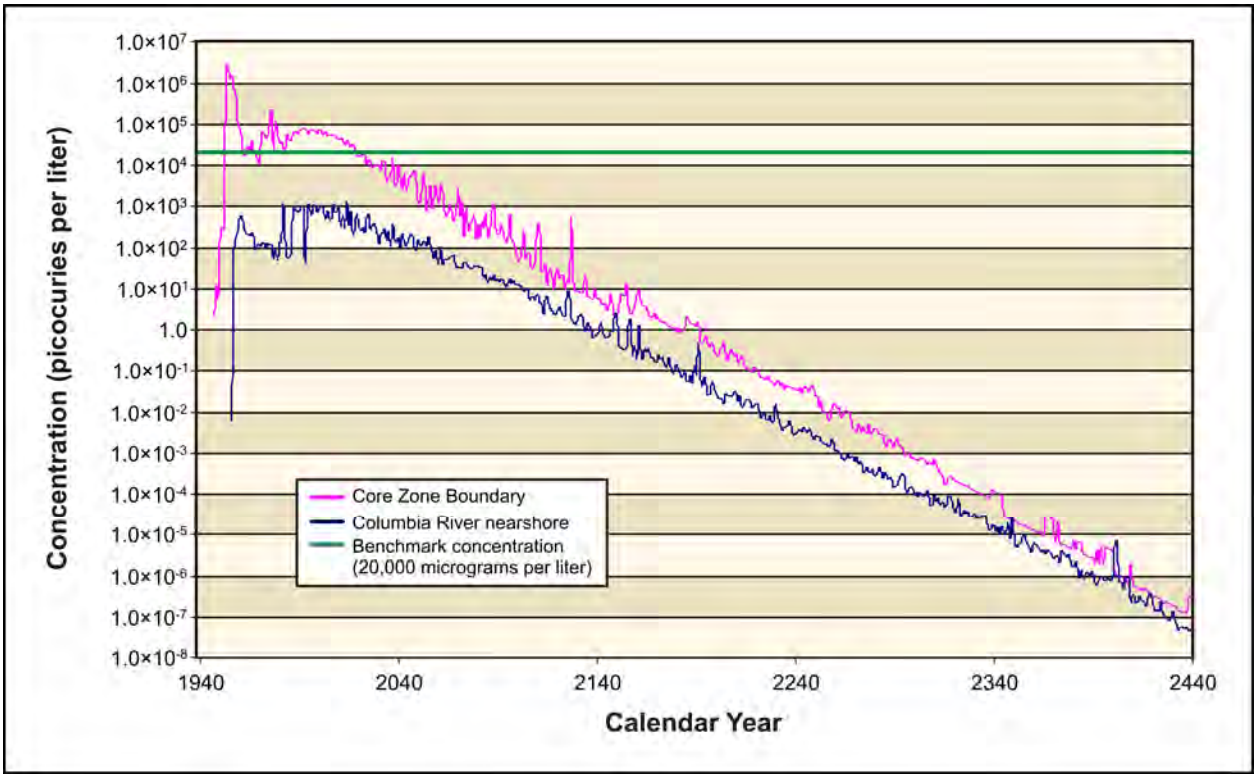


Figure 5–196. Tank Closure Alternative 6A, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

Figures 5–197 through 5–200 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Base Case. All of the conservative tracers show similar patterns. Releases from cribs and trenches (ditches) cause groundwater concentrations in the Core Zone Boundary to exceed benchmark concentrations by about two orders of magnitude during the early part of the period of analysis in CY 1956. The concentrations in the Columbia River nearshore never met or exceeded the benchmark but came to within about one-half to one order of magnitude.

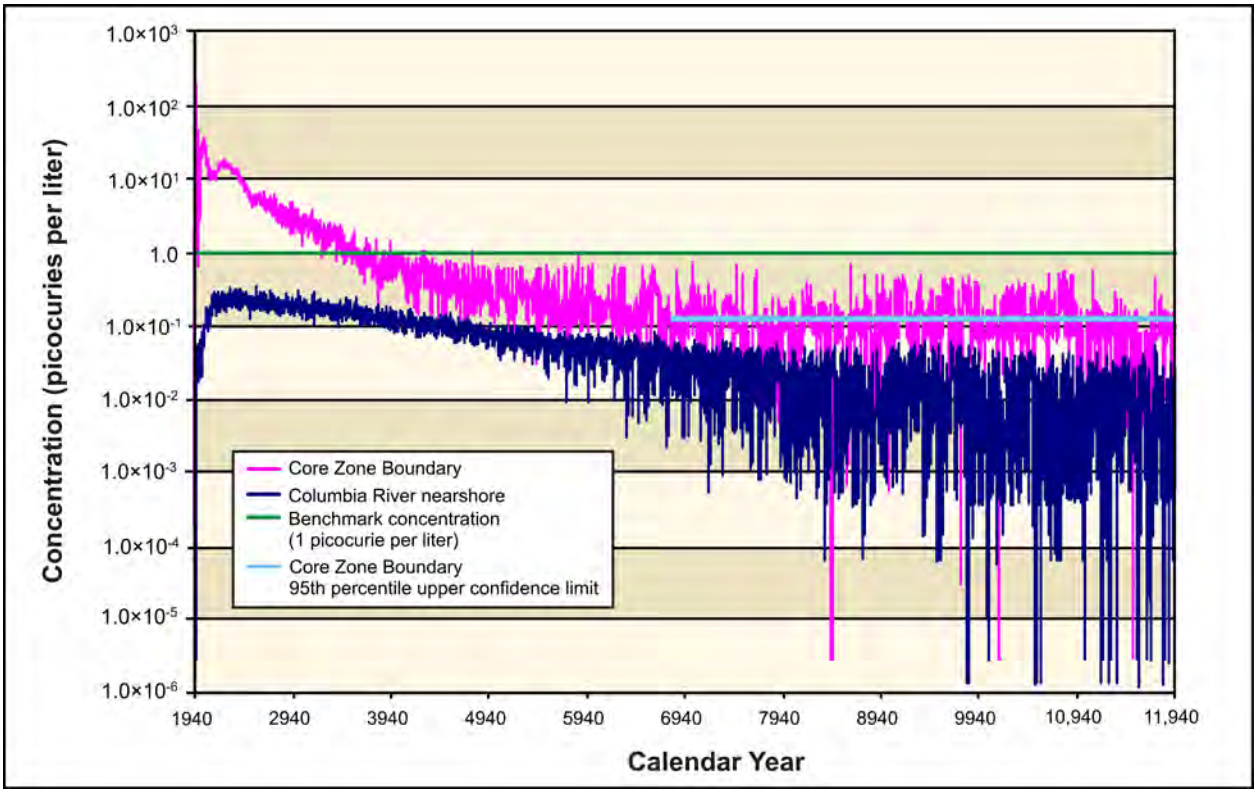


Figure 5–197. Tank Closure Alternative 6A, Base Case, Iodine-129 Concentration Versus Time

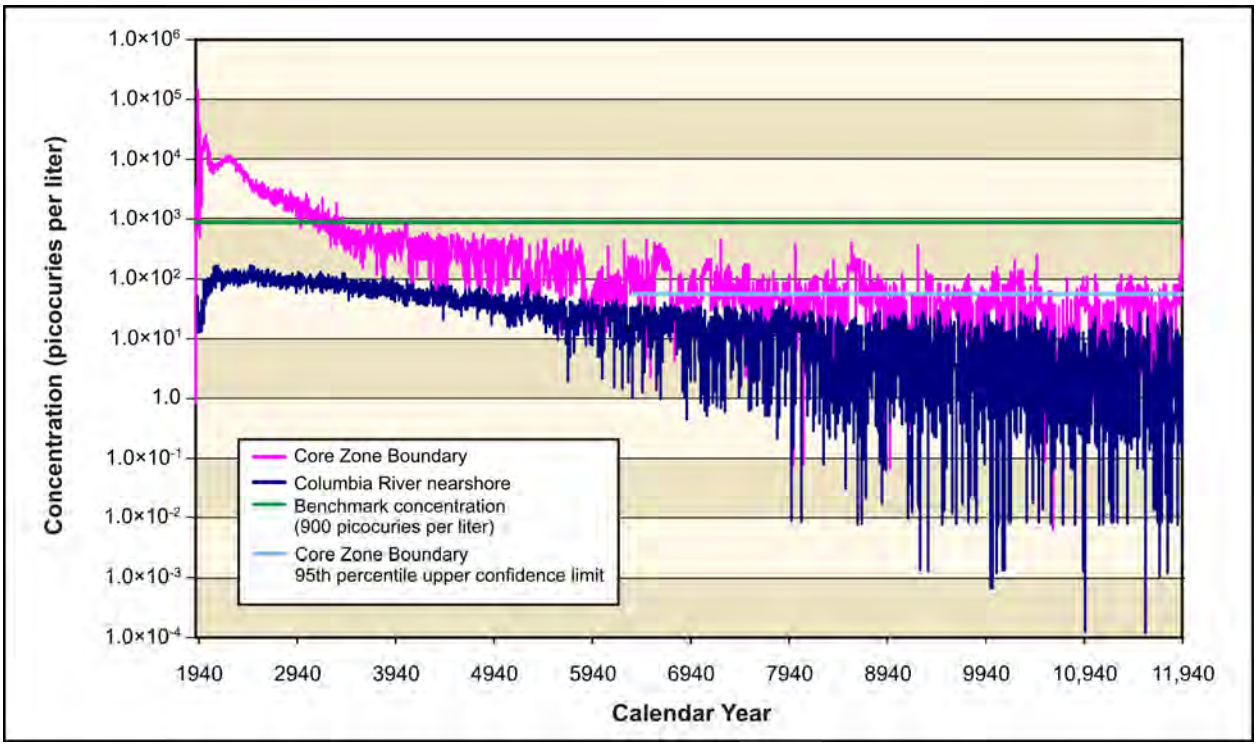


Figure 5–198. Tank Closure Alternative 6A, Base Case, Technetium-99 Concentration Versus Time

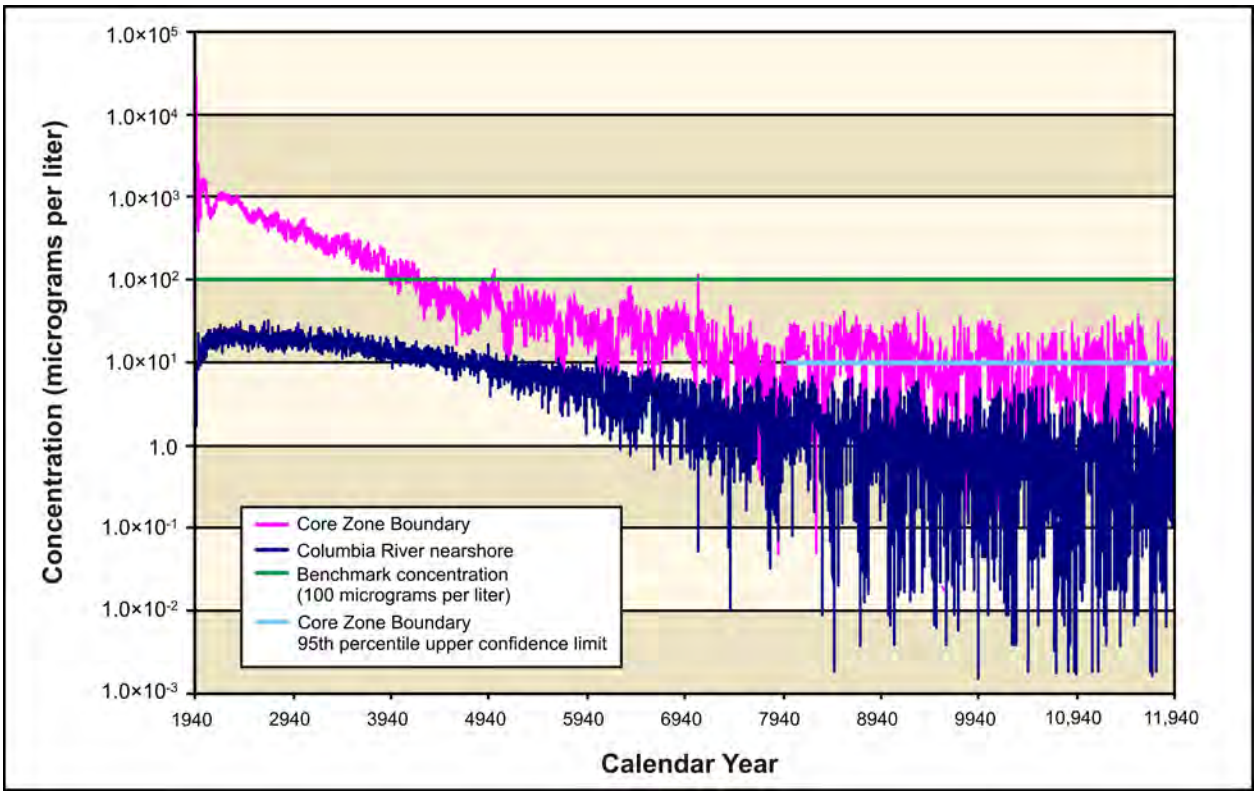


Figure 5–199. Tank Closure Alternative 6A, Base Case, Chromium Concentration Versus Time

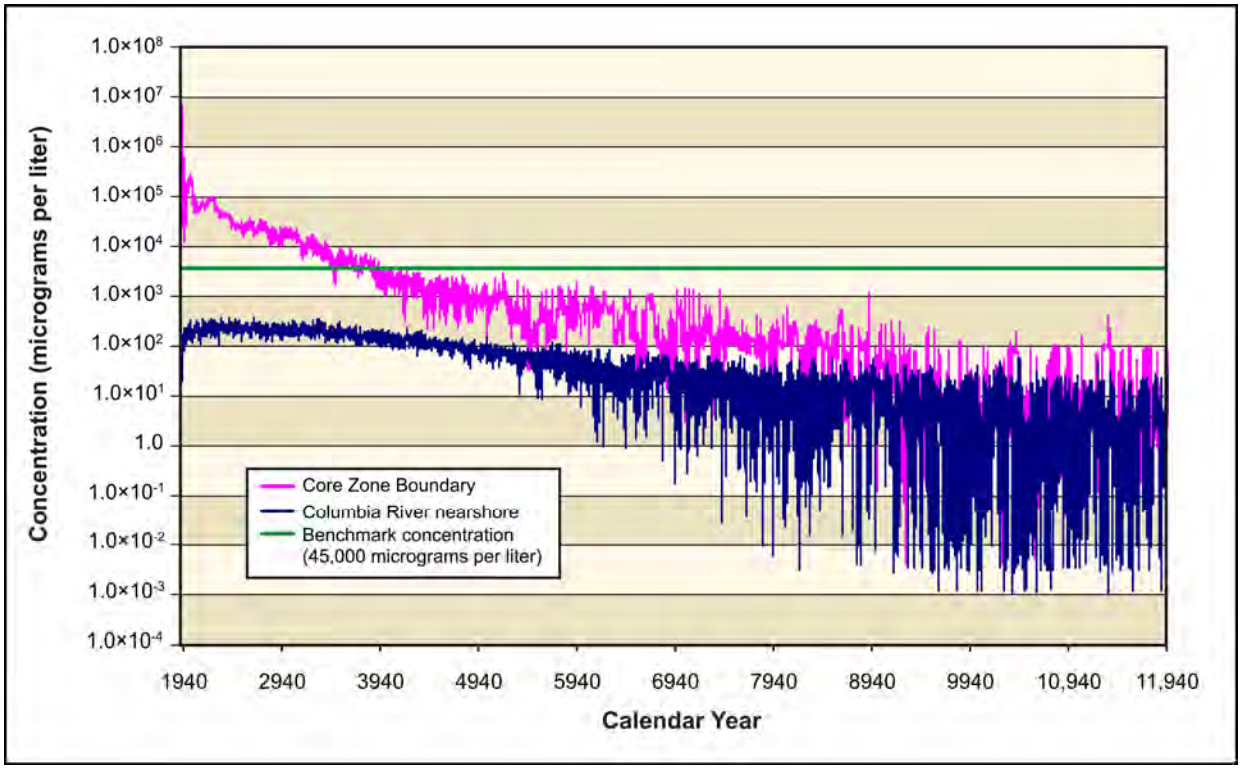


Figure 5–200. Tank Closure Alternative 6A, Base Case, Nitrate Concentration Versus Time

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) versus time under the Option Case are essentially identical to those under the Base Case (see Figures 5–201 through 5–204).

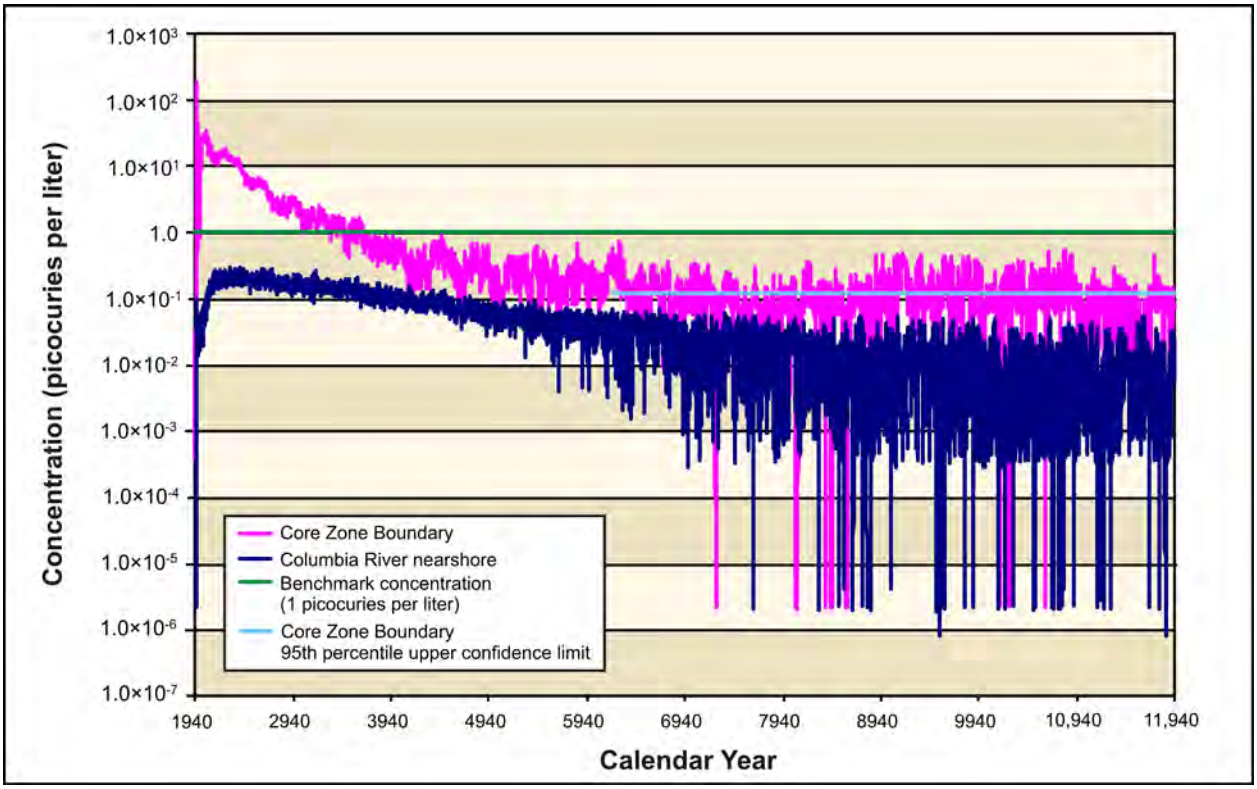


Figure 5–201. Tank Closure Alternative 6A, Option Case, Iodine-129 Concentration Versus Time

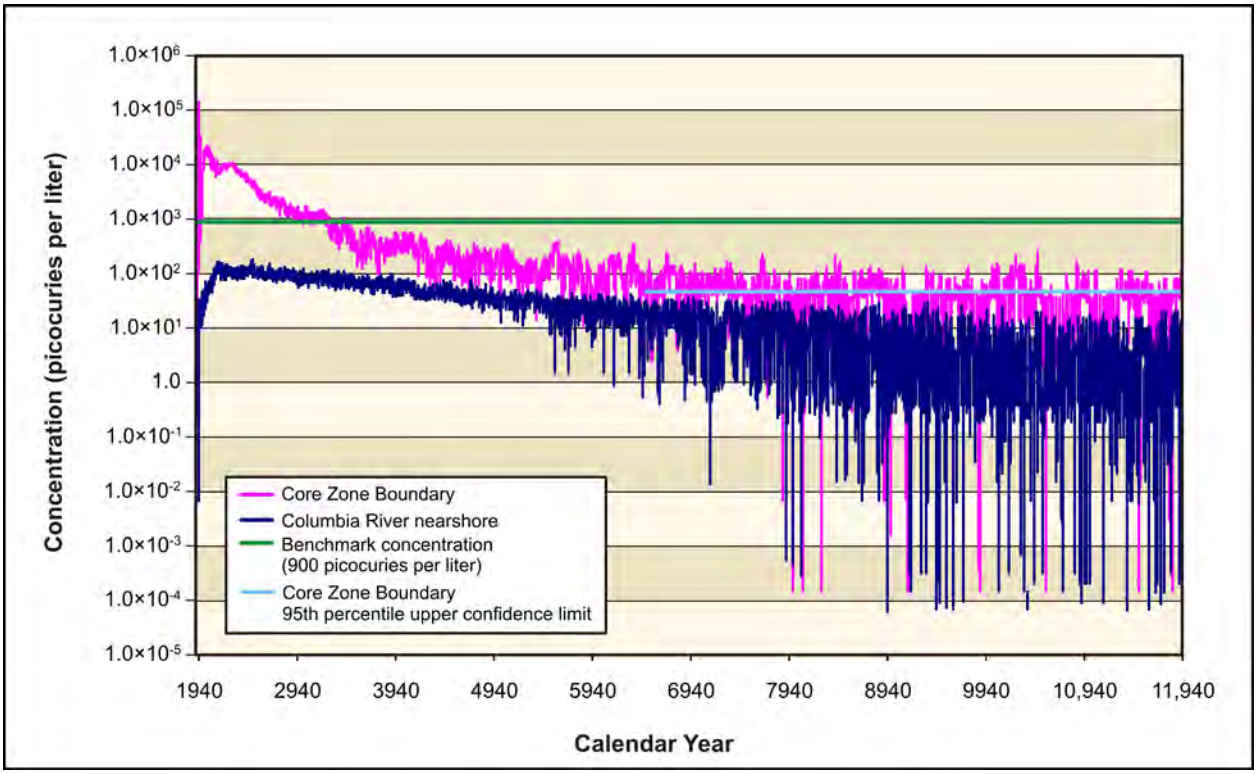


Figure 5–202. Tank Closure Alternative 6A, Option Case, Technetium-99 Concentration Versus Time

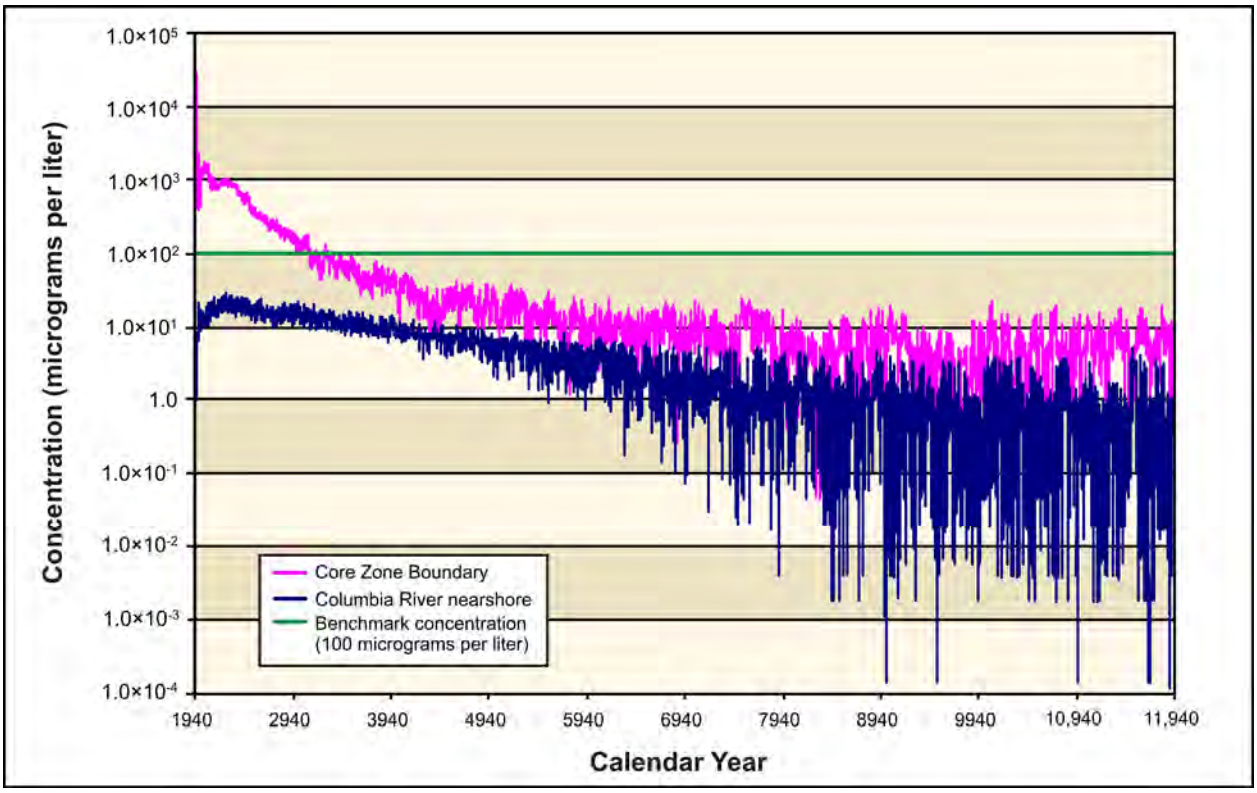


Figure 5–203. Tank Closure Alternative 6A, Option Case, Chromium Concentration Versus Time

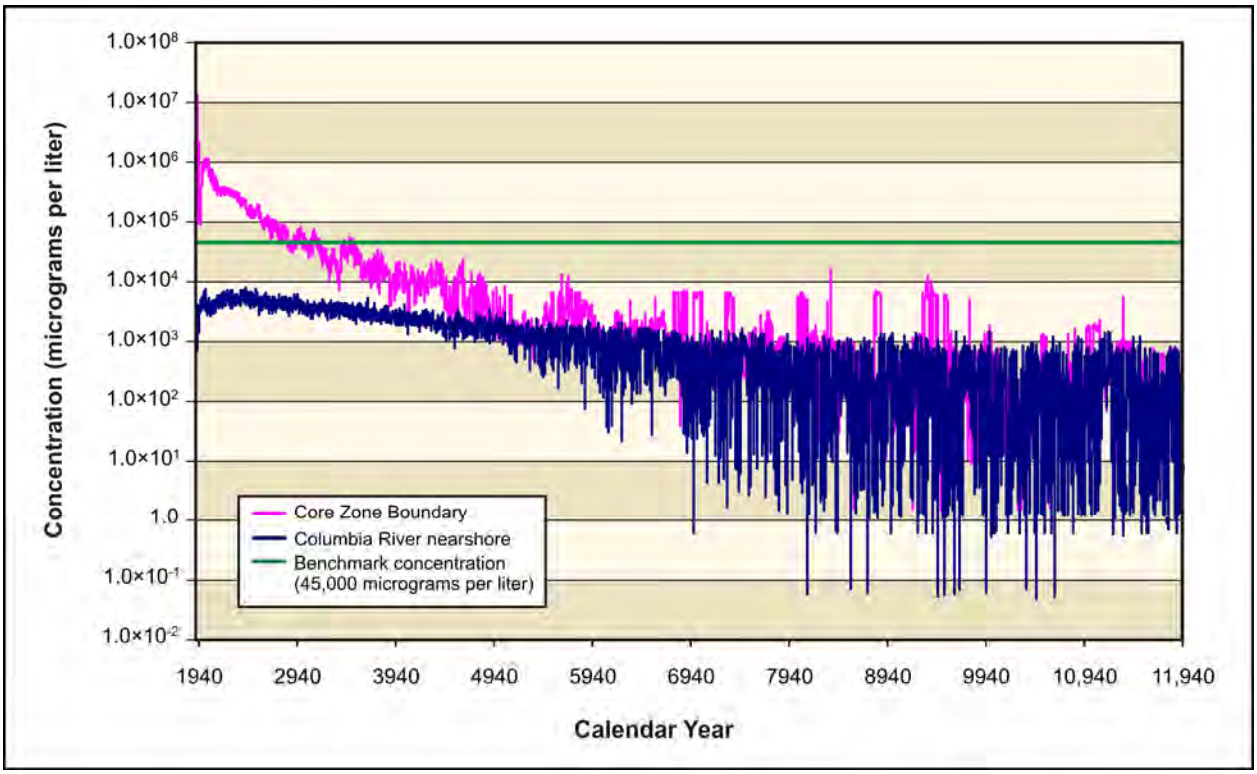


Figure 5–204. Tank Closure Alternative 6A, Option Case, Nitrate Concentration Versus Time

Figures 5–205 and 5–206 show concentration versus time for uranium-238 and total uranium under the Base Case. Although uranium-238 concentrations in the Core Zone Boundary began to approach the benchmark concentration toward the latter part of the period of analysis, they never reached it. Total uranium concentrations at the Core Zone Boundary also began to increase toward the end of the period of analysis but never came to within one order of magnitude of the benchmark. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark.

Under the Option Case, uranium-238 concentrations in the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark concentration, except for a short spike to about one order of magnitude below the benchmark at the beginning of the period of analysis (see Figure 5–207). At around CY 7500, the uranium-238 Core Zone Boundary concentrations fell to about four orders of magnitude below the benchmark. The Columbia River nearshore concentrations of uranium-238 stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark (see Figure 5–208). The Columbia River nearshore concentrations of total uranium remained fairly constant at around four and a half orders of magnitude below the benchmark.

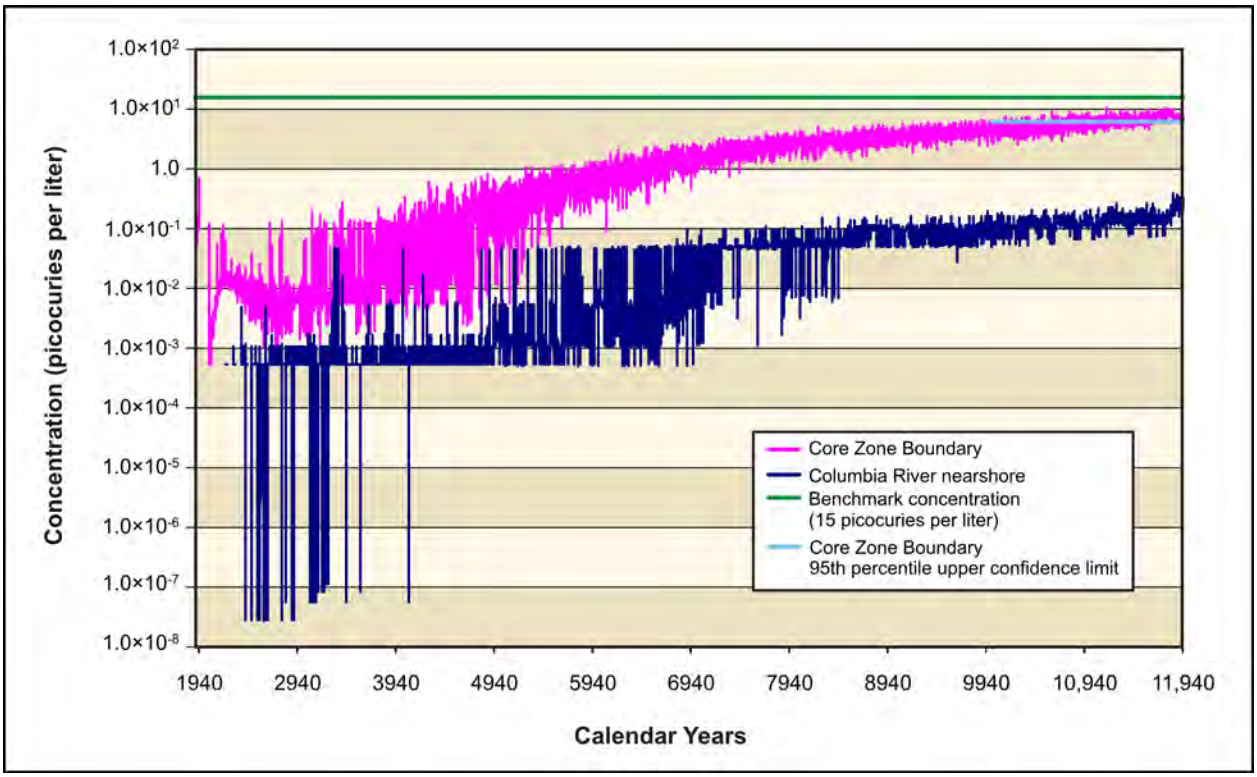


Figure 5–205. Tank Closure Alternative 6A, Base Case, Uranium-238 Concentration Versus Time

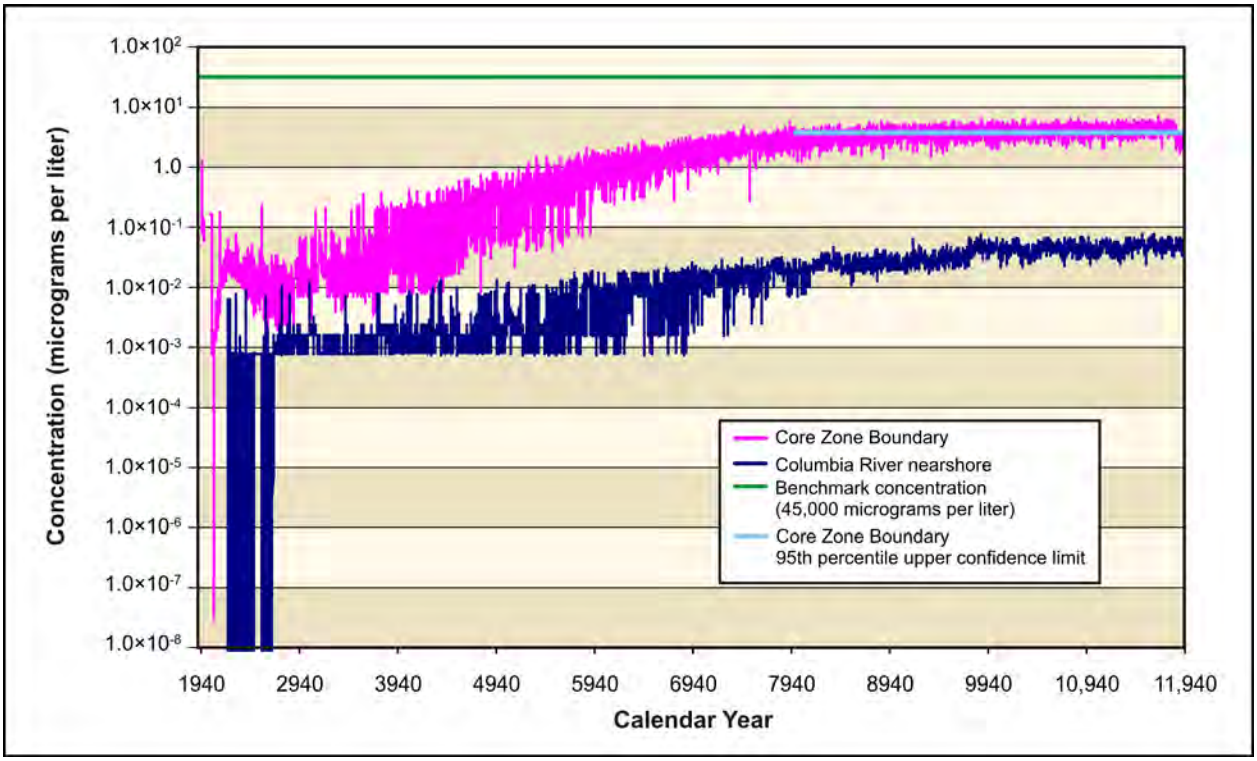


Figure 5–206. Tank Closure Alternative 6A, Base Case, Total Uranium Concentration Versus Time

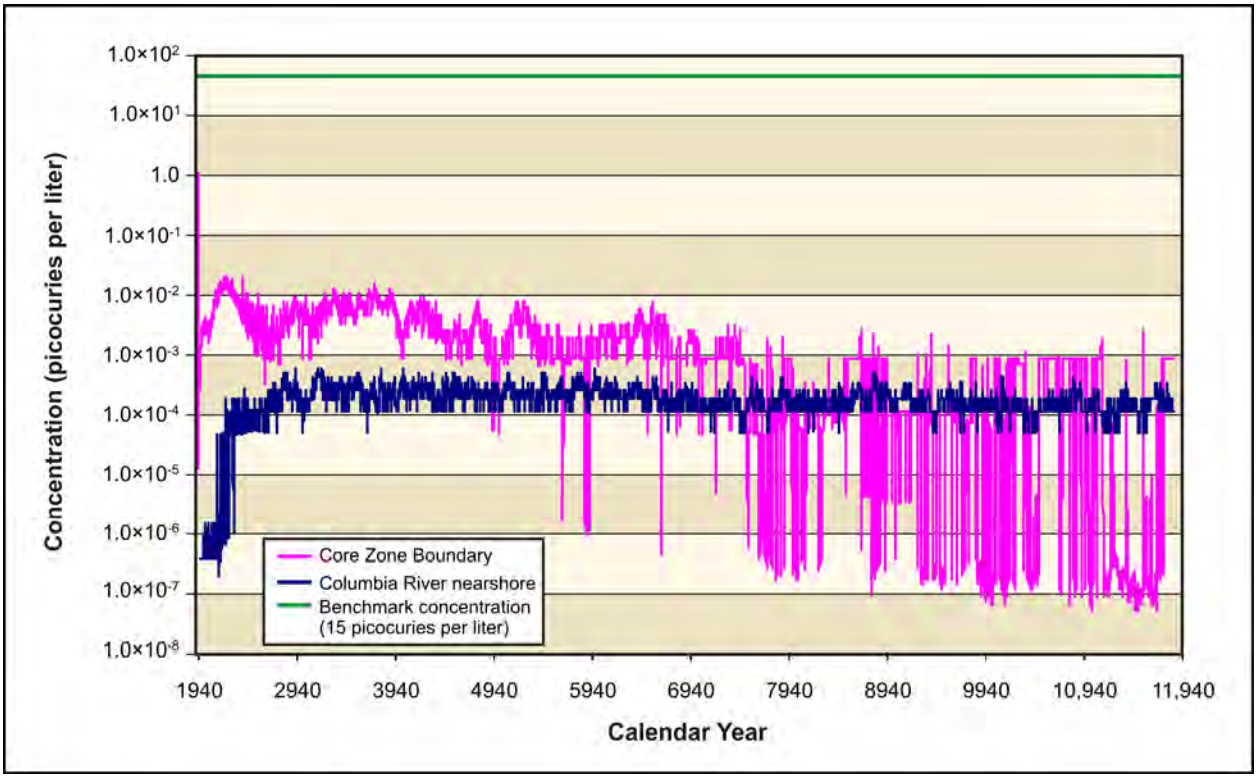


Figure 5–207. Tank Closure Alternative 6A, Option Case, Uranium-238 Concentration Versus Time

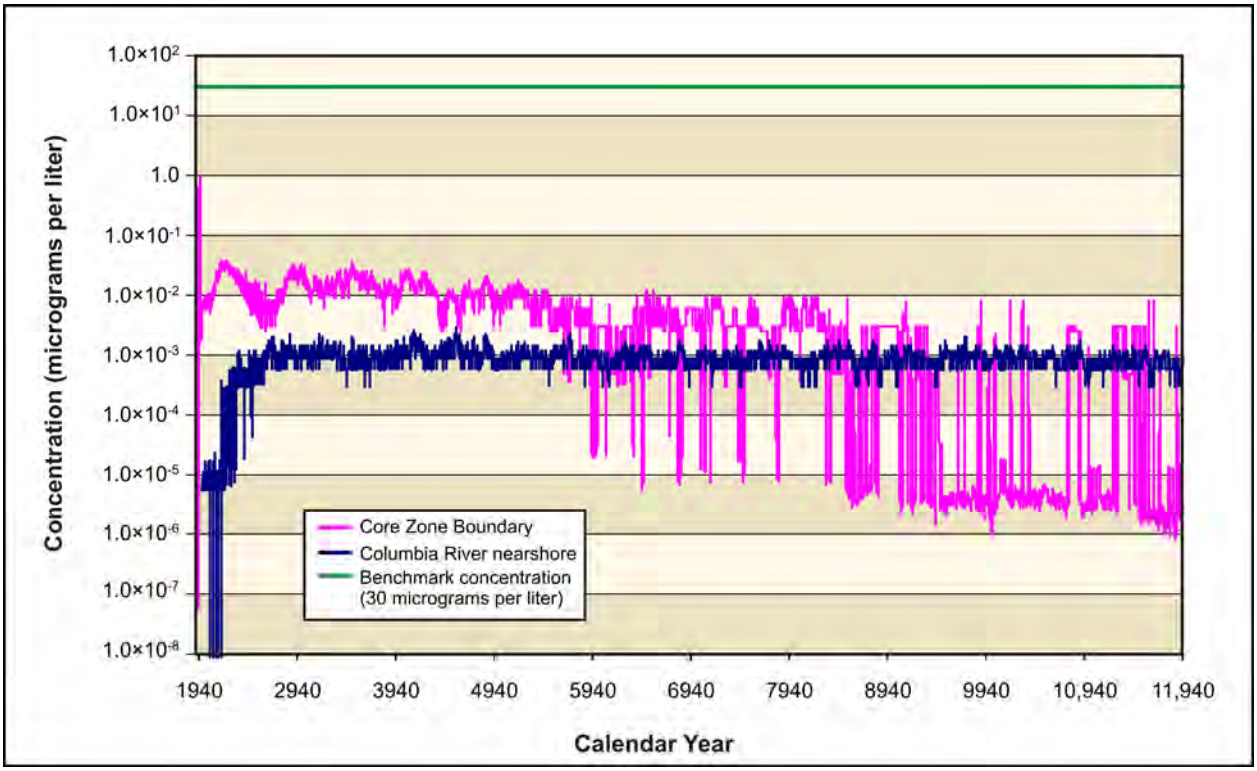


Figure 5–208. Tank Closure Alternative 6A, Option Case, Total Uranium Concentration Versus Time

5.1.1.9.5 Analysis of Spatial Distribution of Concentration

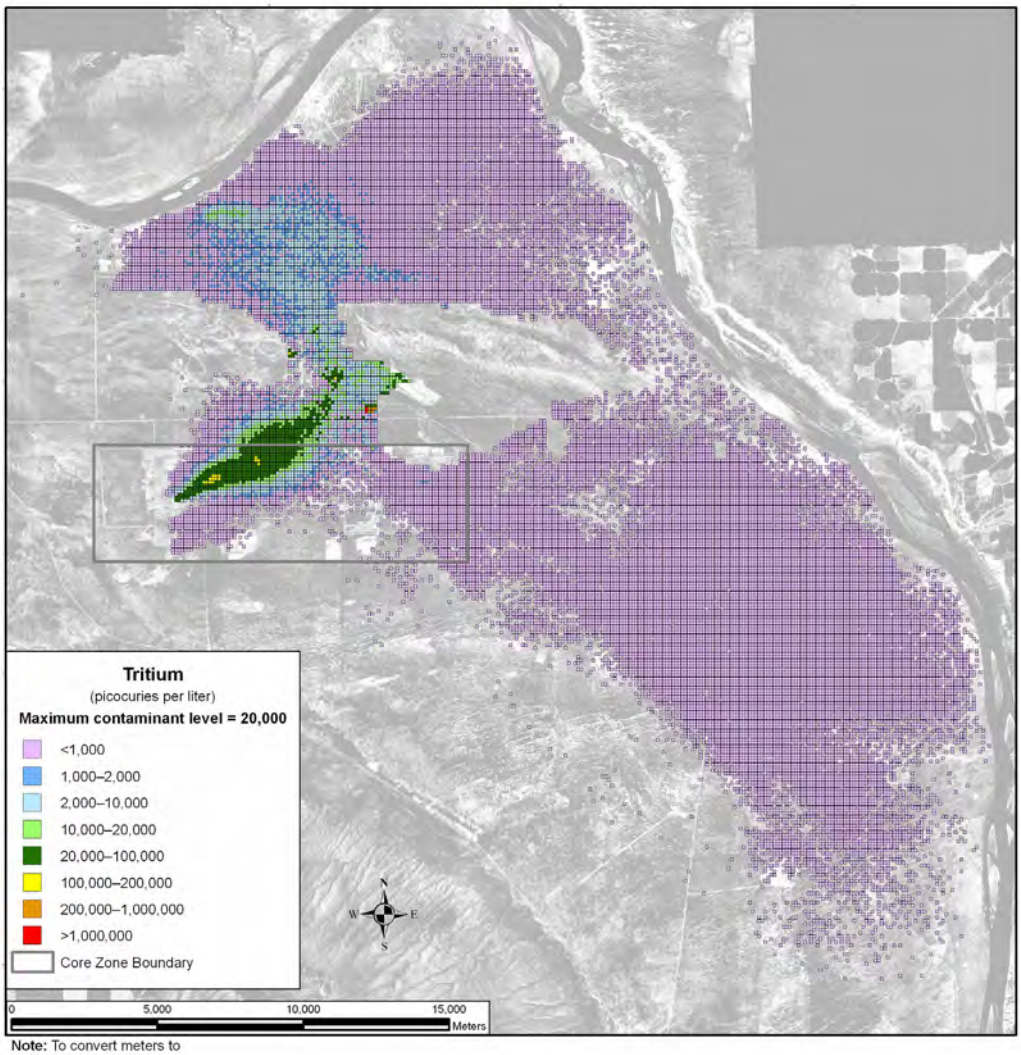
This section presents the impacts of Tank Closure Alternative 6A in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–209 through 5–253). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–209 shows the spatial distribution of groundwater concentration for tritium during CY 2005 under the Base Case, which would include use of a modified RCRA Subtitle C barrier. Analysis releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 10 to 20 times greater than the benchmark concentration, and mostly contained within the Core Zone Boundary. The overall tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135, although a few minor traces, from about one-twentieth to one-tenth below the benchmark, can be found in Gable Gap (see Figure 5–210).

The spatial distribution of groundwater concentrations for tritium under the Option Case, which would include removal of the six sets of cribs and trenches (ditches) and remediation of their plumes within the vadose zone, is essentially identical to that under the Base Case (see Figures 5–211 and 5–212).

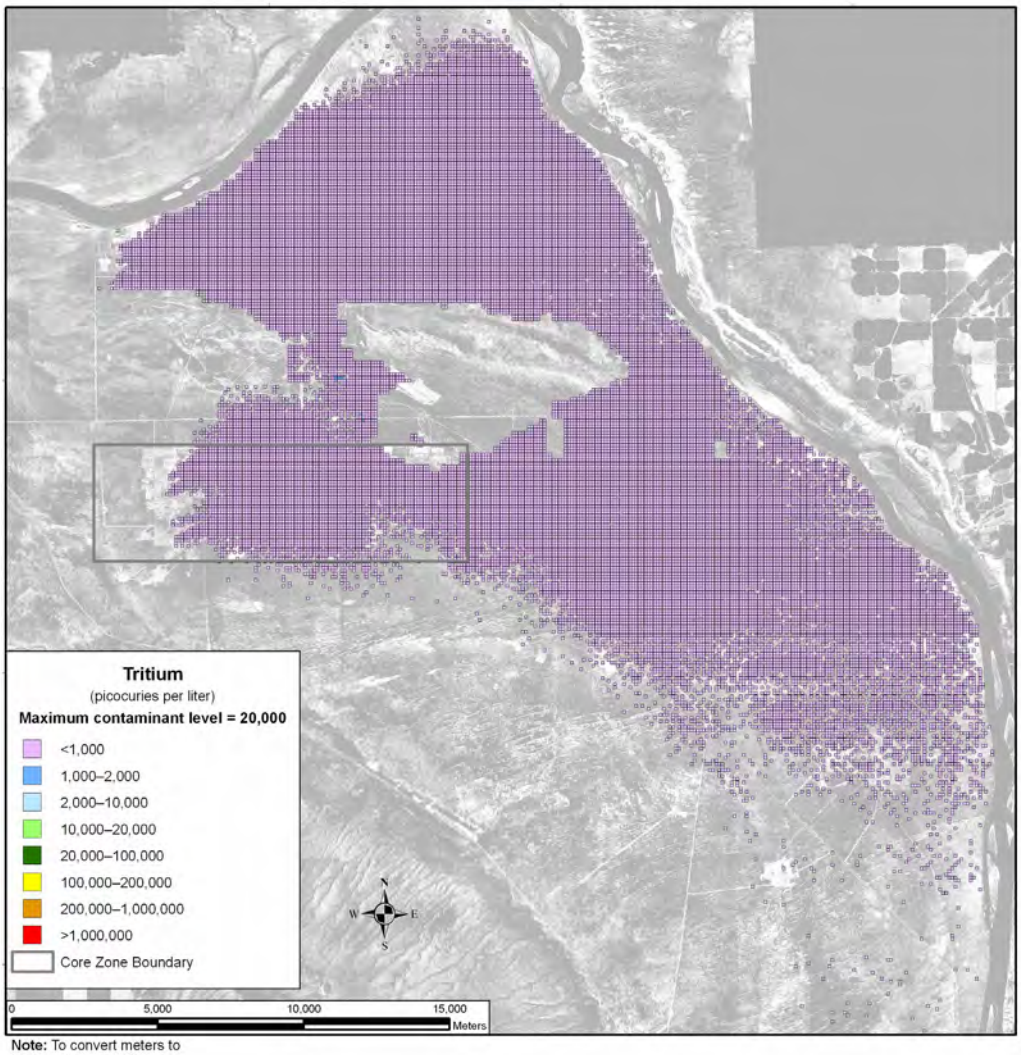
Figure 5–213 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005 under the Base Case. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 30 times greater than the benchmark, and mostly contained within the Core Zone Boundary. By CY 2135, the contaminant plumes have spread further north through Gable Gap and further east toward the Columbia River (see Figure 5–214). In the plume north of Gable Gap, contaminant levels have begun to meet the benchmark concentration. In the east, just outside of the Core Zone Boundary, levels have risen to 5 to 10 times above the benchmark. By CY 7140, most of the mass in the plume has reached the Columbia River, with only a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier (see Figure 5–215). Technetium-99 (see Figures 5–216 through 5–218), chromium (see Figures 5–219 through 5–221), and nitrate (see Figures 5–222 through 5–224) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all essentially conservative tracers (i.e., move at the rate of the pore water velocity) during the period of analysis.

The spatial distribution of groundwater concentrations of the conservative tracers under the Option Case is essentially identical to that under the Base Case (see Figures 5–225 through 5–236).



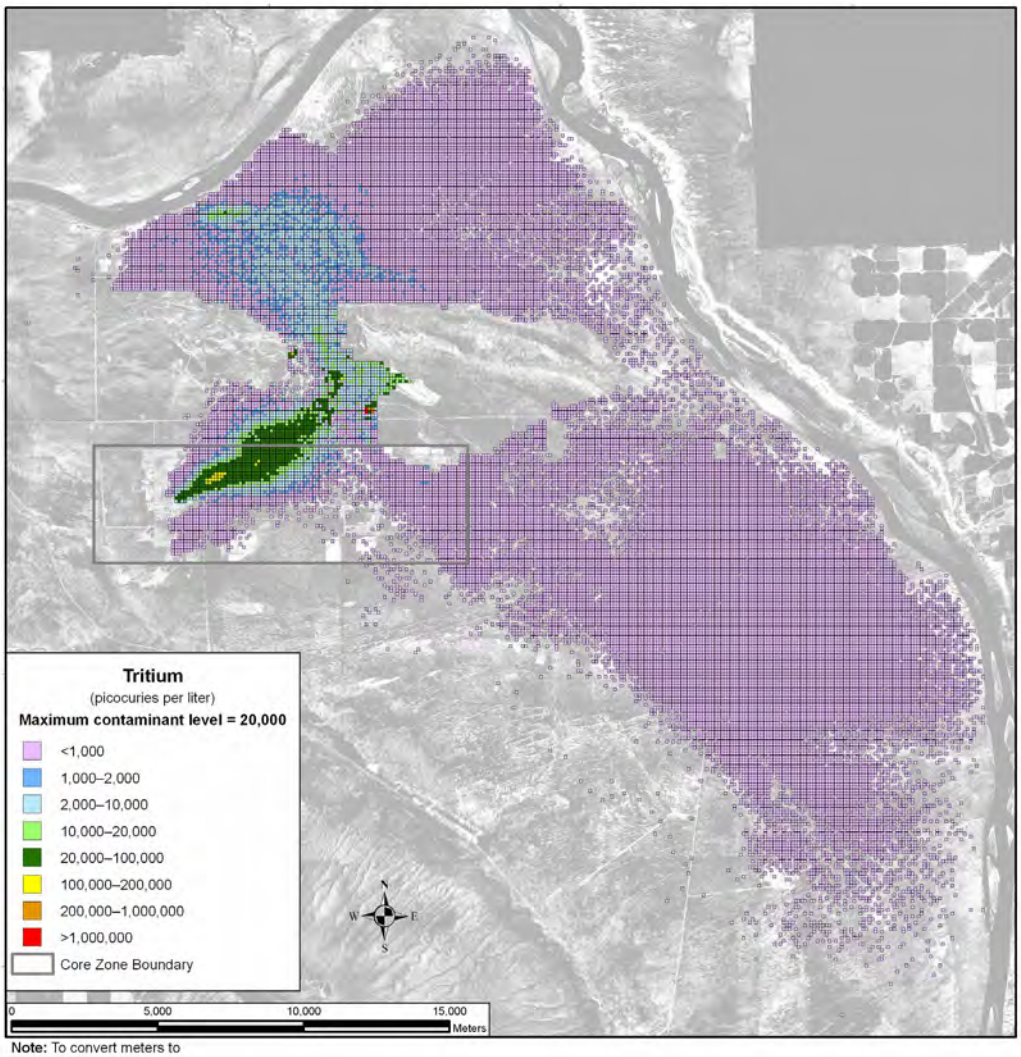
Note: To convert meters to feet, multiply by 3.281

Figure 5–209. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



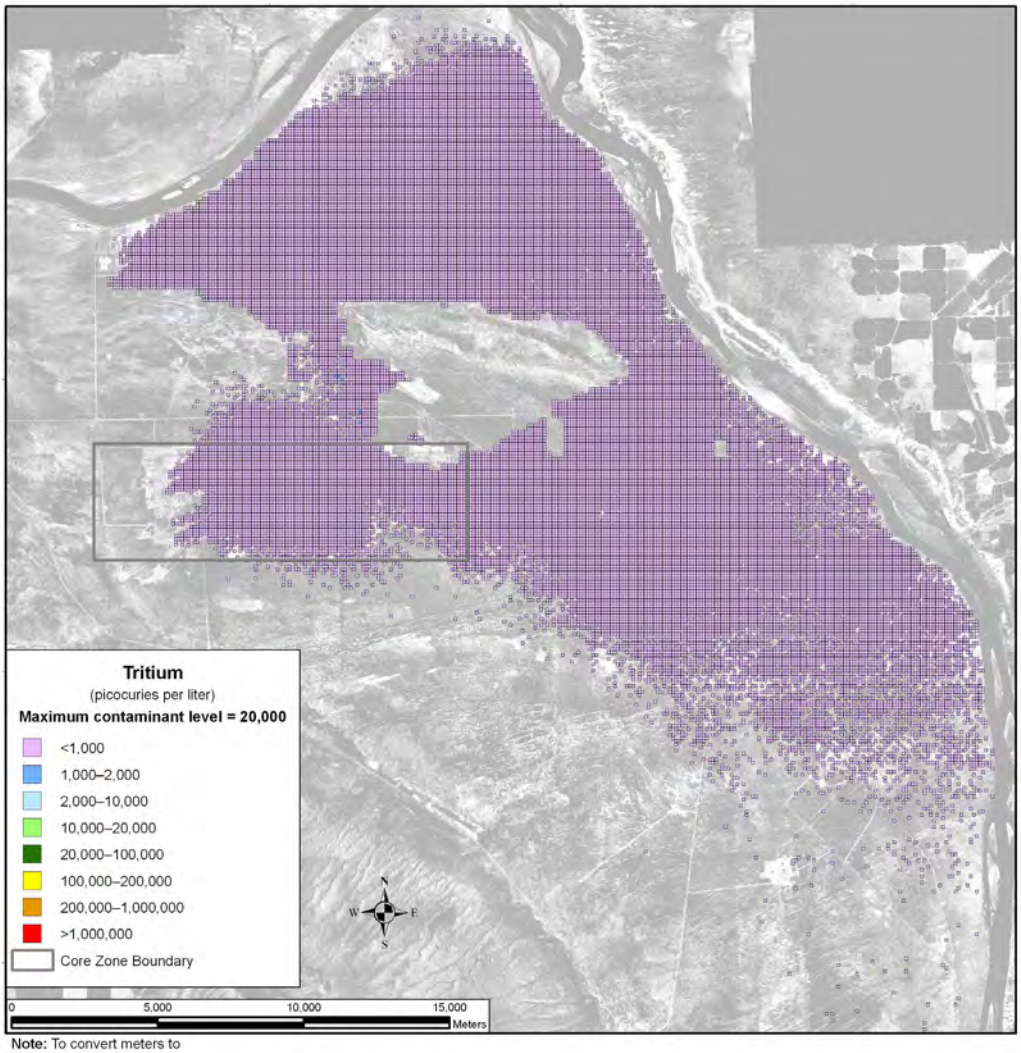
Note: To convert meters to feet, multiply by 3.281

Figure 5–210. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135



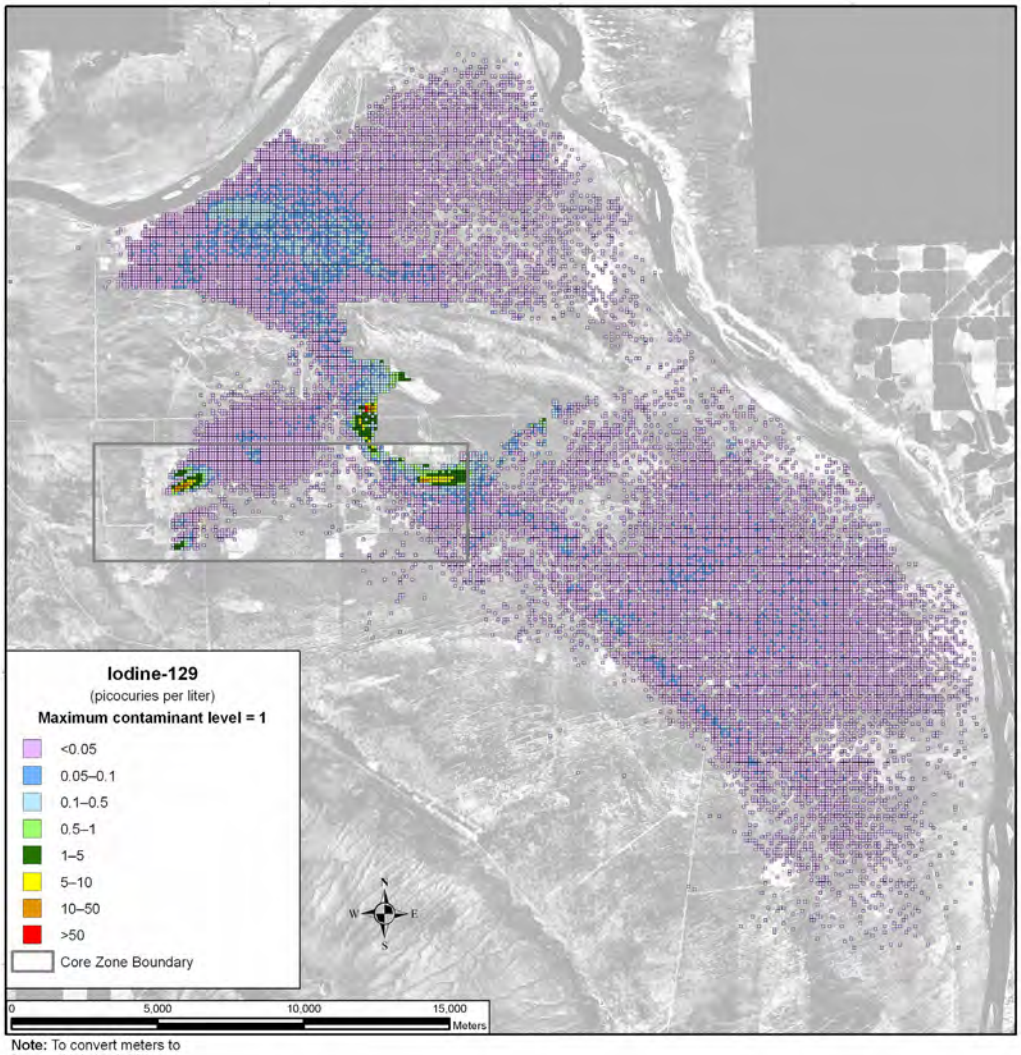
Note: To convert meters to feet, multiply by 3.281

Figure 5–211. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



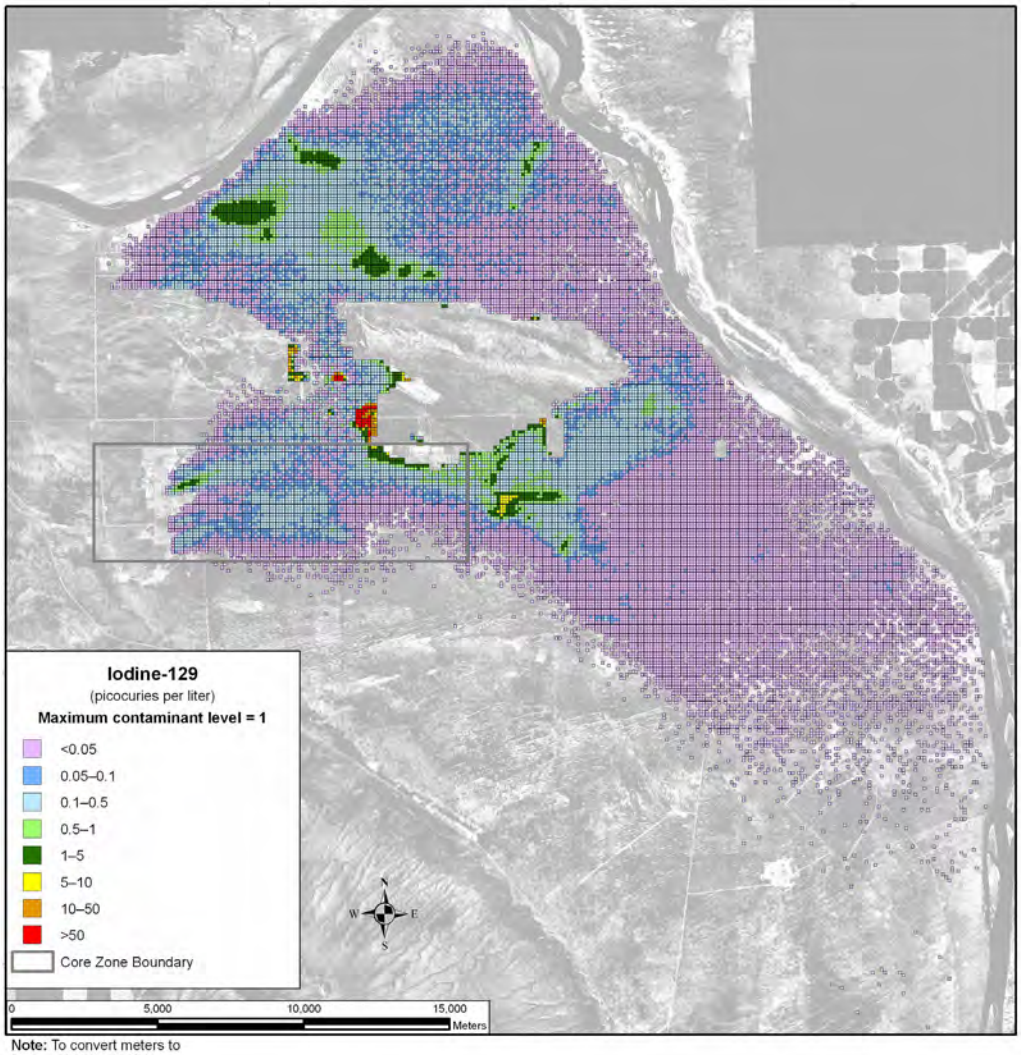
Note: To convert meters to feet, multiply by 3.281

Figure 5–212. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135



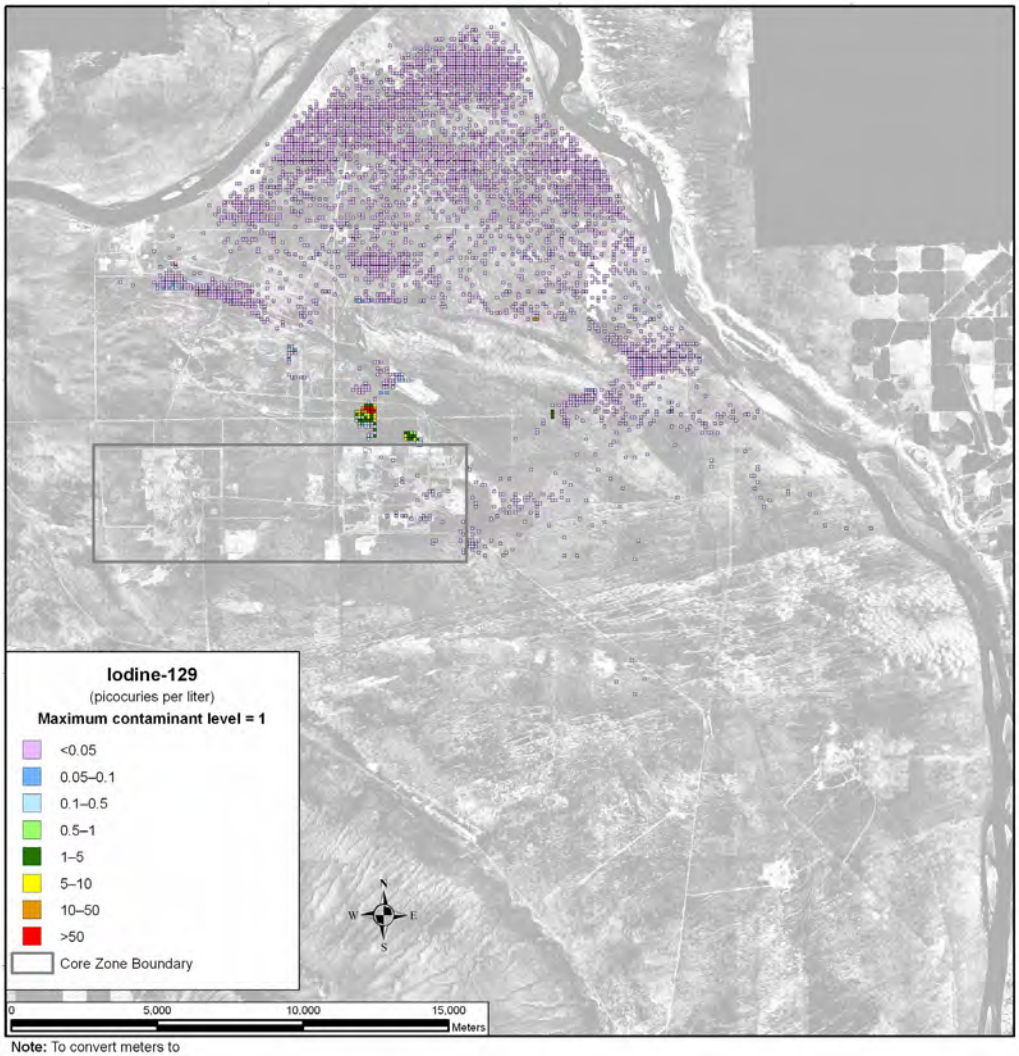
Note: To convert meters to feet, multiply by 3.281

Figure 5–213. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



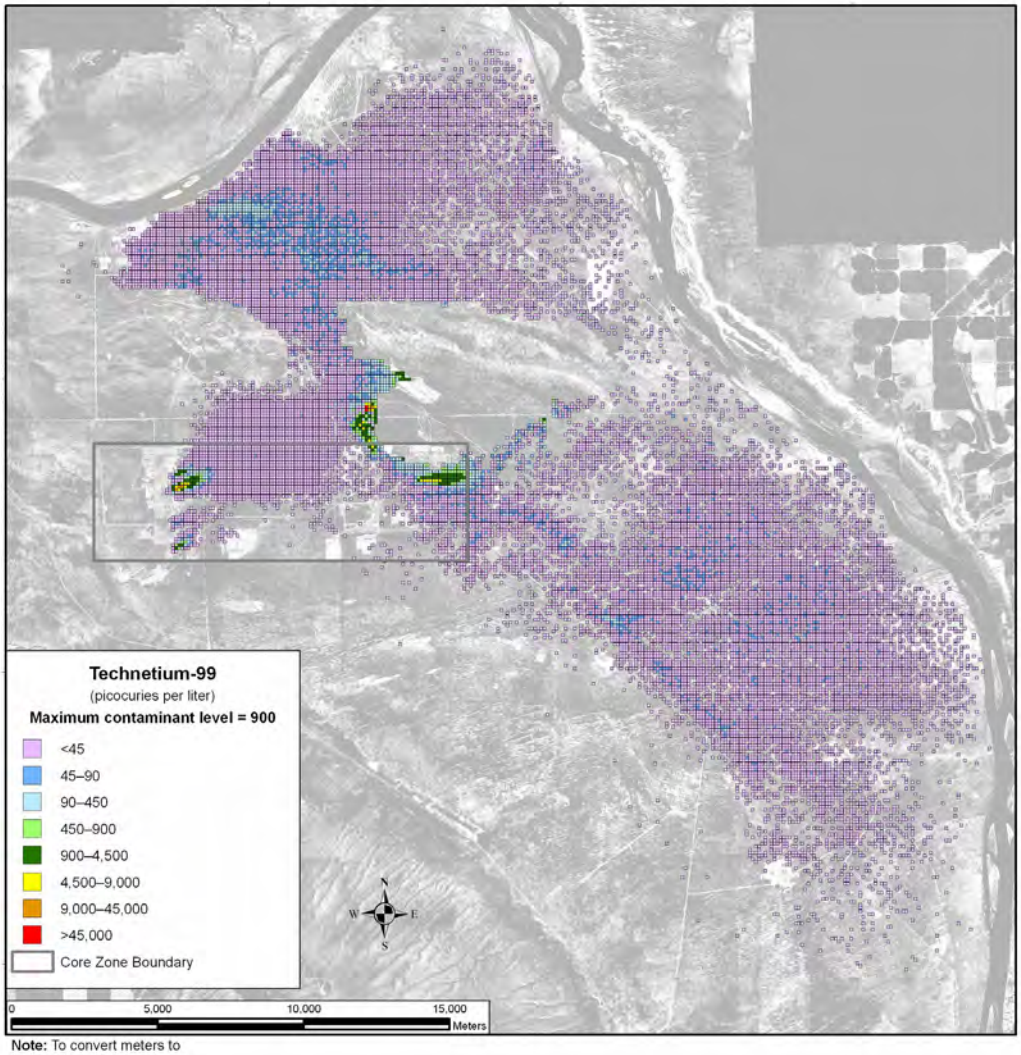
Note: To convert meters to feet, multiply by 3.281

Figure 5–214. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



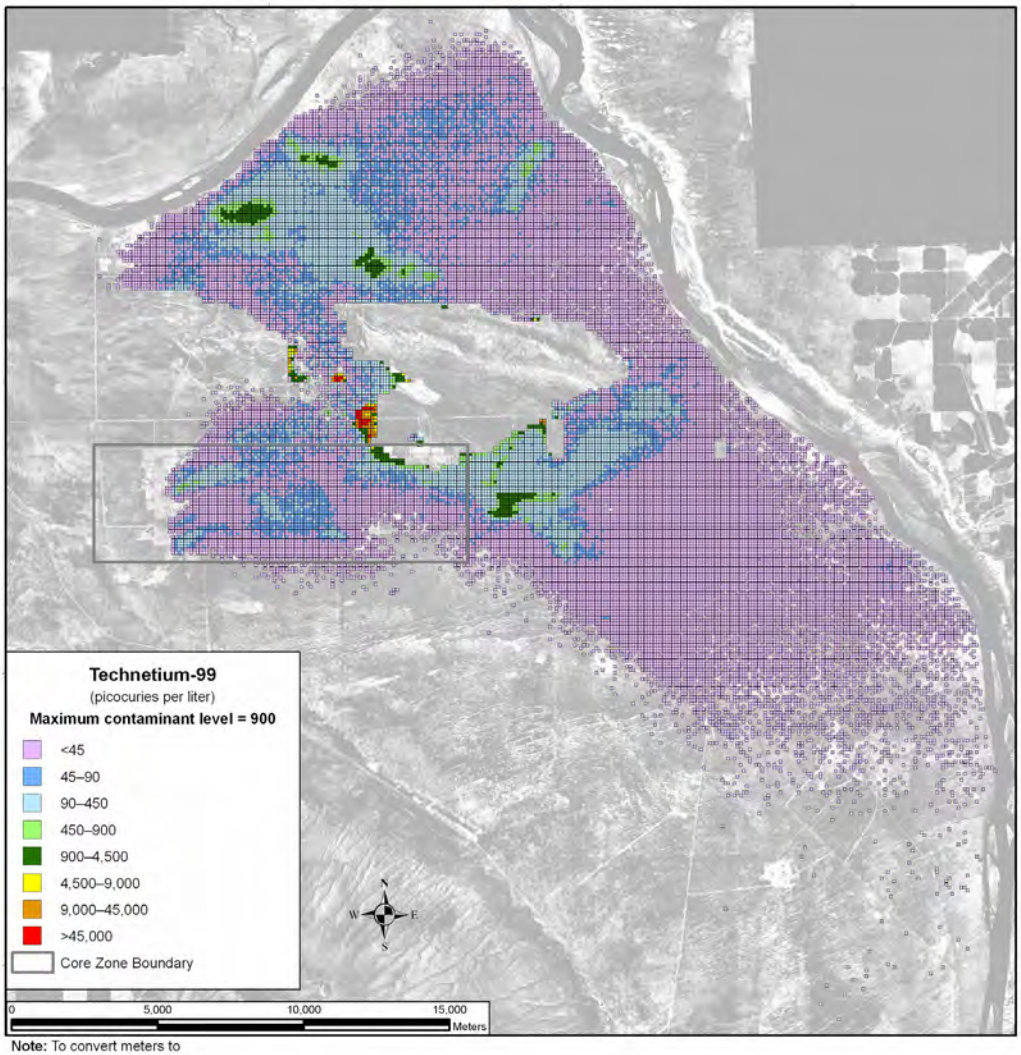
Note: To convert meters to feet, multiply by 3.281

Figure 5–215. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



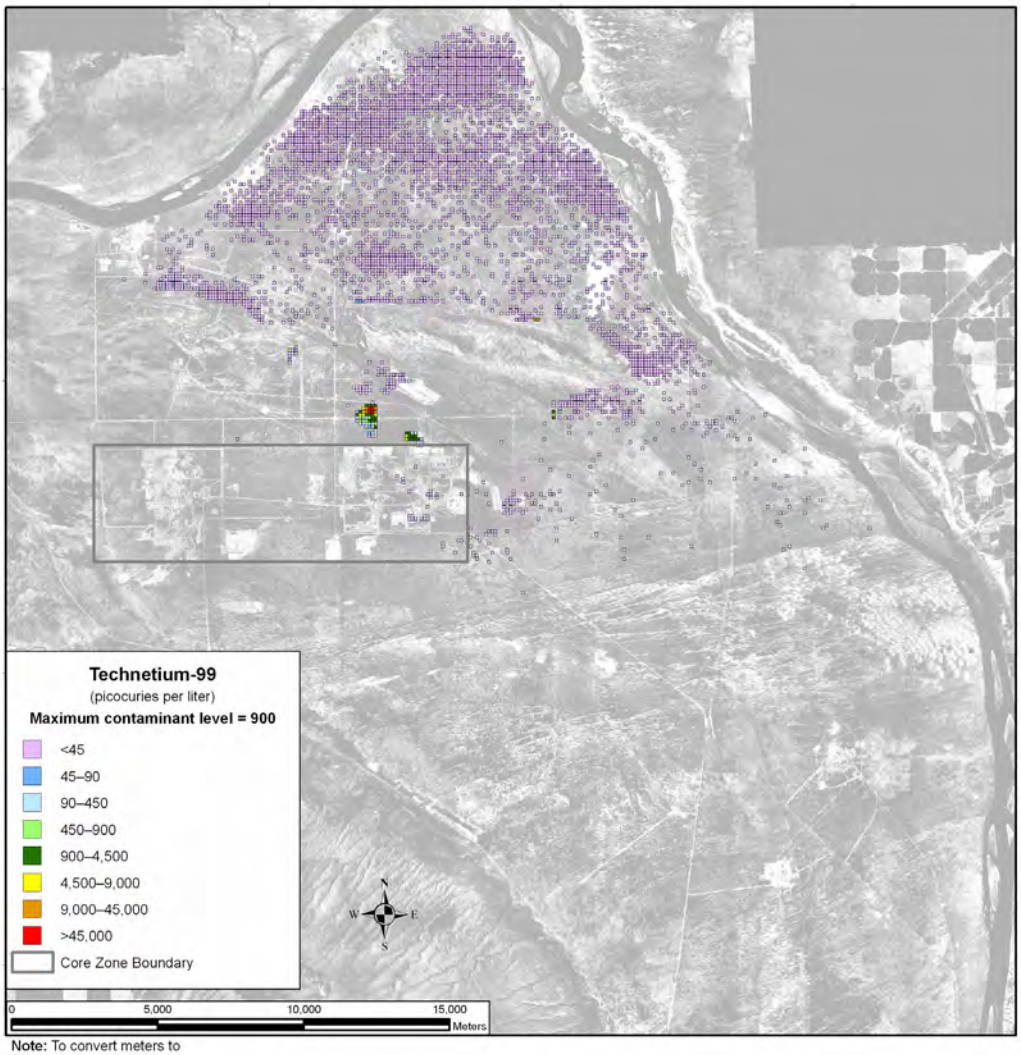
Note: To convert meters to feet, multiply by 3.281

Figure 5–216. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



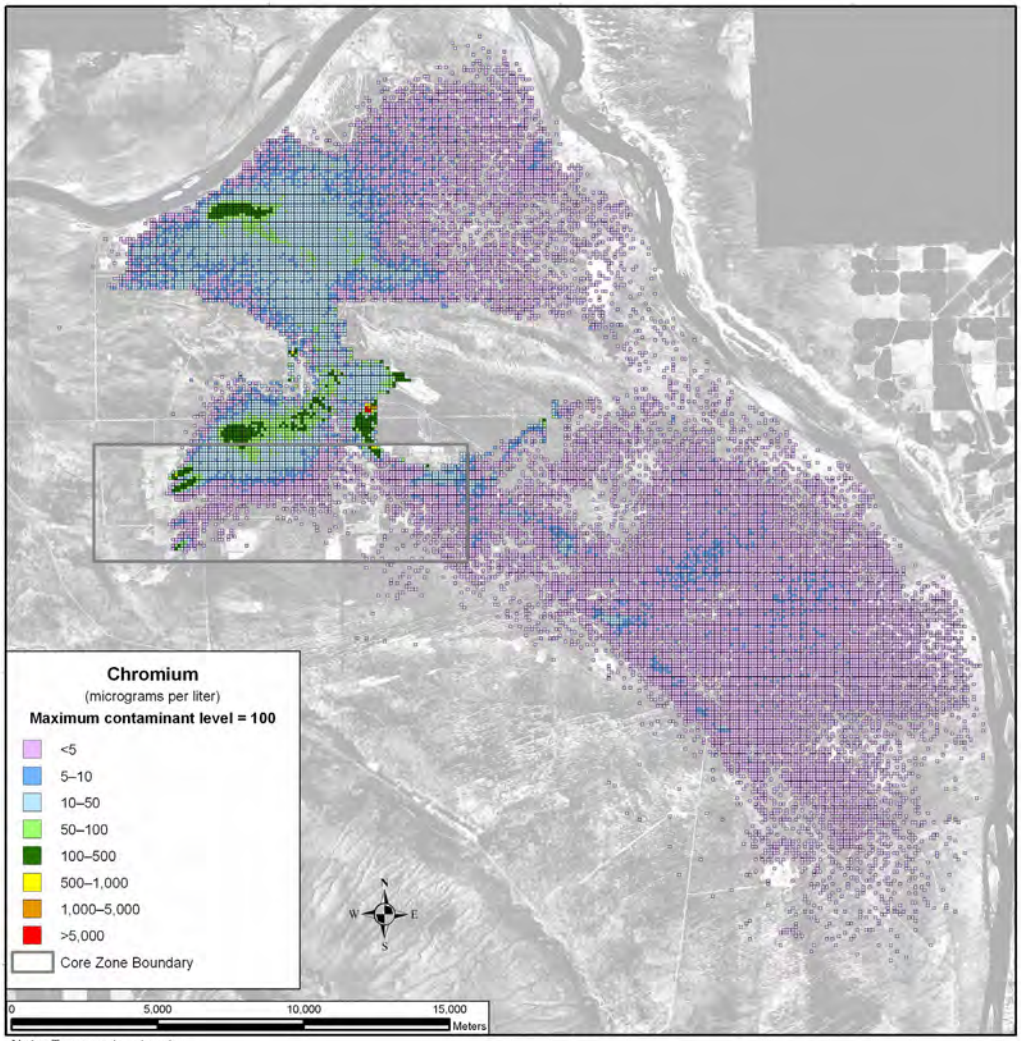
Note: To convert meters to feet, multiply by 3.281

Figure 5–217. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



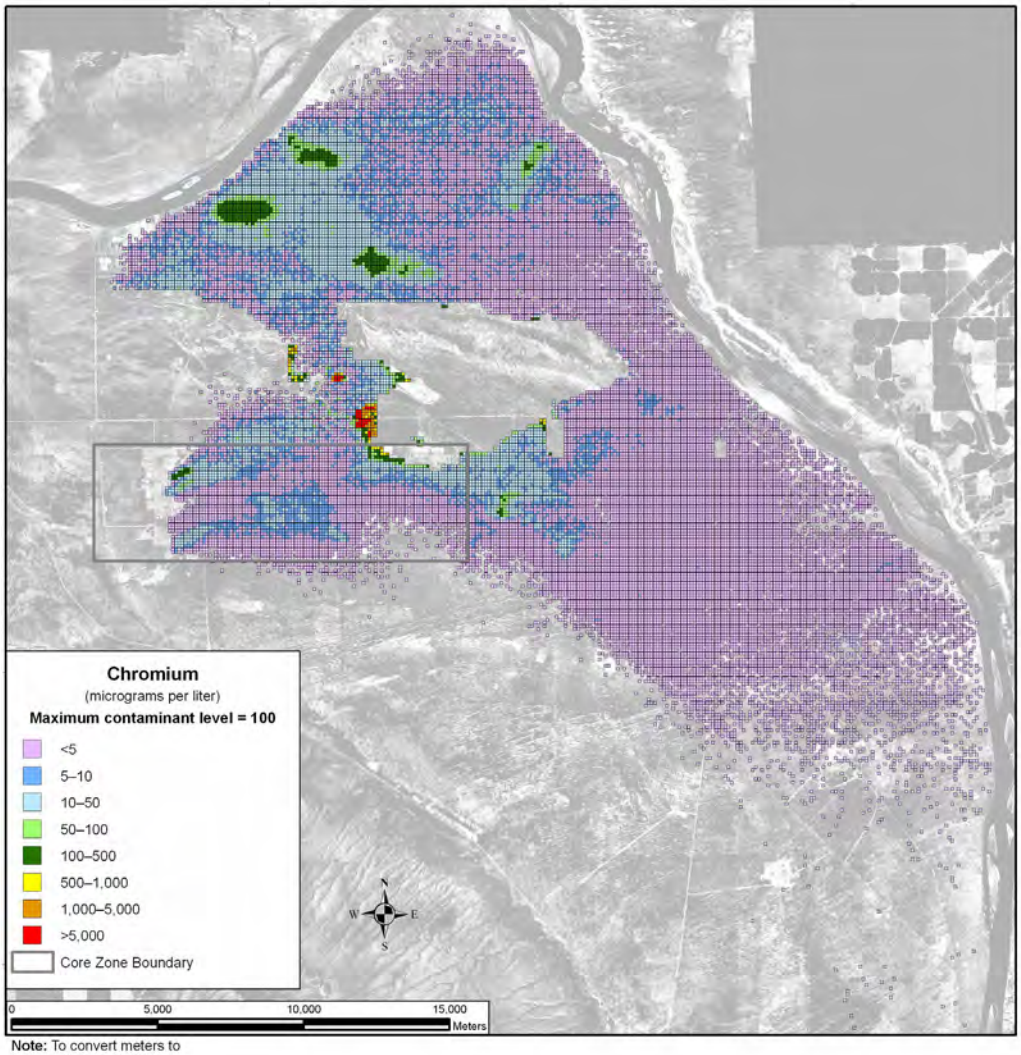
Note: To convert meters to feet, multiply by 3.281

Figure 5–218. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



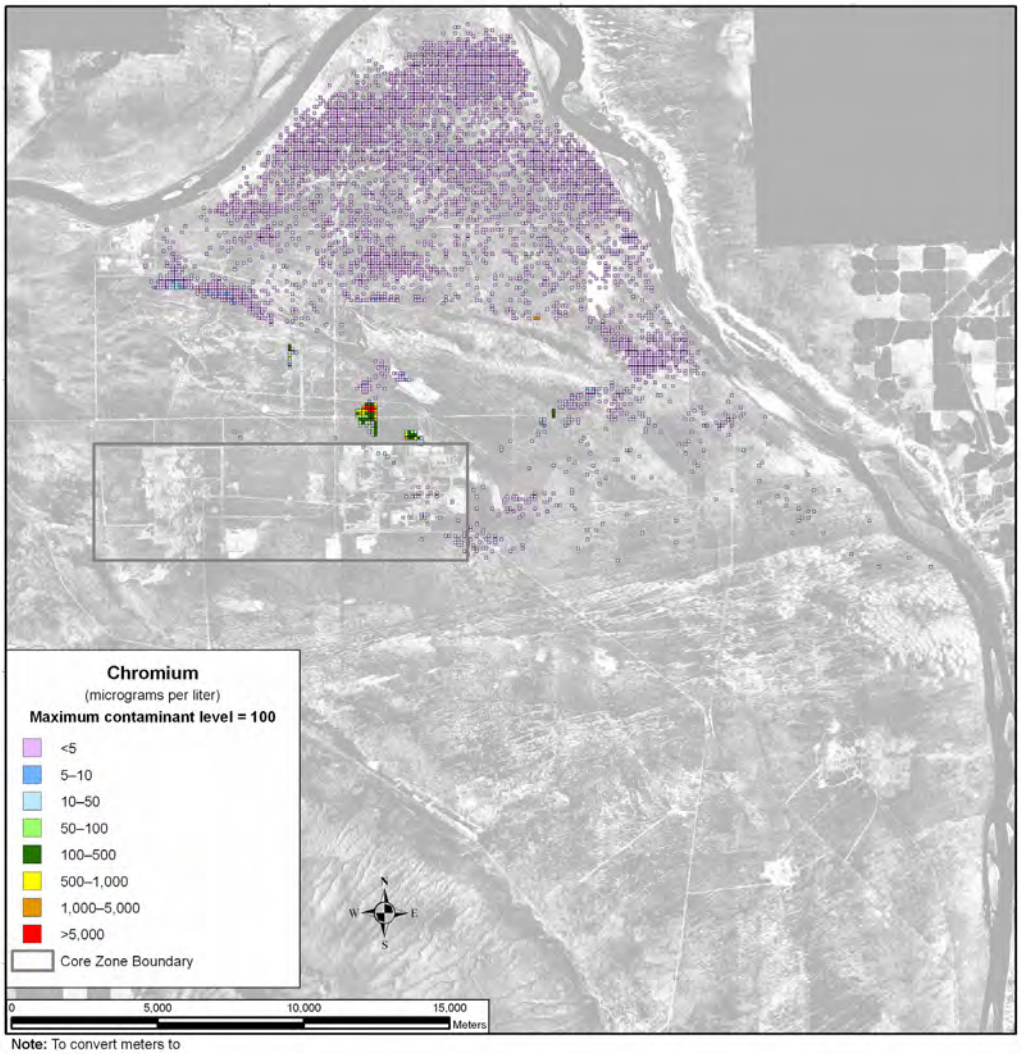
Note: To convert meters to feet, multiply by 3.281

Figure 5–219. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



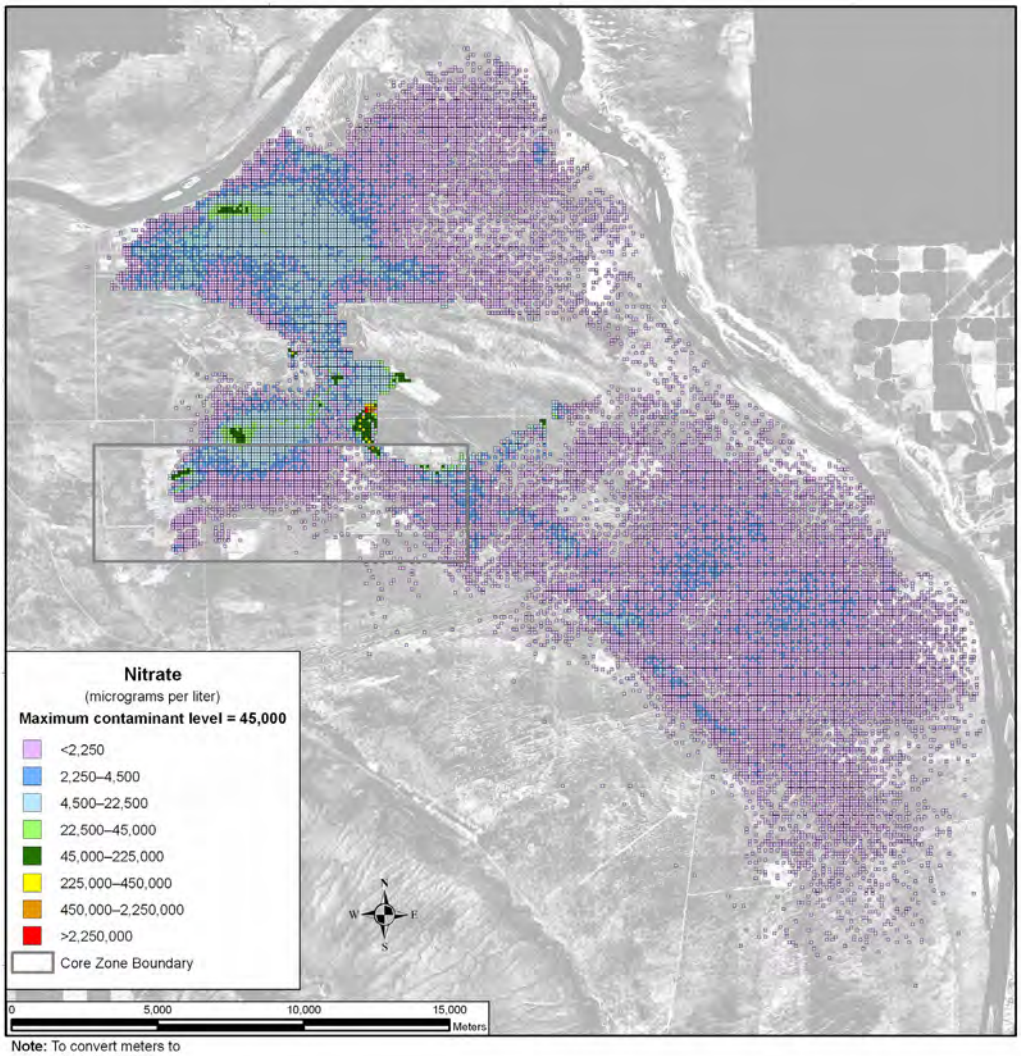
Note: To convert meters to feet, multiply by 3.281

Figure 5–220. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



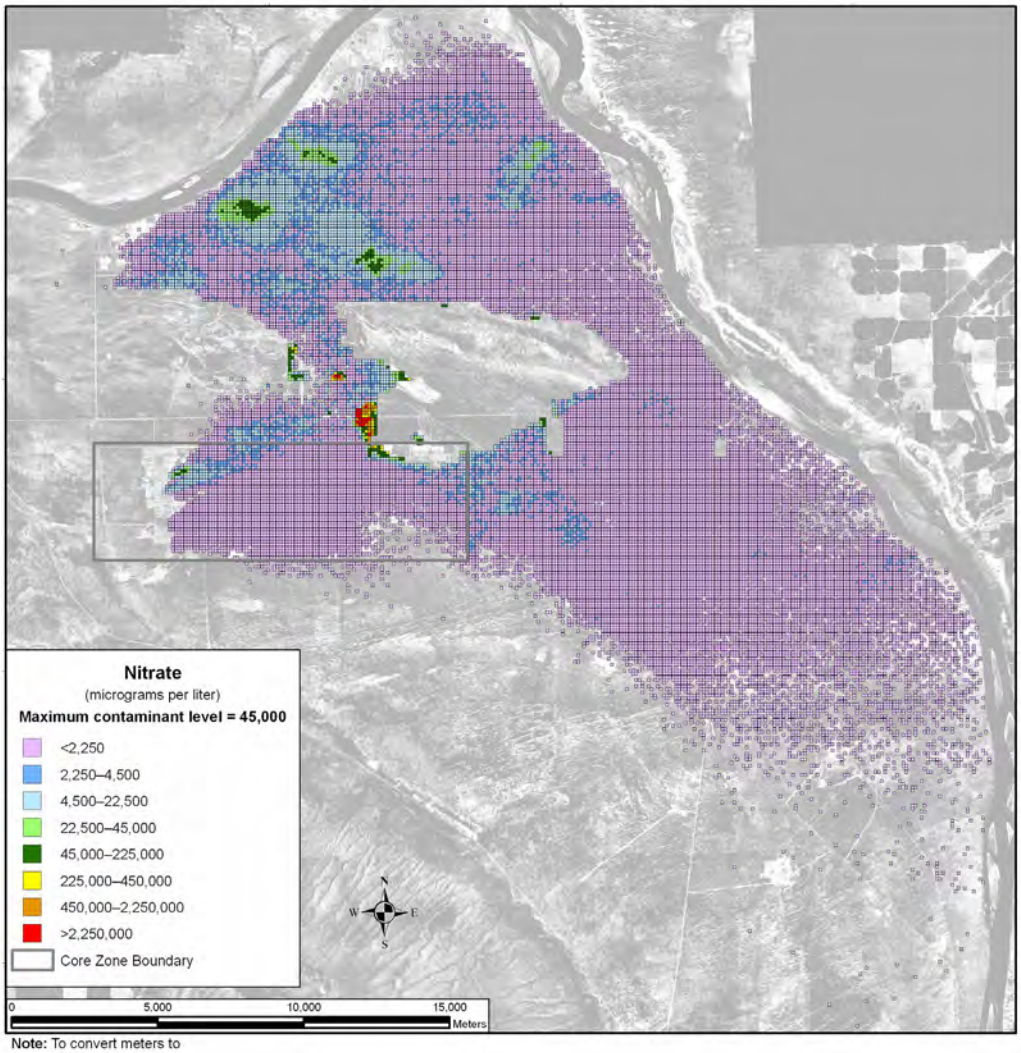
Note: To convert meters to feet, multiply by 3.281

Figure 5–221. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



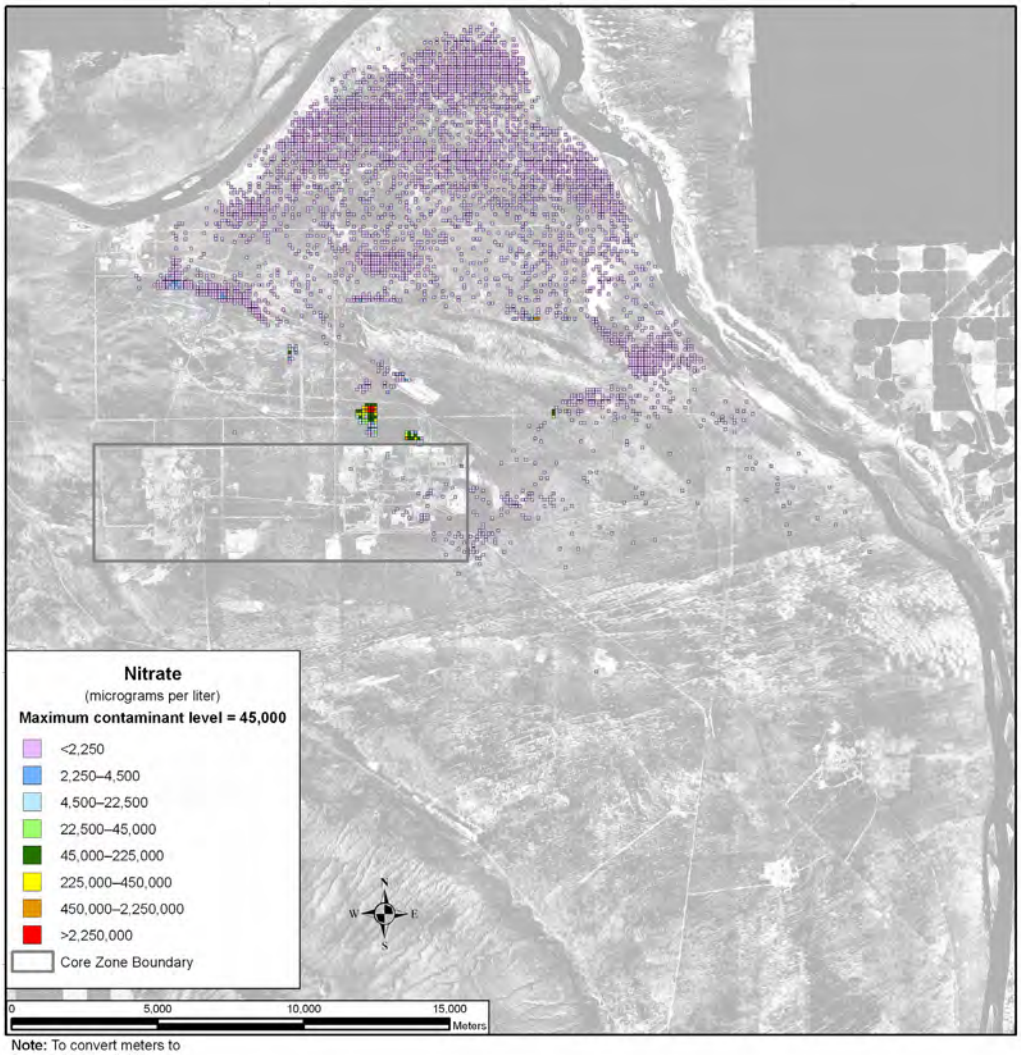
Note: To convert meters to feet, multiply by 3.281

Figure 5–222. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–223. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–224. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

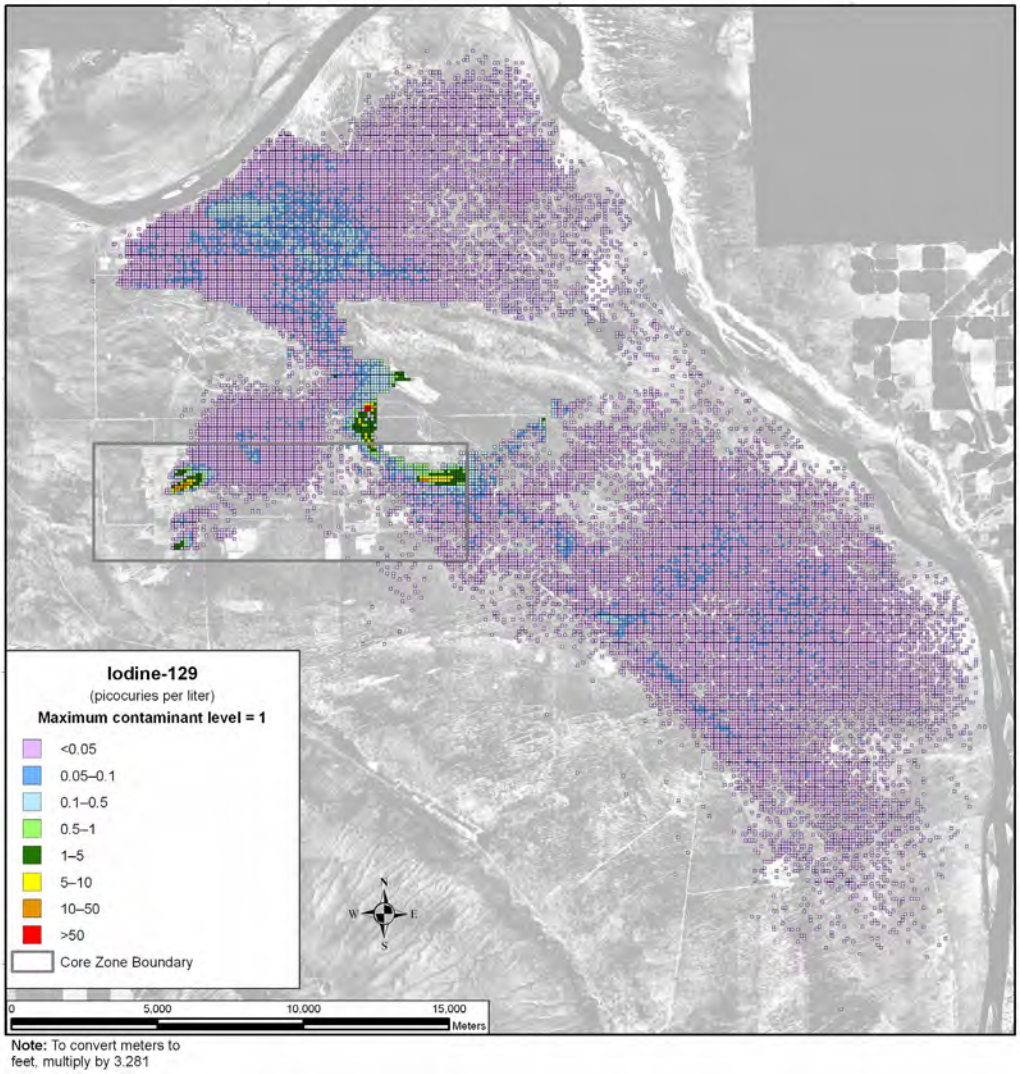
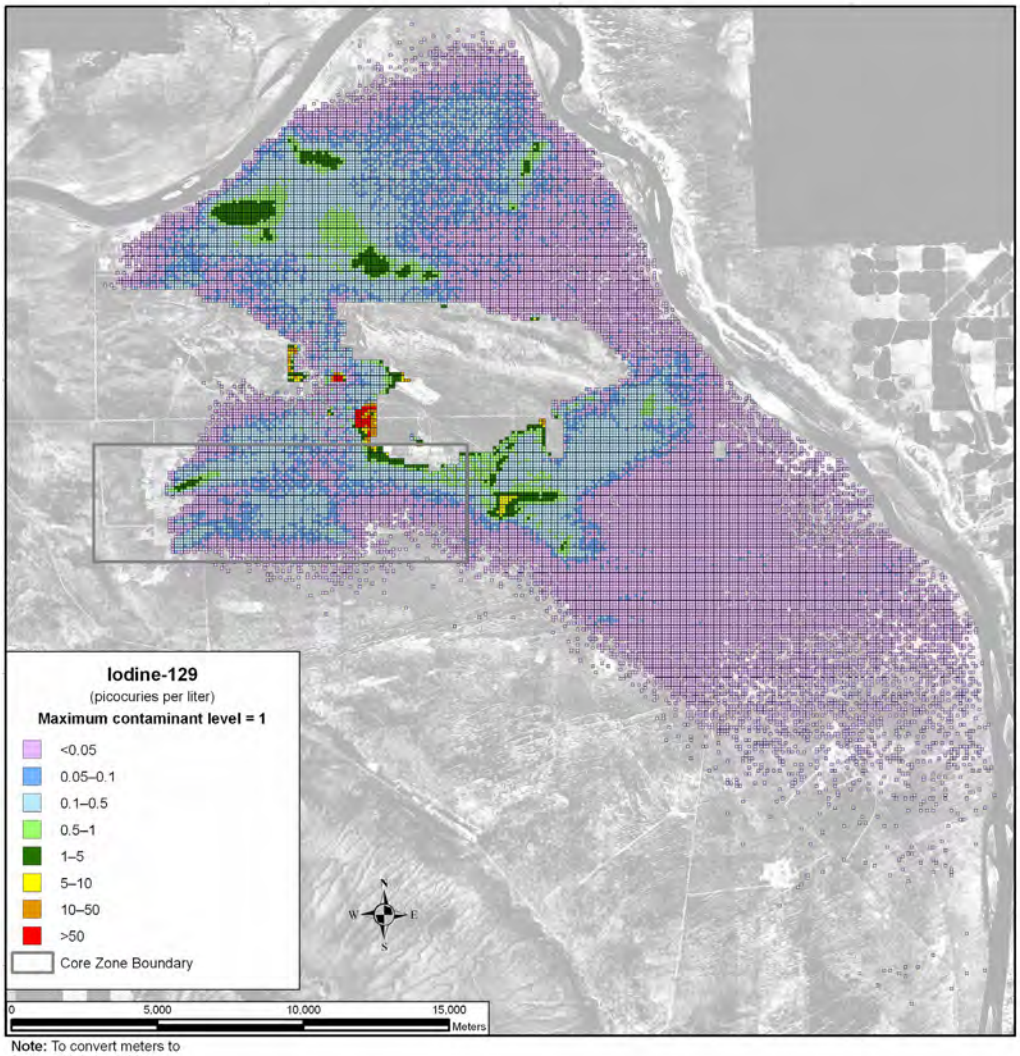
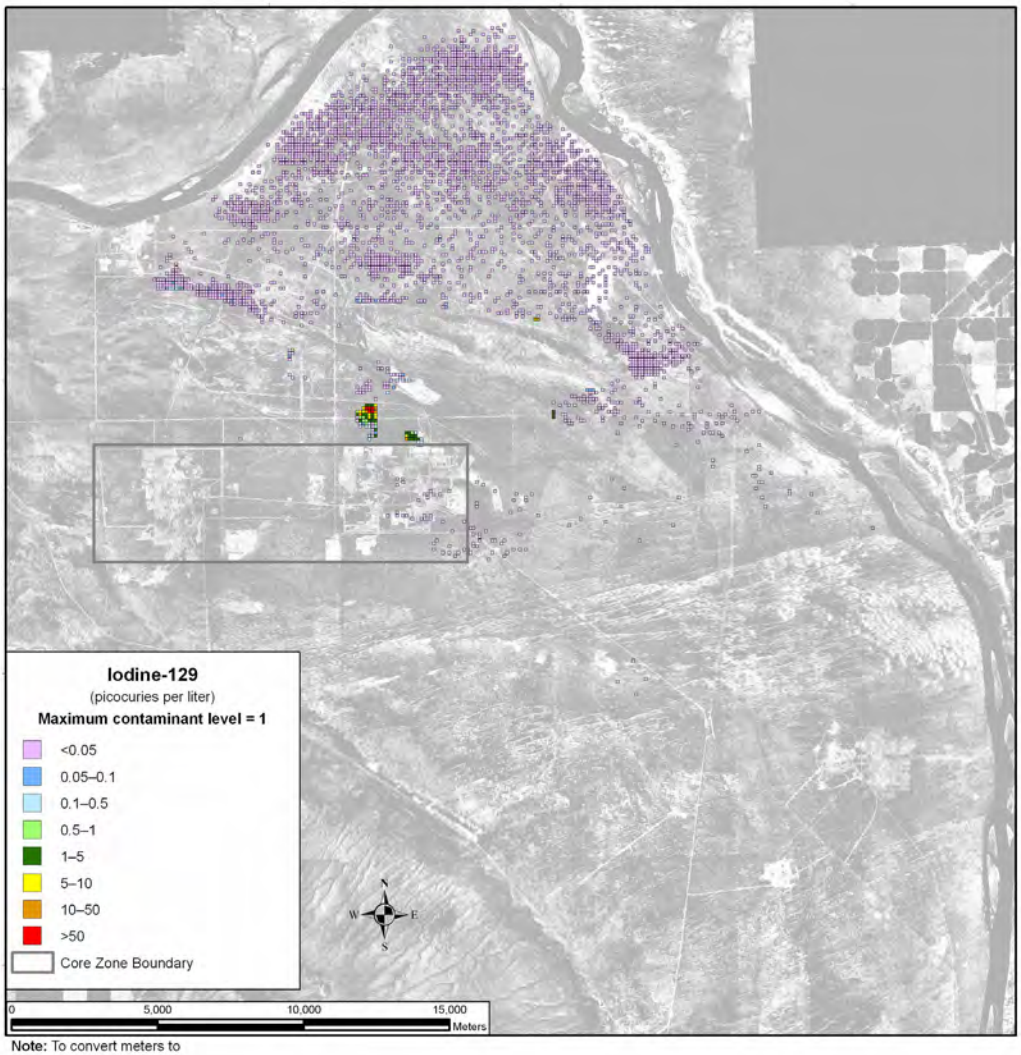


Figure 5–225. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



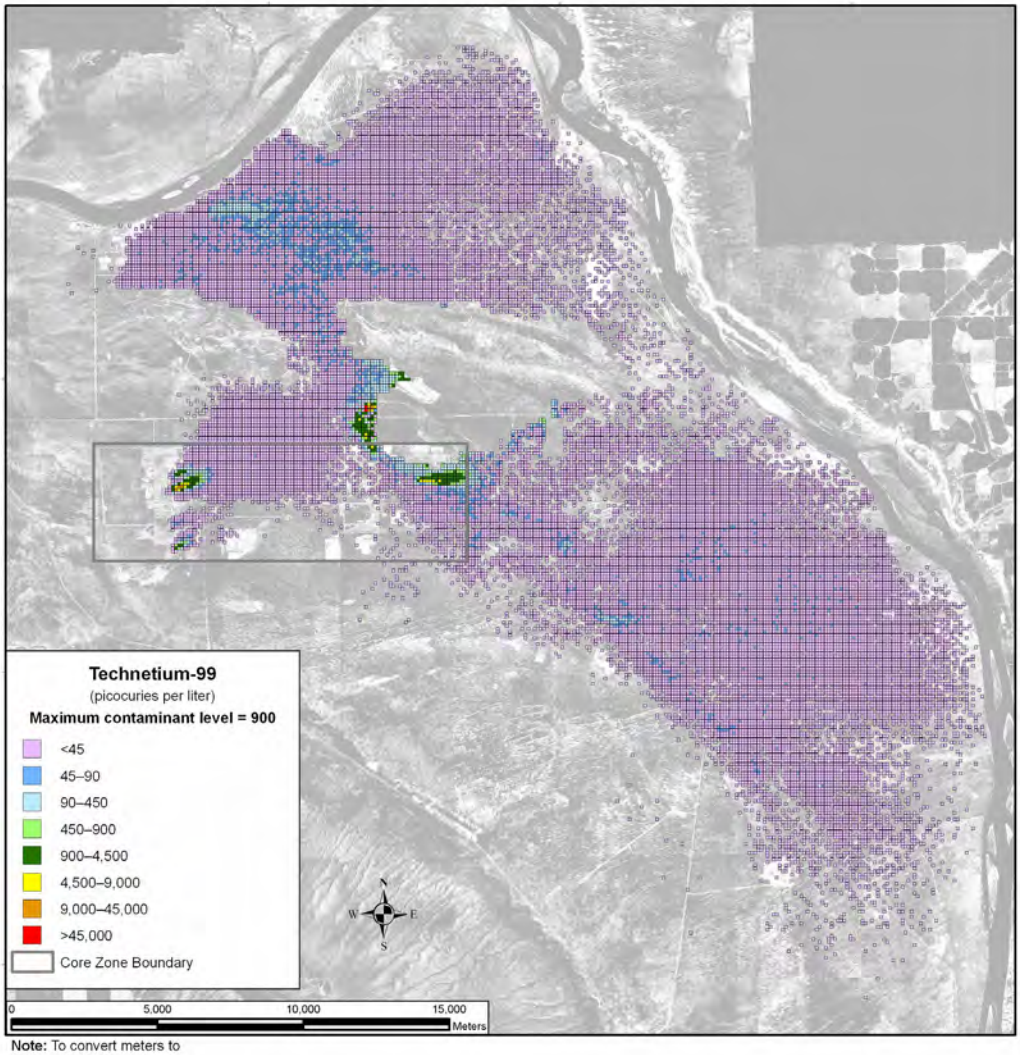
Note: To convert meters to feet, multiply by 3.281

Figure 5–226. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



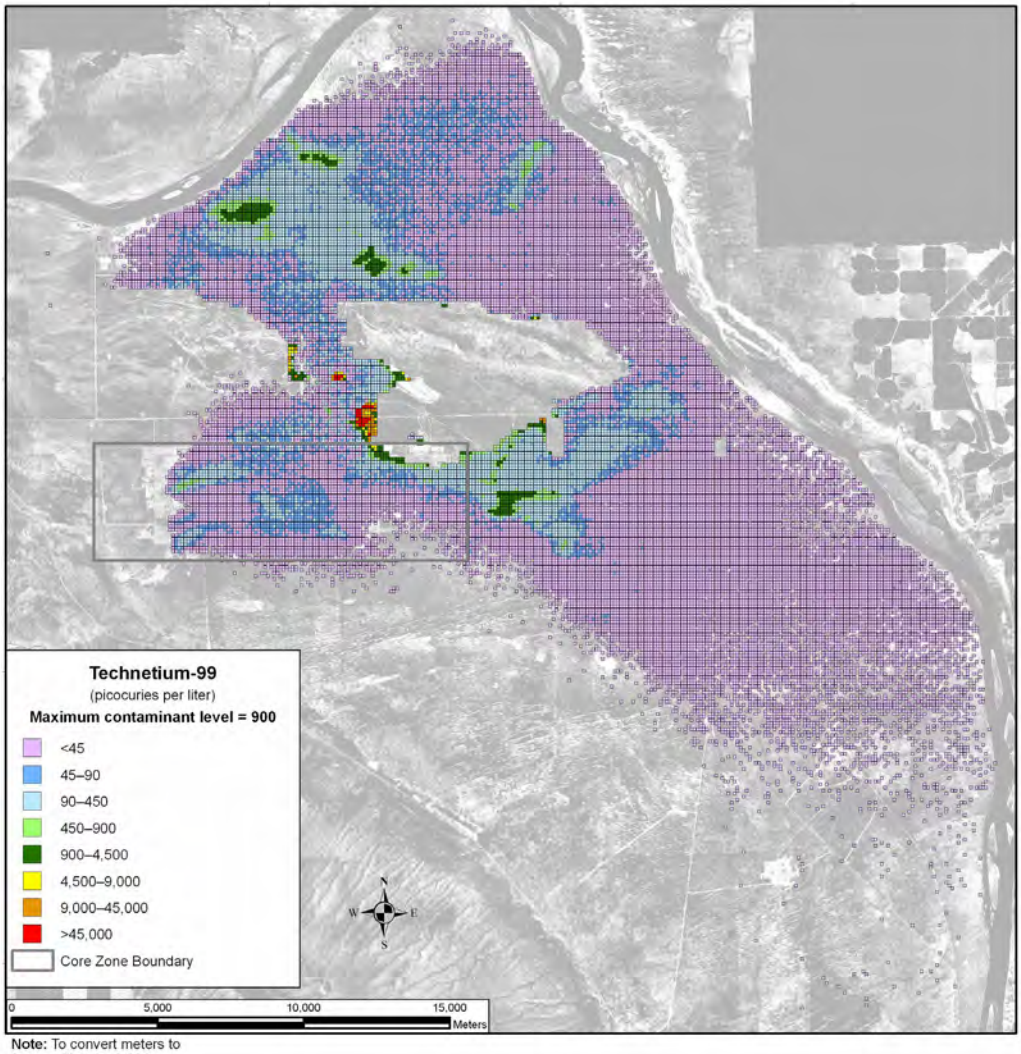
Note: To convert meters to feet, multiply by 3.281

Figure 5–227. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



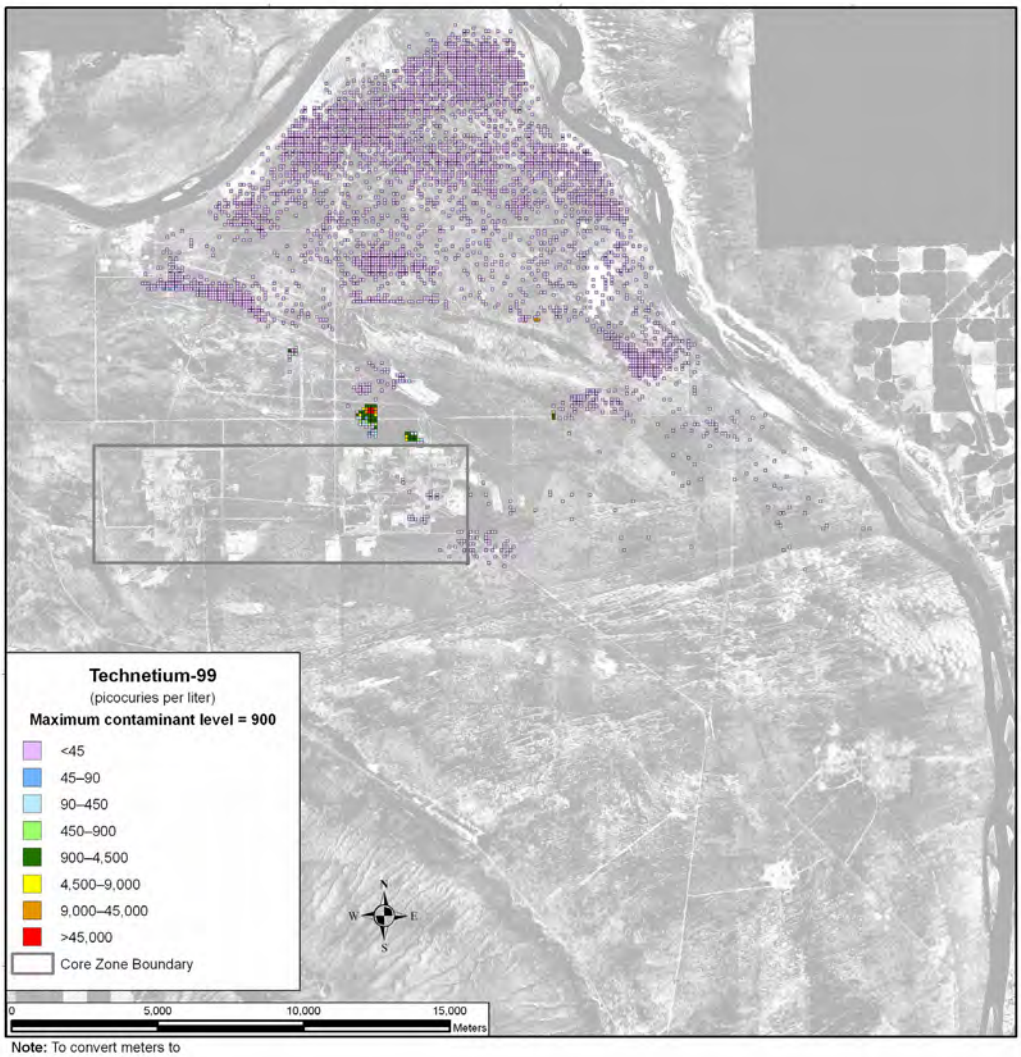
Note: To convert meters to feet, multiply by 3.281

Figure 5–228. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



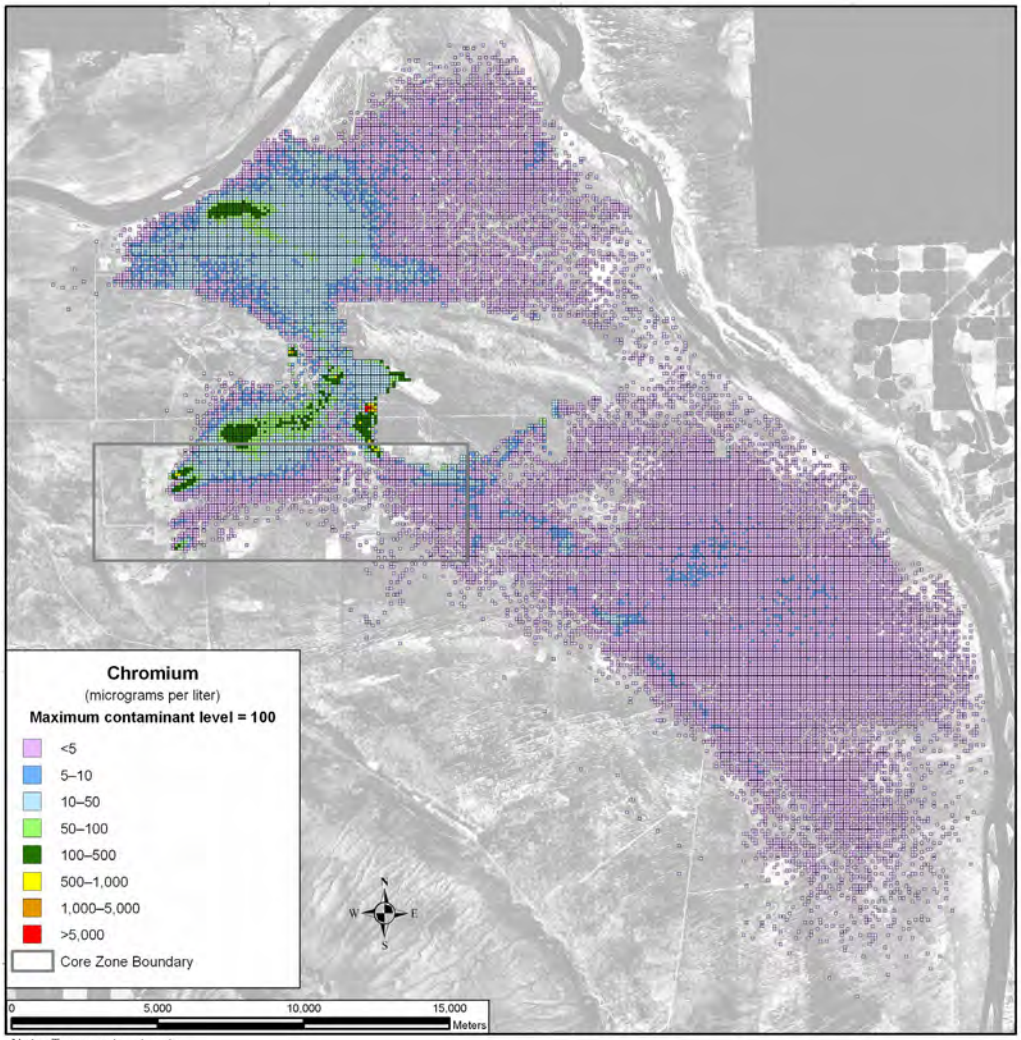
Note: To convert meters to feet, multiply by 3.281

Figure 5–229. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



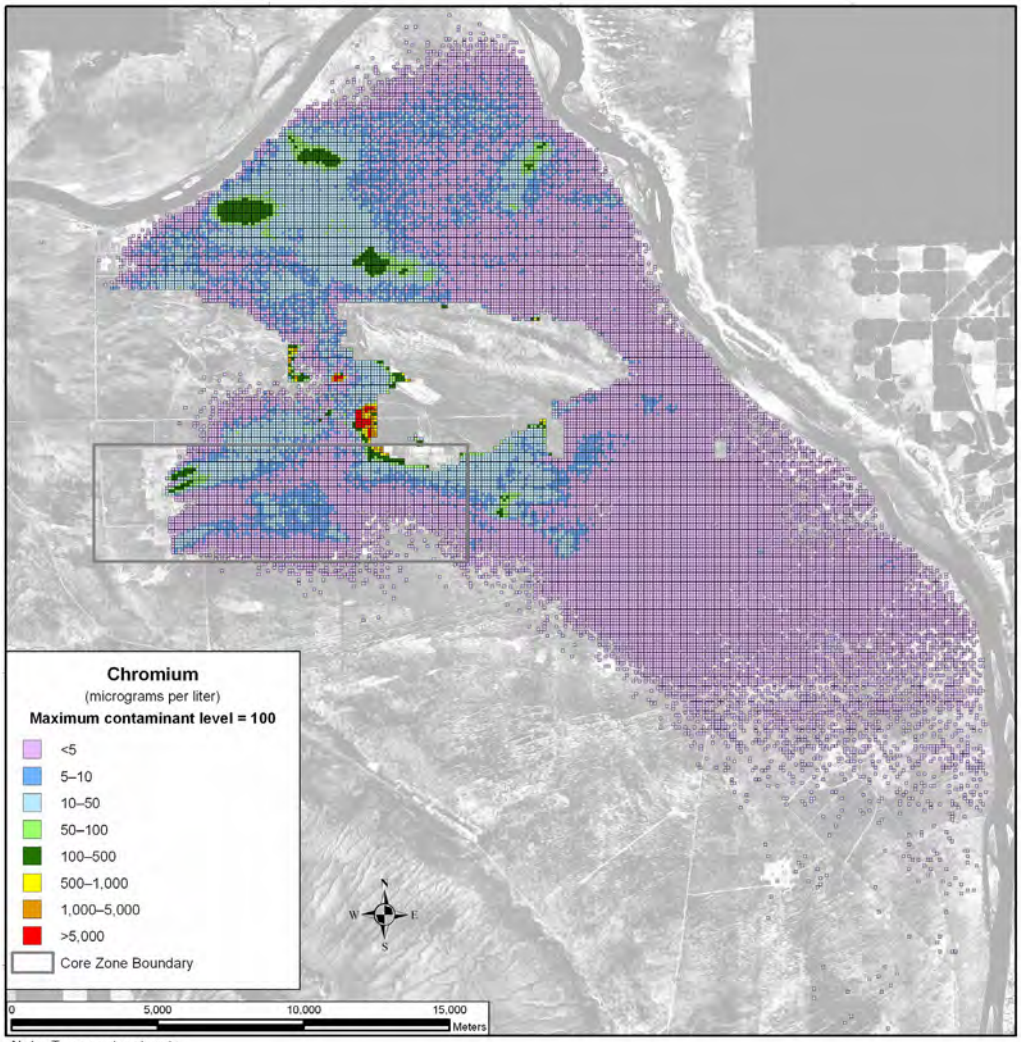
Note: To convert meters to feet, multiply by 3.281

Figure 5–230. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



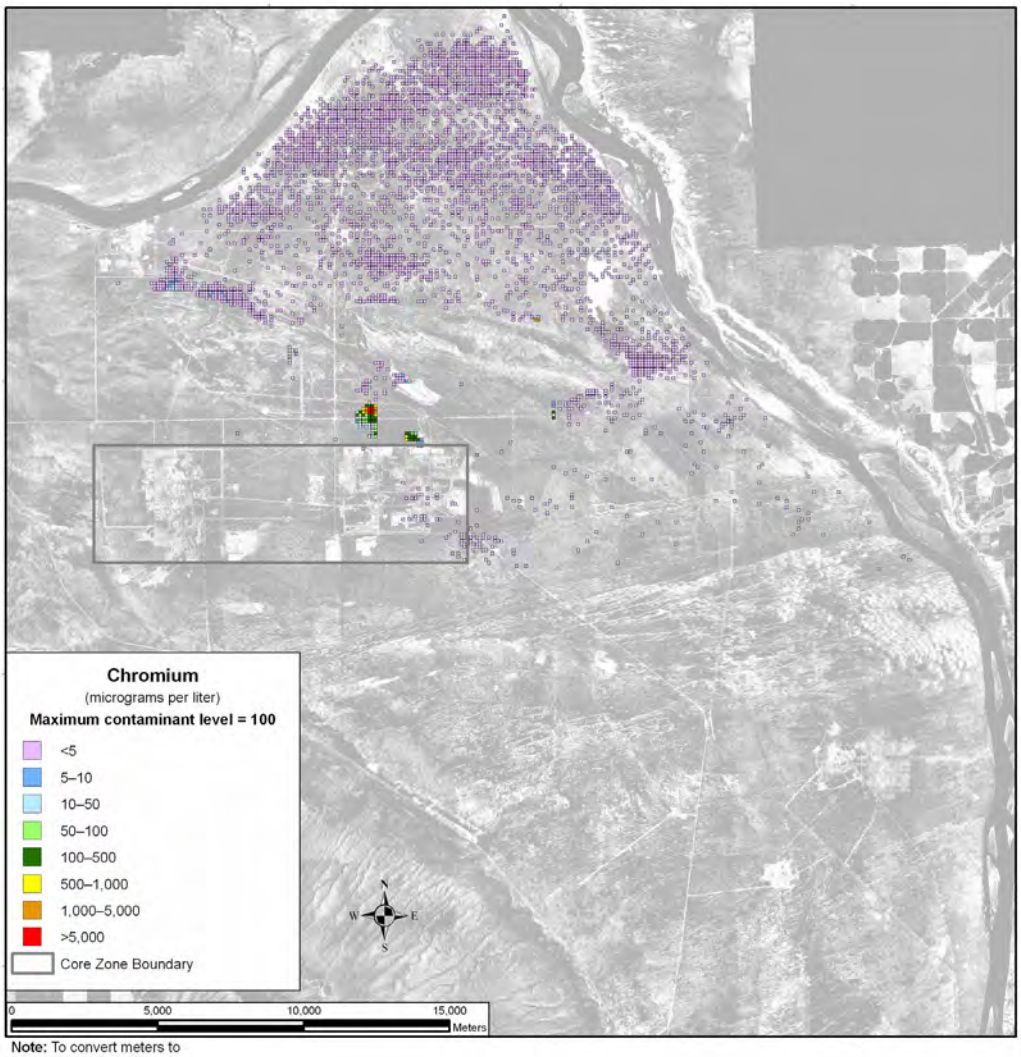
Note: To convert meters to feet, multiply by 3.281

Figure 5–231. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



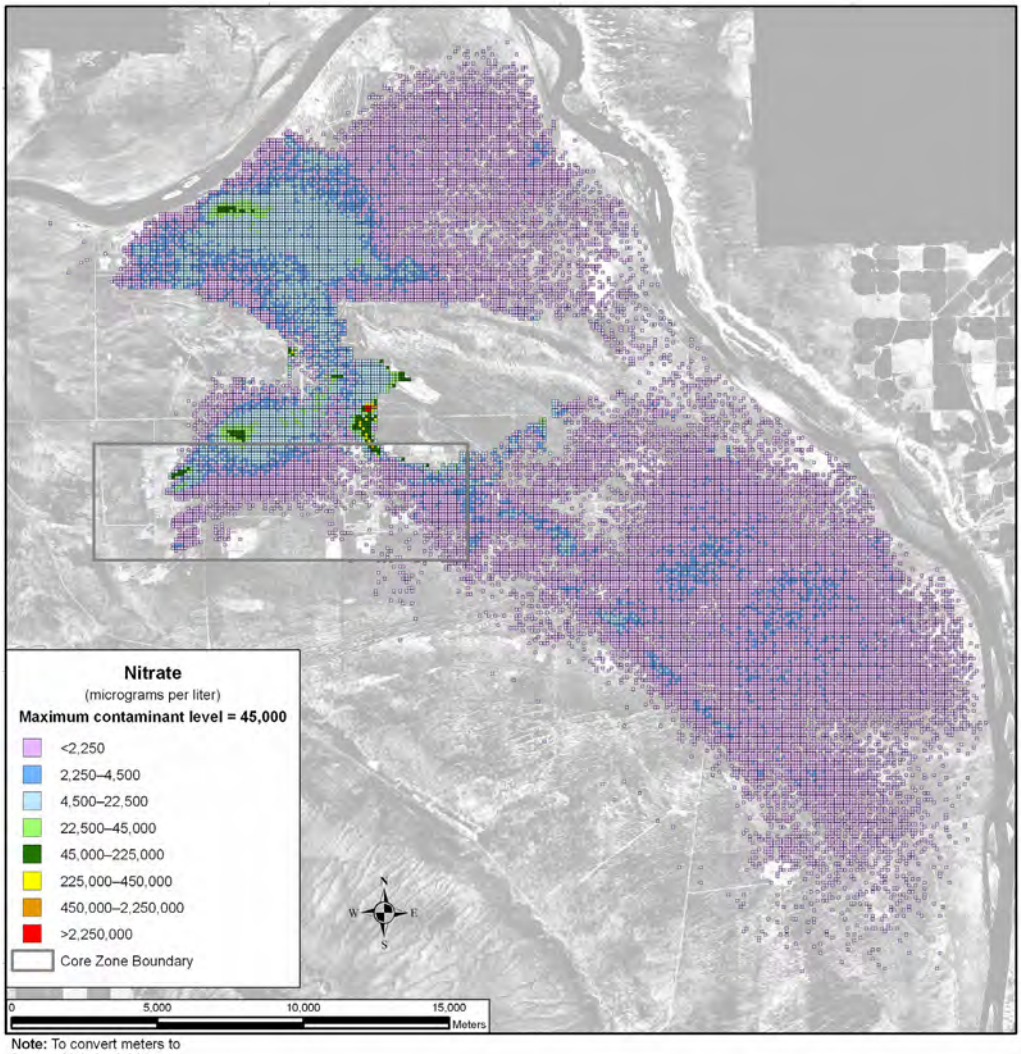
Note: To convert meters to feet, multiply by 3.281

Figure 5–232. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–233. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–234. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005

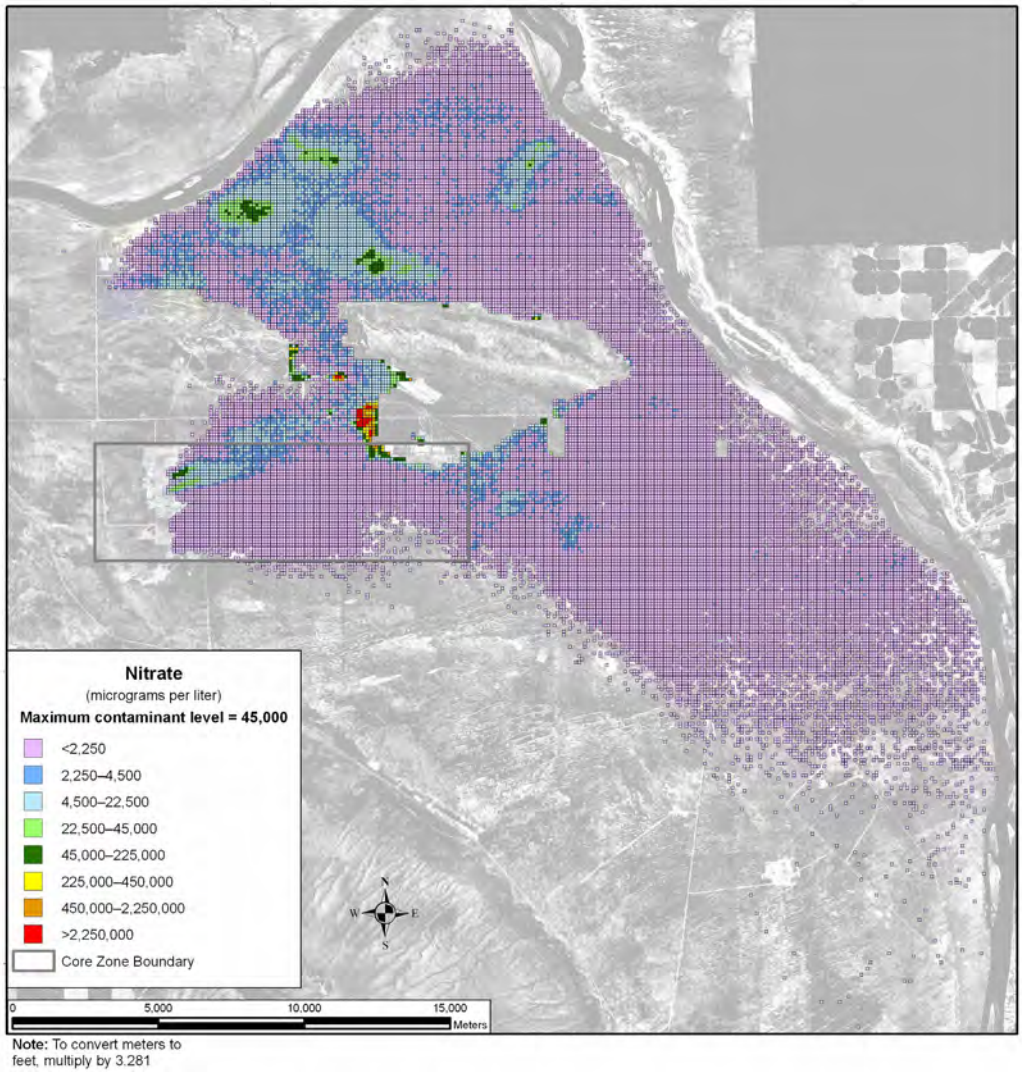


Figure 5–235. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135

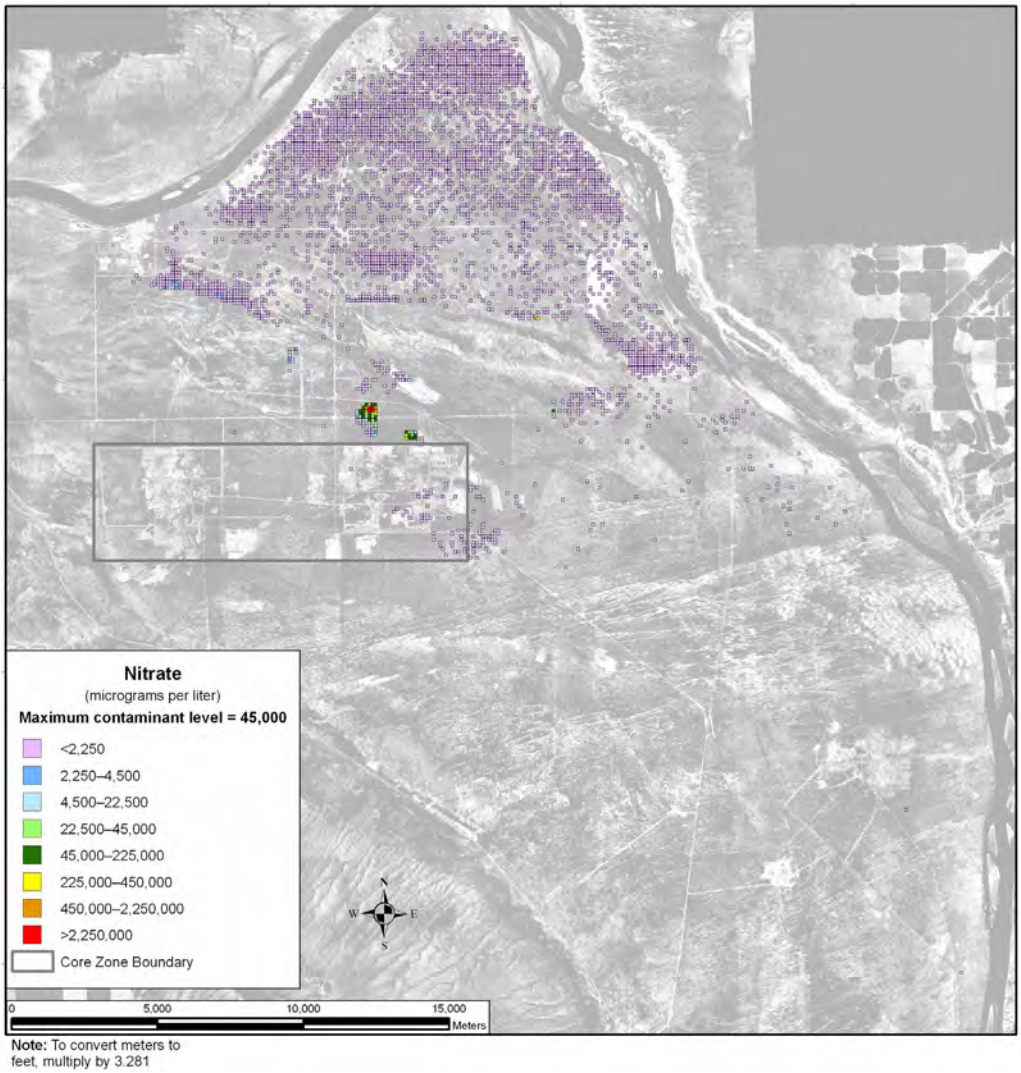
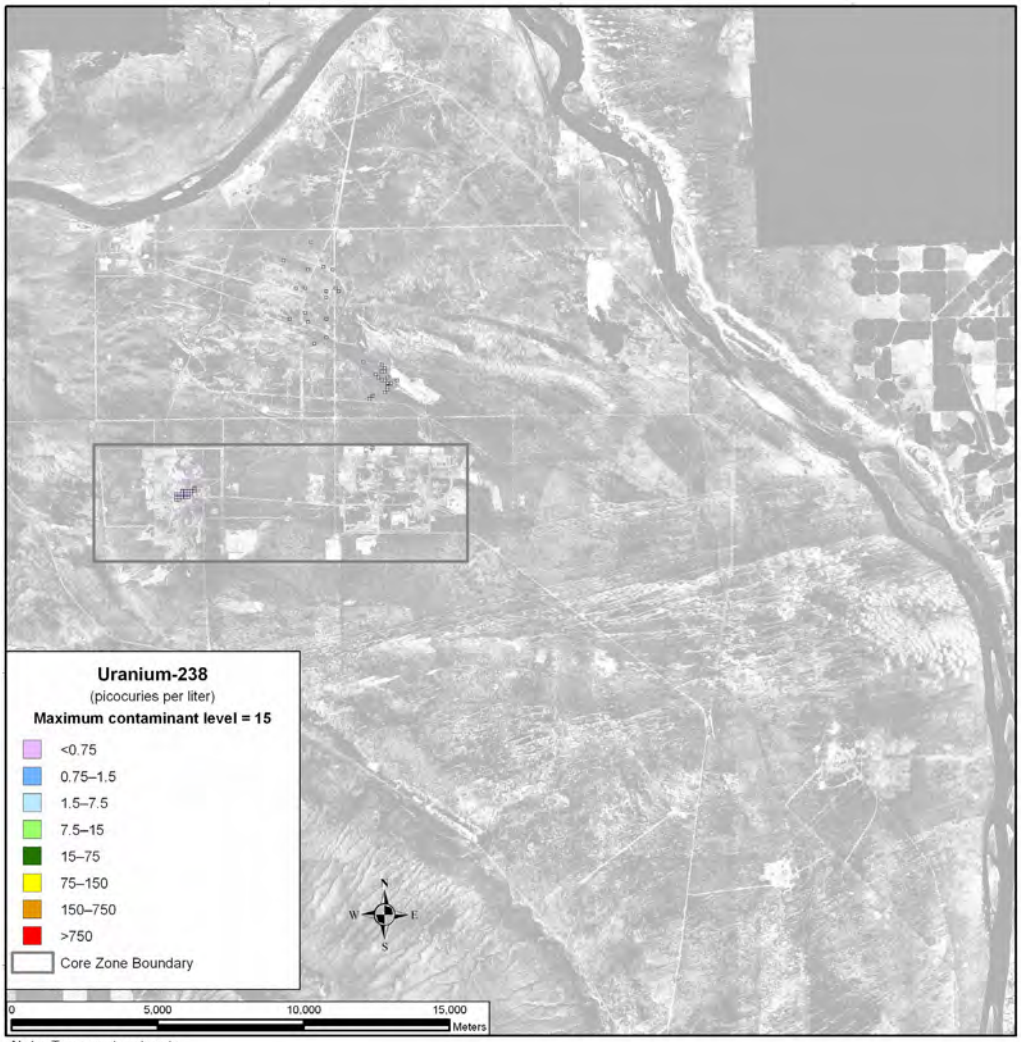


Figure 5–236. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium under the Base Case are not as mobile as those COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–237 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140, the area of the plume has grown and extended to the Columbia River (see Figure 5–238). Most of the plume is significantly below the benchmark except for a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier. At CY 11,885, the greatest development of the plume during the analysis period is seen (see Figure 5–239). The only area with a significant level of contaminant concentration is the area in the southern region of Gable Gap that originates from the B Barrier. Figures 5–240 through 5–242 show similar results for total uranium.



Note: To convert meters to feet, multiply by 3.281

Figure 5–237. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005

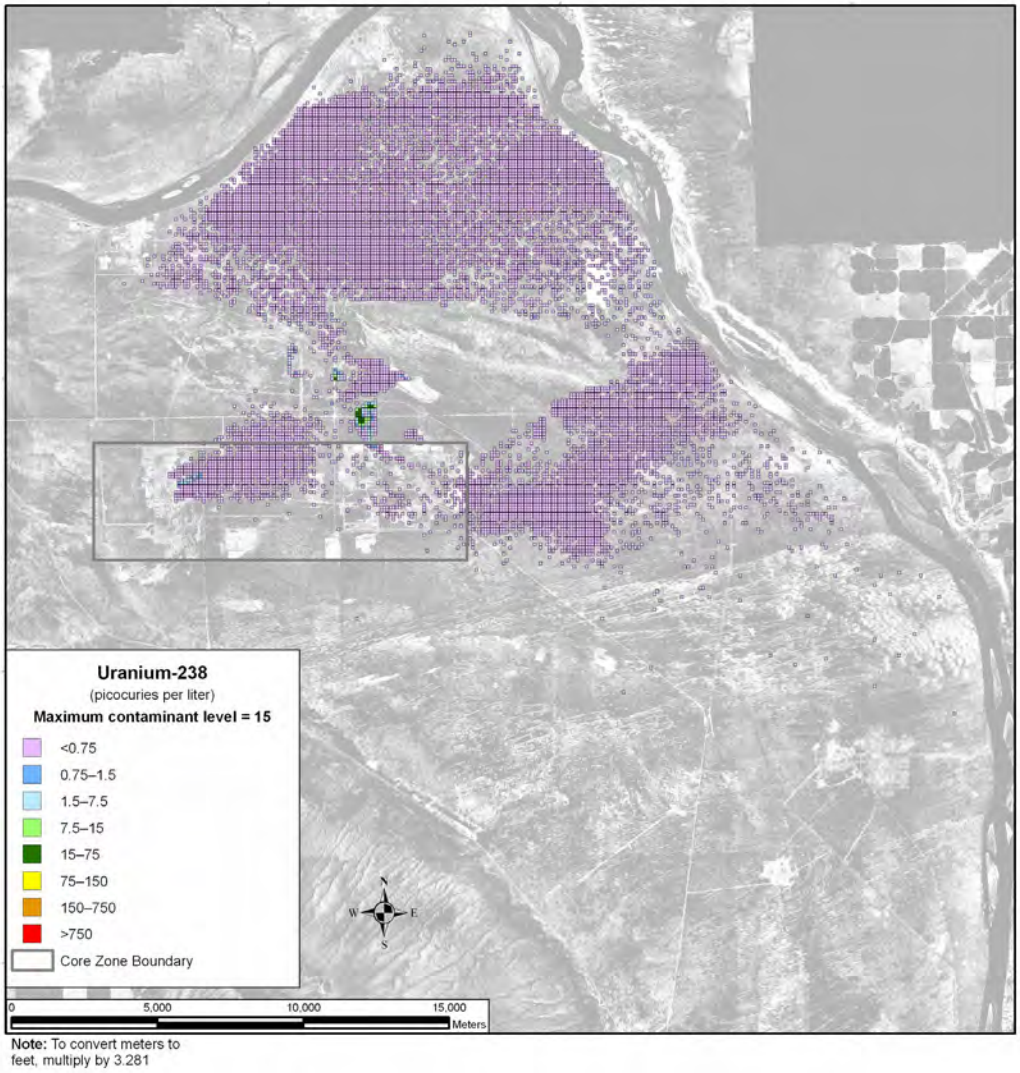
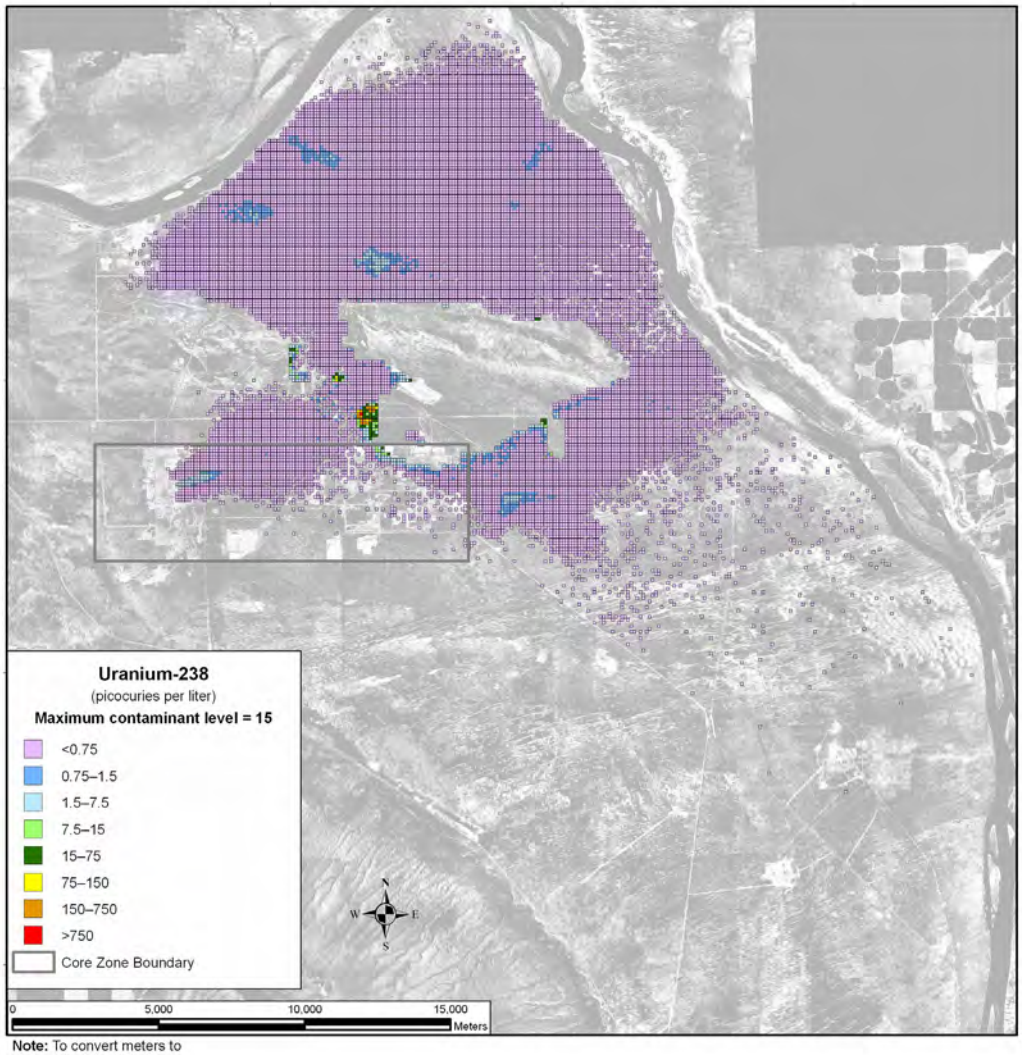


Figure 5–238. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–239. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

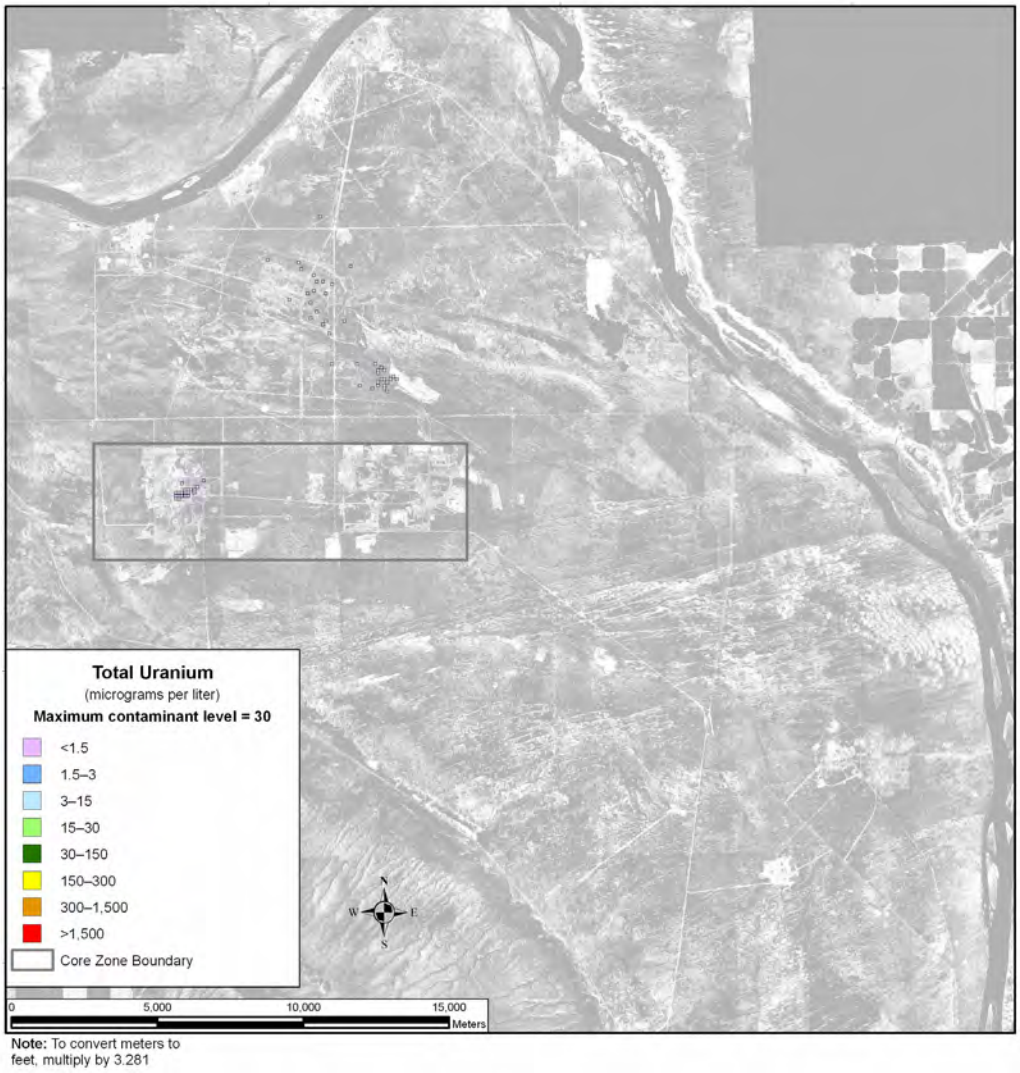
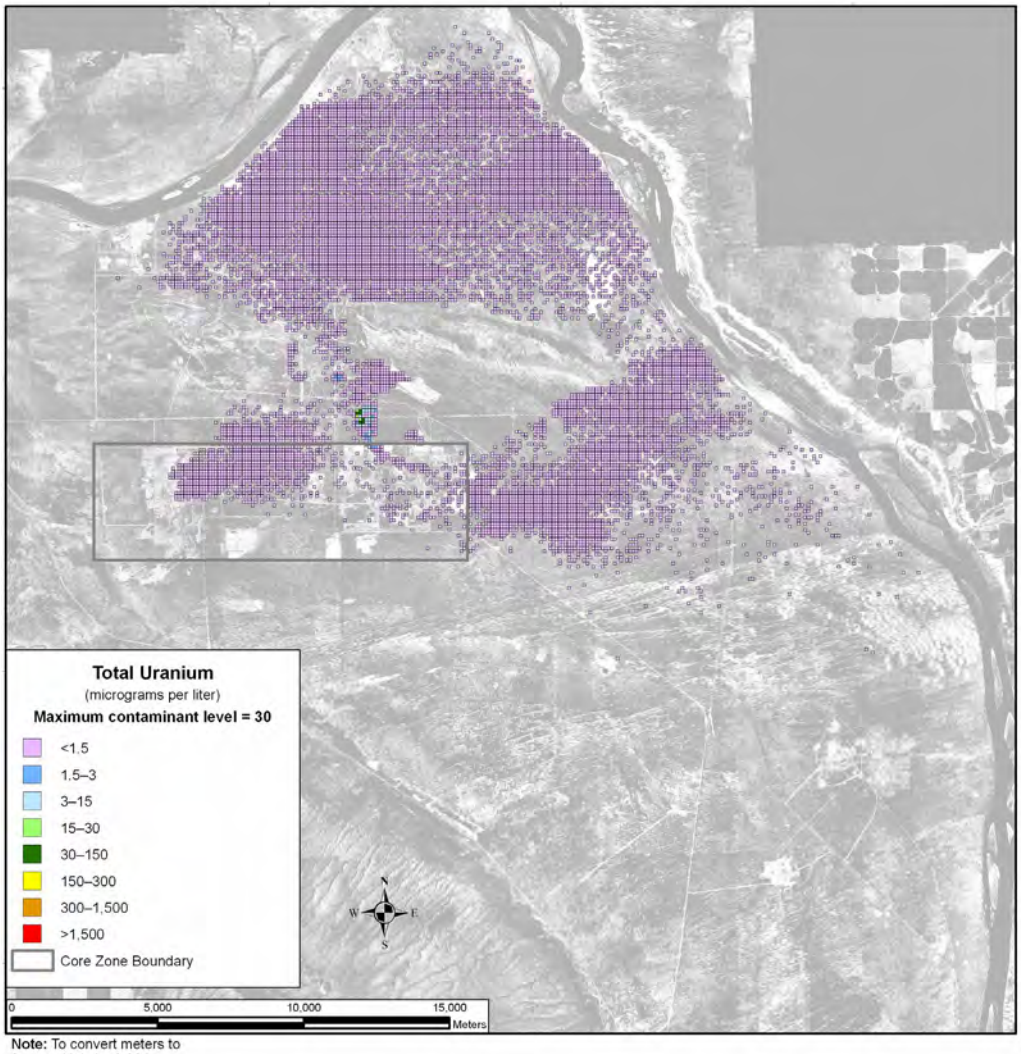
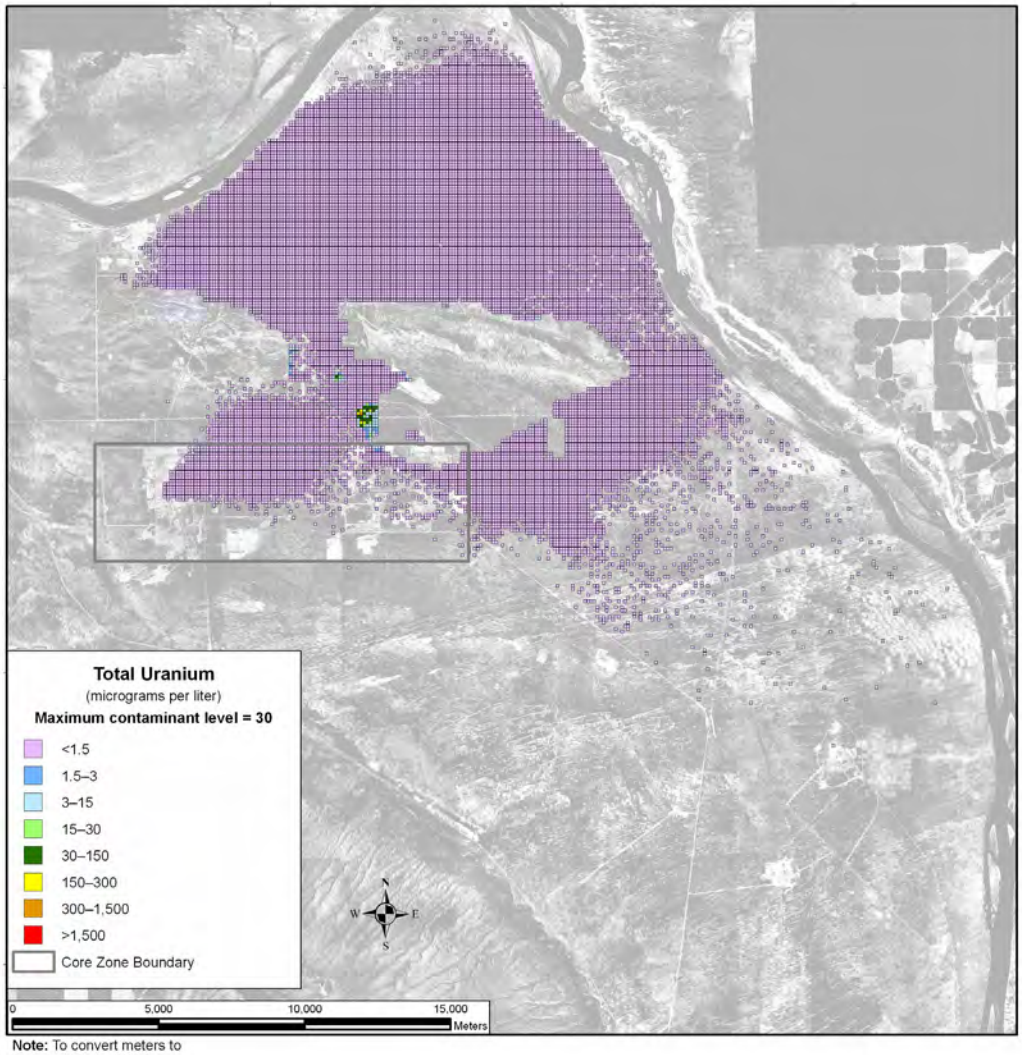


Figure 5–240. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

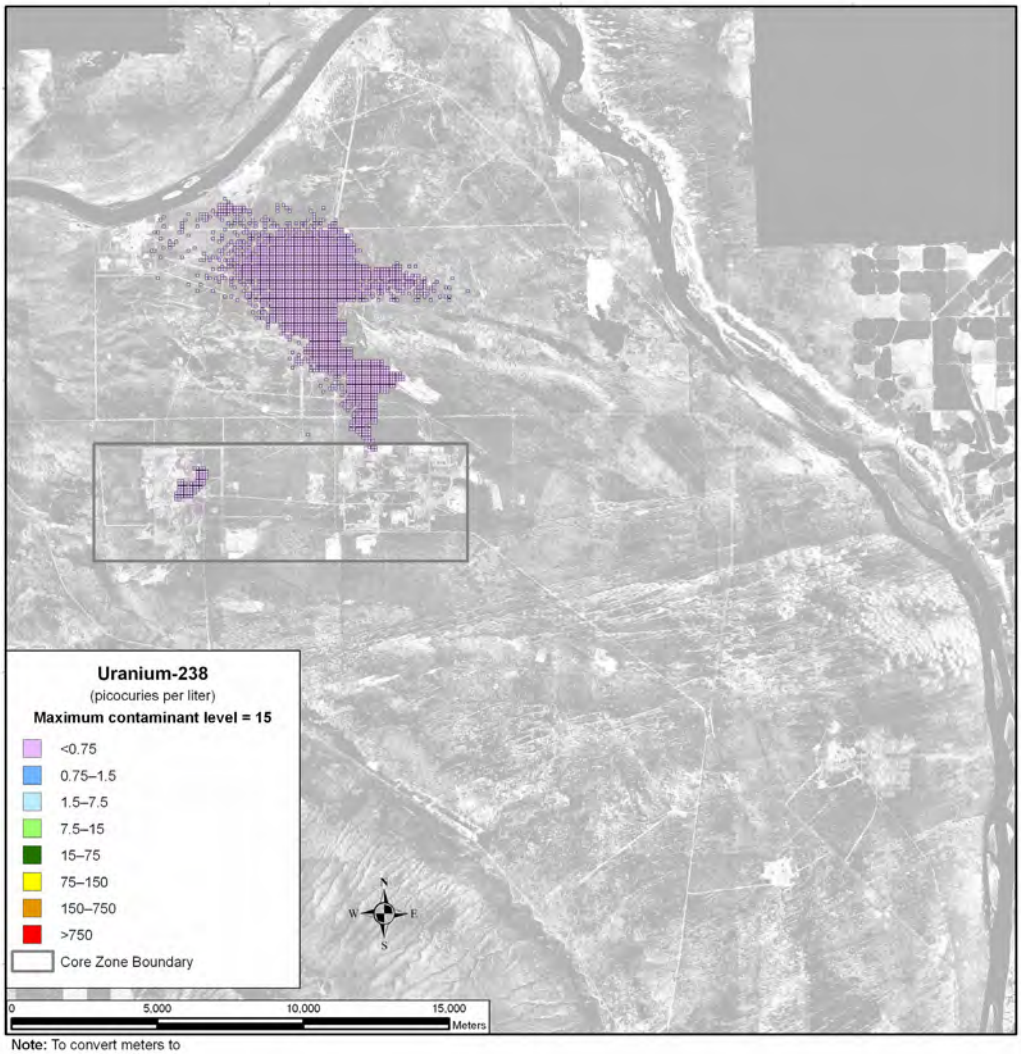
Figure 5–241. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

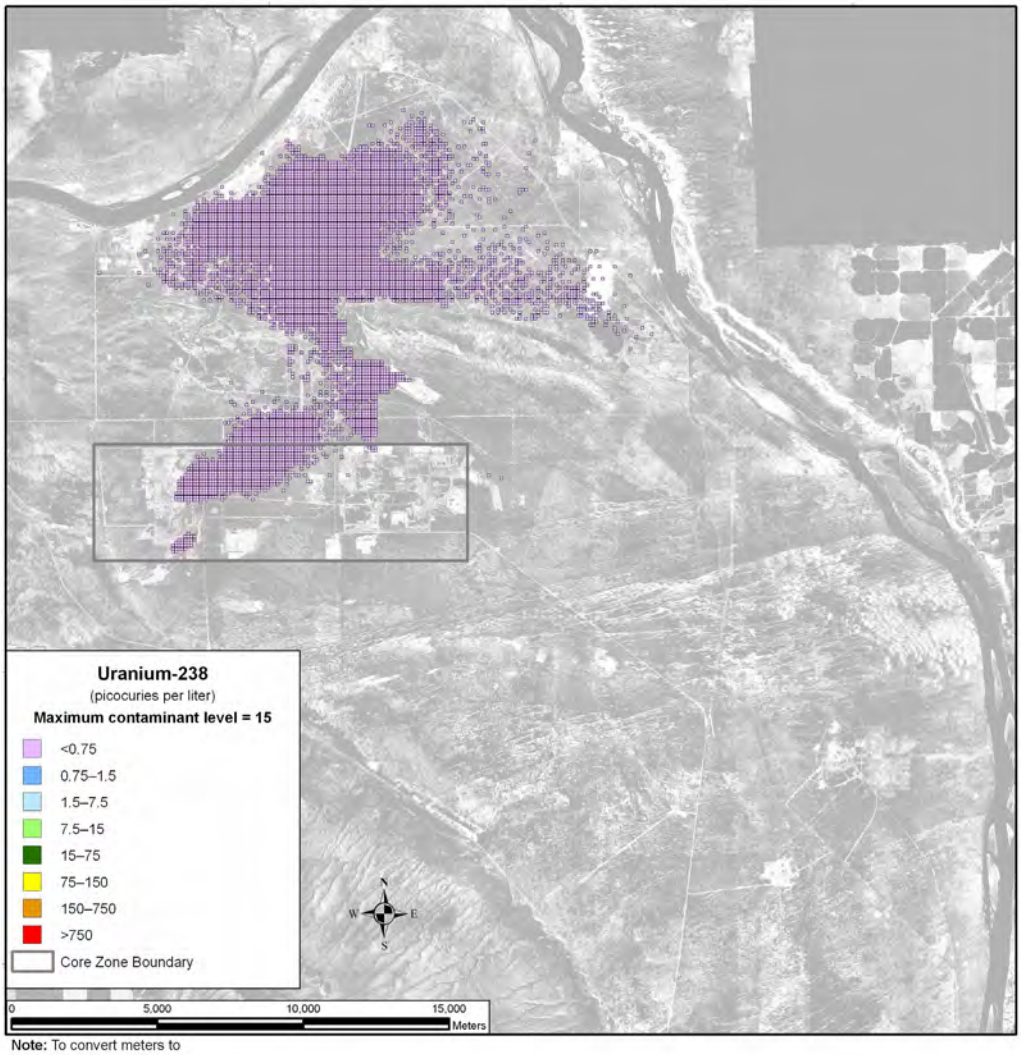
Figure 5–242. Tank Closure Alternative 6A, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–243 shows the distribution of uranium-238 during CY 2005 under the Option Case. There are two plumes associated with this case, one originating from the T Barrier and the other from the B Barrier. Although there are no significant contaminant concentrations, the plumes under the Option Case are much larger than under the Base Case. By CY 2135, the contaminant plume has grown and reached the Columbia River, but there are still no significant peaks in concentration levels (see Figure 5–244). By CY 11,885, while the greatest development of the plume occurred under the Base Case, the contaminant plume under the Option Case has begun to recede (see Figure 5–245). This recession is due to the removal of the six sets of cribs and trenches (ditches) and the remediation of their contaminant plumes. Figures 5–246 through 5–248 show similar results for total uranium.



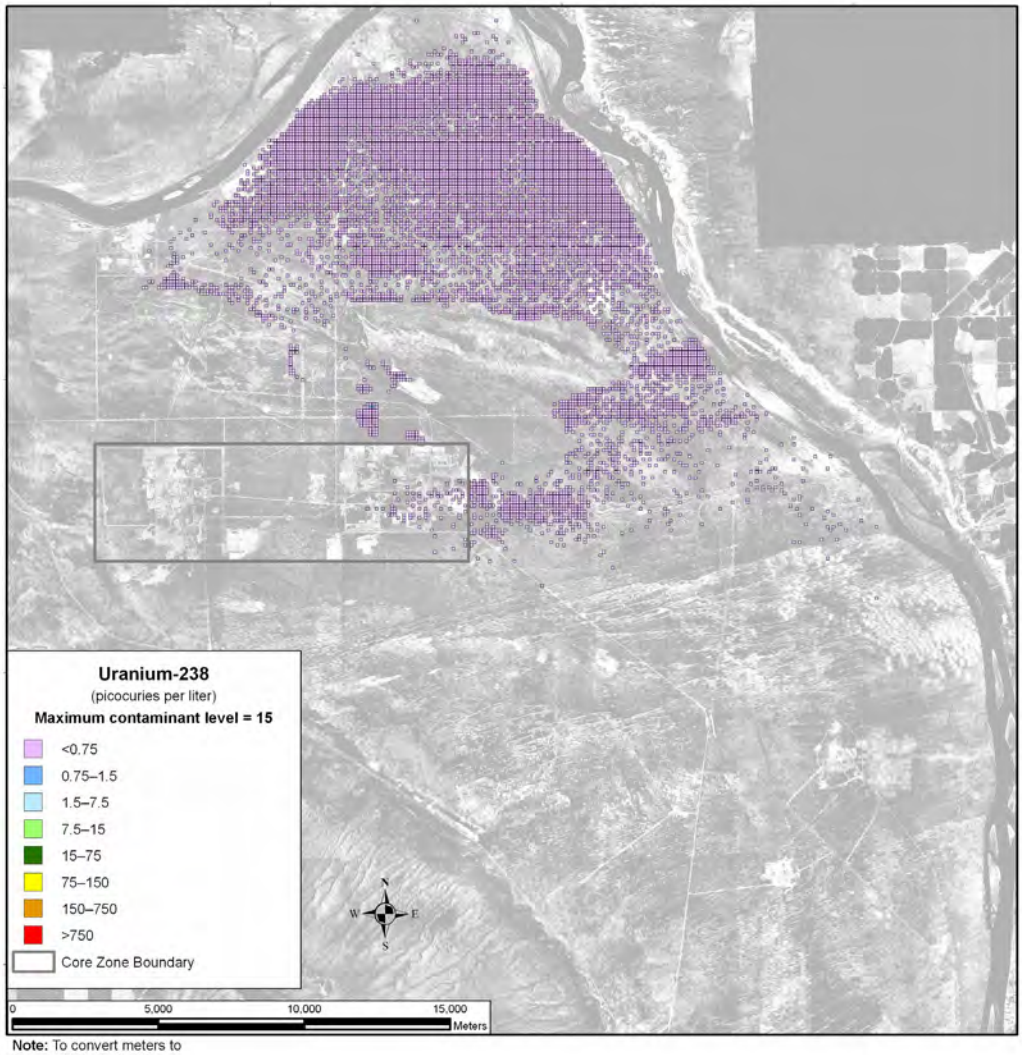
Note: To convert meters to feet, multiply by 3.281

Figure 5–243. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–244. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–245. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

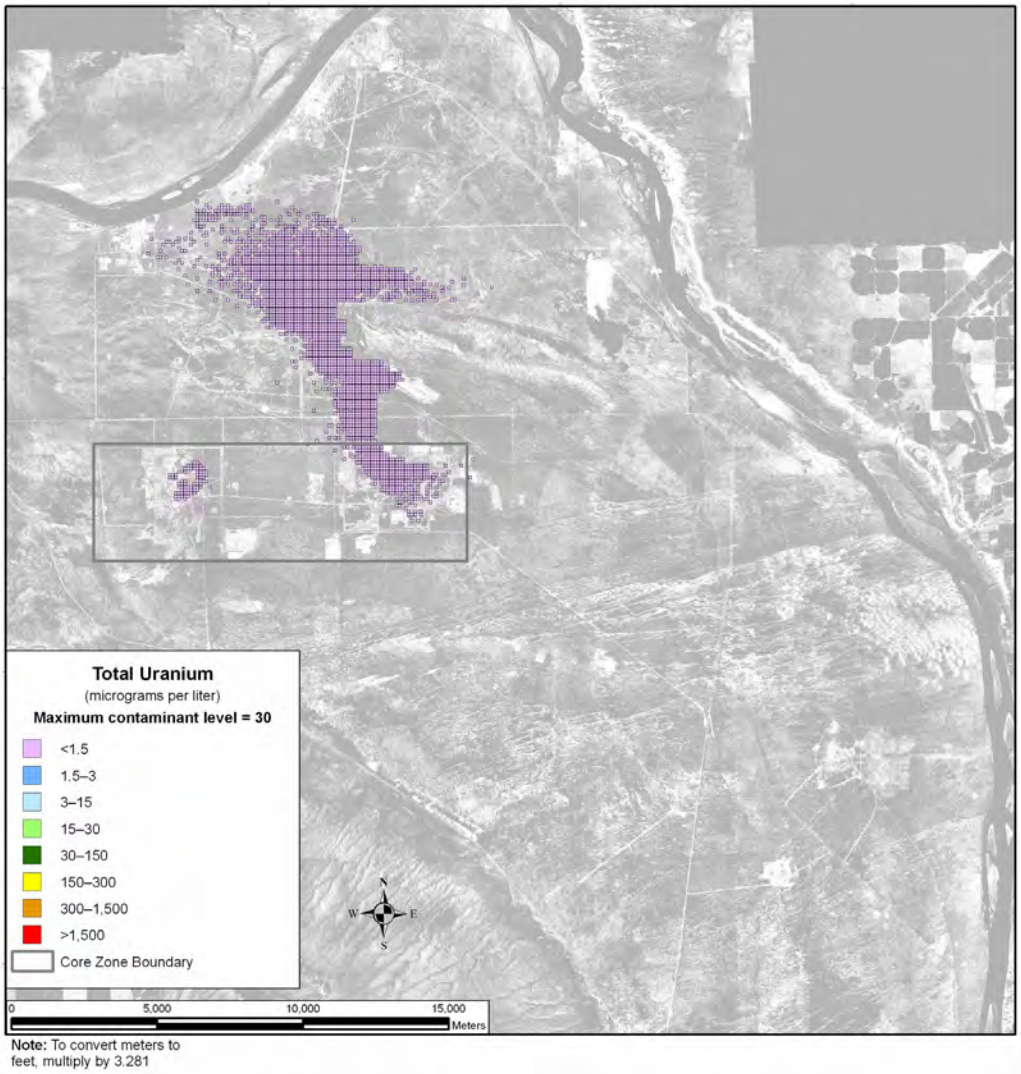
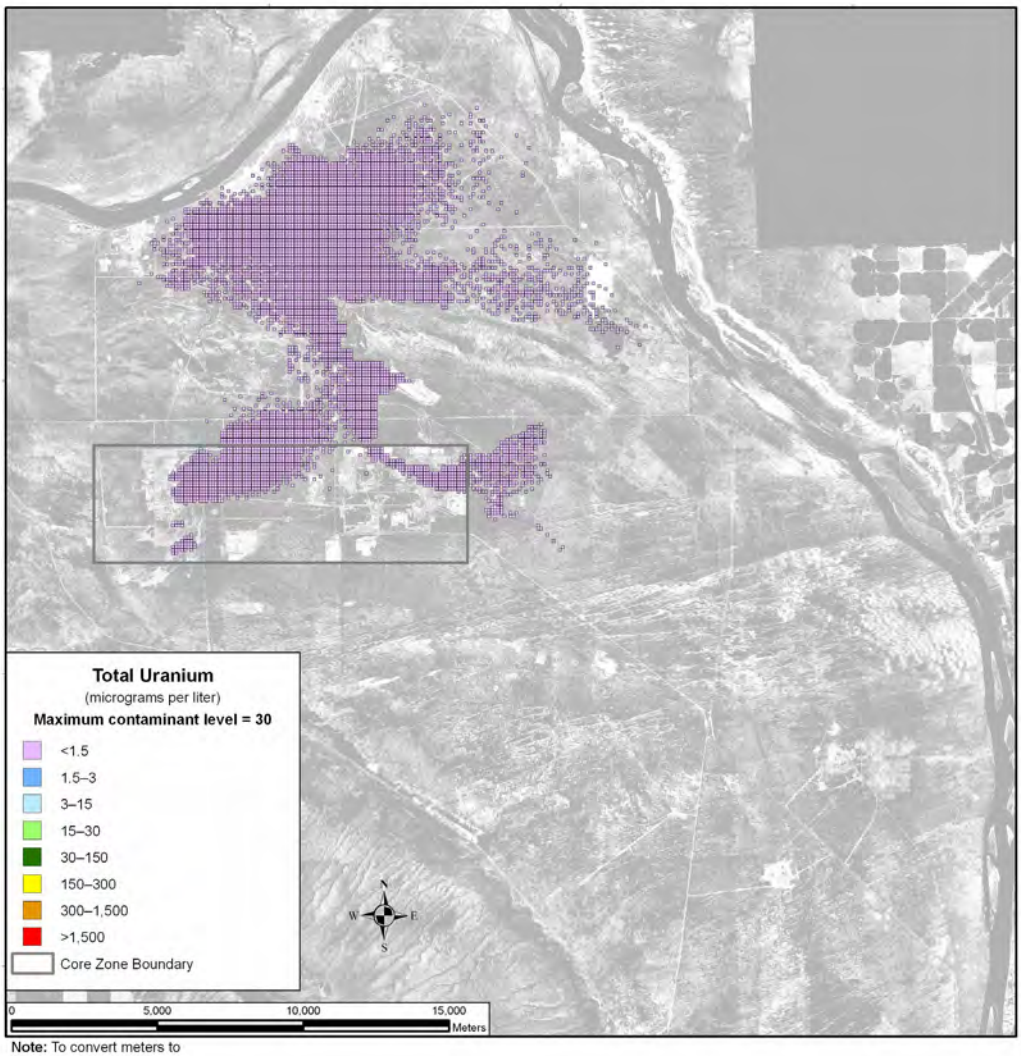
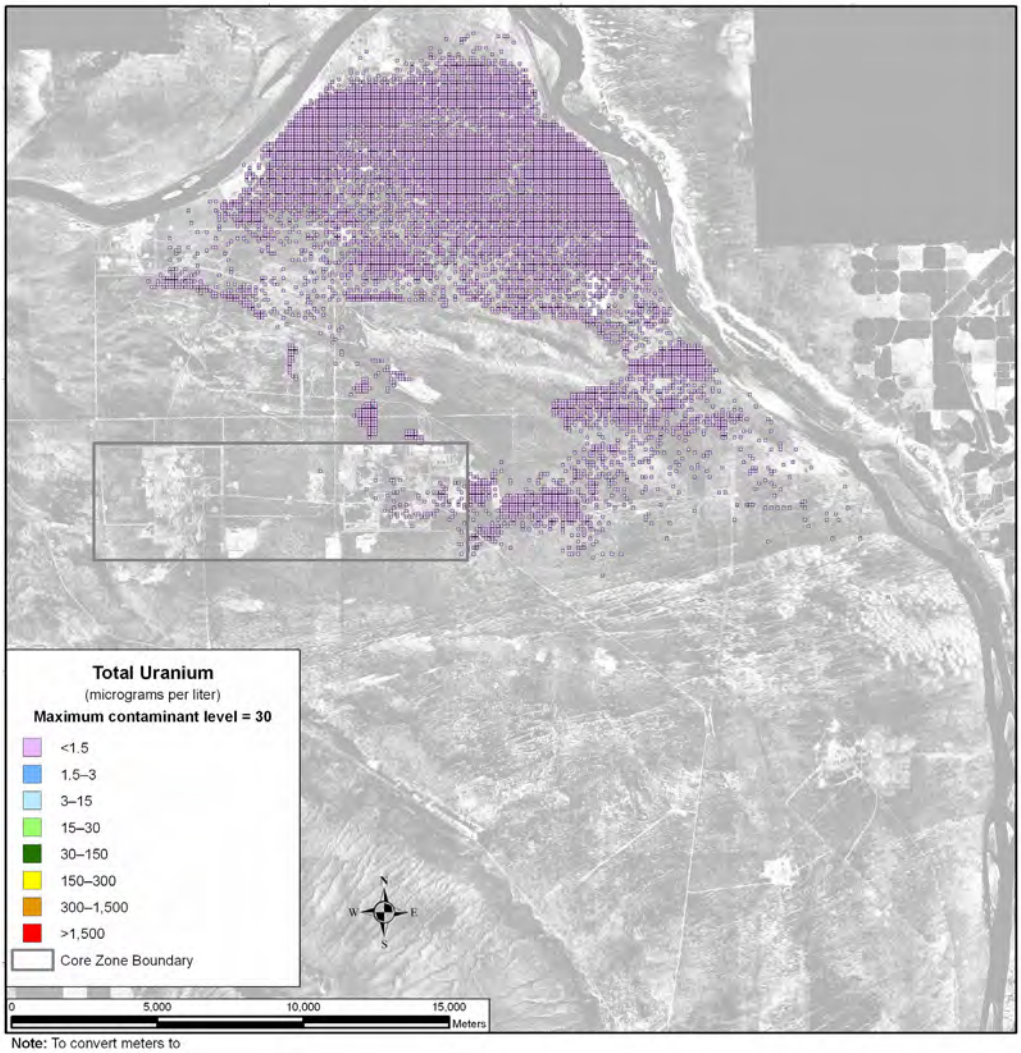


Figure 5–246. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–247. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–248. Tank Closure Alternative 6A, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–249 shows the area in square kilometers in which groundwater concentrations of technetium-99 exceed the benchmark concentration in the analysis as a function of time under the Base Case. A peak of almost 4.5 square kilometers (1.7 square miles) occurs around CY 2135, followed by a fairly sharp decrease. By about CY 4000, the area with a concentration above the benchmark begins to level out around 0.5 square kilometers (0.19 square miles). Iodine-129 shows a similar pattern (see Figure 5–250), as both constituents are conservative tracers.

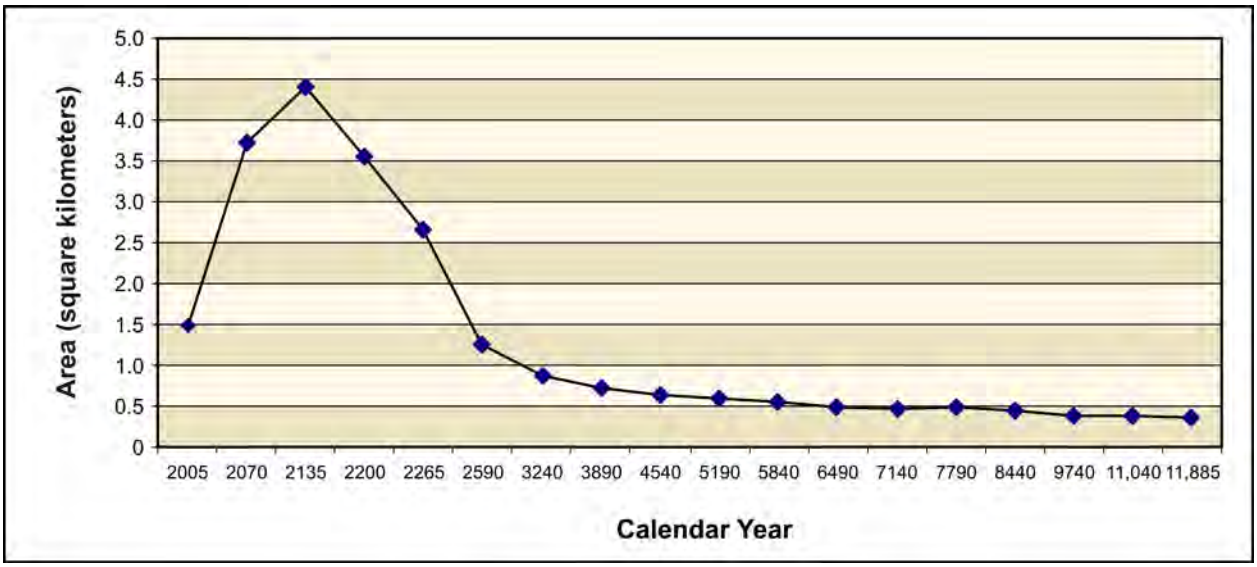


Figure 5–249. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

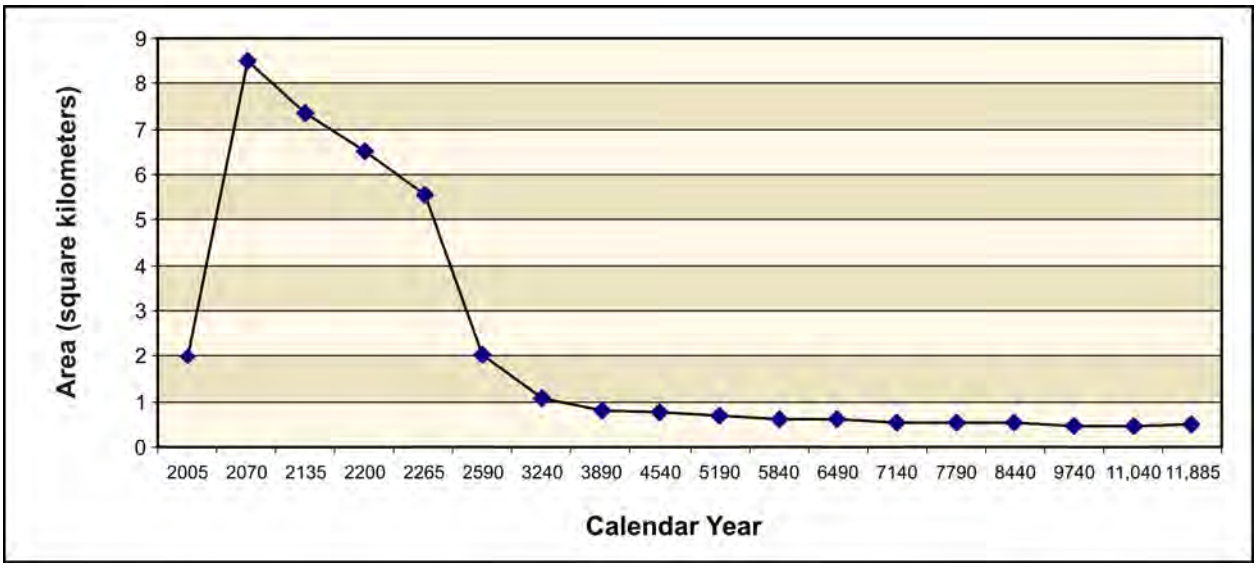


Figure 5–250. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, the areas with concentrations of technetium-99 and iodine-129 above the benchmarks are essentially identical to those under the Base Case (see Figures 5–251 and 5–252).

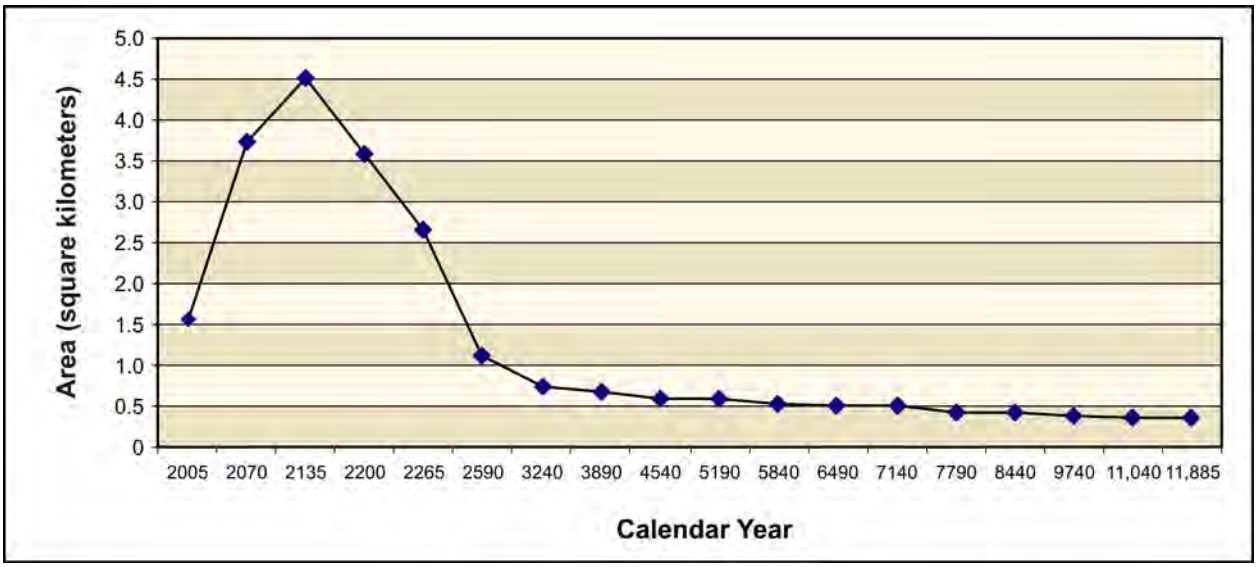


Figure 5–251. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

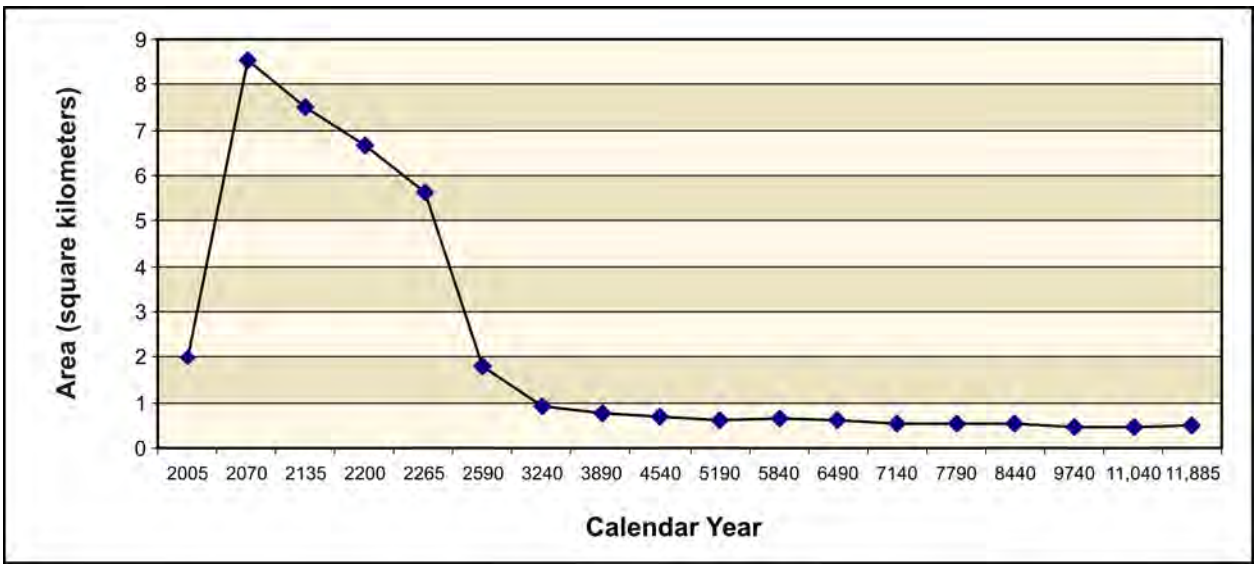


Figure 5–252. Tank Closure Alternative 6A, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Base Case, uranium-238 did not register above the benchmark concentration in any area until after CY 5840 (see Figure 5–253). A sharp increase in area with concentrations above the maximum contaminant level occurs after CY 5840 and continues to rise through the end of the period of analysis (CY 11,940). It is expected that the majority of the uranium-238 would continue to migrate through the vadose zone after the period of analysis is over.

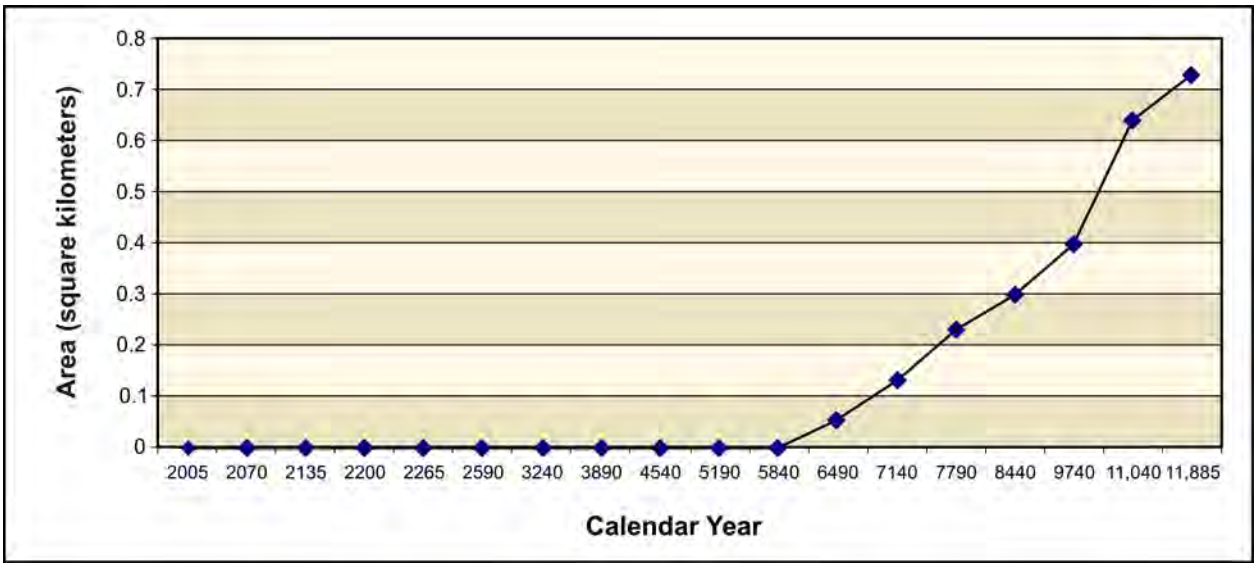


Figure 5–253. Tank Closure Alternative 6A, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, uranium-238 did not register above the benchmark concentration in any area during the period of analysis. This is a result of the high retardation rate and the removal and remediation of the cribs and trenches (ditches).

5.1.1.9.6 Summary of Impacts

For the conservative tracers under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark standards by about two orders of magnitude during the early part of the period of analysis, around CY 1956. Columbia River nearshore concentrations never reached the benchmark concentration and peaked at about one-half to one order of magnitude below it. The intensities and areas of these groundwater plumes peaked around CY 1956.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Option Case are essentially identical to those under the Base Case.

For tritium under the Base Case, concentrations at the Core Zone Boundary exceed the benchmark by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

The concentrations of tritium under the Option Case are essentially identical to those under the Base Case.

For uranium-238 and total uranium under the Base Case, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species began to approach the benchmark at the Core Zone Boundary toward the latter part of the period of

analysis but never reached it. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark. The intensity and area of the contaminant plumes peaked at the end of the period of analysis.

Under the Option Case, uranium-238 concentrations in the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark, except for a short spike in the Core Zone Boundary to about one order of magnitude below the benchmark at the beginning of the period of analysis. The Columbia River nearshore concentrations stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark. The Columbia River nearshore concentrations remained fairly constant at around four and a half orders of magnitude below the benchmark.

5.1.1.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure, Base and Option Cases

This section describes the groundwater analysis results for Tank Closure Alternative 6B, including long-term groundwater impacts of contaminant sources within the tank farm barriers. Impacts of sources removed from within the tank farm barriers and disposed of in an IDF and the RPPDF are presented in Section 5.3, which discusses waste management impacts.

Tank Closure Alternative 6B, Base and Option Cases, resembles Tank Closure Alternative 6A, Base and Option Cases, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date.

Under Tank Closure Alternative 6B, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier.

Under Tank Closure Alternative 6B, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval; all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed.

5.1.1.10.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Tank Closure Alternative 6B are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, three major periods were identified for Tank Closure Alternative 6B, as follows:

- The past-practice period was assumed to start with the onset of tank farm operations in 1944 and continue through 2007, when tank and infrastructure upgrades were complete. Releases to the vadose zone occurred during the past-practice period from past leaks at the SST farms and discharges to the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. The groundwater impacts during the past-practice period under Tank Closure Alternative 6B that are presented in this section are common to all of the Tank Closure alternatives.

- The retrieval period was assumed to start in 2008 and end in CY 2101. During this period, 99.9 percent of the waste would be retrieved from the tanks and all tank farms would be clean-closed.

- The post–administrative control period was assumed to start in CY 2102 and continue through the 10,000-year period of analysis until CY 11,940.

5.1.1.10.2 COPC Drivers

A total of 19 COPCs were analyzed for Tank Closure Alternative 6B. Complete results for all 19 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Tank Closure Alternative 6B is focused on the following COPC drivers:

- Radiological risk drivers: tritium, iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and total uranium

The COPC drivers for Tank Closure Alternative 6B were selected by evaluating the risk or hazard associated with all 19 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers, although their contribution to risk and hazard are not dominant during the year of peak risk or hazard. Tritium was added to the list of COPC drivers because of its contribution to risk during the early part of the period of analysis. The radiological risk drivers account for essentially 100 percent of the radiological risk. The only predicted chemical risk is from 2,4,6-trichlorophenol, calculated as 1×10^{-11}, which is negligible for purposes of this discussion. The chemical hazard drivers account for 100 percent of the chemical hazard associated with Tank Closure Alternative 6B.

The COPC drivers that are discussed in detail in this section fall into three categories. Iodine-129, technetium-99, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. Finally, uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these three groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of limited inventories, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.1.1.10.3 Analysis of Release and Mass Balance

This section presents the impacts of Tank Closure Alternative 6B in terms of total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies, chemicals in kilograms (see Figures 5–254 through 5–265). Two subtotals are plotted representing releases from cribs and trenches (ditches) and from past leaks. Amounts released from other tank farm sources are negligible for the purposes of this discussion. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–254 shows the estimated release to the vadose zone for the radiological risk drivers under the Base Case, which would include use of a modified RCRA Subtitle C barrier, and Figure 5–255, the chemical hazard drivers. The predominant sources for tritium, chromium, and nitrate are the cribs and trenches (ditches) associated with the B, BX, BY, T, TX, and TY tank farms. For all other COPC drivers the predominant sources are from past leaks. This suggests that past leaks, which were released during the past-practice period, as well as the cribs and trenches (ditches) are both important impact drivers under Tank Closure Alternative 6B, Base Case.

Figure 5–256 shows the estimated release to the vadose zone for the radiological risk drivers under the Option Case, which would include clean closure of cribs and trenches (ditches), and Figure 5–257, the chemical hazard drivers. The predominant sources for tritium, the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), uranium-238, and total uranium are similar to those in the vadose zone under the Base Case.

Figure 5–258 shows the estimated release to groundwater for the radiological risk drivers under the Base Case and Figure 5–259, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

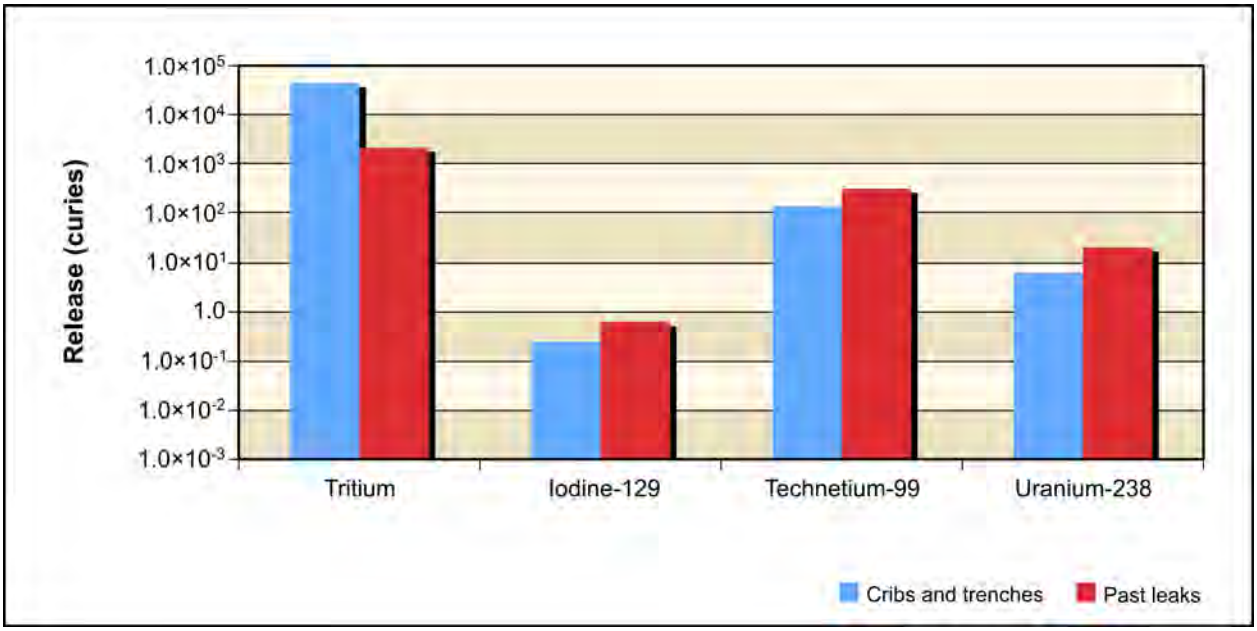


Figure 5–254. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

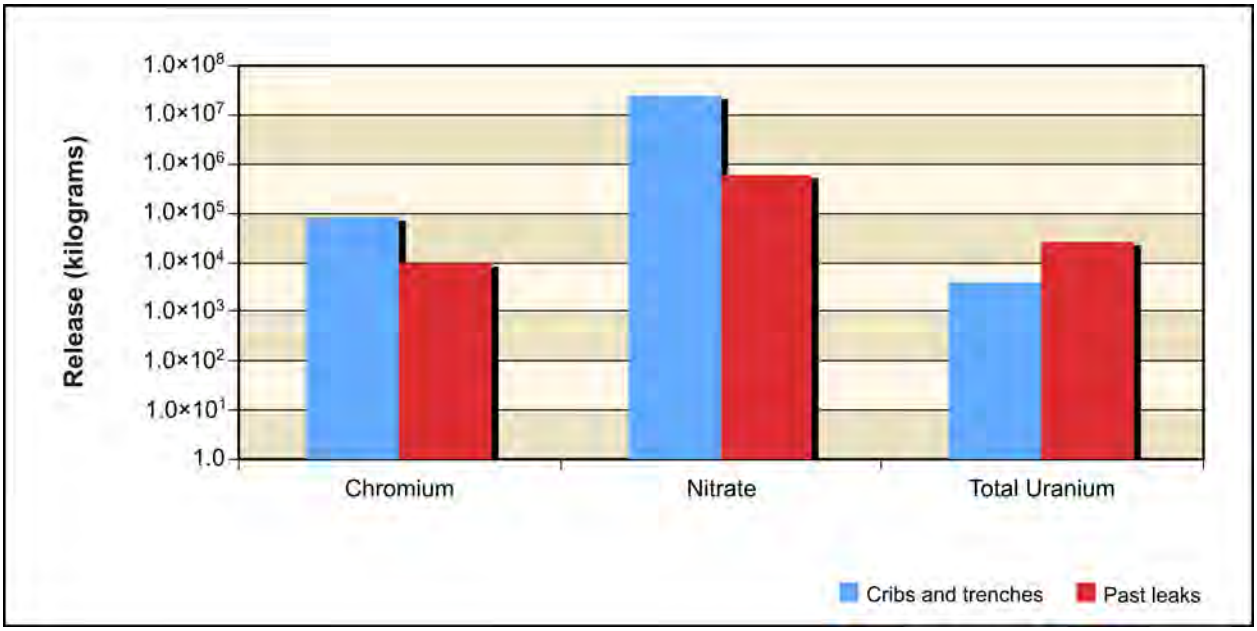


Figure 5–255. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

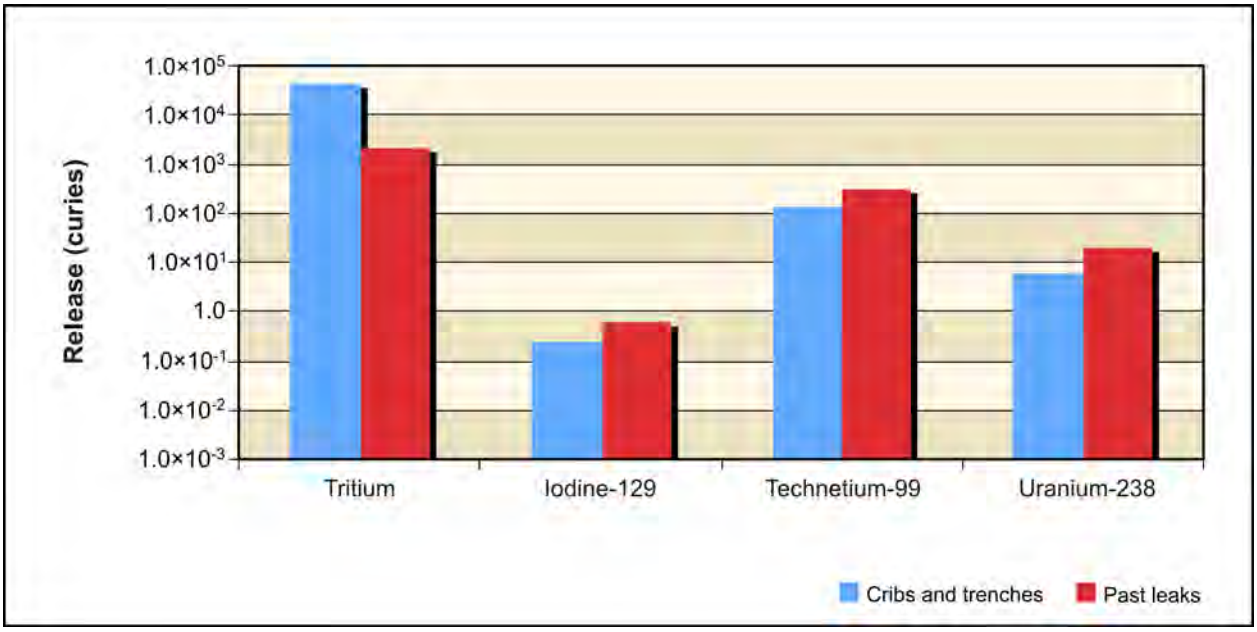


Figure 5–256. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

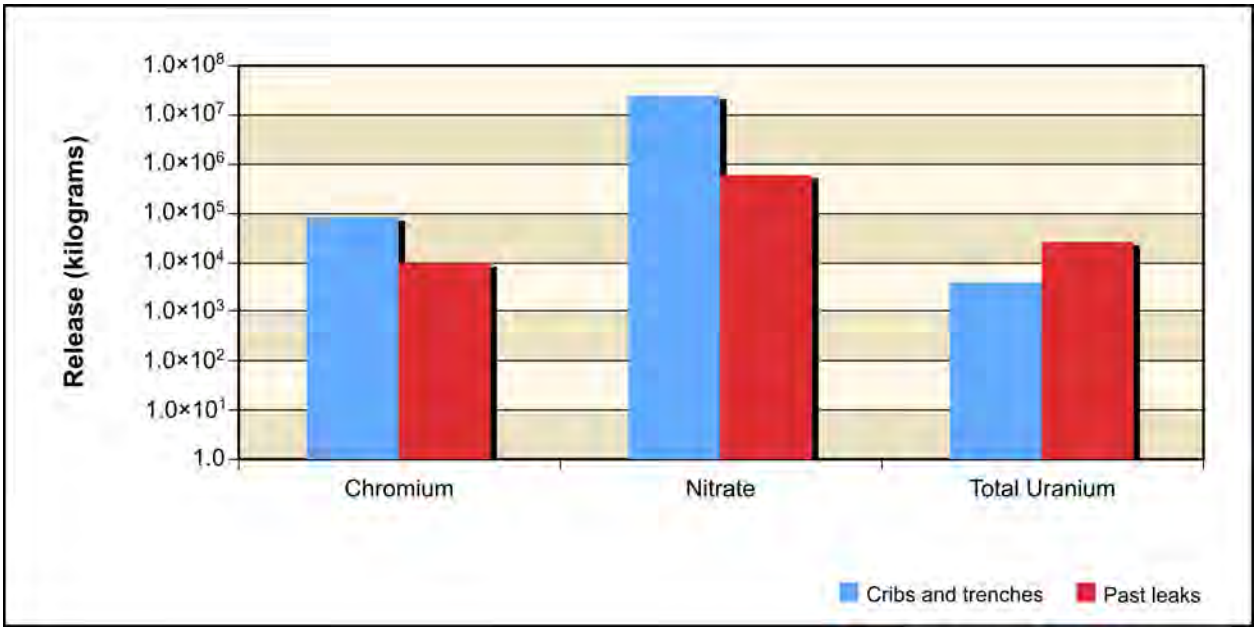


Figure 5–257. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Vadose Zone for Entire 10,000-Year Analysis Period

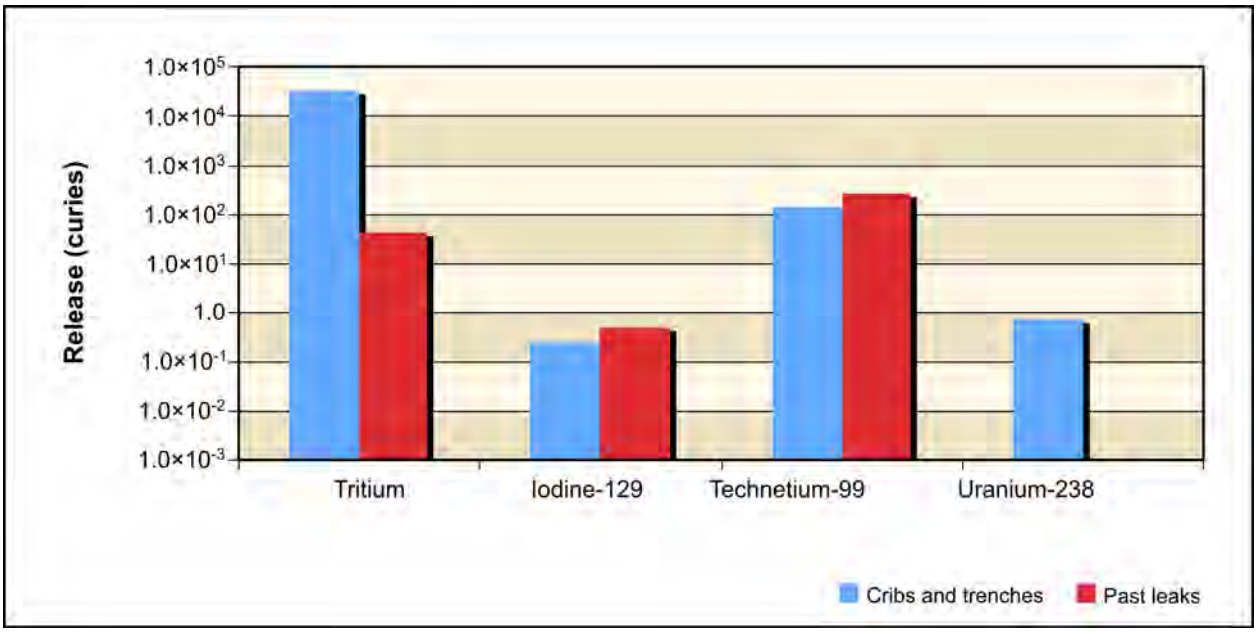


Figure 5–258. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

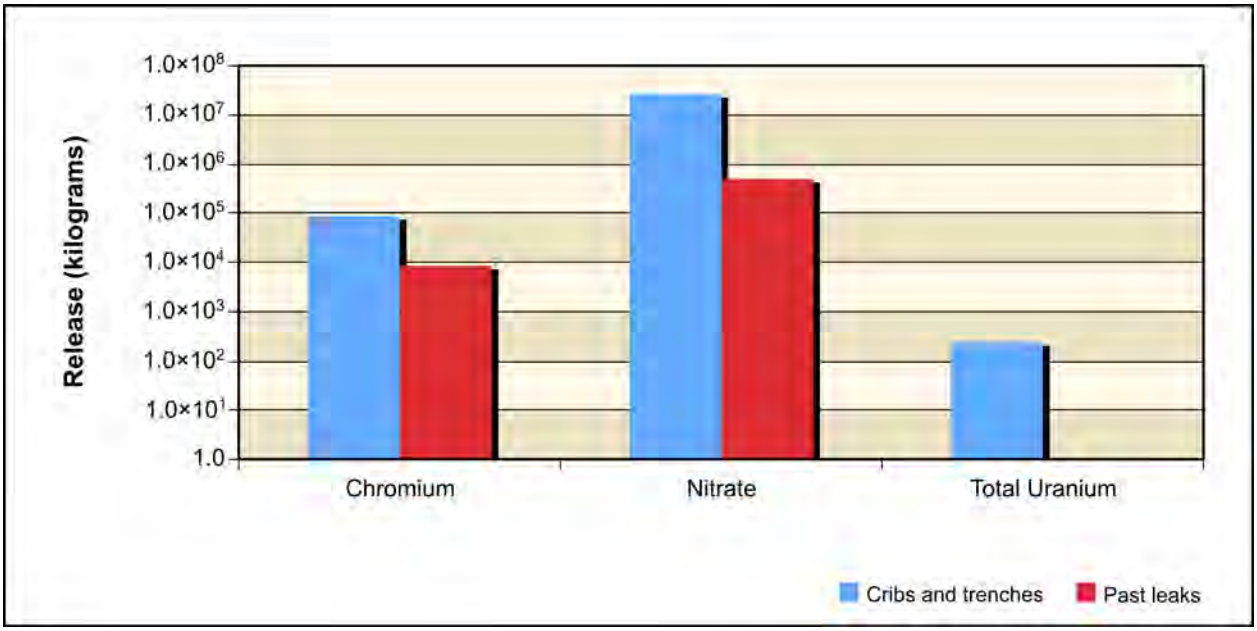


Figure 5–259. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 74 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would occur later in the post–administrative control period because of the long travel times in the vadose zone for these COPCs.

Figure 5–260 shows the estimated release to groundwater for the radiological risk drivers under the Option Case and Figure 5–261, the chemical hazard drivers. In addition to the total inventory released, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is about 7 percent less than the amount released to the vadose zone.

For uranium-238 and total uranium, the amount released to groundwater is less than that of the release to the vadose zone because of vadose zone retention. The amount of this retention depends on the type of contaminant source, specifically volume and timing of moisture movement through the vadose zone. For cribs and trenches (ditches), where moisture movement through the vadose zone is relatively rapid (because of the volume of water associated with the source), essentially none of the total inventory reached groundwater during the period of analysis. For past leaks, essentially none of the total inventory reached groundwater during the period of analysis.

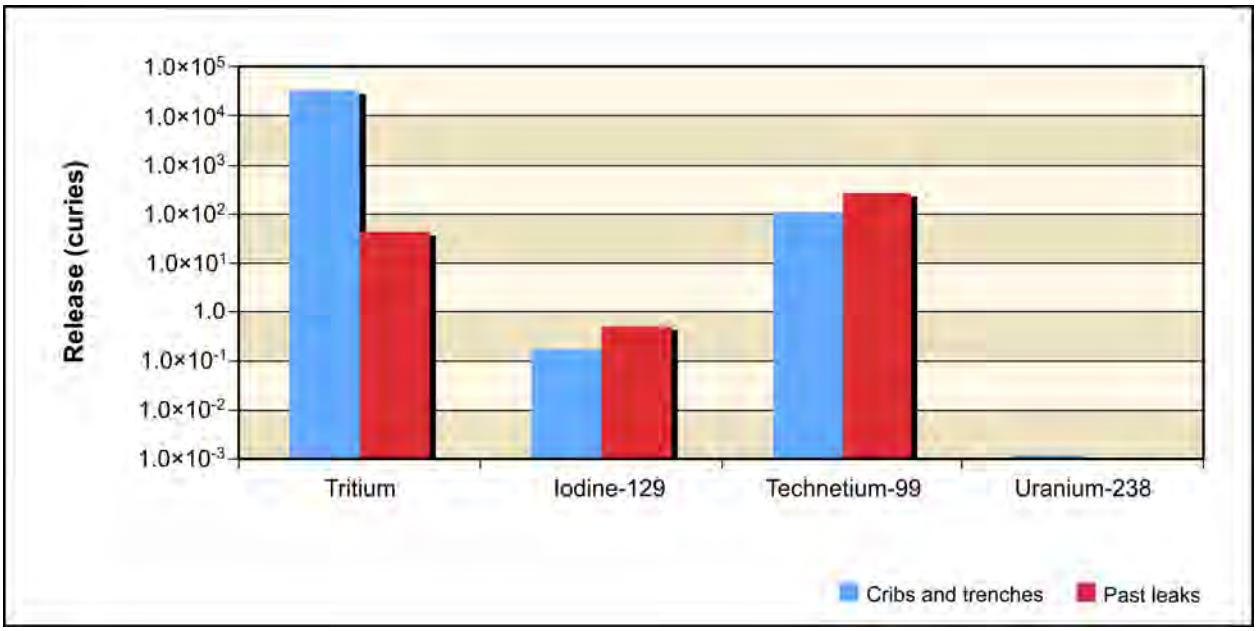


Figure 5–260. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

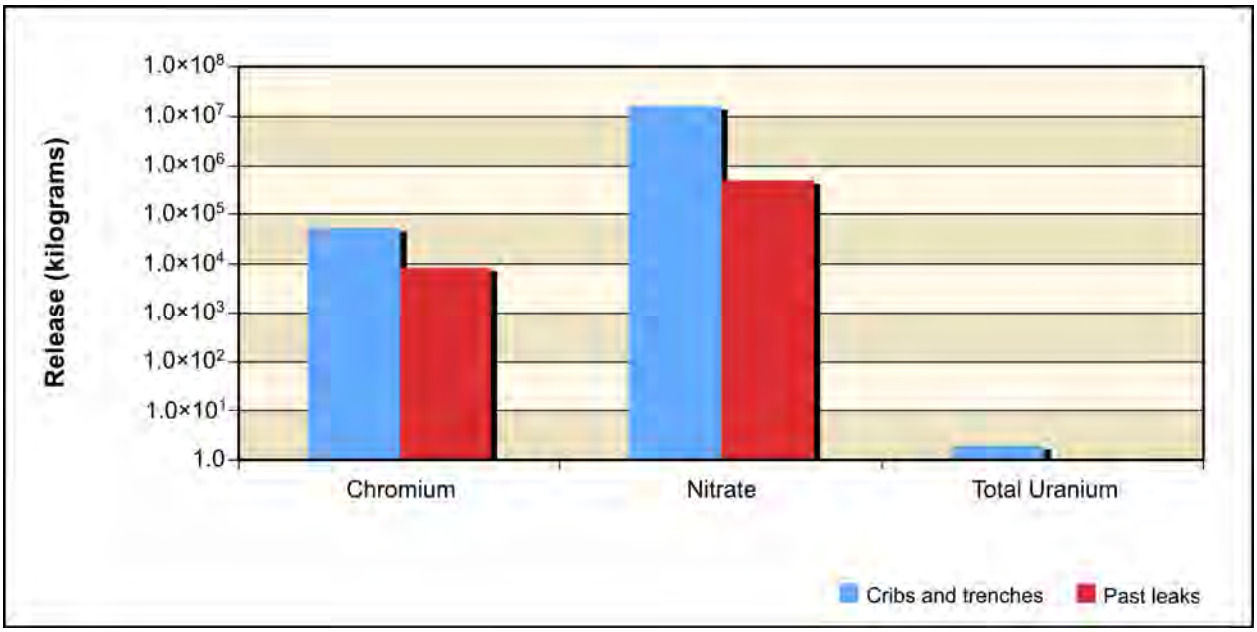


Figure 5–261. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Groundwater for Entire 10,000-Year Analysis Period

For tritium, the amount released to groundwater is attenuated by radioactive decay. For cribs and trenches (ditches), about 85 percent of the total inventory reached groundwater in the analysis; for past leaks, only 2 percent reached groundwater. These results suggest that tritium impacts on groundwater are dominated by releases from cribs and trenches (ditches), and that radioactive decay of tritium is an important attenuation process. They also suggest that uranium-238 and total uranium impacts would decrease over time because the long travel times in the vadose zone for these COPCs allow much of what was released to be collected and treated when the cribs and trenches (ditches) are removed and their deep plumes remediated.

Figure 5–262 shows the estimated release to the Columbia River for the radiological risk drivers under the Base Case and Figure 5–263, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

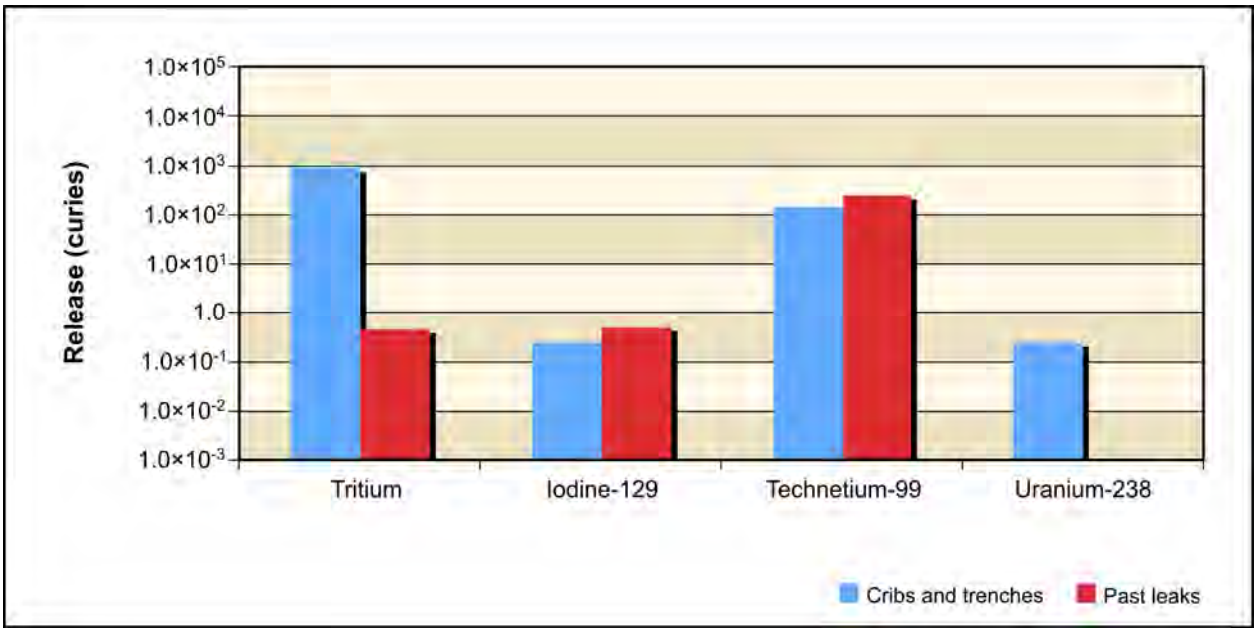


Figure 5–262. Tank Closure Alternative 6B, Base Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

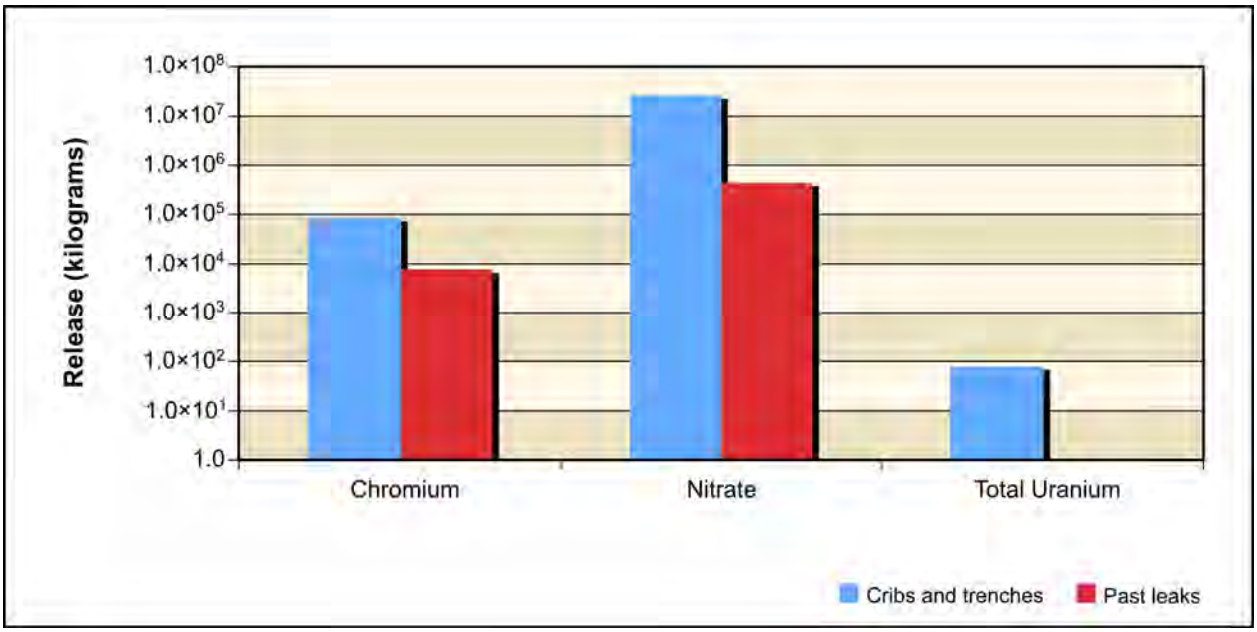


Figure 5–263. Tank Closure Alternative 6B, Base Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River is less than that of the release to groundwater because of retardation. For cribs and trenches (ditches), about 40 percent of the amount released to groundwater during the period of analysis reached the Columbia River.

For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium impacts on the Columbia River would occur later in the post–administrative control period because of the long travel times in the vadose zone and through the groundwater system for these COPCs.

Figure 5–264 shows the estimated release to the Columbia River for the radiological risk drivers under the Option Case and Figure 5–265, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater.

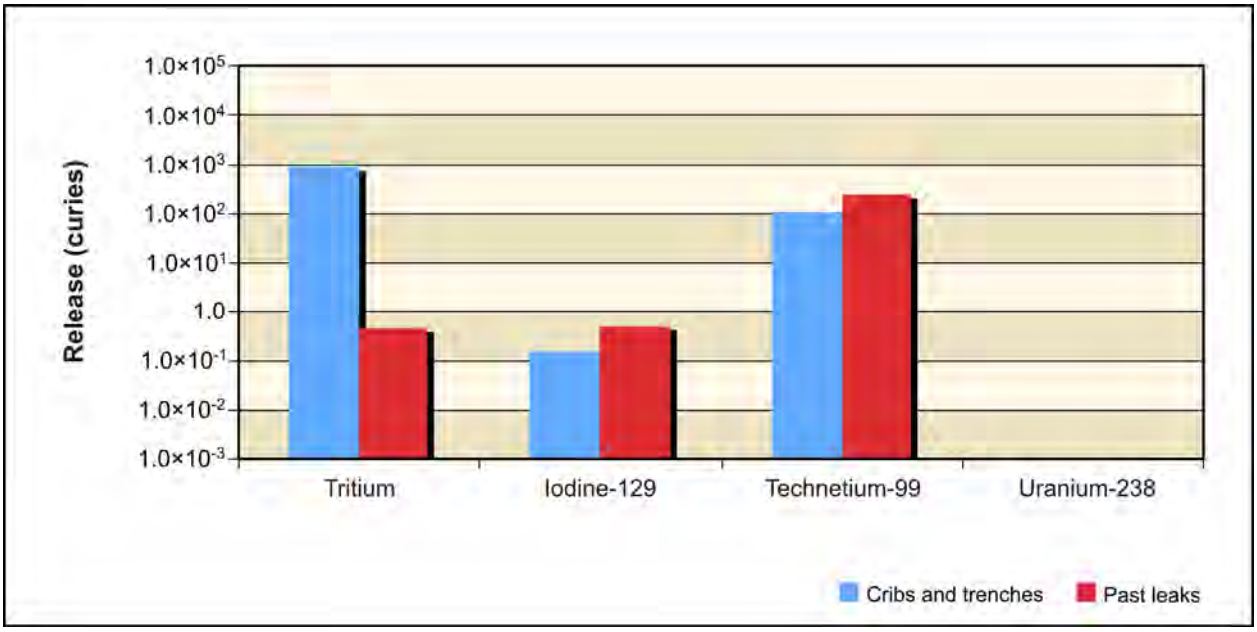


Figure 5–264. Tank Closure Alternative 6B, Option Case, Releases of Radiological Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

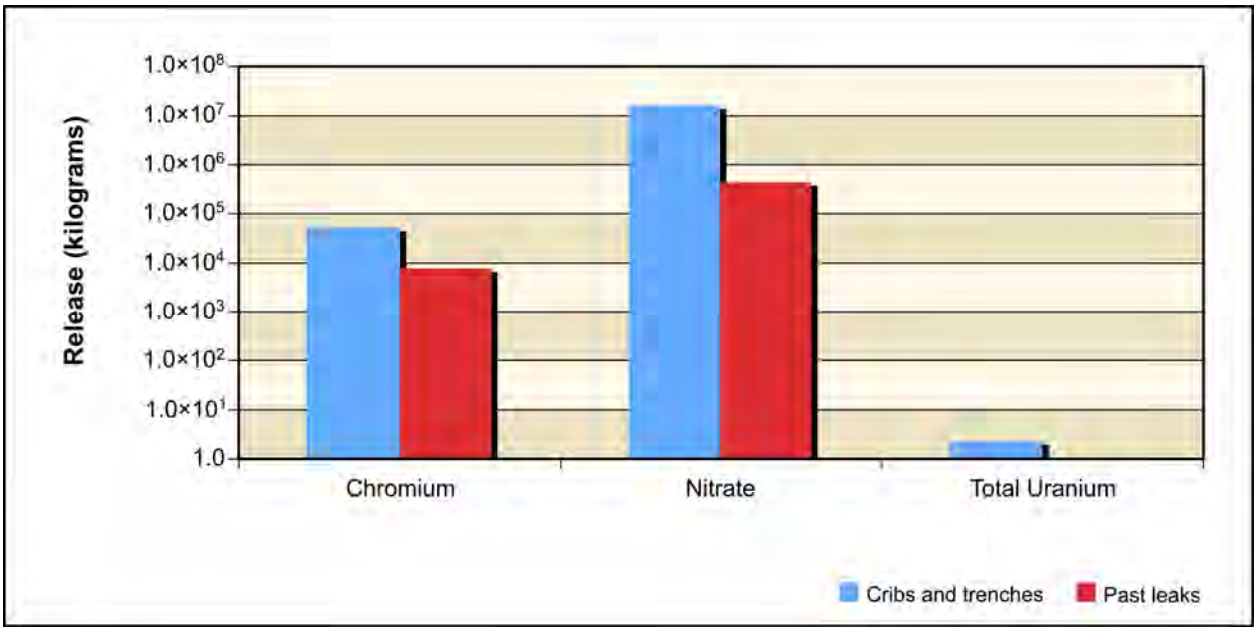


Figure 5–265. Tank Closure Alternative 6B, Option Case, Releases of Chemical Constituent of Potential Concern Drivers to Columbia River for Entire 10,000-Year Analysis Period

For uranium-238 and total uranium, the amount released to the Columbia River from the groundwater is effectively zero, as essentially no uranium reached the groundwater from the vadose zone. For tritium, the amount released to the Columbia River is attenuated by radioactive decay. For cribs and trenches (ditches), only about 3 percent of the tritium released to groundwater reached the Columbia River during the period of analysis. For past leaks, only about 1 percent of the tritium released to groundwater reached the Columbia River. These results suggest that tritium impacts on the Columbia River are strongly attenuated by radioactive decay. They also suggest that uranium-238 and total uranium would not impact the Columbia River, as much of what was released is to be collected when the cribs and trenches (ditches) are removed and their deep plumes remediated.

5.1.1.10.4 Analysis of Concentration Versus Time

This section presents the analysis of Tank Closure Alternative 6B impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Tables 5–8 and 5–9 and Figures 5–266 through 5–279). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–8 and 5–9 list the maximum concentrations under the Base and Option Cases of the COPCs in the peak year after CY 2050 at the tank farm barriers, Core Zone Boundary, and Columbia River nearshore.

Figure 5–266 shows the concentration versus time for tritium under the Base Case. Releases from cribs and trenches (ditches) cause the groundwater concentrations at the Core Zone Boundary to exceed the benchmark concentrations by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark concentration. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration.

The concentrations of tritium versus time under the Option Case are essentially identical to those under the Base Case (see Figure 5–267).

Figures 5–268 through 5–271 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Base Case. All of the conservative tracers show similar patterns. Releases from cribs and trenches (ditches) cause groundwater concentrations in the Core Zone Boundary to exceed benchmark concentrations by about two orders of magnitude during the early part of the period of analysis in CY 1956. The Columbia River nearshore concentrations never met or exceeded the benchmark concentration, but came to within about one-half to one order of magnitude.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) versus time under the Option Case are essentially identical to those under the Base Case (see Figures 5–272 through 5–275).

Table 5–8. Tank Closure Alternative 6B, Base Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	30	5,010	46	7,300	13	6,000	178	20,000
	(2051)	(2054)	(2050)	(2055)	(2052)	(2054)	(2050)	
Technetium-99	**1,390**	**29,300**	**2,560**	**15,500**	140	**24,800**	168	900
	(2050)	(2050)	(2050)	(2051)	(2060)	(2050)	(2214)	
Iodine-129	**3**	**39**	**5**	**29**	0.3	**31**	0.3	1
	(2050)	(2057)	(2050)	(2050)	(2054)	(2057)	(2319)	
Uranium isotopes (includes uranium-233, -234, -235, -238)	0	**34**	0	13	0	10	0	15
	(1940)	(11,742)	(1940)	(11,780)	(1940)	(11,758)	(11,844)	
Chemical in micrograms per liter								
Chromium	7	**3,180**	**283**	**771**	9	**1,660**	33	100
	(2050)	(2055)	(2050)	(2050)	(2050)	(2050)	(2695)	
Nitrate	511	**1,540,000**	8,650	**133,000**	624	**1,010,000**	8,420	45,000
	(2059)	(2050)	(2050)	(2051)	(2057)	(2050)	(2450)	
Total uranium	0	10	0	4	0	7	0	30
	(1940)	(11,678)	(1940)	(11,755)	(1940)	(11,678)	(11,508)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

Table 5–9. Tank Closure Alternative 6B, Option Case, Maximum COPC Concentrations in the Peak Year at the Tank Farm Barriers, Core Zone Boundary, and Columbia River Nearshore

Contaminant	A Barrier	B Barrier	S Barrier	T Barrier	U Barrier	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter								
Hydrogen-3 (tritium)	30	4,870	46	6,680	13	5,190	172	20,000
	(2051)	(2073)	(2050)	(2067)	(2052)	(2073)	(2088)	
Technetium-99	**1,390**	**27,000**	**2,560**	**15,500**	140	**22,700**	162	900
	(2050)	(2058)	(2050)	(2051)	(2060)	(2058)	(2304)	
Iodine-129	**3**	**38**	**5**	**29**	0.3	**30**	0.3	1
	(2050)	(2051)	(2050)	(2050)	(2054)	(2052)	(2319)	
Chemical in microgram per liter								
Chromium	7	**3,770**	**283**	**778**	9	**1,760**	28	100
	(2050)	(2087)	(2050)	(2050)	(2050)	(2061)	(2166)	
Nitrate	511	**1,690,000**	8,650	**154,000**	624	**1,230,000**	7,110	45,000
	(2059)	(2053)	(2050)	(2084)	(2057)	(2053)	(2056)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern.

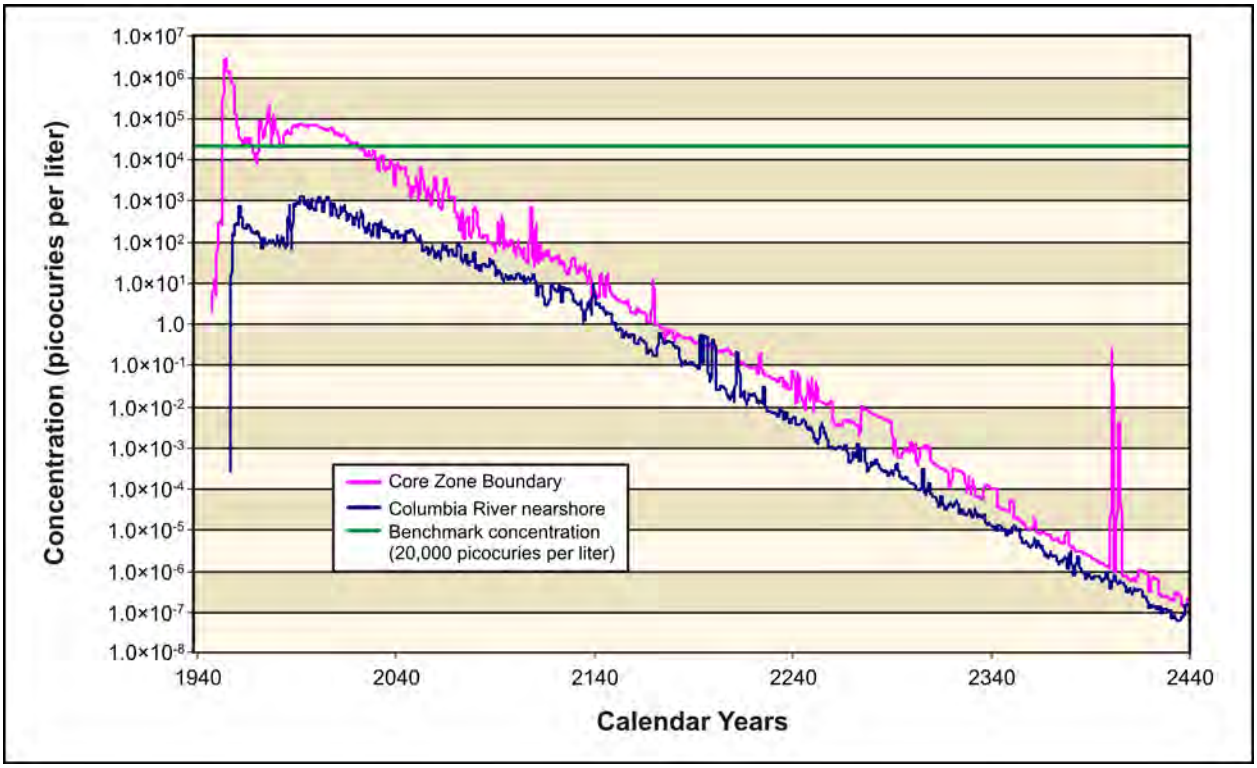


Figure 5–266. Tank Closure Alternative 6B, Base Case, Hydrogen-3 (Tritium) Concentration Versus Time

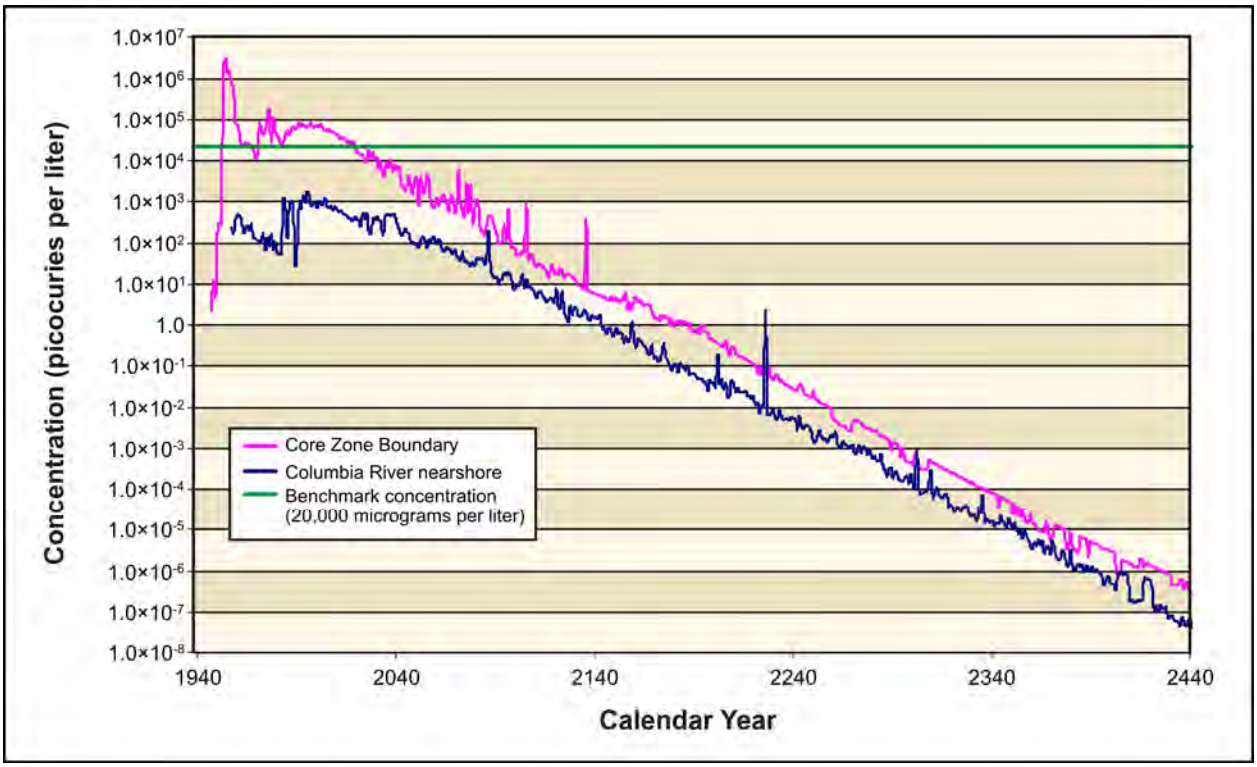


Figure 5–267. Tank Closure Alternative 6B, Option Case, Hydrogen-3 (Tritium) Concentration Versus Time

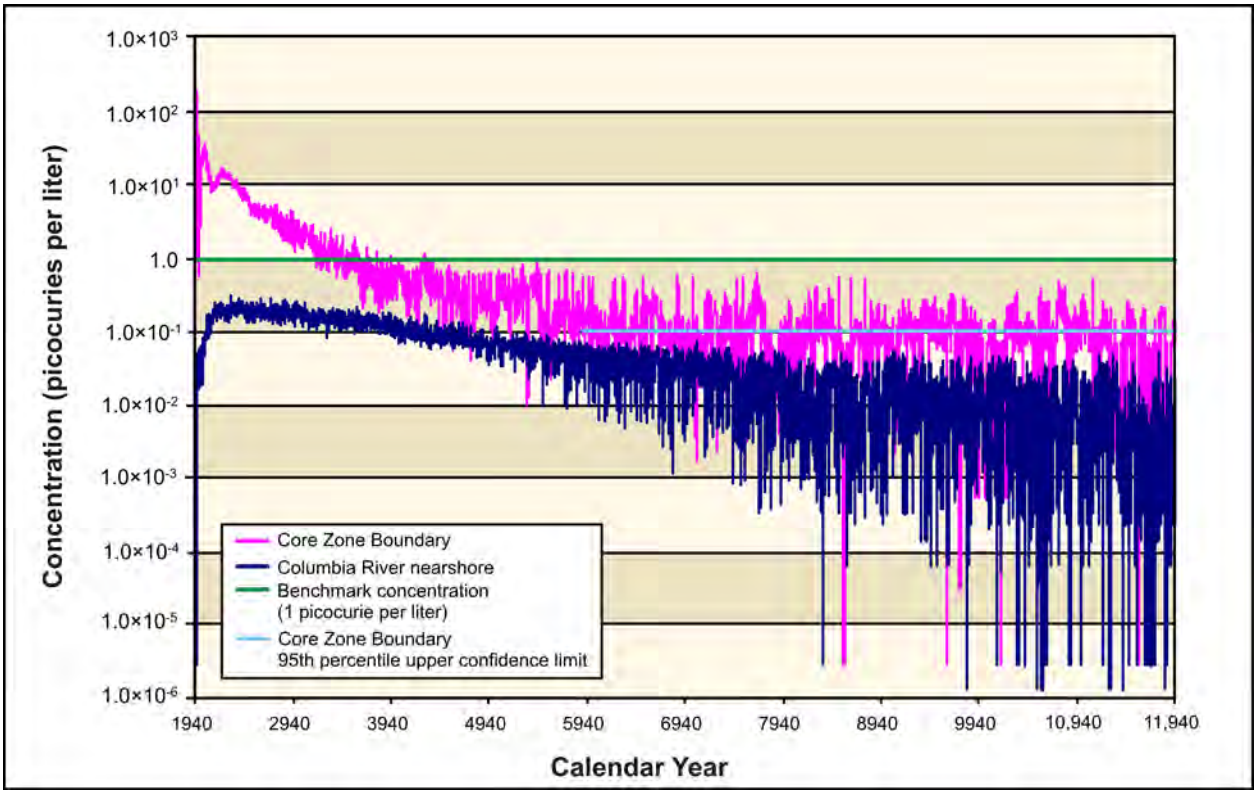


Figure 5–268. Tank Closure Alternative 6B, Base Case, Iodine-129 Concentration Versus Time

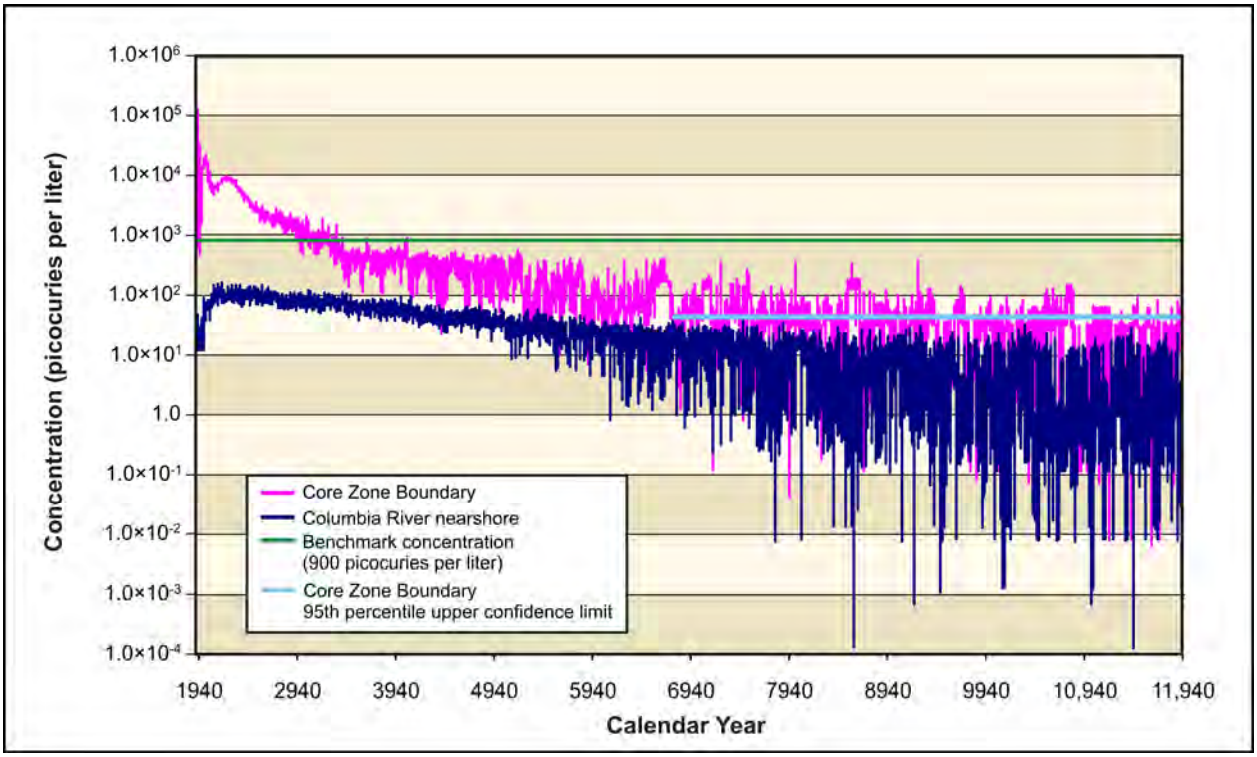


Figure 5–269. Tank Closure Alternative 6B, Base Case, Technetium-99 Concentration Versus Time

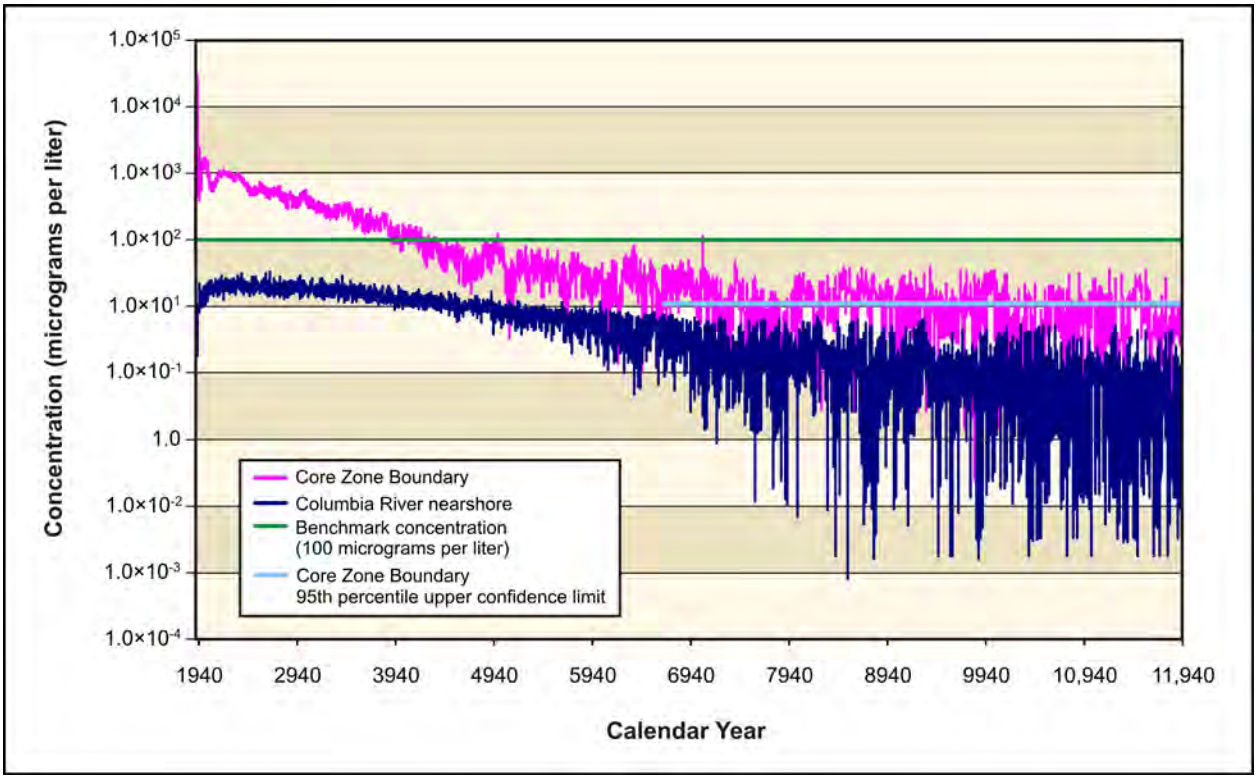


Figure 5–270. Tank Closure Alternative 6B, Base Case, Chromium Concentration Versus Time

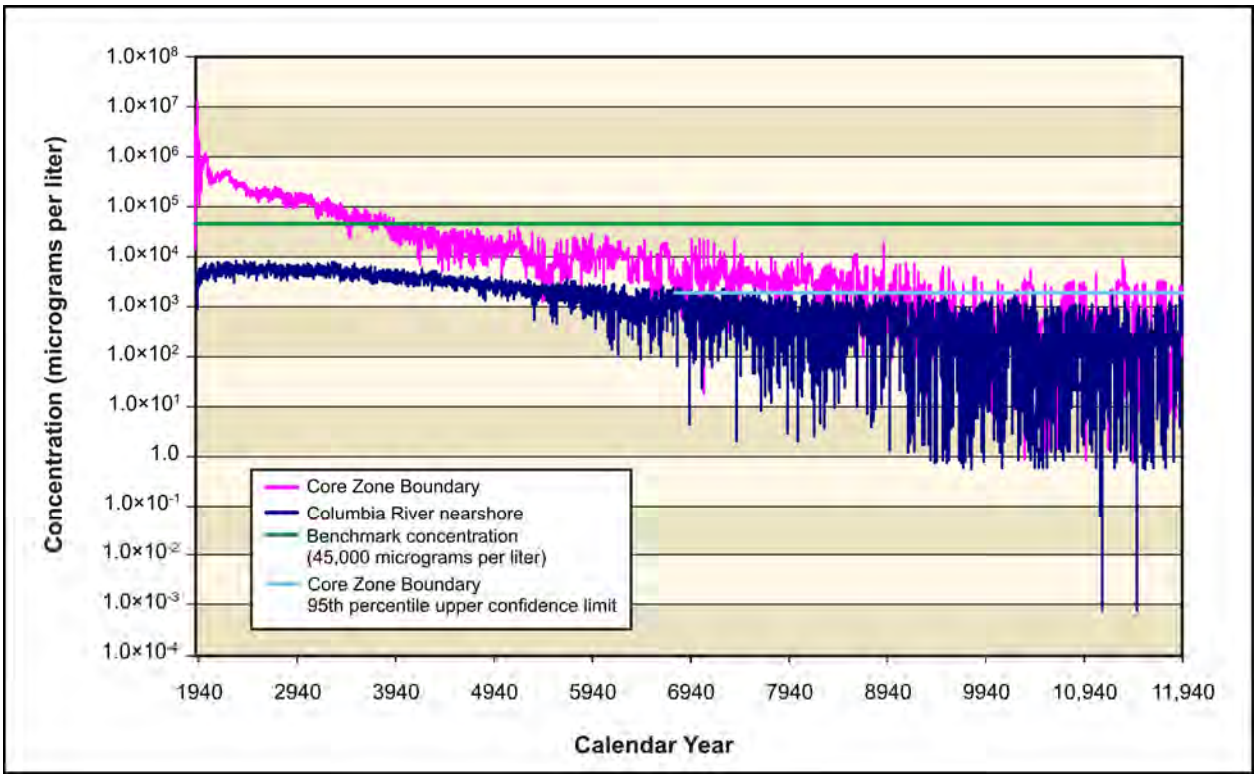


Figure 5–271. Tank Closure Alternative 6B, Base Case, Nitrate Concentration Versus Time

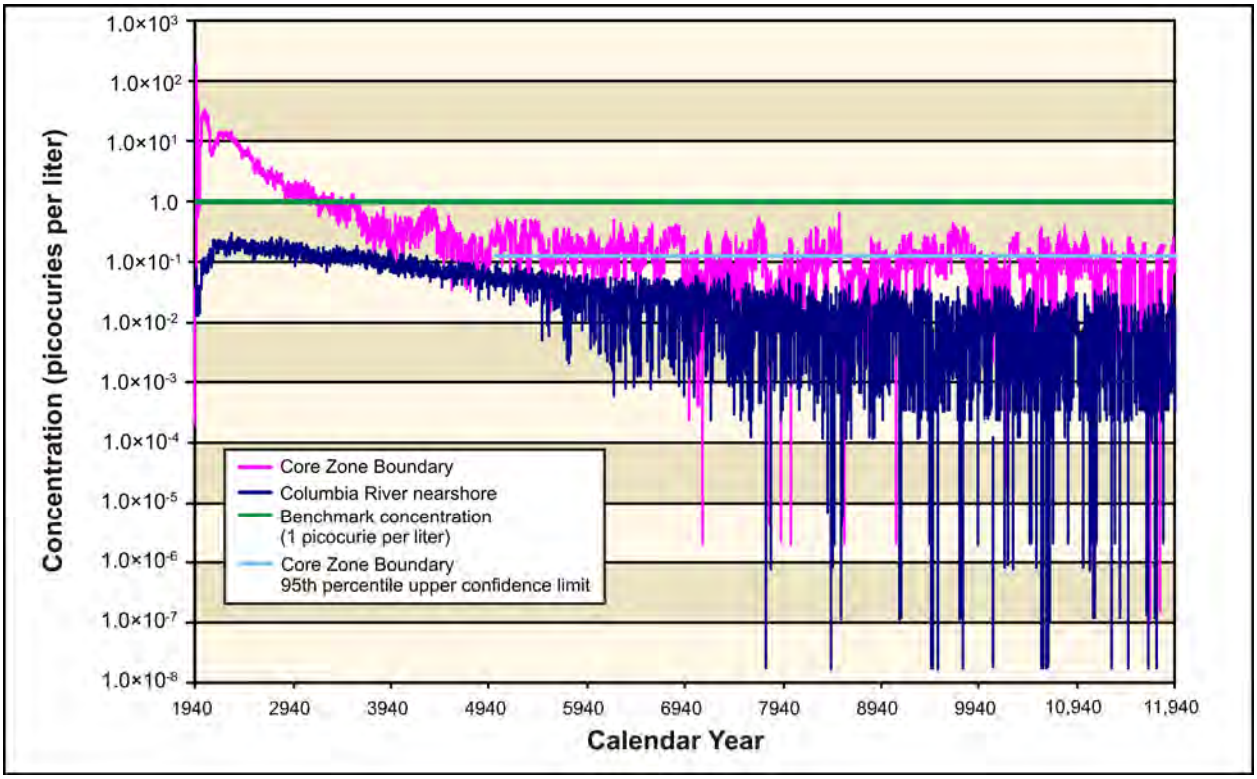


Figure 5–272. Tank Closure Alternative 6B, Option Case, Iodine-129 Concentration Versus Time

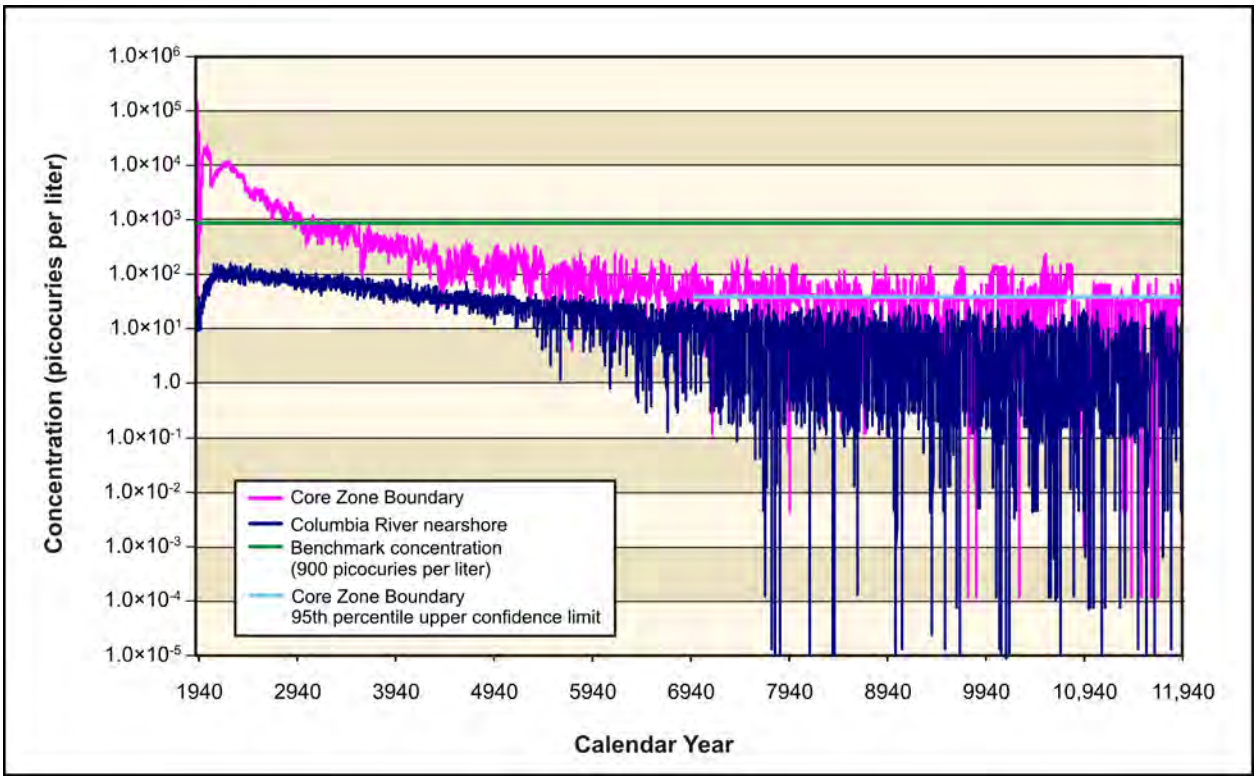


Figure 5–273. Tank Closure Alternative 6B, Option Case, Technetium-99 Concentration Versus Time

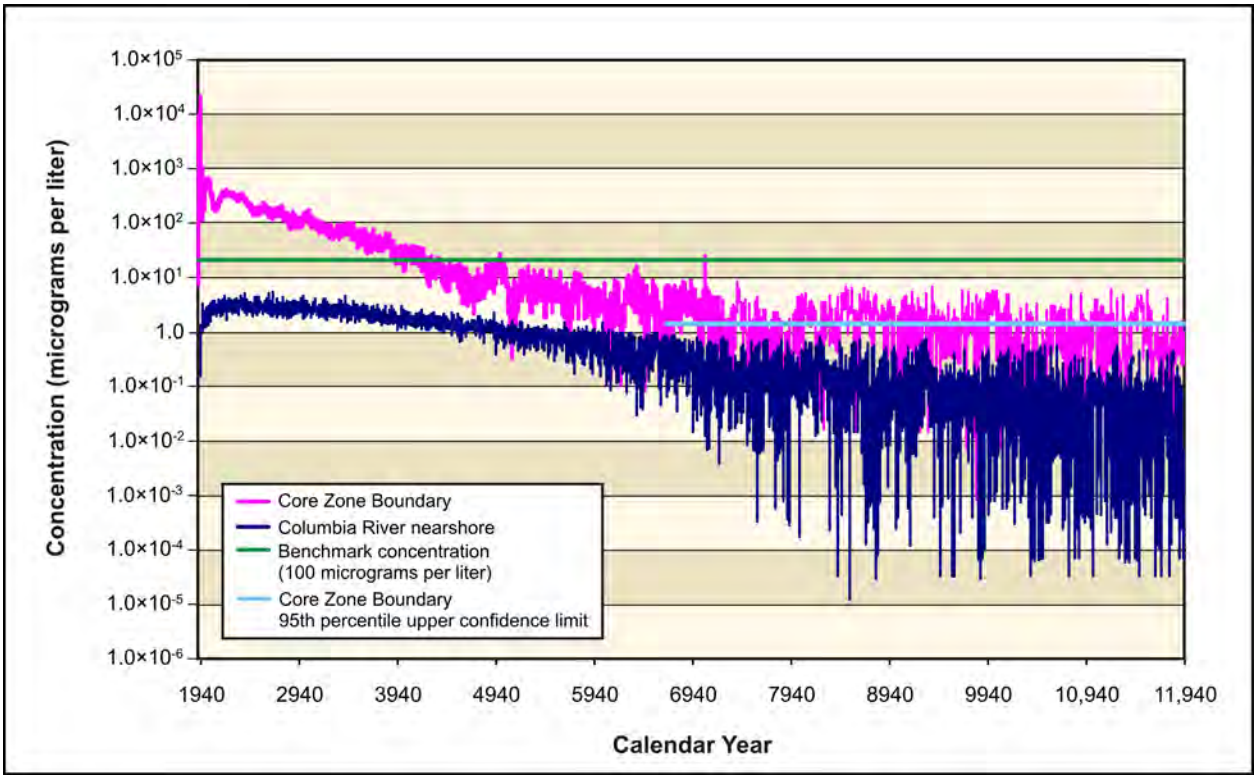


Figure 5–274. Tank Closure Alternative 6B, Option Case, Chromium Concentration Versus Time

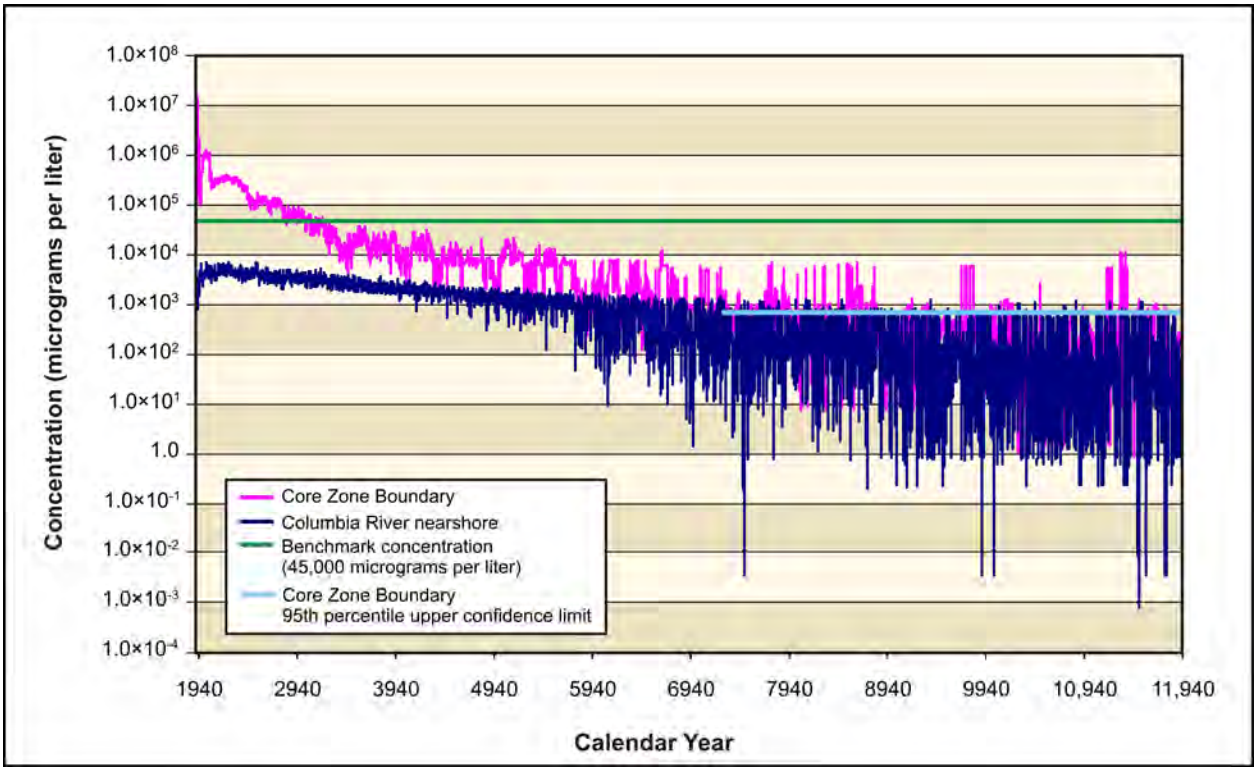


Figure 5–275. Tank Closure Alternative 6B, Option Case, Nitrate Concentration Versus Time

Figures 5–276 and 5–277 show concentration versus time for uranium-238 and total uranium under the Base Case. Although uranium-238 concentrations in the Core Zone Boundary began to approach the benchmark toward the latter part of the period of analysis, they never reached it. Total uranium concentrations at the Core Zone Boundary also began to increase toward the end of the period of analysis but never came to within one order of magnitude of the benchmark. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark.

Under the Option Case, uranium-238 concentrations in the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark concentration, except for a short spike to about one order of magnitude below the benchmark at the beginning of the period of analysis (see Figure 5–278). At around CY 7500, the uranium-238 Core Zone Boundary concentrations fell to about four orders of magnitude below the benchmark. The Columbia River nearshore concentrations of uranium-238 stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark (see Figure 5–279). The Columbia River nearshore concentrations of total uranium remained fairly constant at around four and a half orders of magnitude below the benchmark.

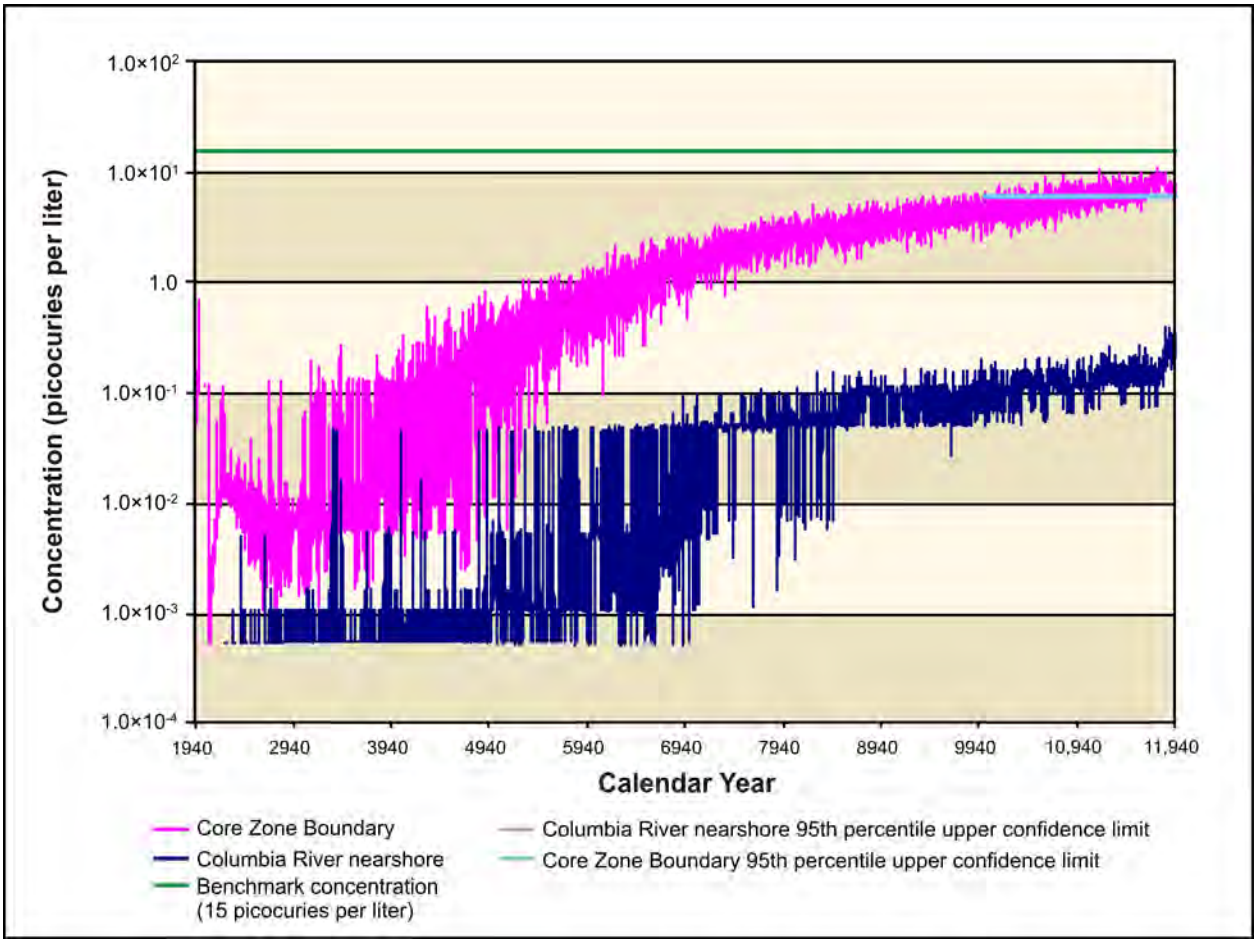


Figure 5–276. Tank Closure Alternative 6B, Base Case, Uranium-238 Concentration Versus Time

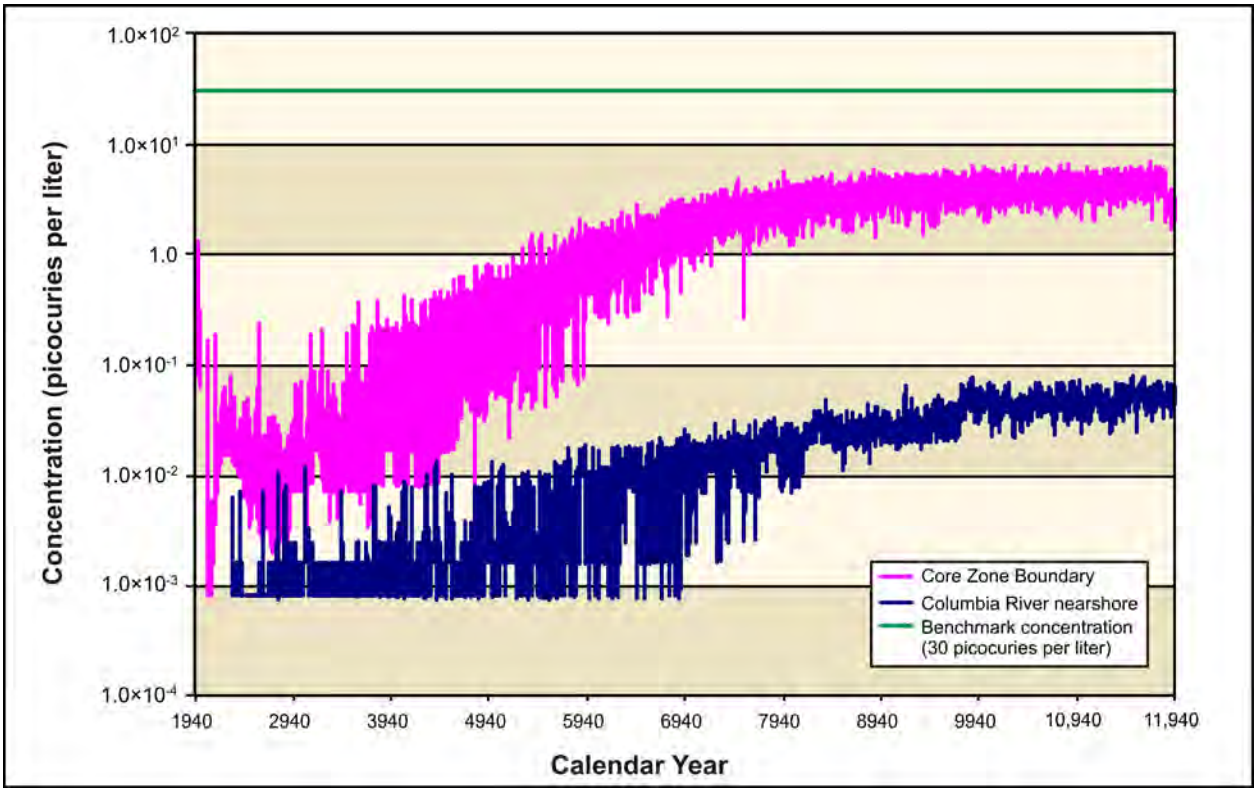


Figure 5–277. Tank Closure Alternative 6B, Base Case, Total Uranium Concentration Versus Time

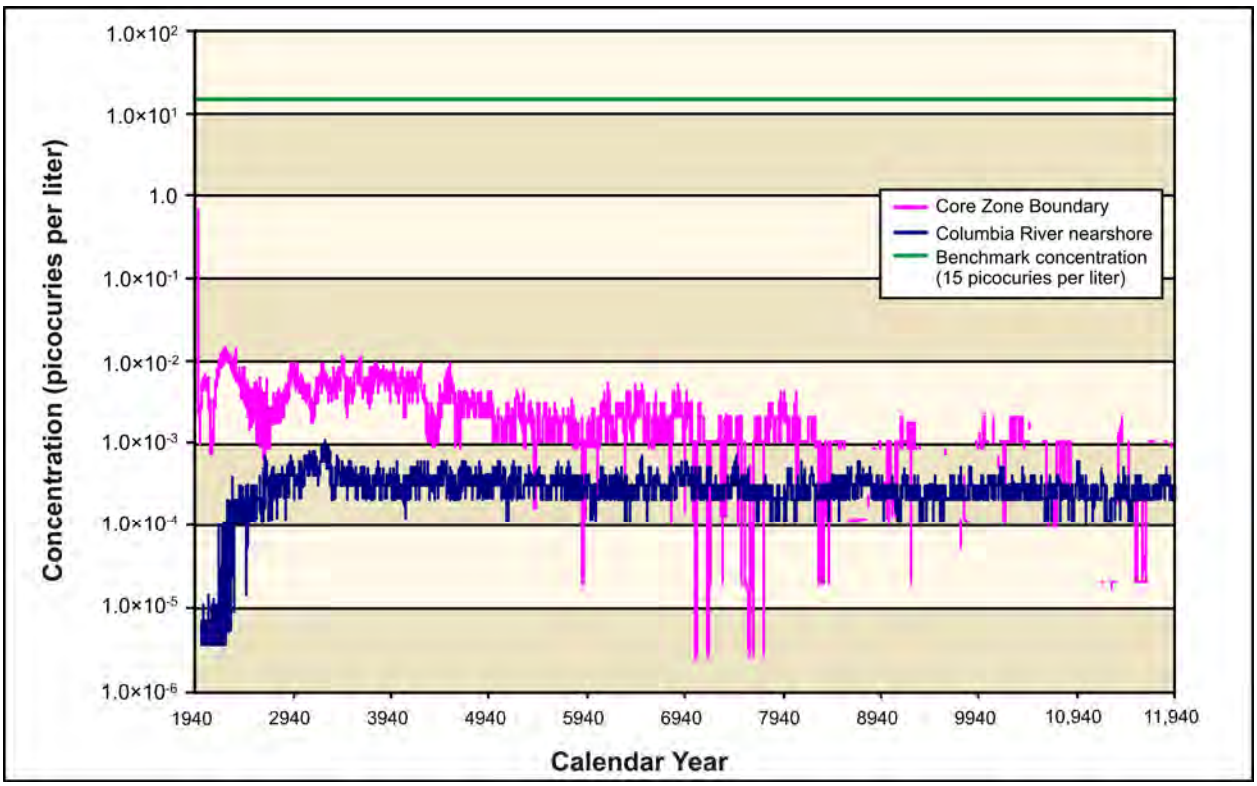


Figure 5–278. Tank Closure Alternative 6B, Option Case, Uranium-238 Concentration Versus Time

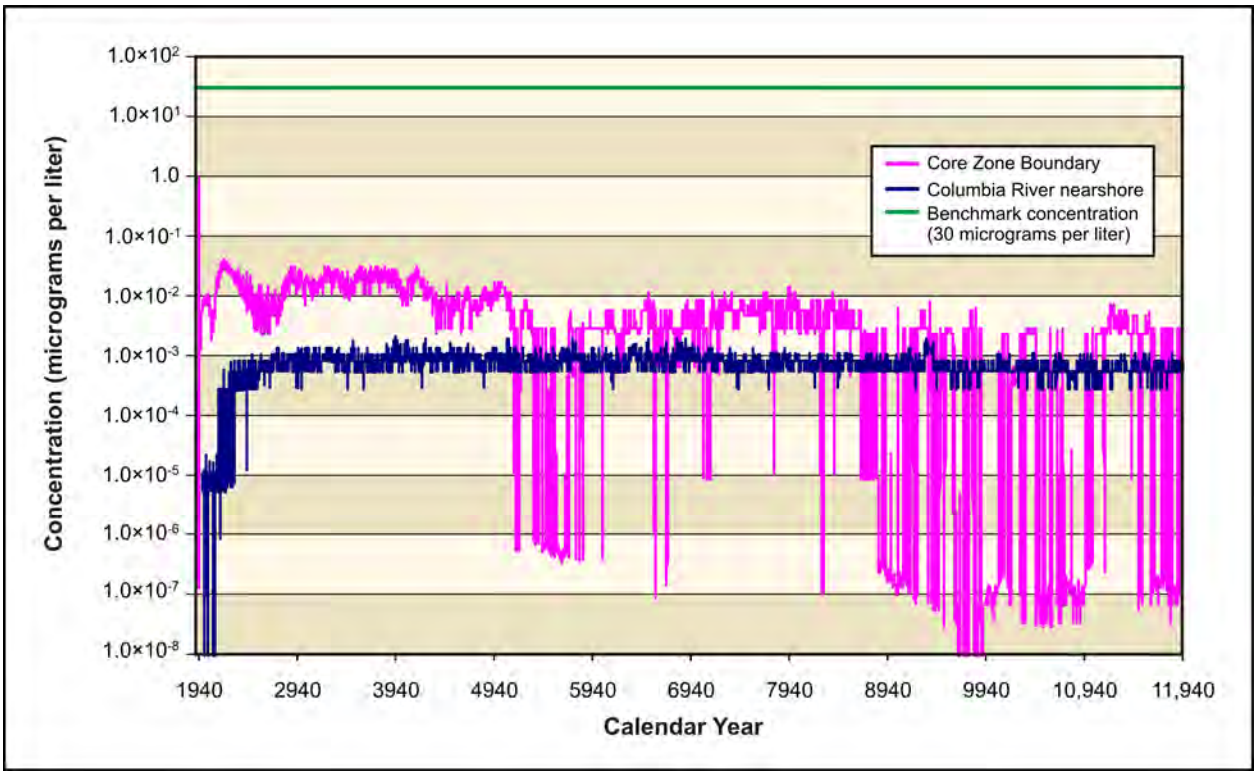
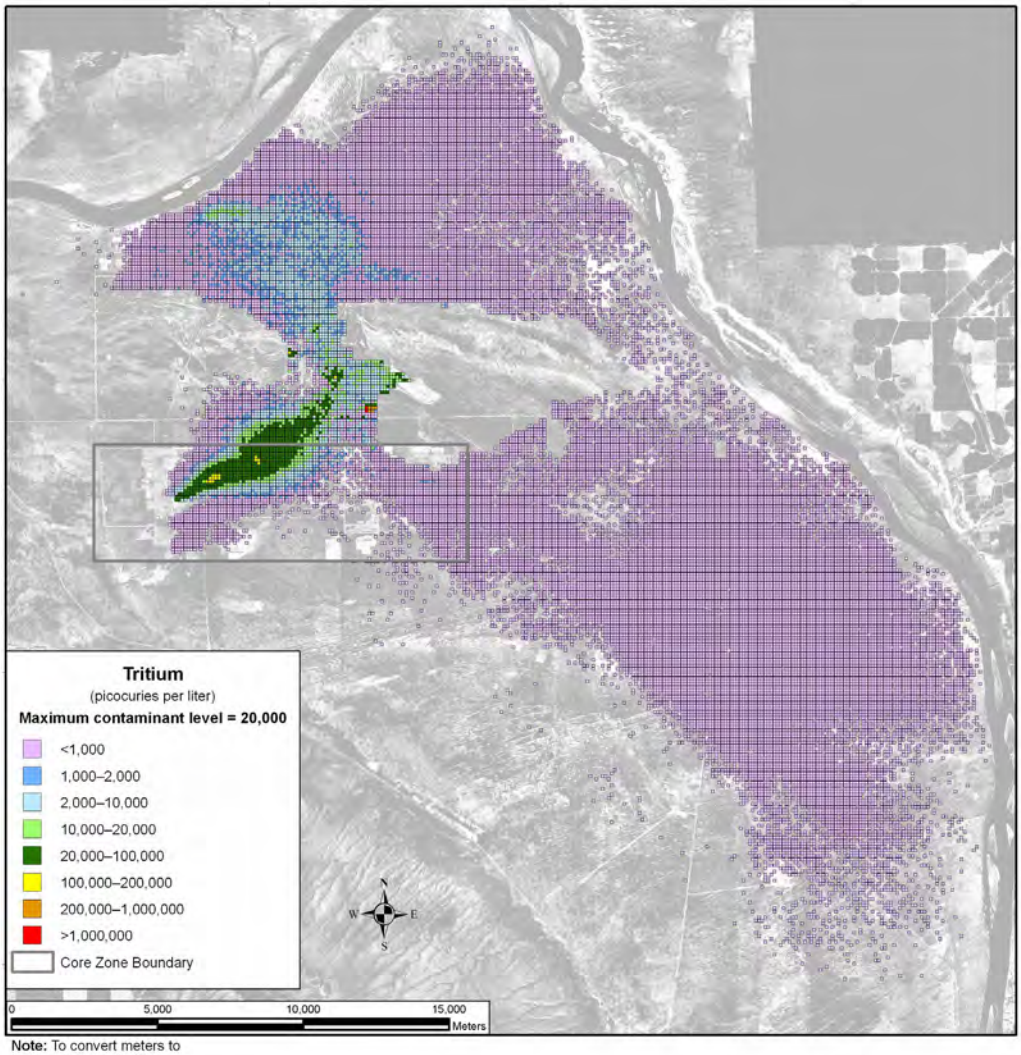


Figure 5–279. Tank Closure Alternative 6B, Option Case, Total Uranium Concentration Versus Time

5.1.1.10.5 Analysis of Spatial Distribution of Concentration

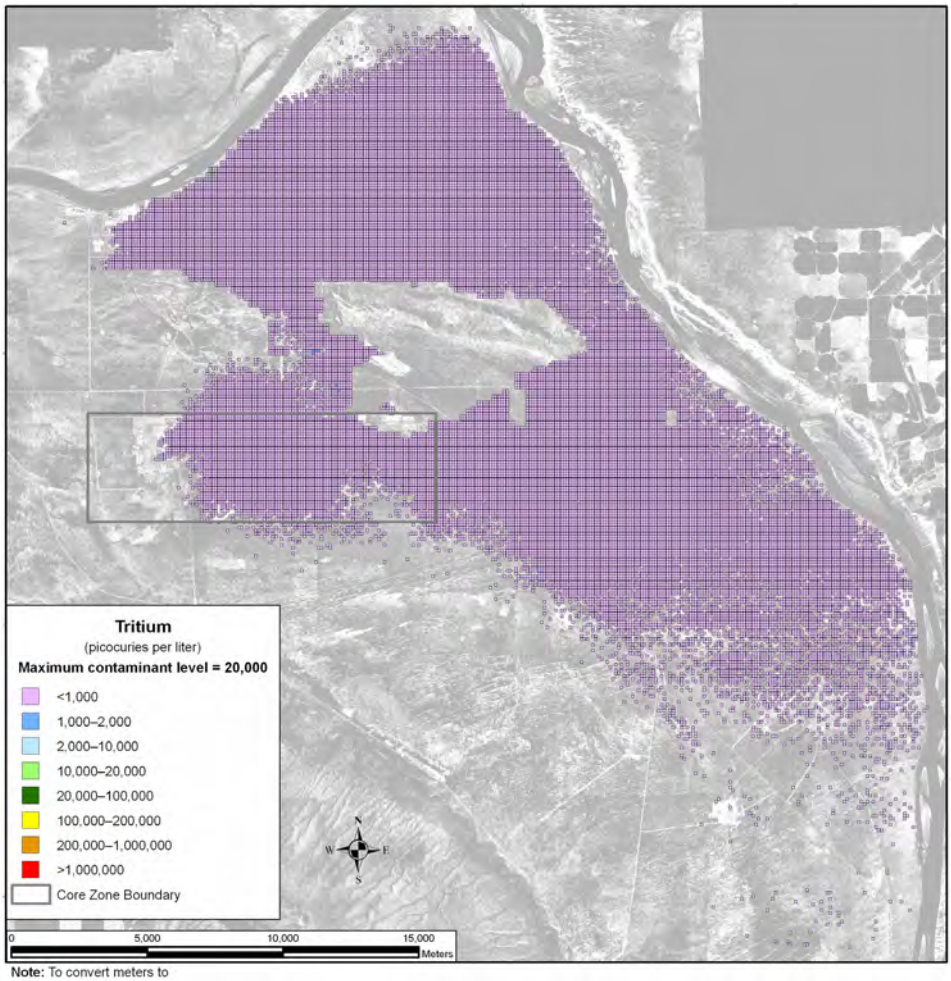
This section presents the impacts of Tank Closure Alternative 6B in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–280 through 5–324). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–280 shows the spatial distribution of groundwater concentration for tritium during CY 2005 under the Base Case. Releases from cribs and trenches (ditches) and past leaks, associated primarily with the T, TX, and TY tank farms, result in a groundwater concentration plume (exceeding the benchmark concentration) that extends from the center part of the 200-West Area northeast, crossing the Core Zone Boundary, and extending toward Gable Gap. Peak concentrations in this plume are about 10 to 20 times greater than the benchmark, and mostly contained within the Core Zone Boundary. The overall tritium concentrations are attenuated by radioactive decay to levels less than one-twentieth of the benchmark concentration by CY 2135, although a few minor traces from about one-twentieth to one-tenth below the benchmark can be found in Gable Gap (see Figure 5–281).



Note: To convert meters to feet, multiply by 3.281

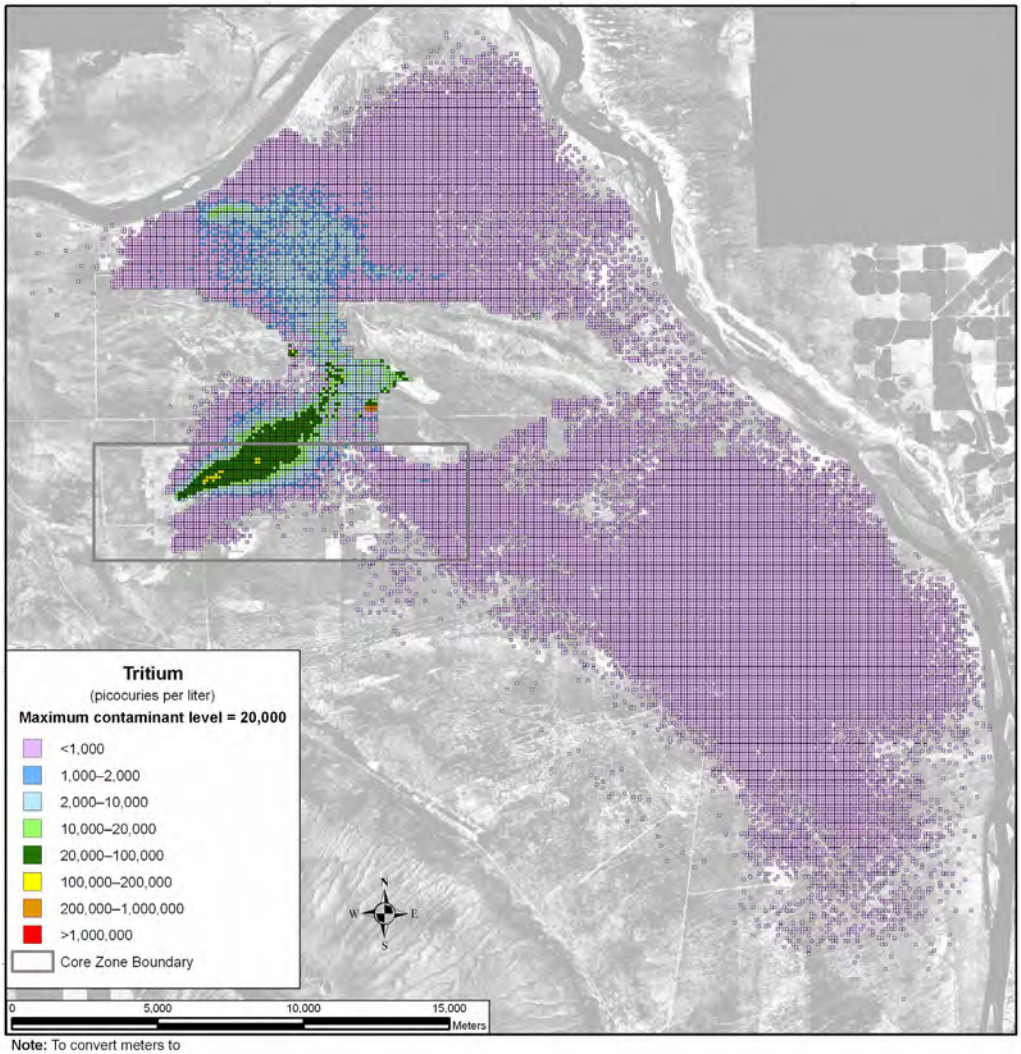
Figure 5–280. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

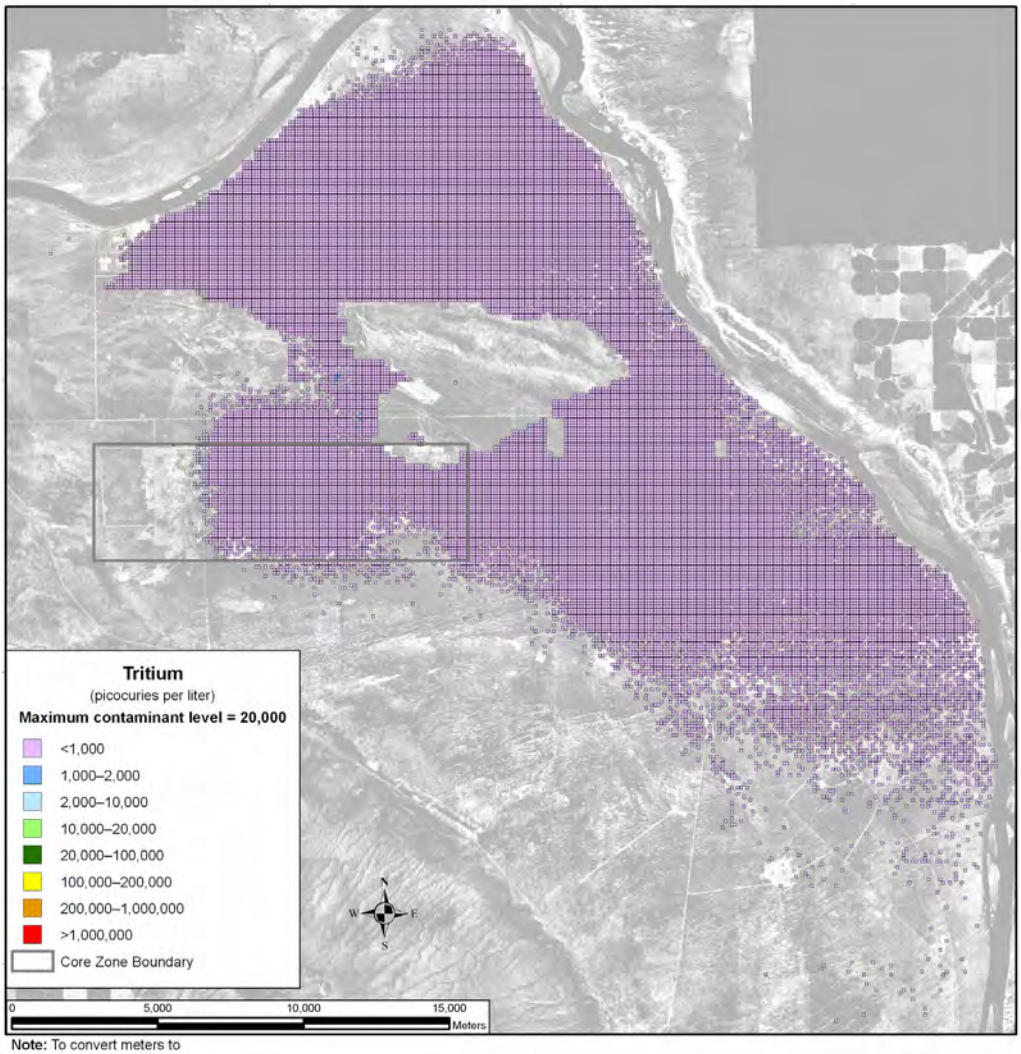
Figure 5–281. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

The spatial distribution of groundwater concentrations for tritium under the Option Case, which would include removal of the six sets of cribs and trenches (ditches) and remediation of their plumes within the vadose zone, is essentially identical to that under the Base Case (see Figures 5–282 and 5–283).



Note: To convert meters to feet, multiply by 3.281

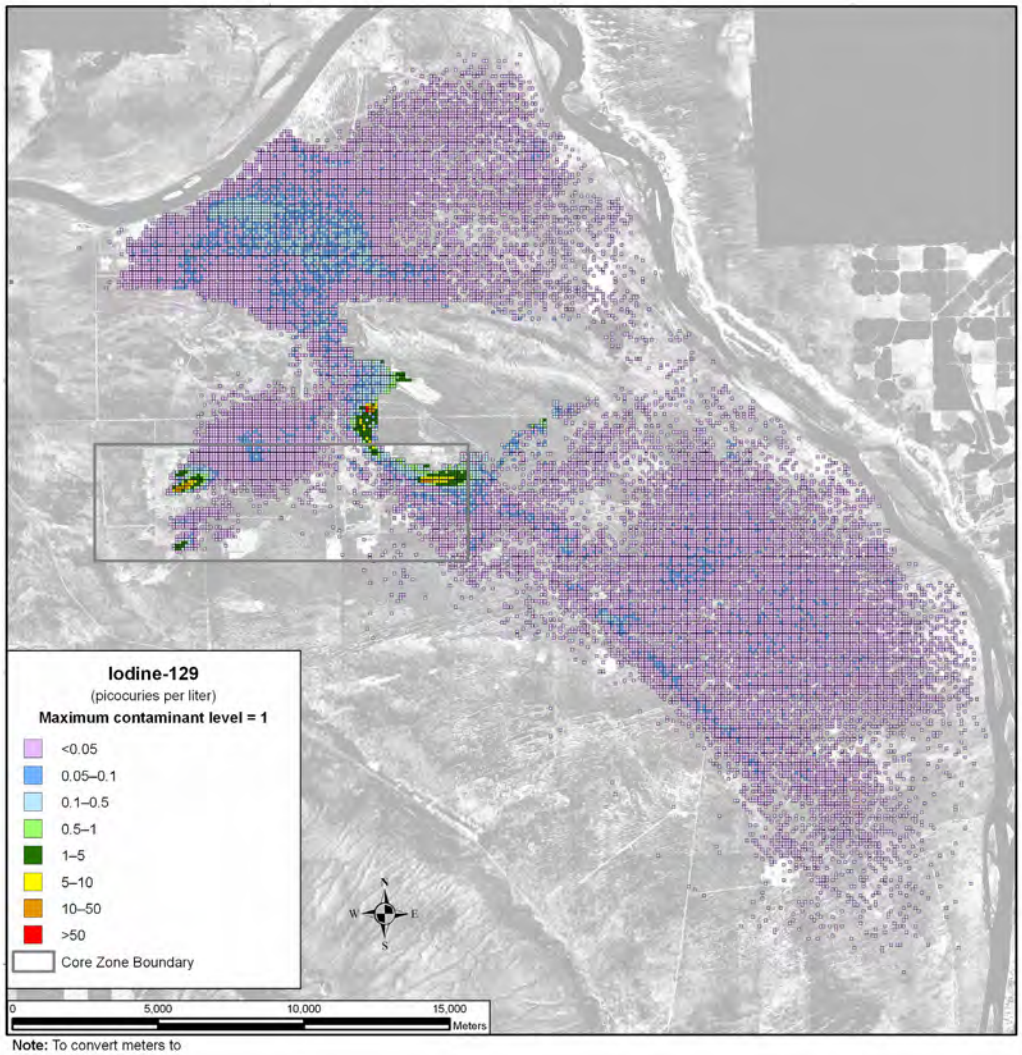
Figure 5–282. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

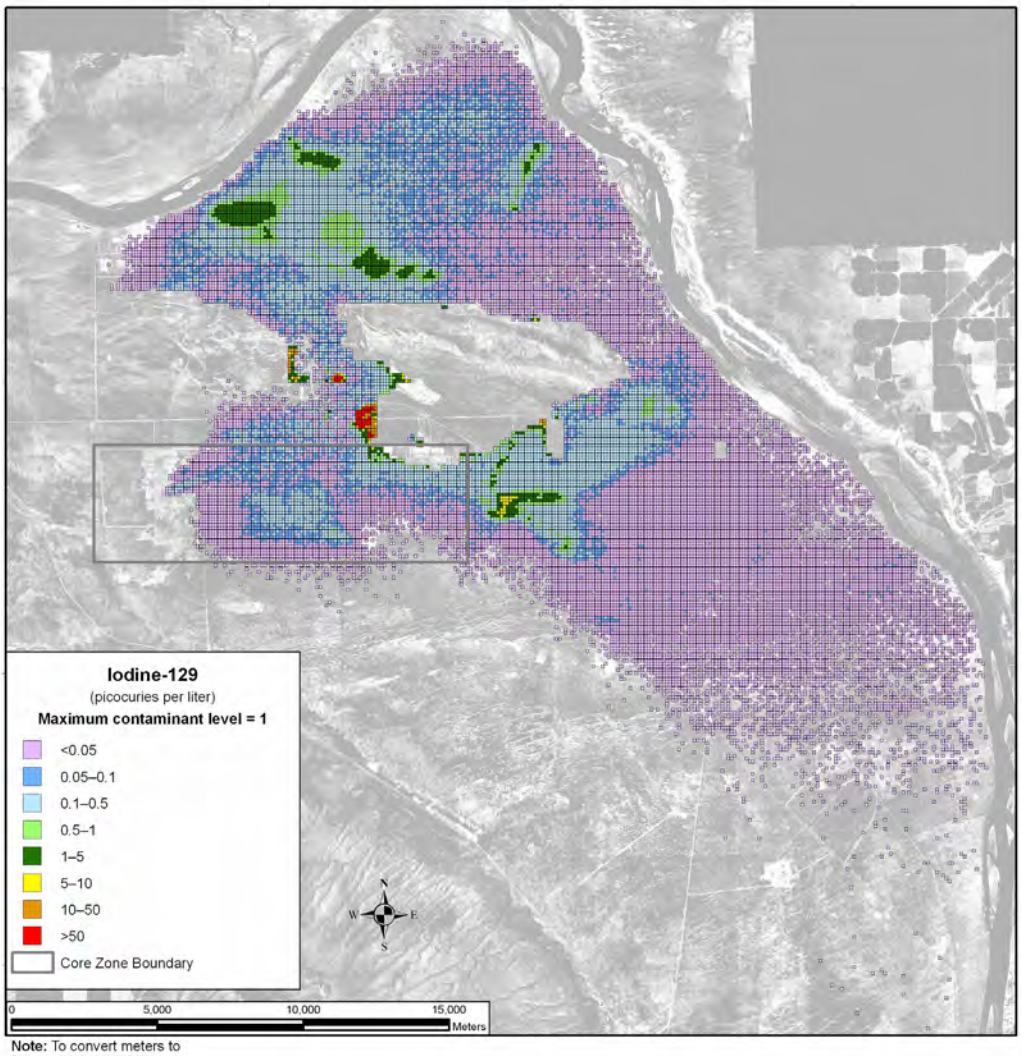
Figure 5–283. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

Figure 5–284 shows the spatial distribution of groundwater concentration for iodine-129 during CY 2005 under the Base Case. Analysis releases from cribs and trenches (ditches) and past leaks result in groundwater concentration plumes that exceed the benchmark concentration associated with the T Barrier, B Barrier, and A Barrier. Peak concentrations in this plume are about 10 to 30 times greater than the benchmark, and mostly contained within the Core Zone Boundary. By CY 2135, the contaminant plumes have spread further north through Gable Gap and further east toward the Columbia River (see Figure 5–285). In the plume north of Gable Gap, contaminant levels have begun to meet the benchmark. In the east, just outside of the Core Zone Boundary, levels have risen 5 to 10 times above the benchmark. By CY 7140, most of the mass in the plume has reached the Columbia River, with only a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier (see Figure 5–286). Technetium-99, chromium, and nitrate (see Figures 5–287 through 5–295) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



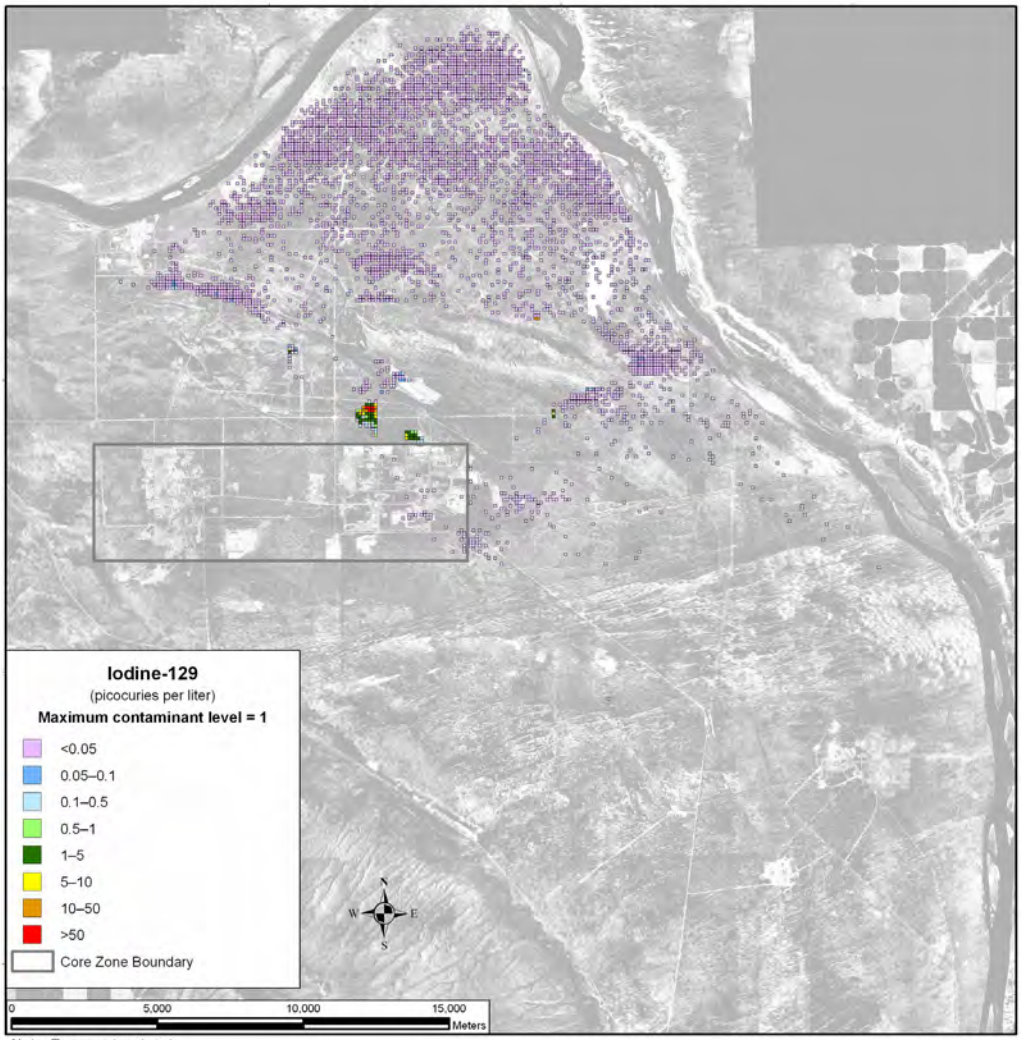
Note: To convert meters to feet, multiply by 3.281

Figure 5–284. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



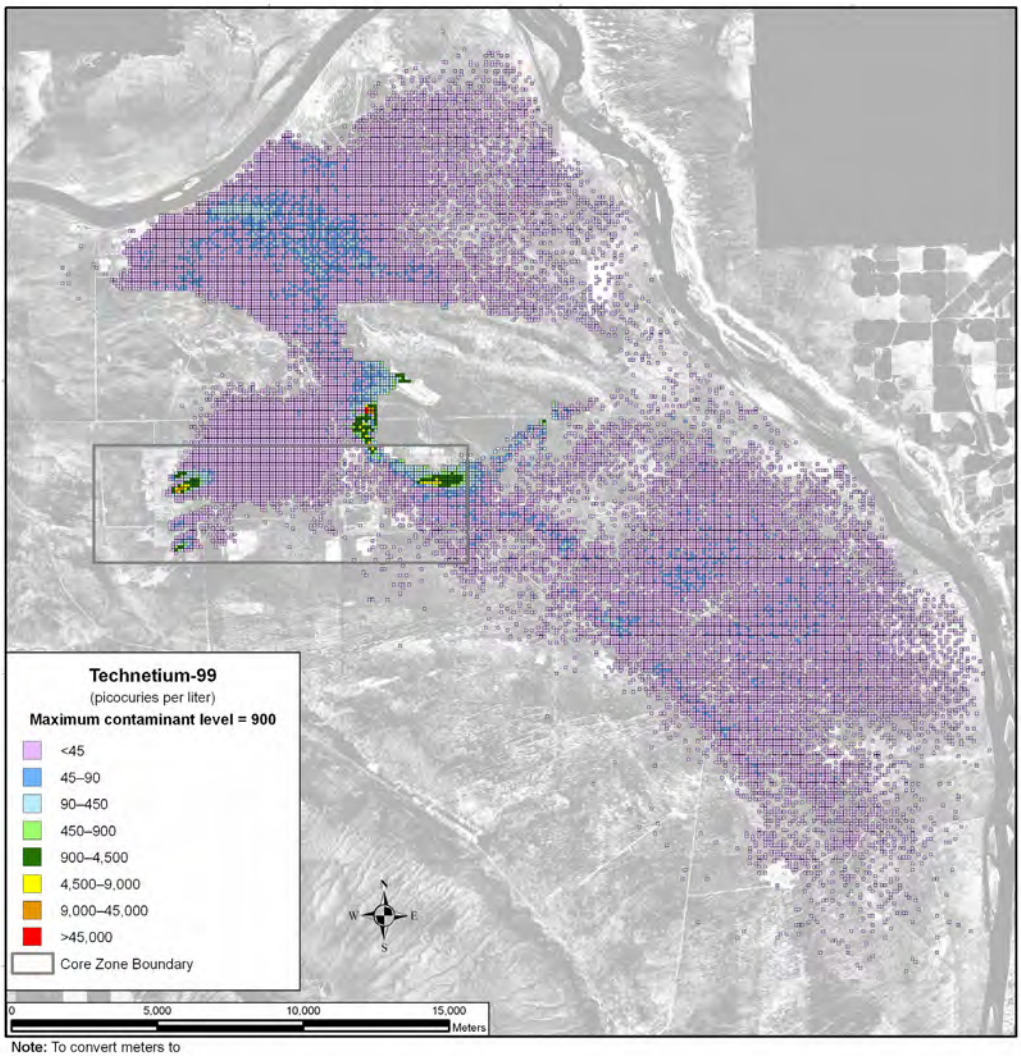
Note: To convert meters to feet, multiply by 3.281

Figure 5–285. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



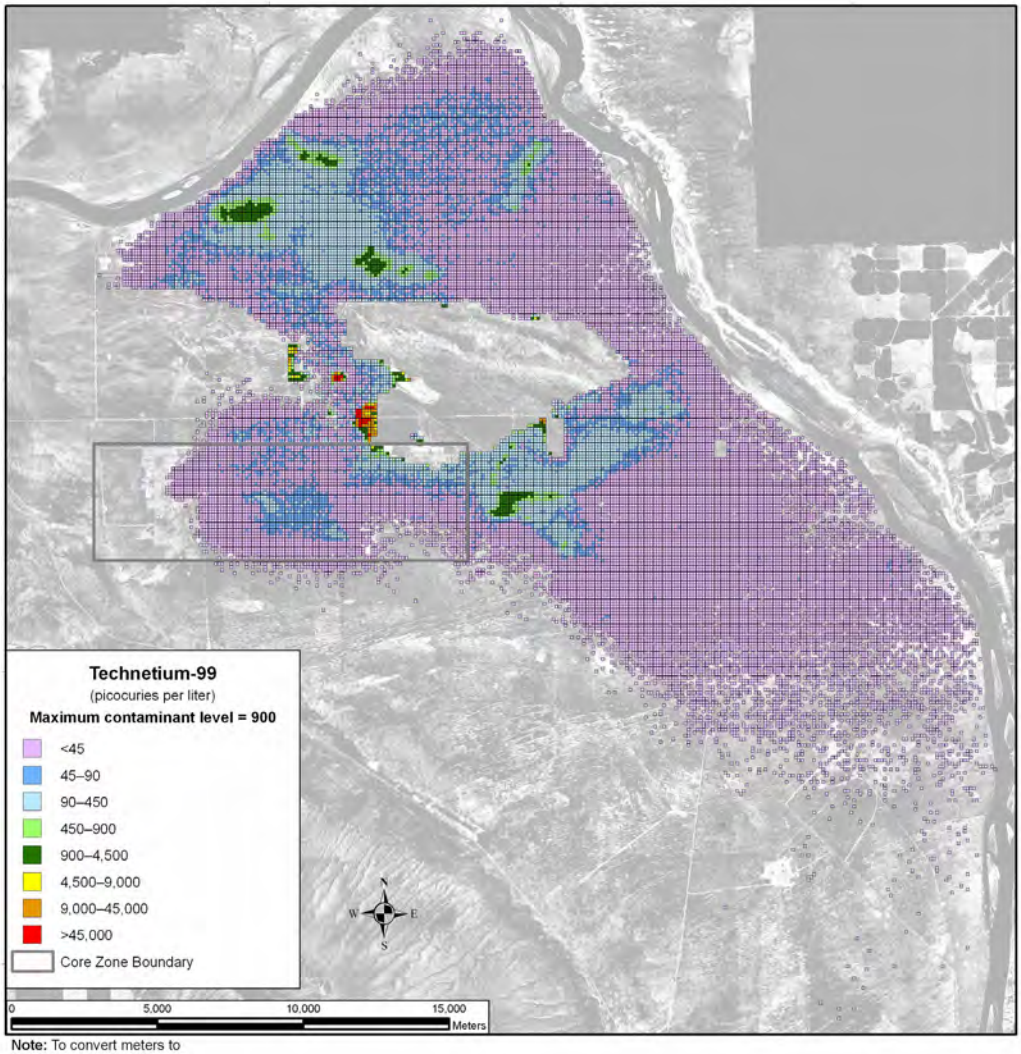
Note: To convert meters to feet, multiply by 3.281

Figure 5–286. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



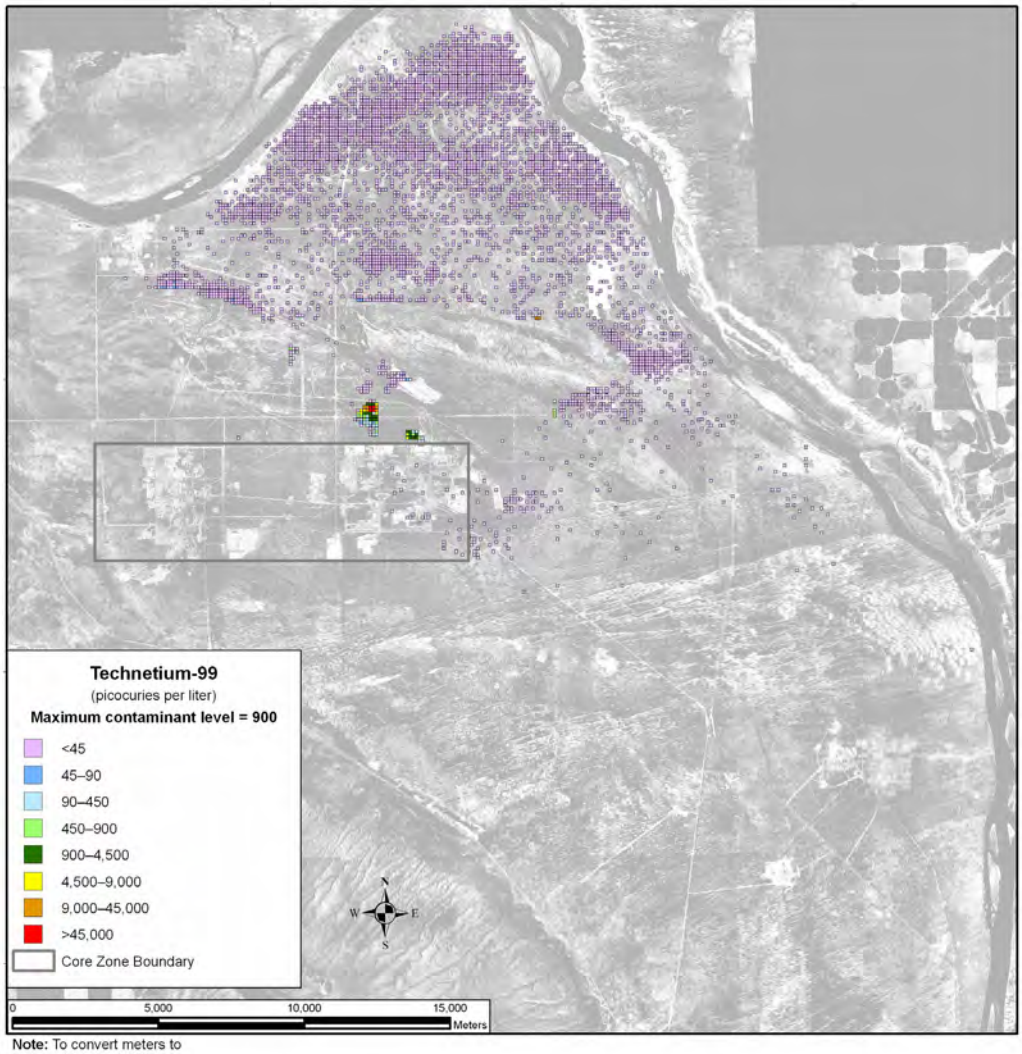
Note: To convert meters to feet, multiply by 3.281

Figure 5–287. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–288. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–289. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140

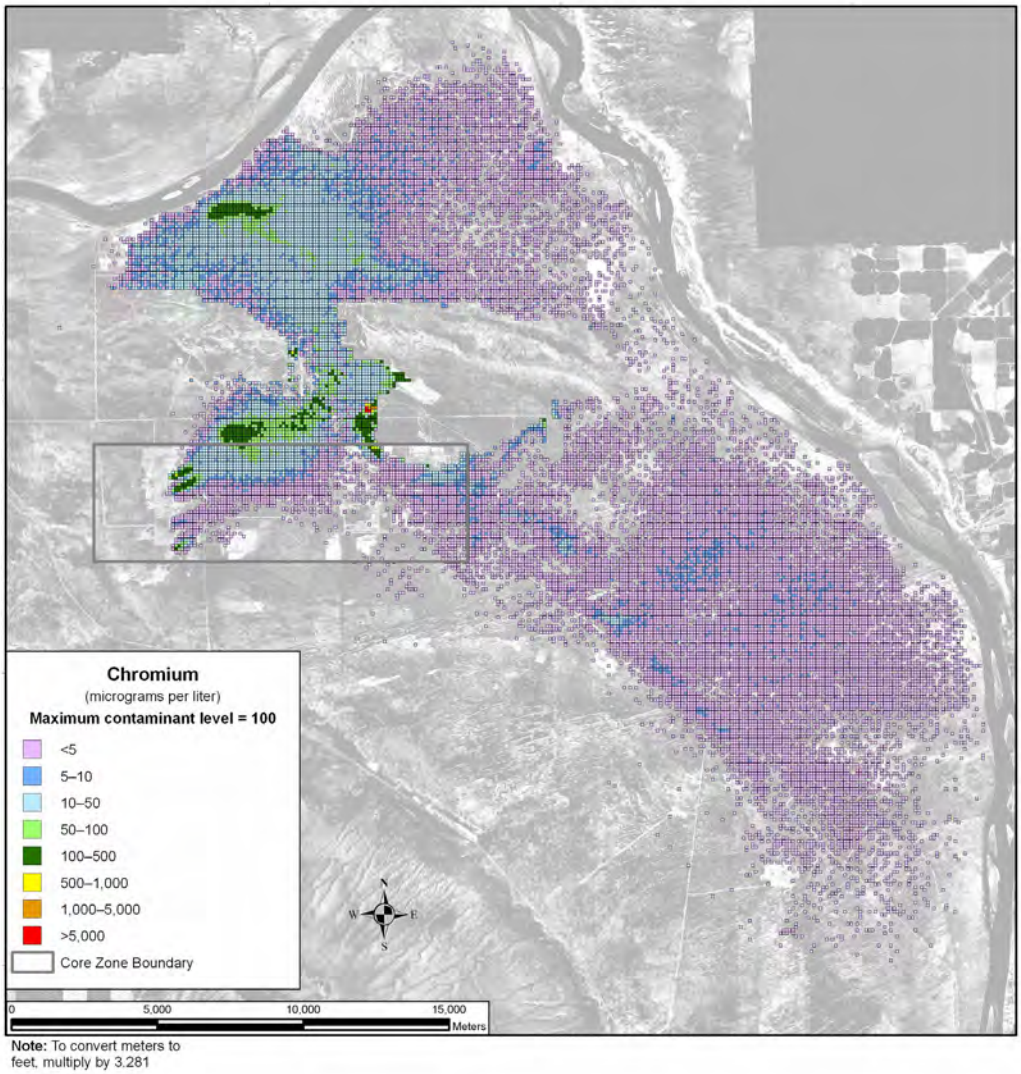
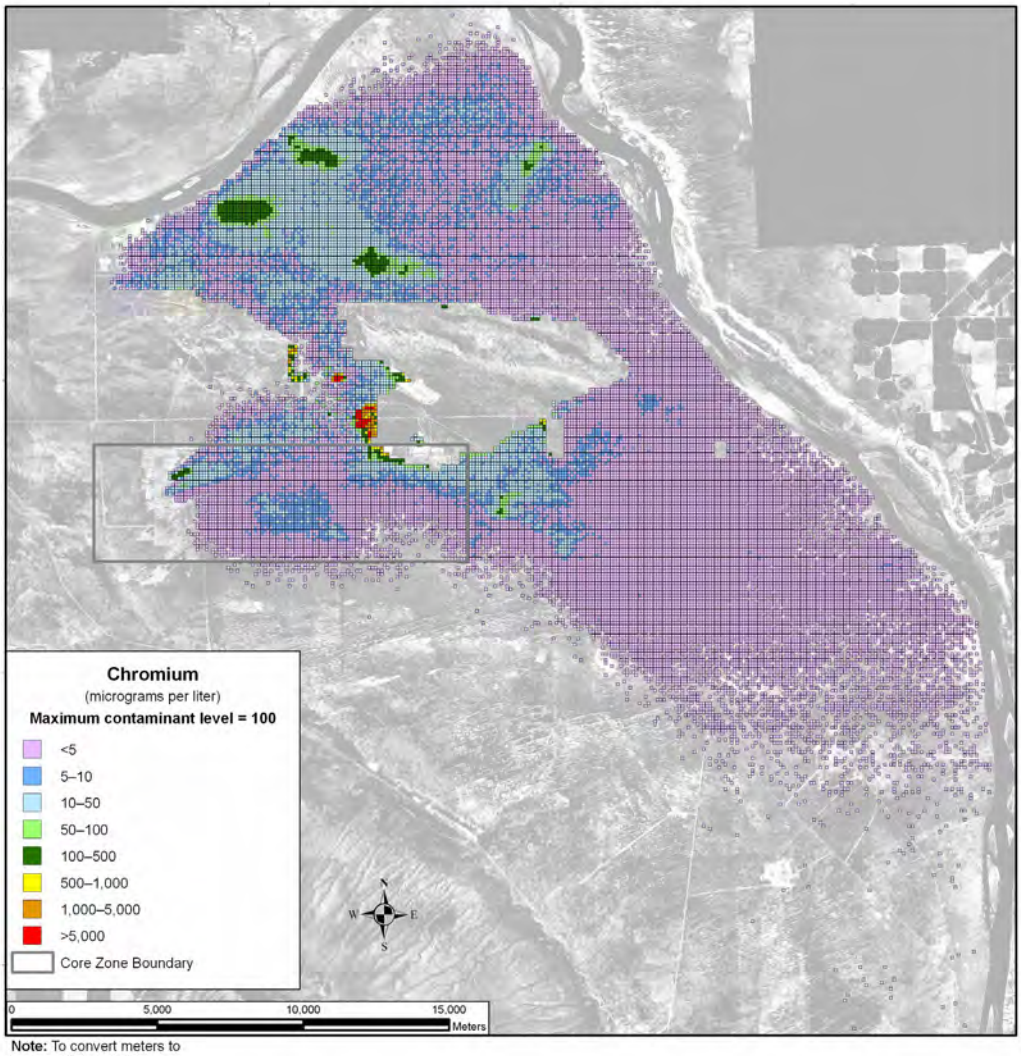
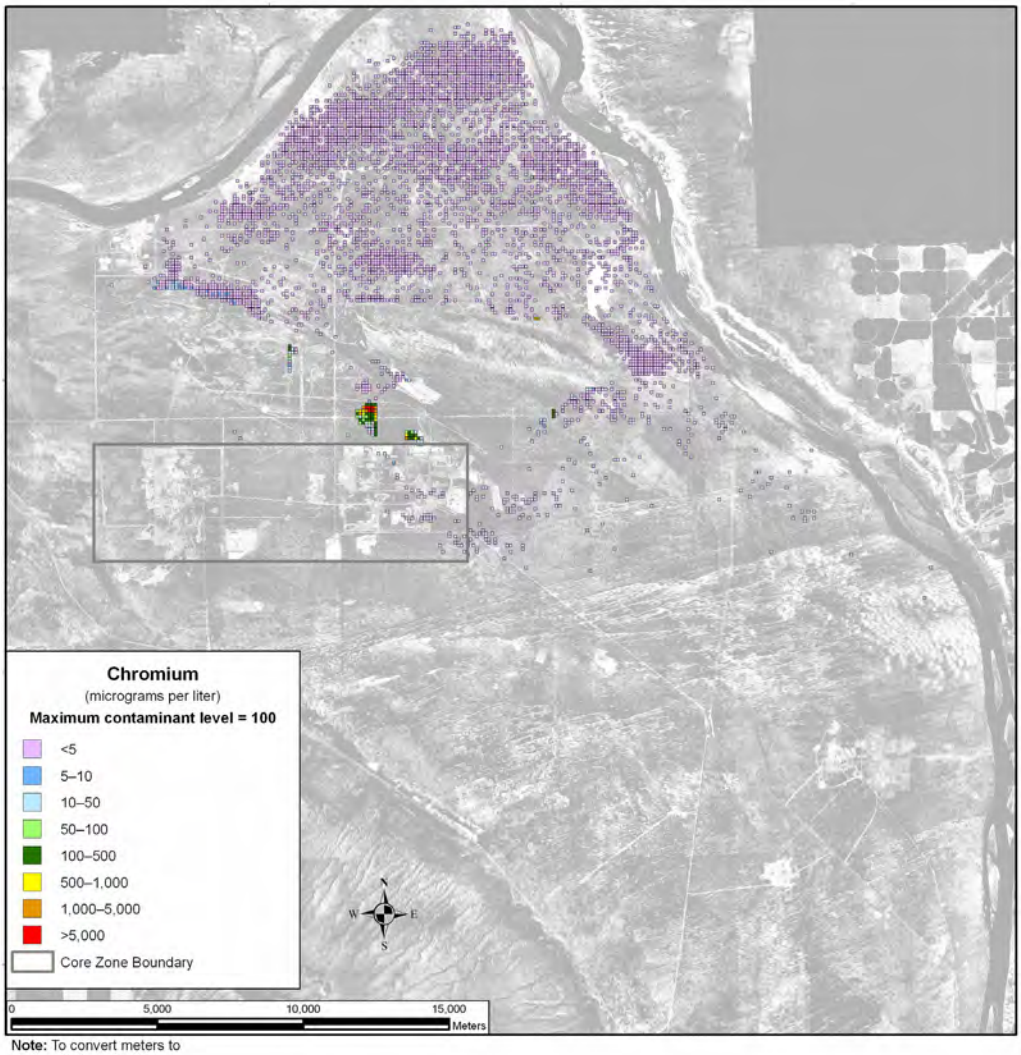


Figure 5–290. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



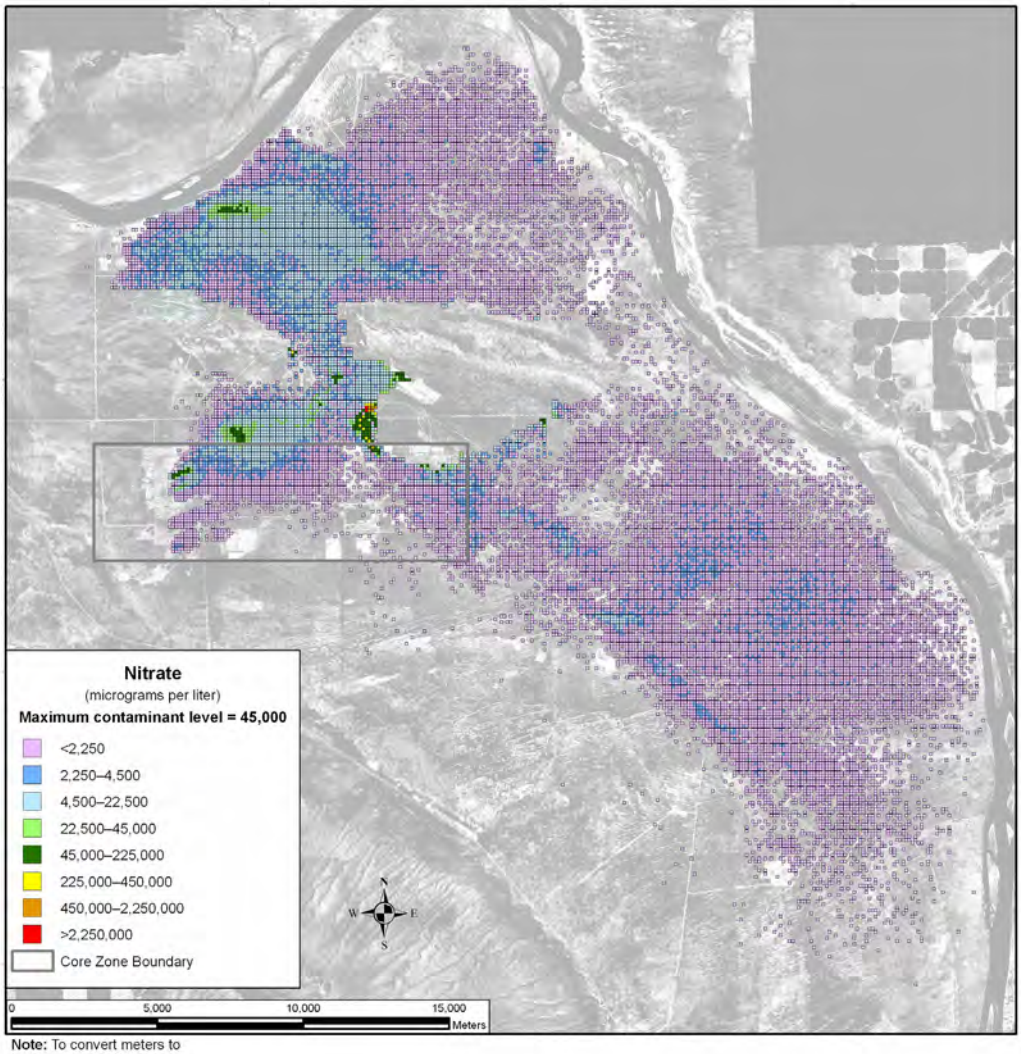
Note: To convert meters to feet, multiply by 3.281

Figure 5–291. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



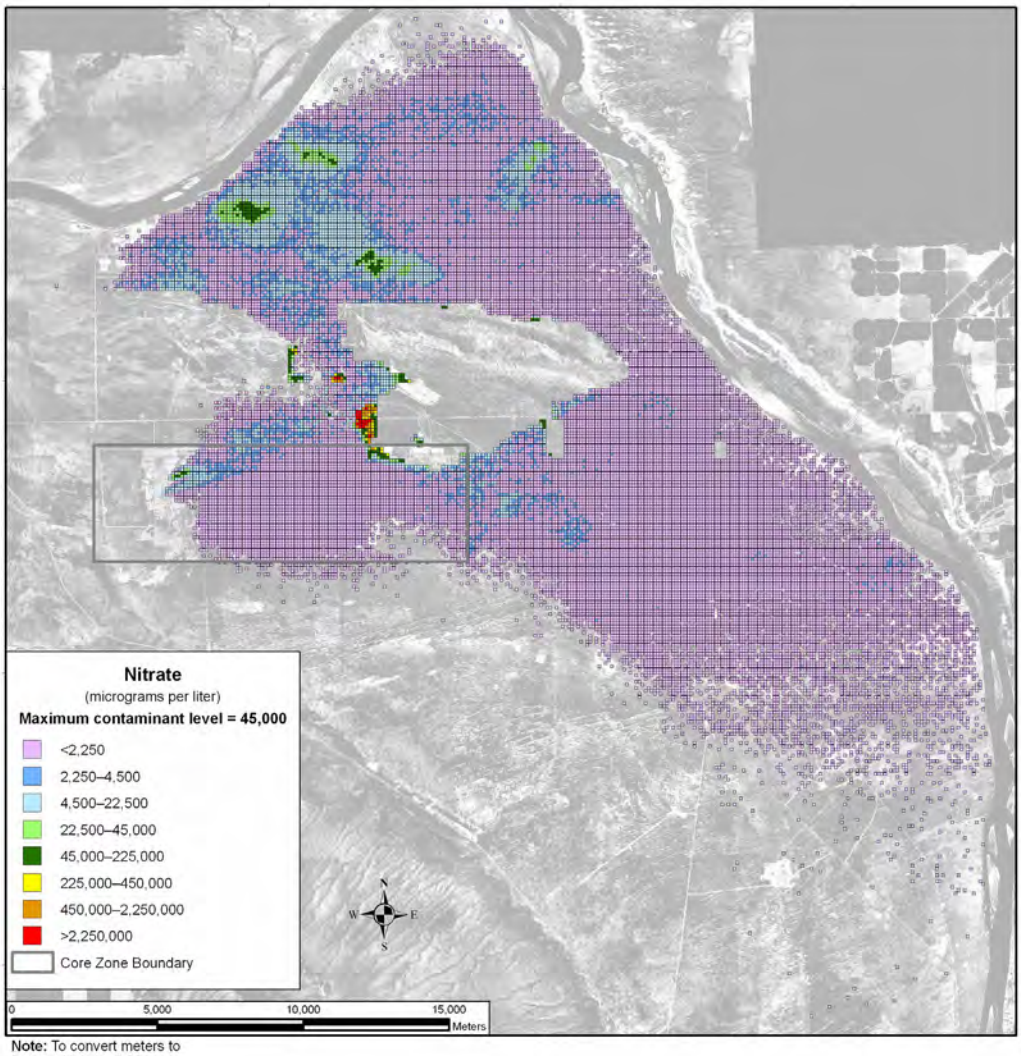
Note: To convert meters to feet, multiply by 3.281

Figure 5–292. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–293. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–294. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135

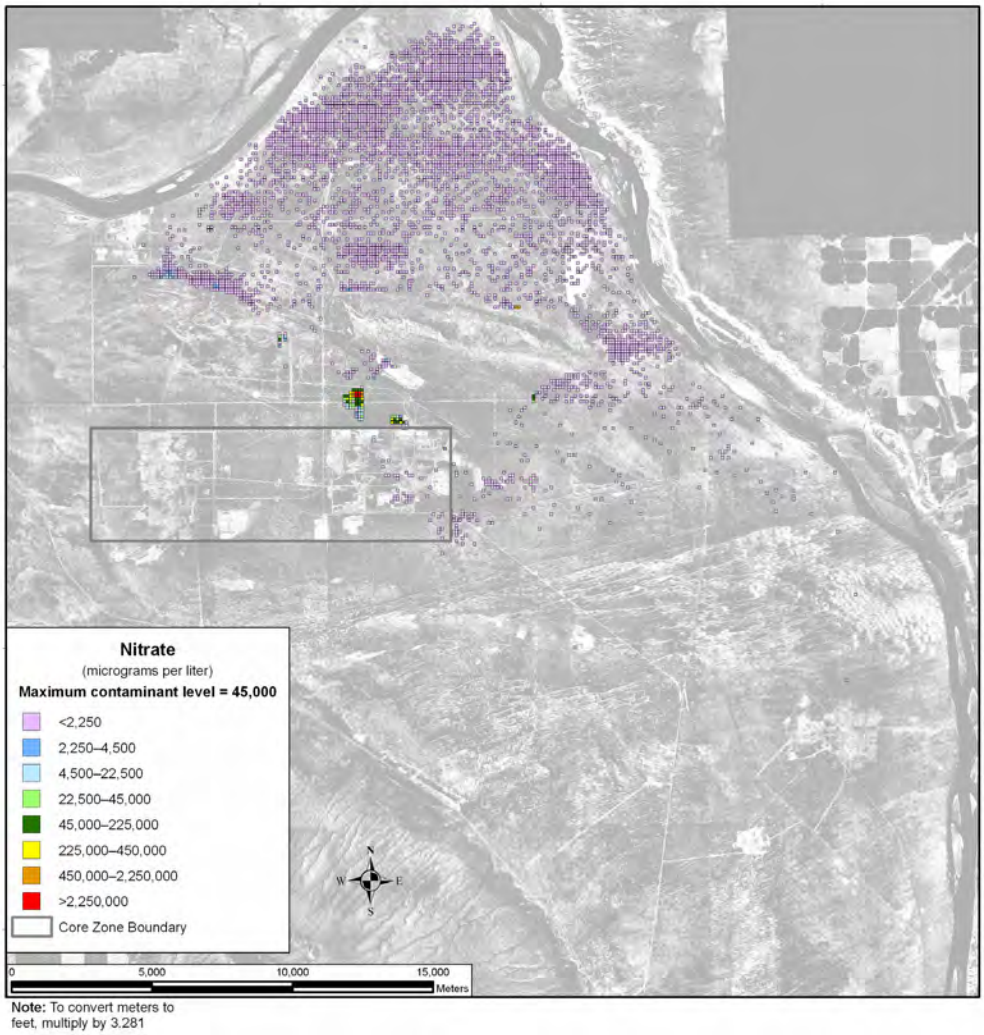
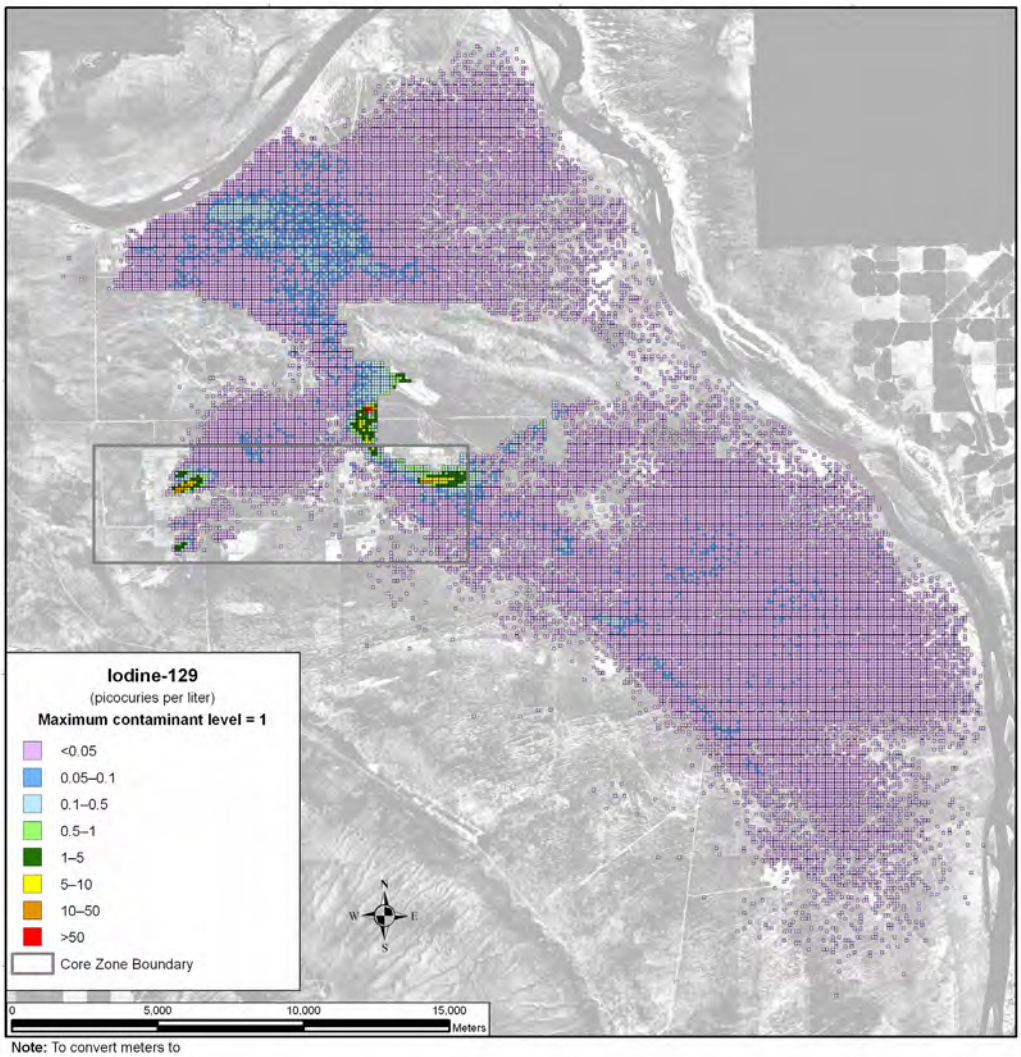


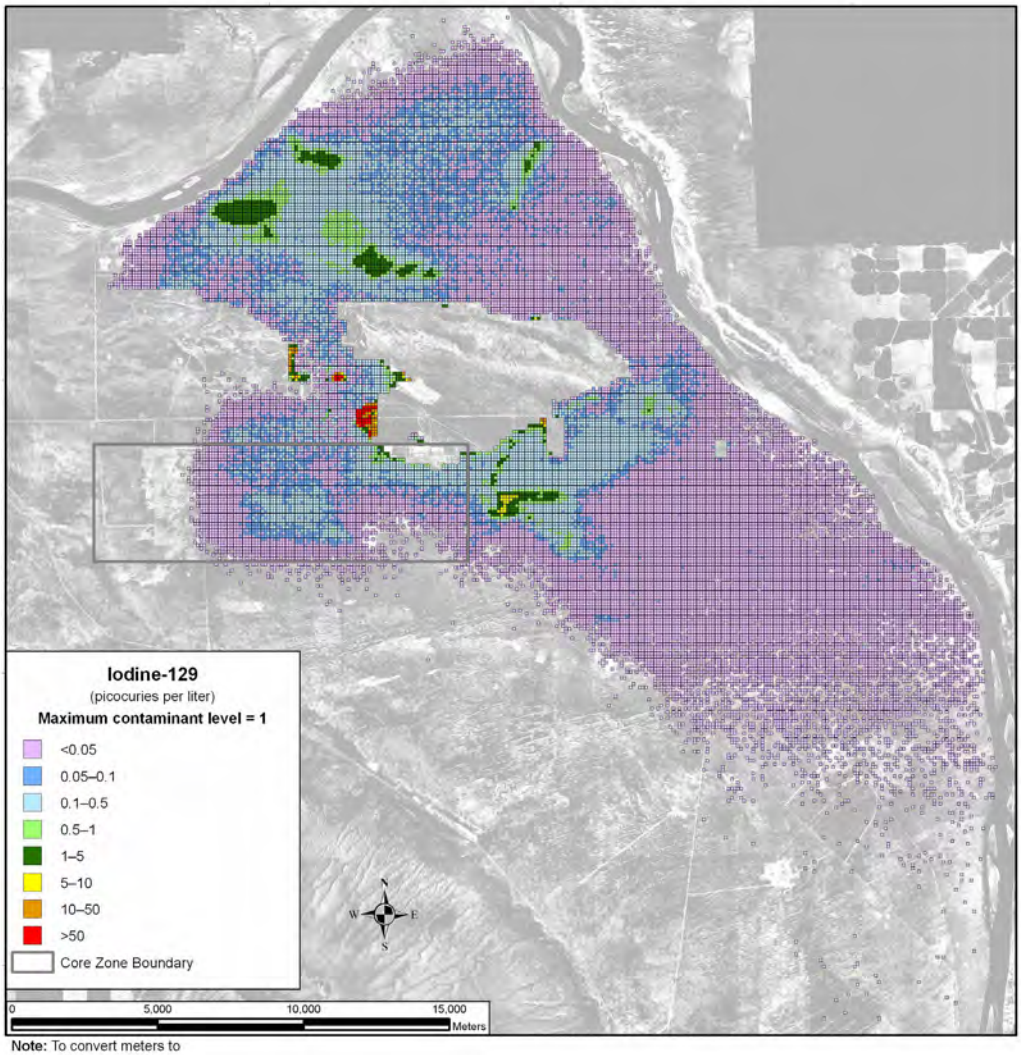
Figure 5–295. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

The spatial distribution of groundwater concentrations for the conservative tracers under the Option Case is essentially identical to that under the Base Case (see Figures 5–296 through 5–307).



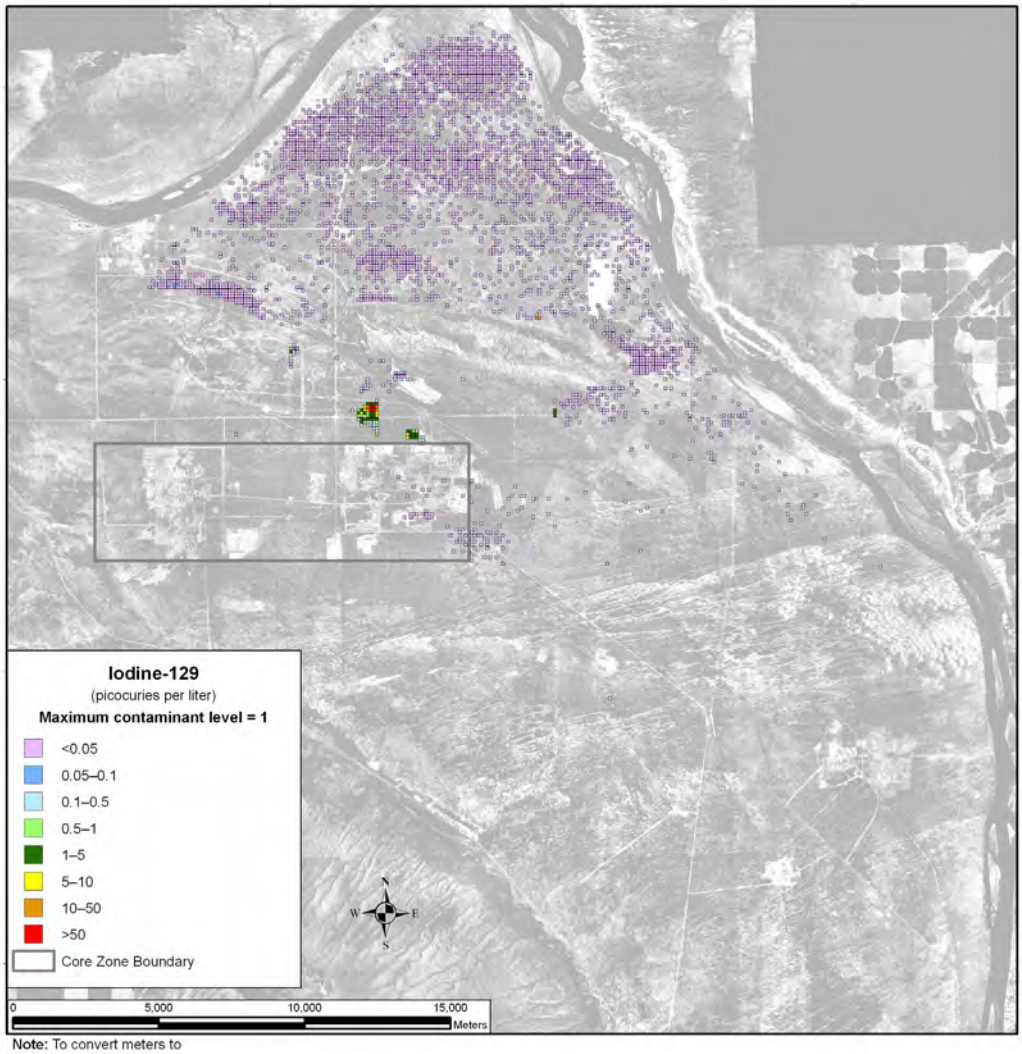
Note: To convert meters to feet, multiply by 3.281

Figure 5–296. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2005



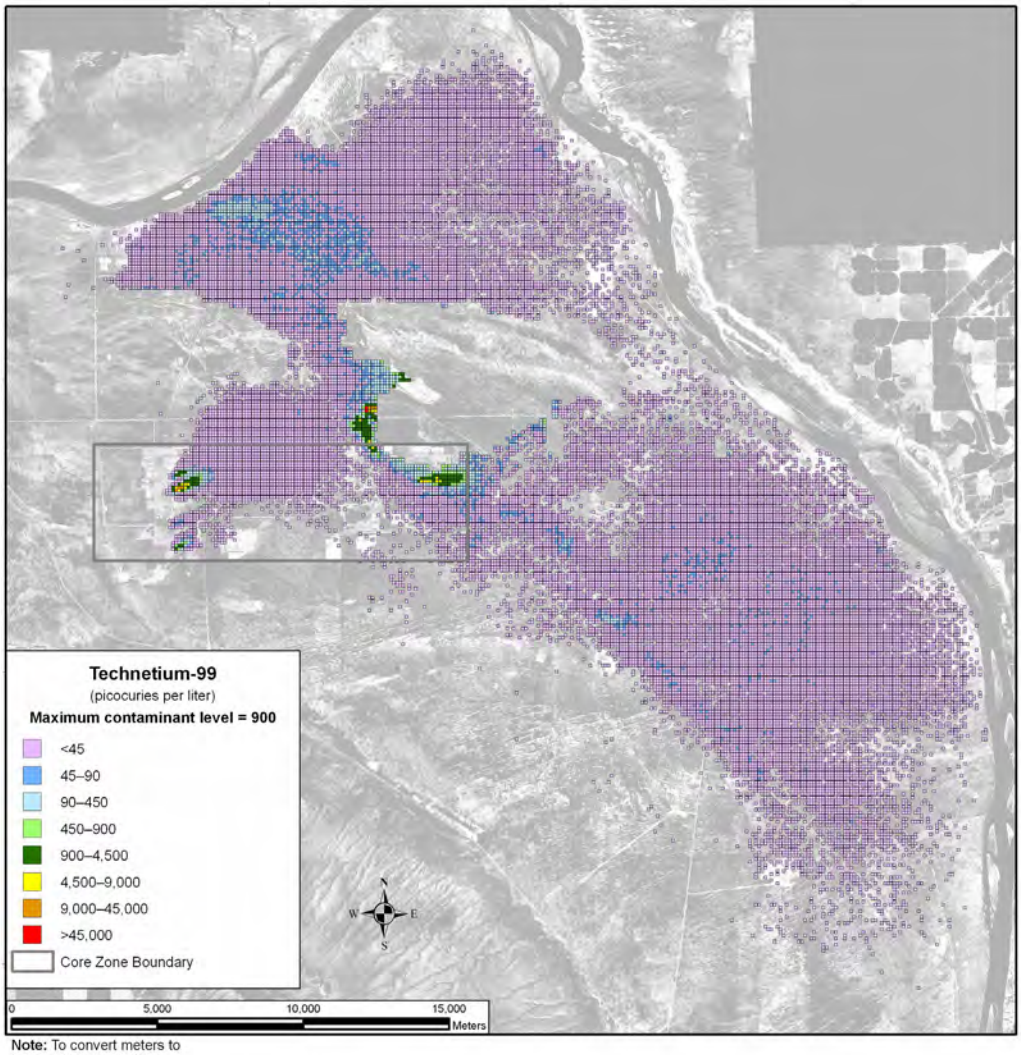
Note: To convert meters to feet, multiply by 3.281

Figure 5–297. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 2135



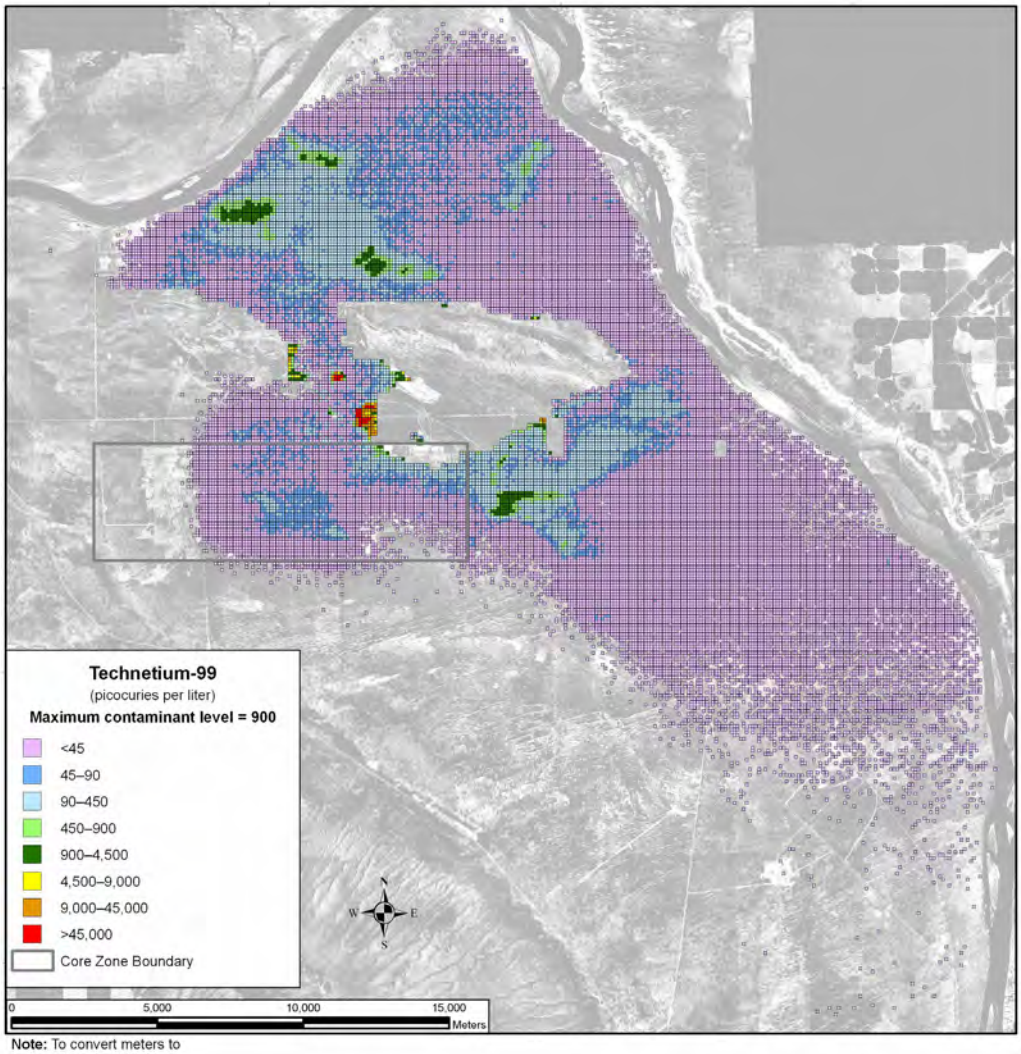
Note: To convert meters to feet, multiply by 3.281

Figure 5–298. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



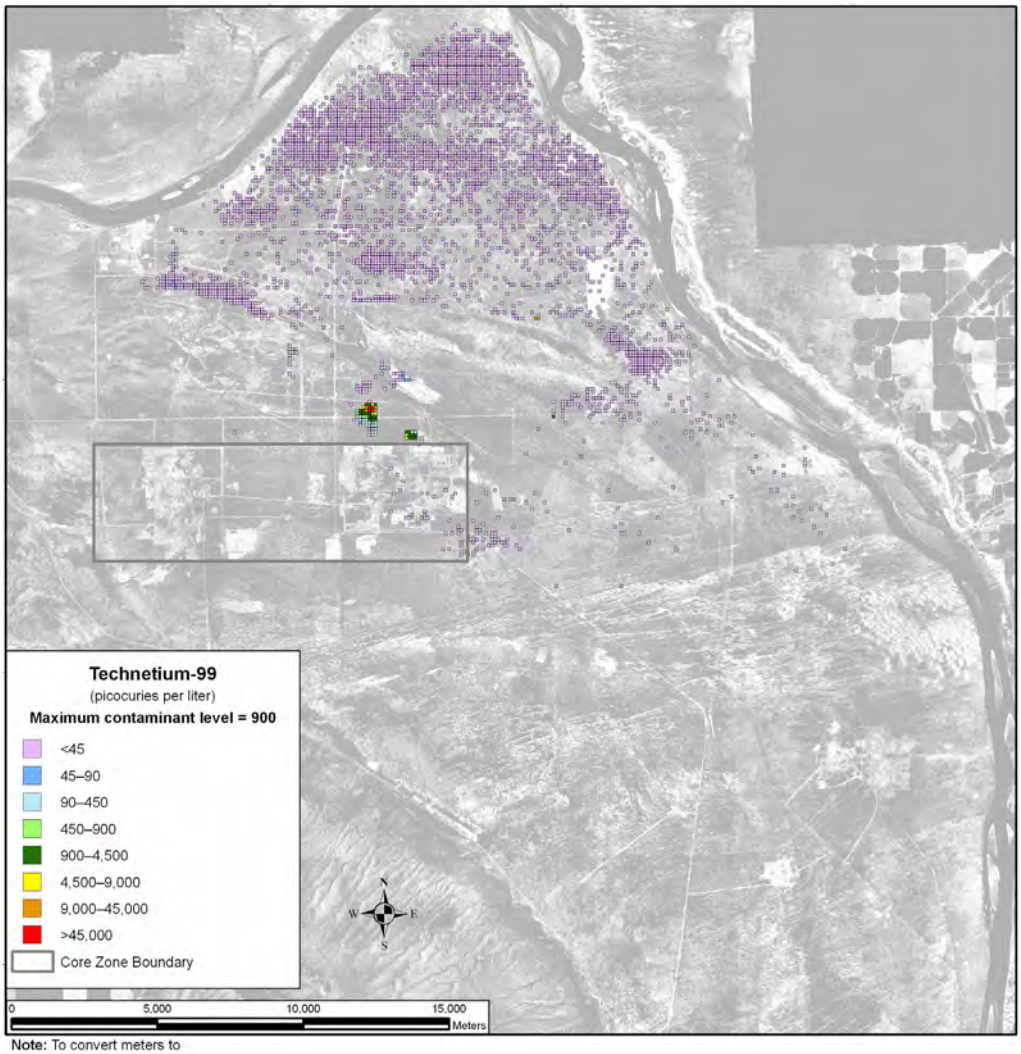
Note: To convert meters to feet, multiply by 3.281

Figure 5–299. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2005



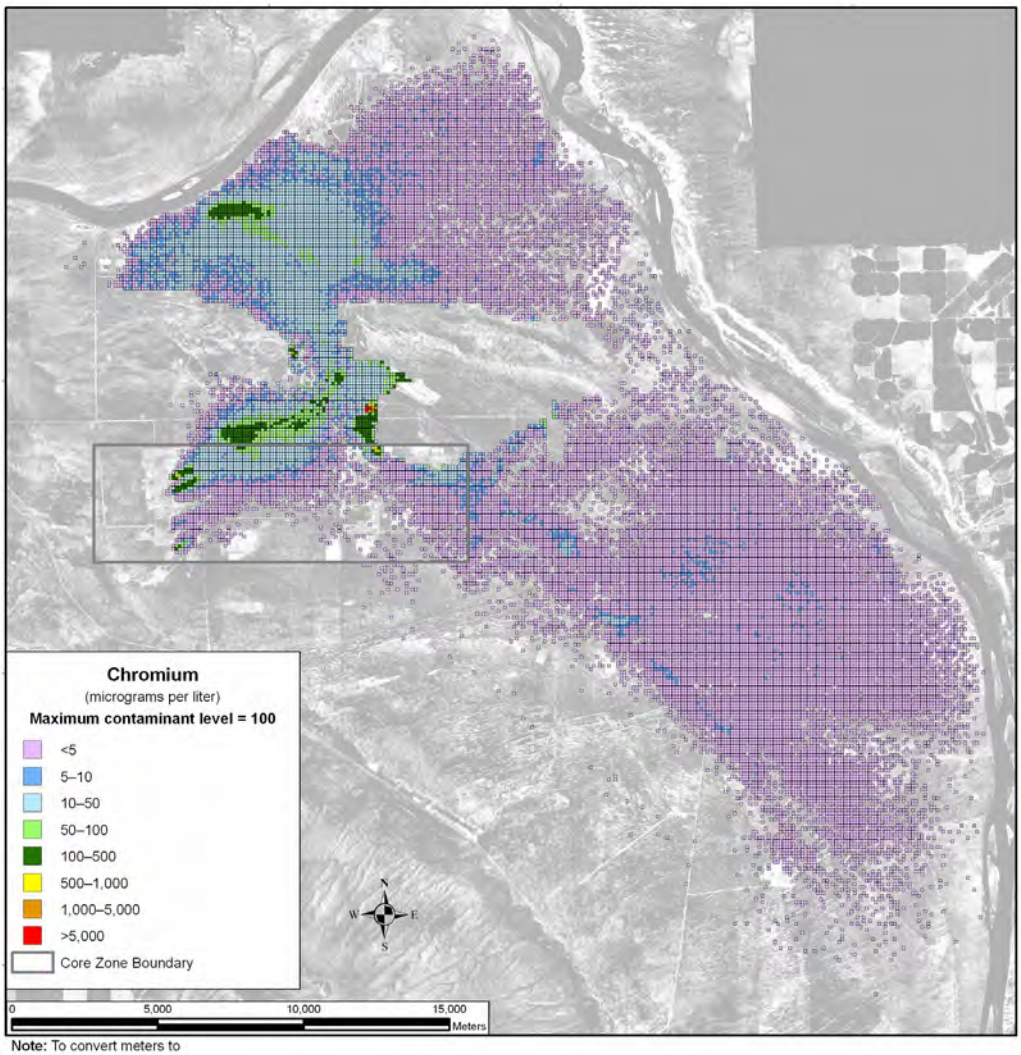
Note: To convert meters to feet, multiply by 3.281

Figure 5–300. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2135



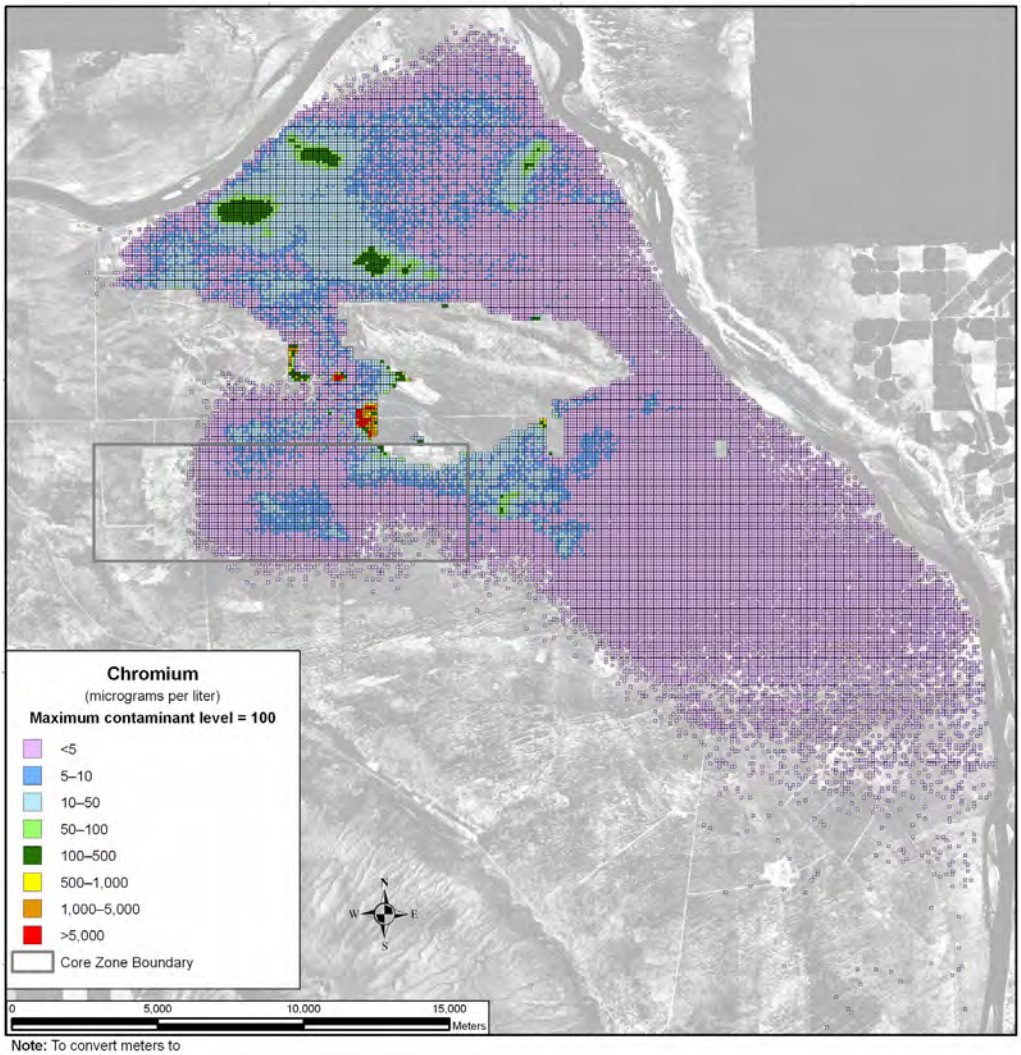
Note: To convert meters to feet, multiply by 3.281

Figure 5–301. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



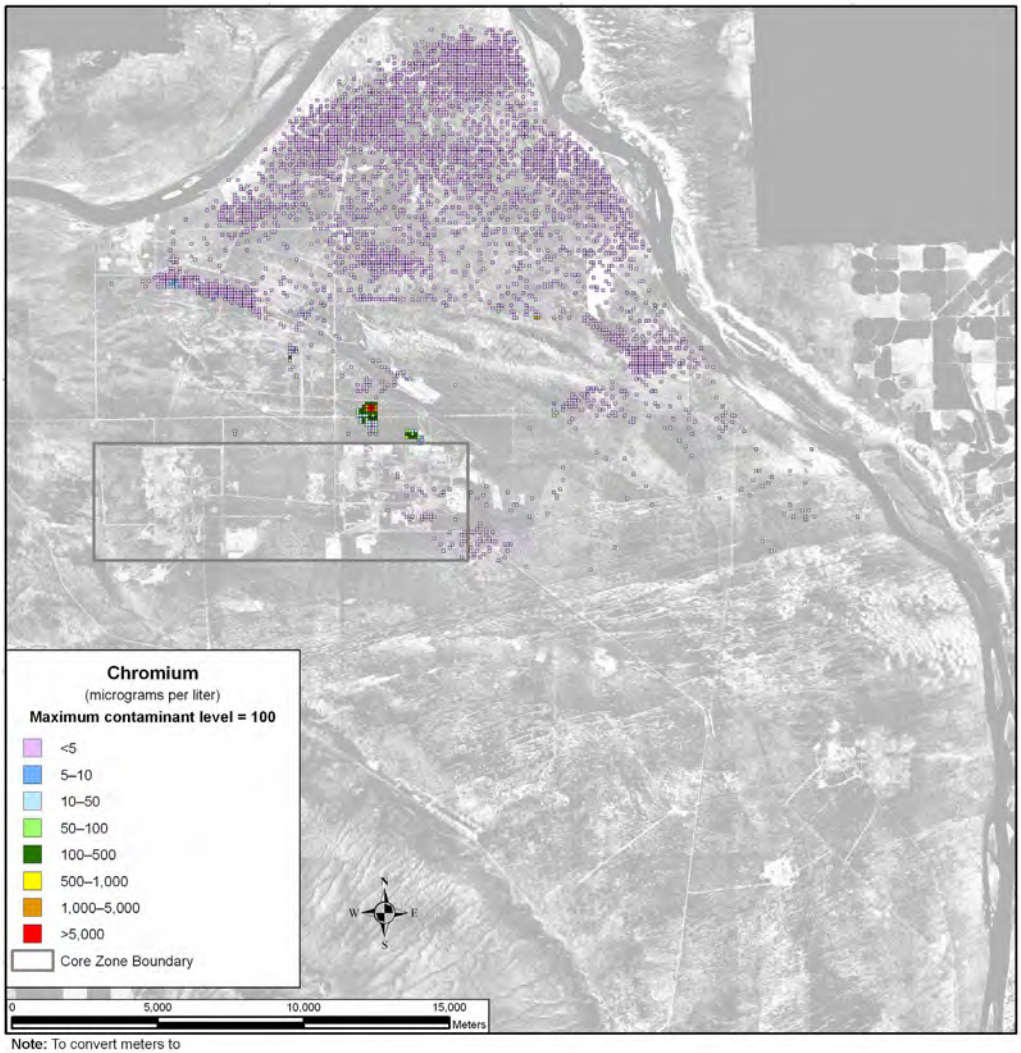
Note: To convert meters to feet, multiply by 3.281

Figure 5–302. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2005



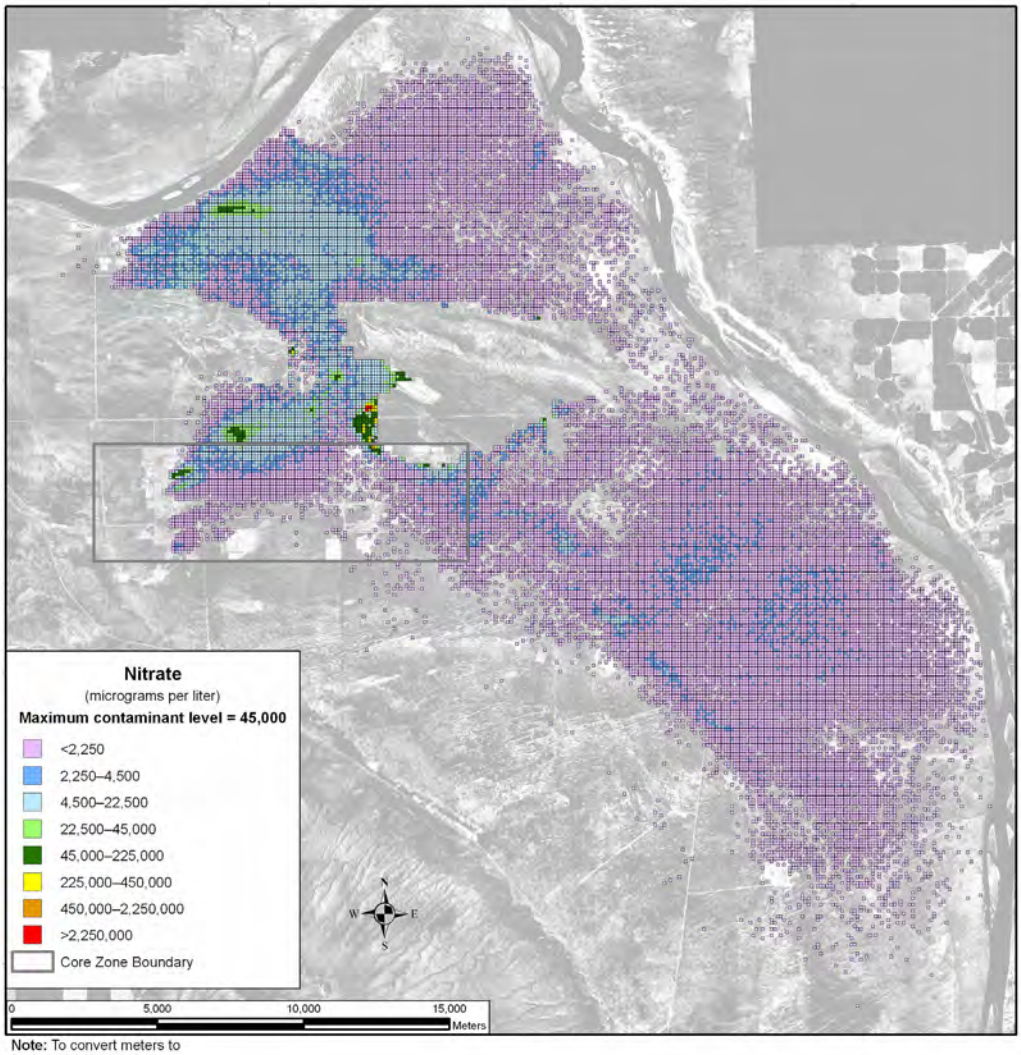
Note: To convert meters to feet, multiply by 3.281

Figure 5–303. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 2135



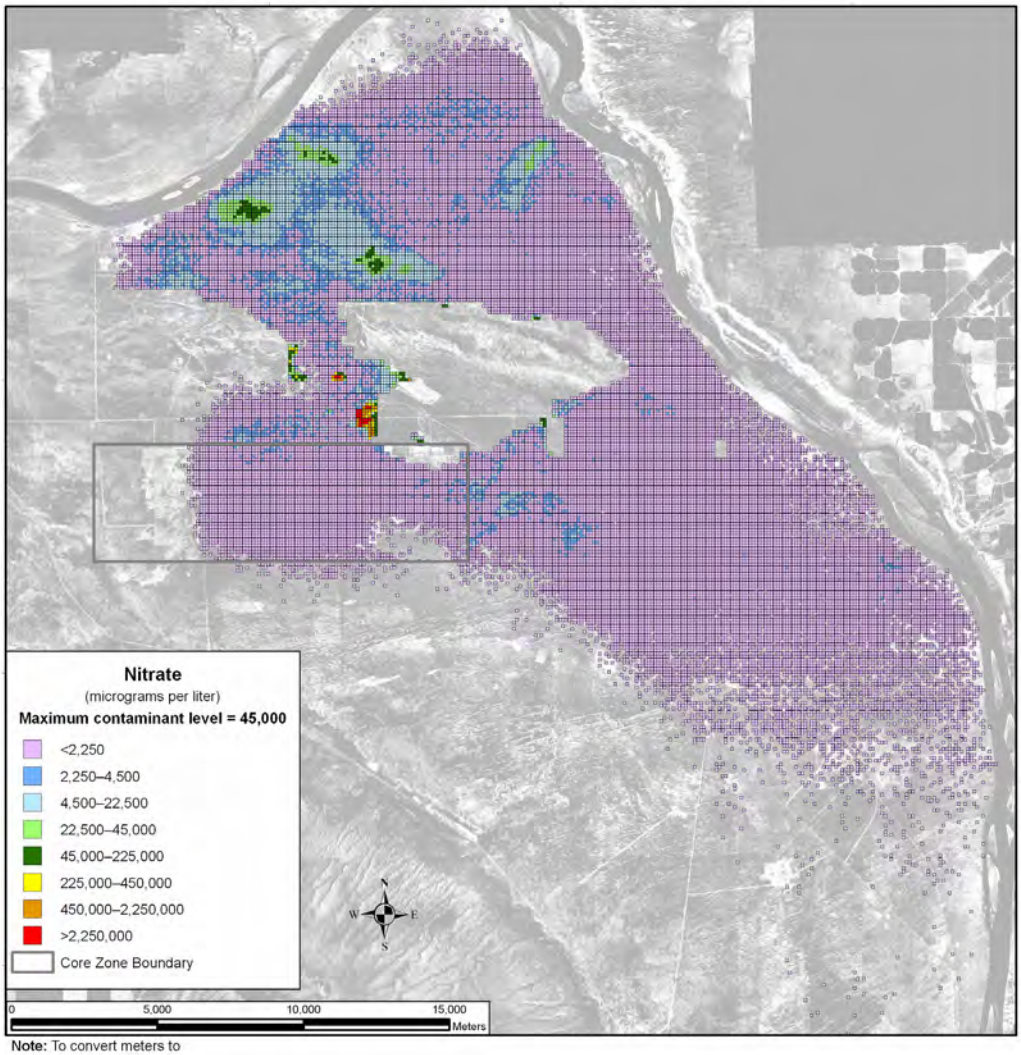
Note: To convert meters to feet, multiply by 3.281

Figure 5–304. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



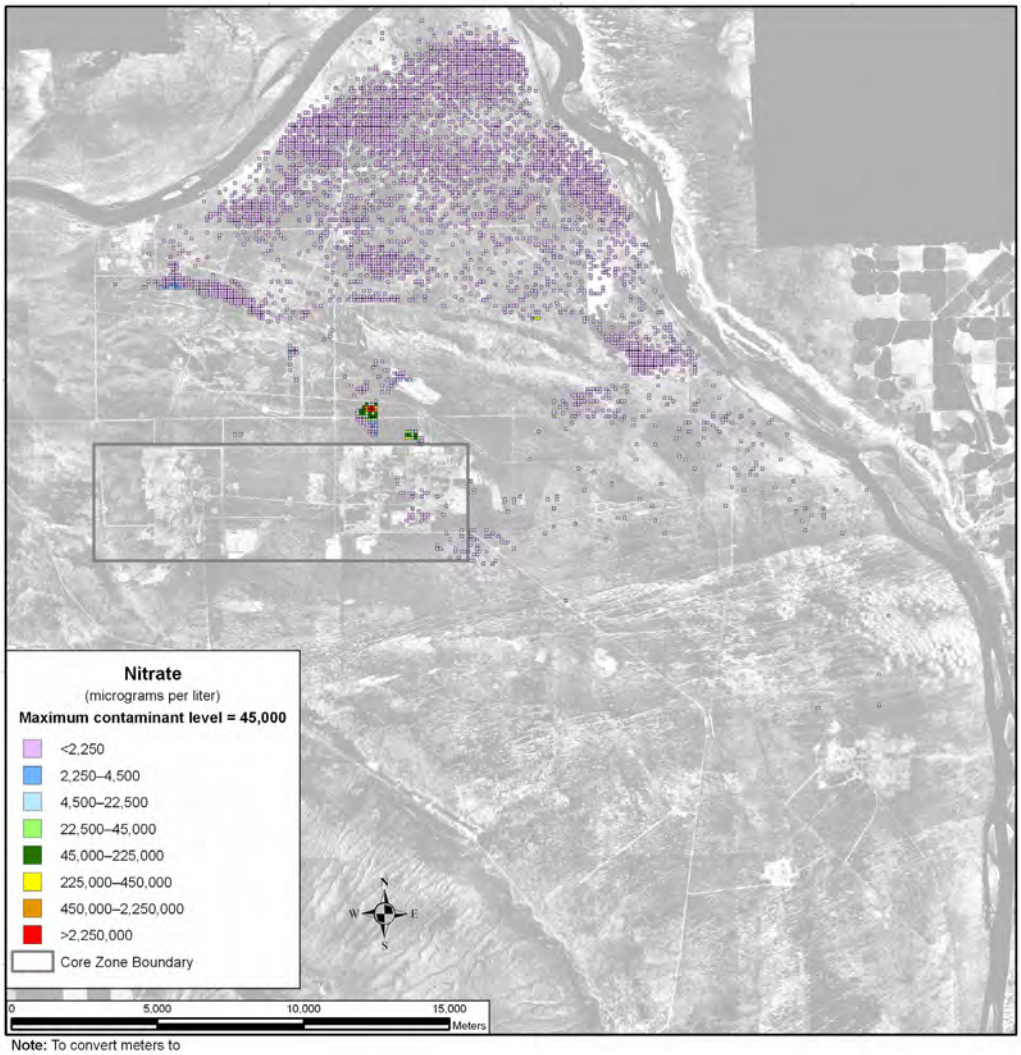
Note: To convert meters to feet, multiply by 3.281

Figure 5–305. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

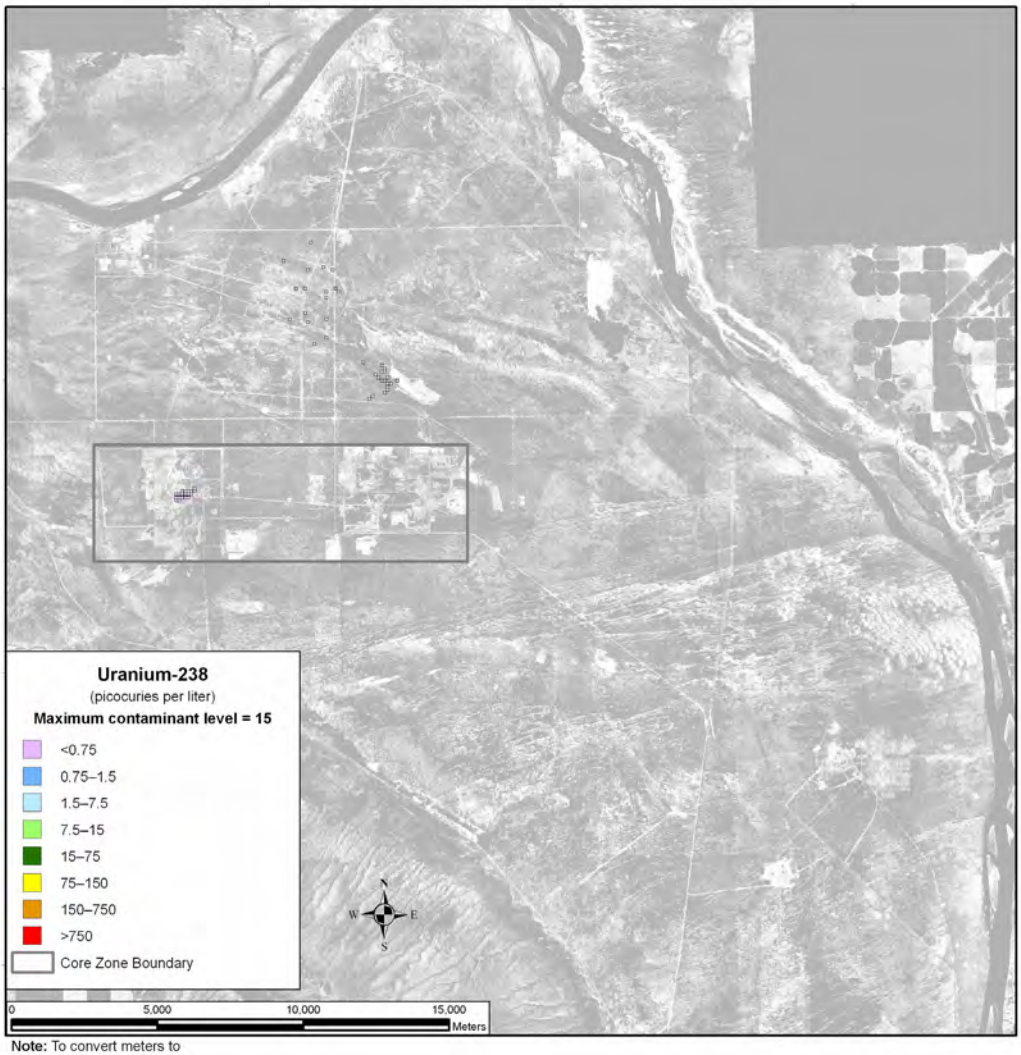
Figure 5–306. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

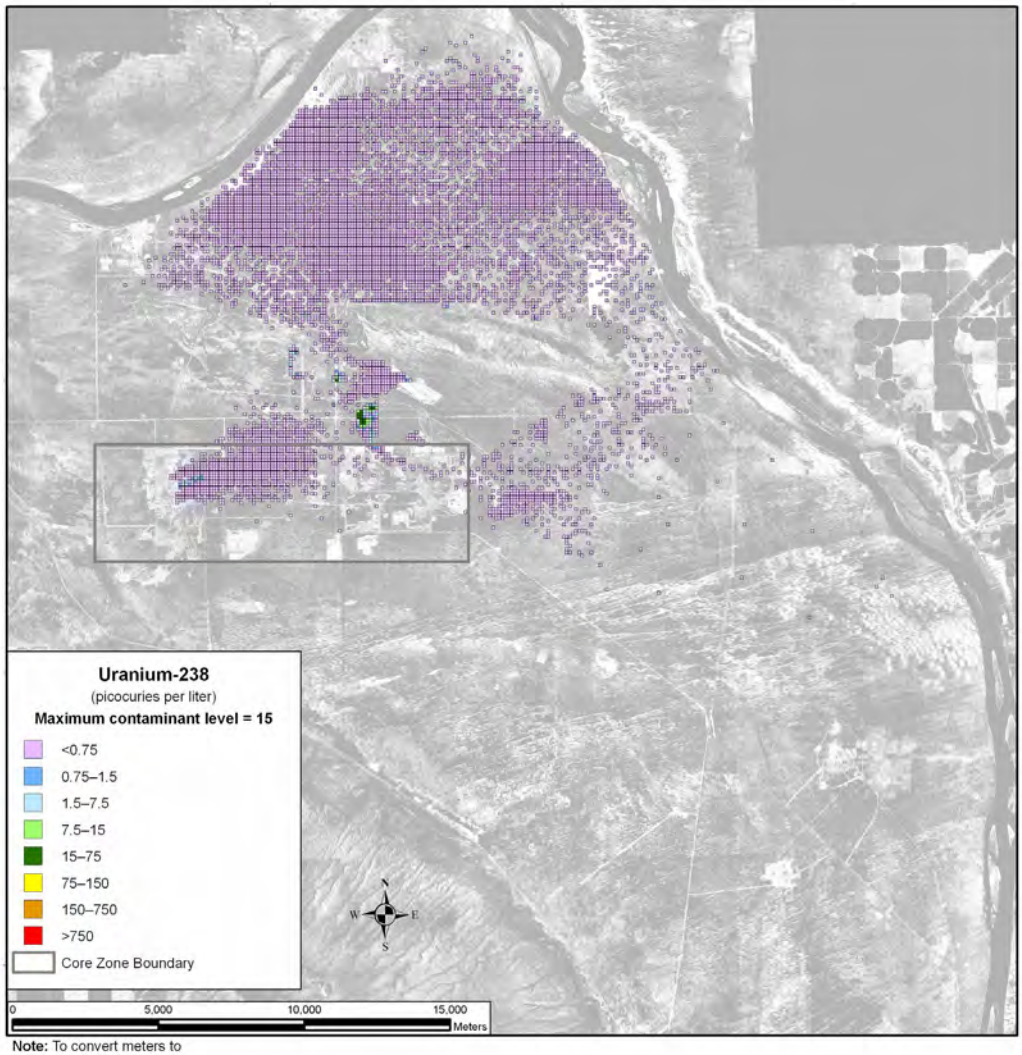
Figure 5–307. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140

Uranium-238 and total uranium under the Base Case are not as mobile as those COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–308 shows the distribution of uranium-238 during CY 2005. There is a small plume associated with cribs and trenches (ditches) and past leaks at the T Barrier that is less than one-twentieth of the benchmark concentration and is contained within the Core Zone Boundary. By CY 7140, the area of the plume has grown and extended to the Columbia River (see Figure 5–309). Most of the plume is significantly below the benchmark except for a small pocket with high concentrations in the southern region of Gable Gap extending north from the B Barrier. At CY 11,885, the greatest development of the plume during the analysis period is seen (see Figure 5–310). The only area with a significant level of contaminant concentration is the area in the southern region of Gable Gap that originates from the B Barrier. Figures 5–311 through 5–313 show similar results for total uranium.



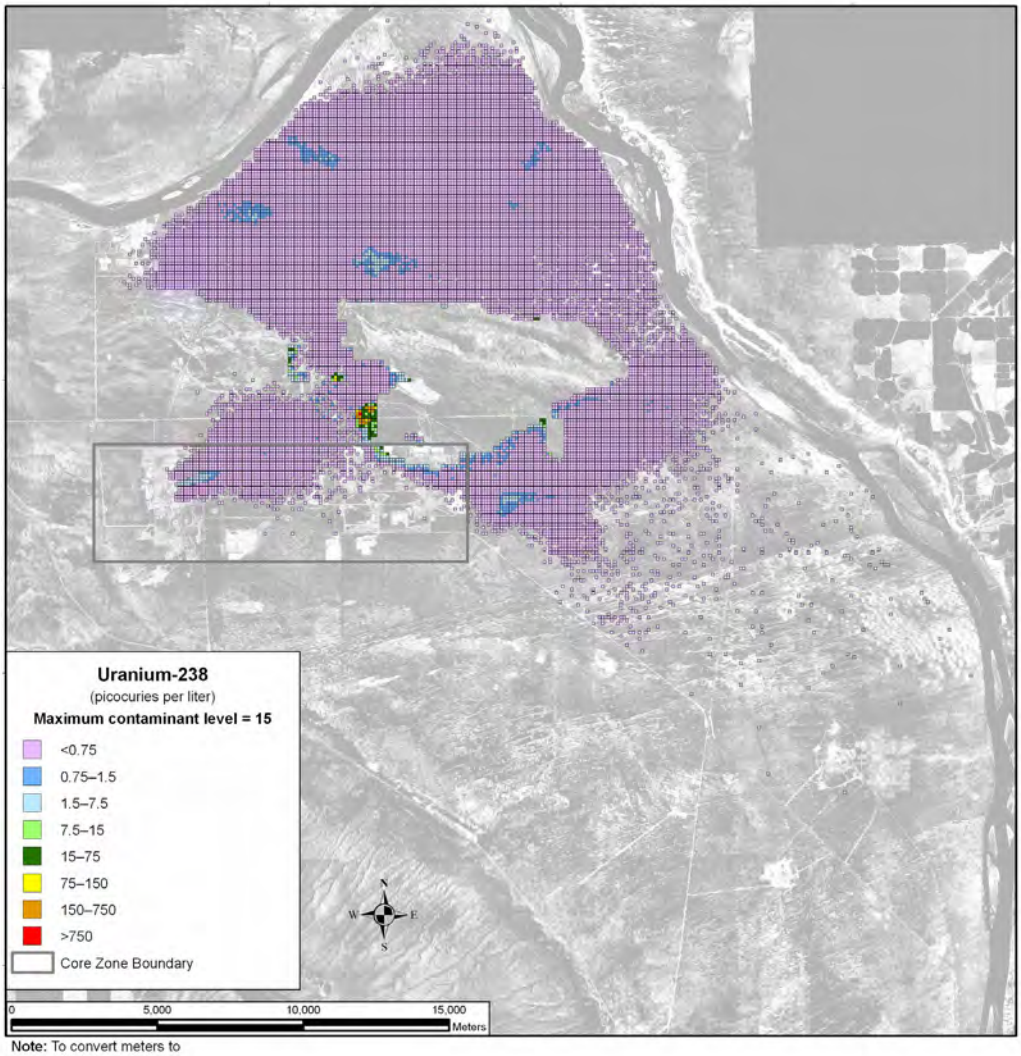
Note: To convert meters to feet, multiply by 3.281

Figure 5–308. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



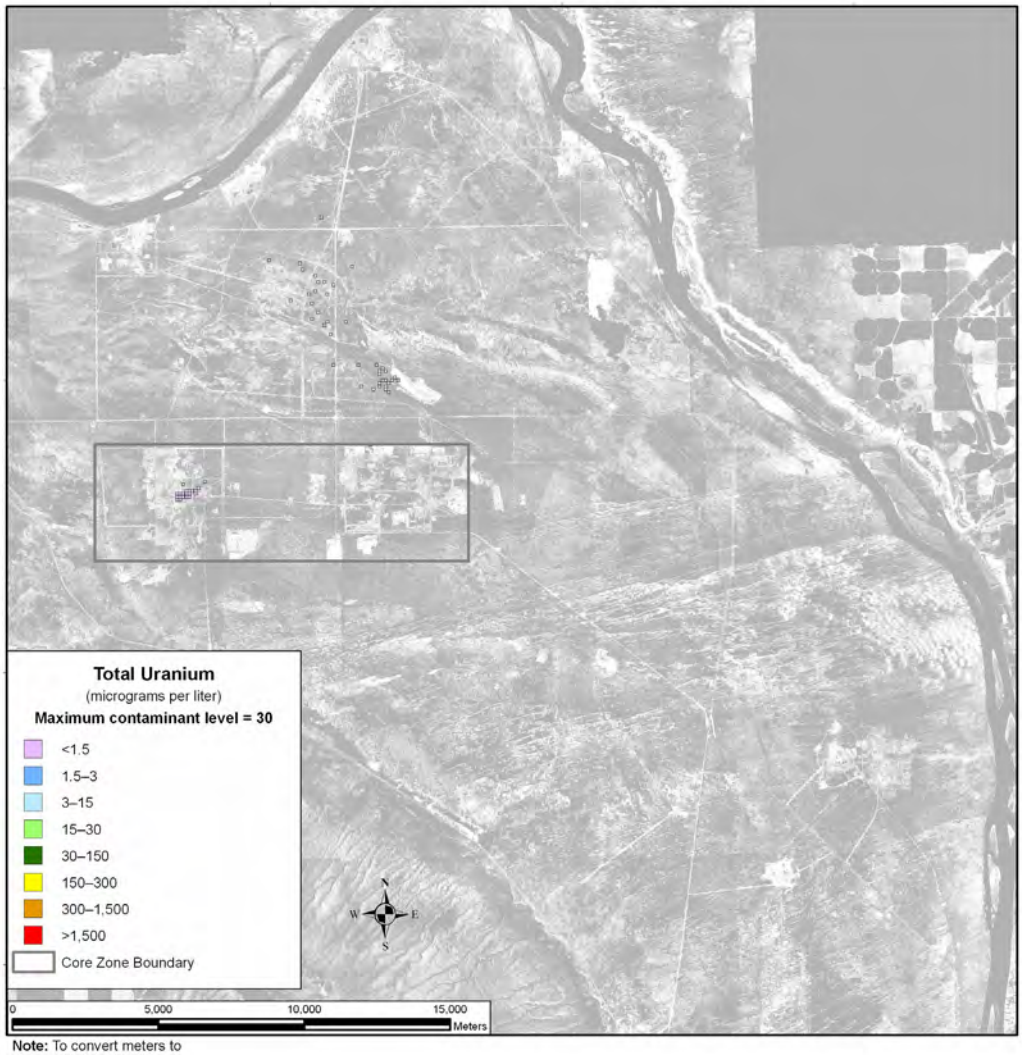
Note: To convert meters to feet, multiply by 3.281

Figure 5–309. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–310. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–311. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005

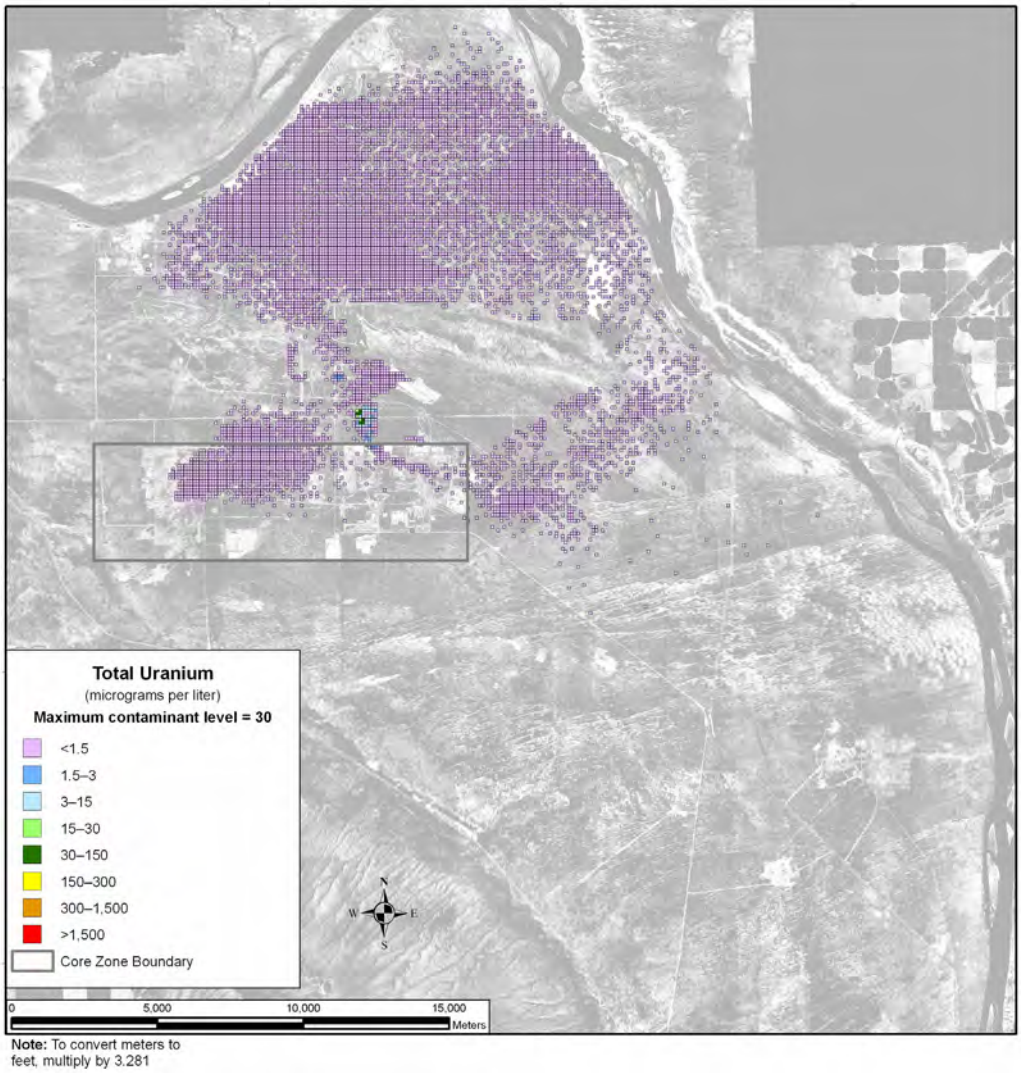
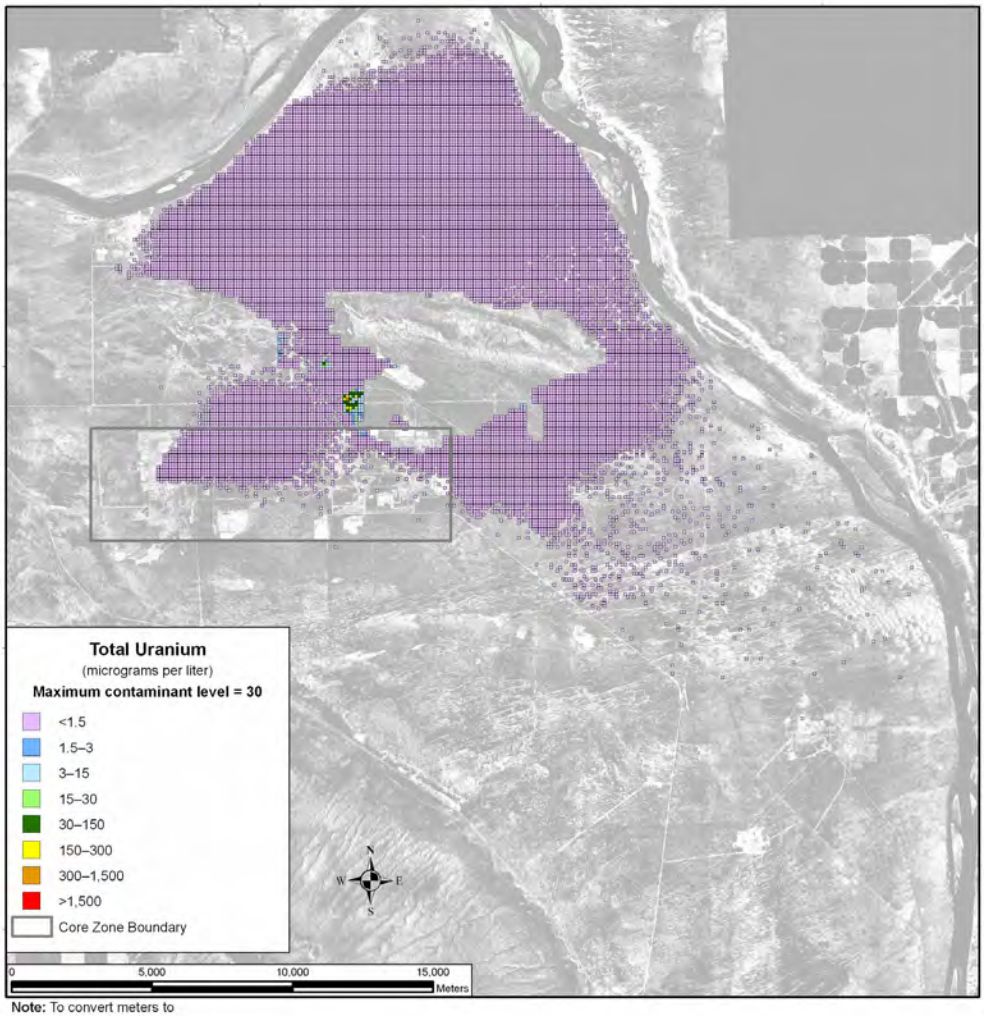


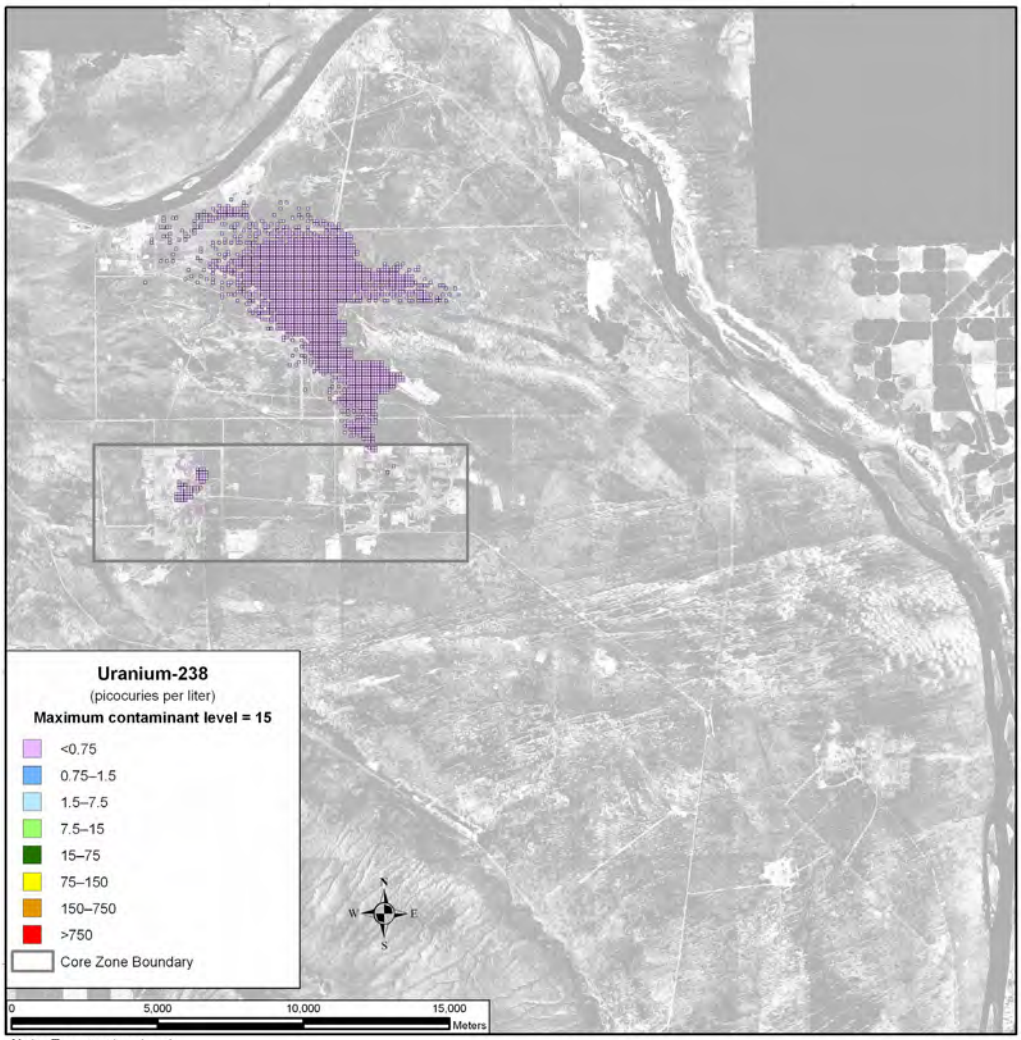
Figure 5–312. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

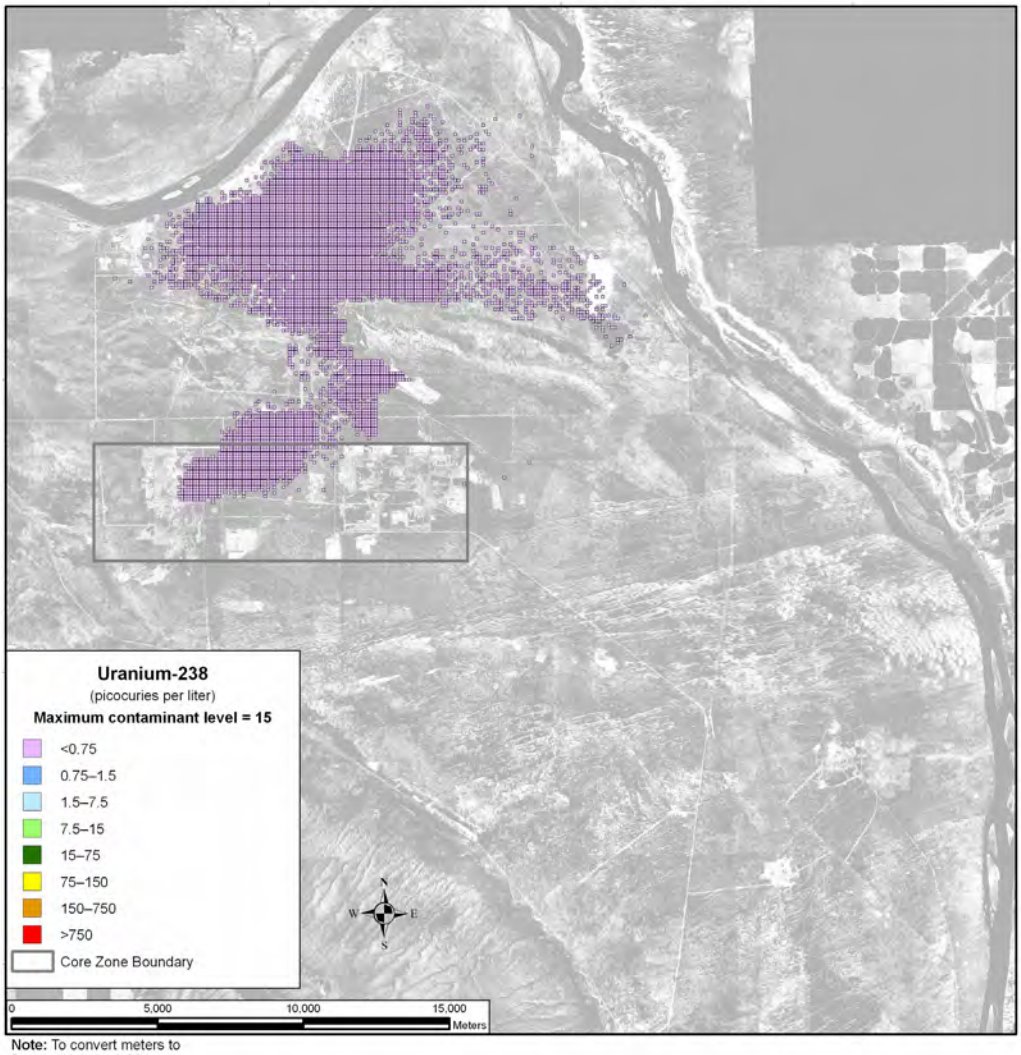
Figure 5–313. Tank Closure Alternative 6B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–314 shows the distribution of uranium-238 during CY 2005 under the Option Case. There are two plumes associated with this case, one originating from the T Barrier and the other from the B Barrier. Although there are no significant contaminant concentrations, the plumes under the Option Case are much larger than those under the Base Case. By CY 2135, the contaminant plume has grown and reached the Columbia River, but there are still no significant peaks in concentration levels (see Figure 5–315). By CY 11,885, while the greatest development of the plume occurred under the Base Case, the contaminant plume under the Option Case has begun to recede (see Figure 5–316). This recession is due to the removal of the six sets of cribs and trenches (ditches) and the remediation of their contaminant plumes. Figures 5–317 through 5–319 show similar results for total uranium.



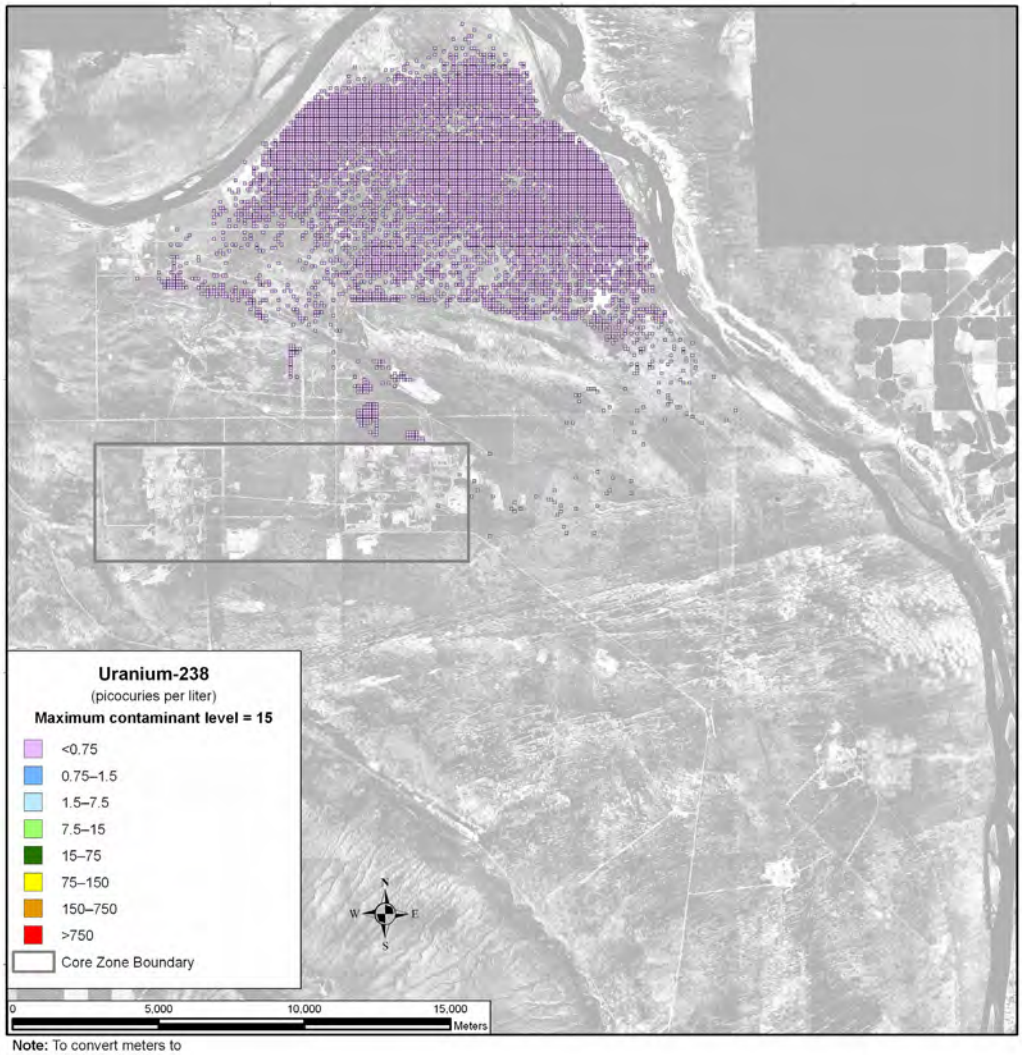
Note: To convert meters to feet, multiply by 3.281

Figure 5–314. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2005



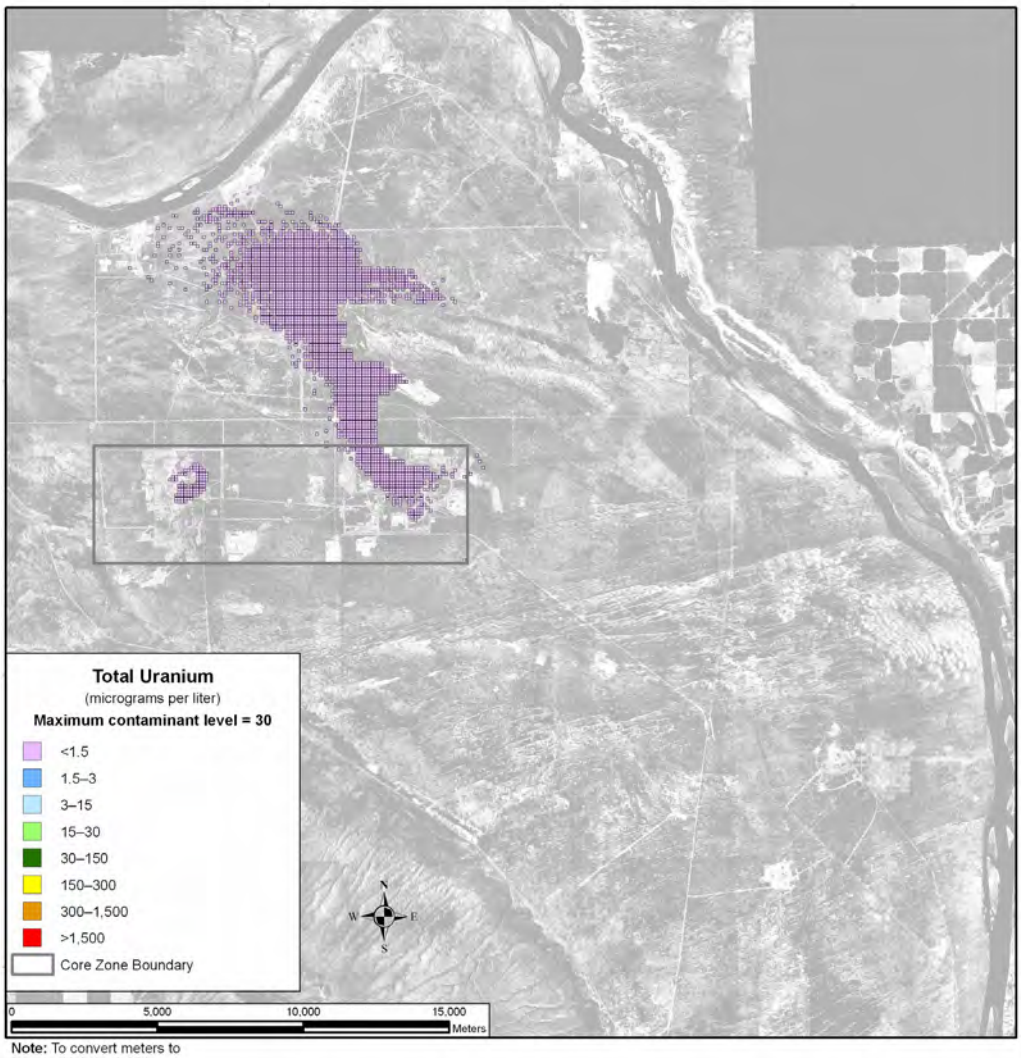
Note: To convert meters to feet, multiply by 3.281

Figure 5–315. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 2135



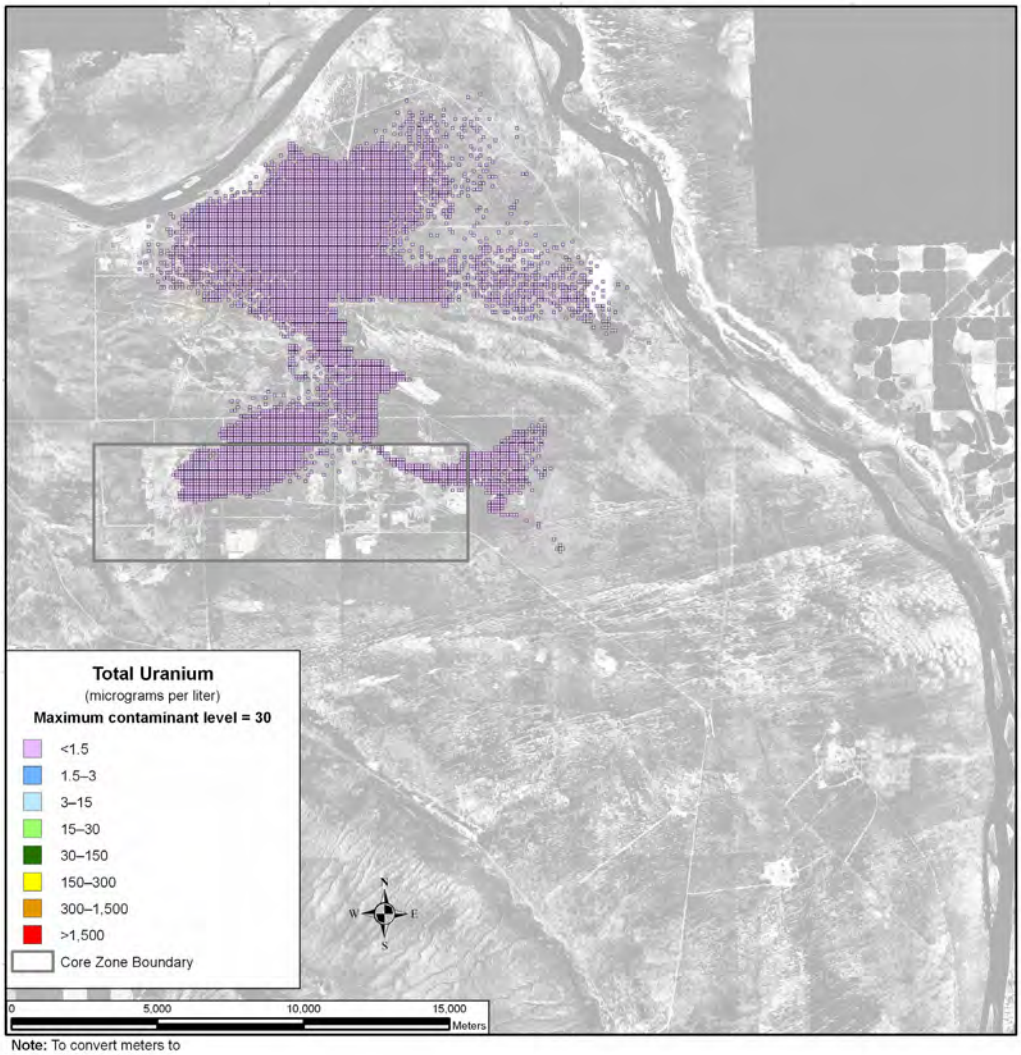
Note: To convert meters to feet, multiply by 3.281

Figure 5–316. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885



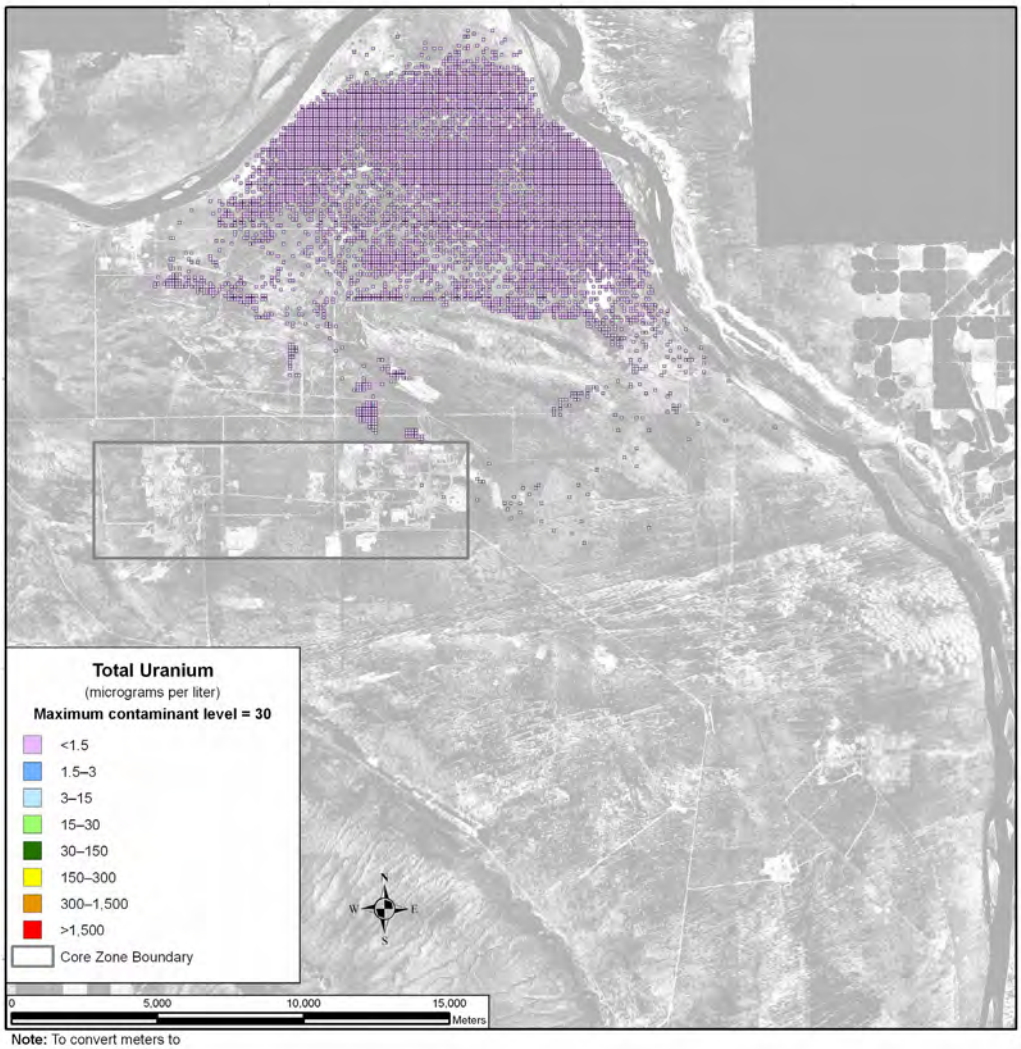
Note: To convert meters to feet, multiply by 3.281

Figure 5–317. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2005



Note: To convert meters to feet, multiply by 3.281

Figure 5–318. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 2135



Note: To convert meters to feet, multiply by 3.281

Figure 5–319. Tank Closure Alternative 6B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

Figure 5–320 shows the area in square kilometers in which groundwater concentrations of technetium-99 exceed the benchmark concentration in the analysis as a function of time under the Base Case. A peak of almost 4.0 square kilometers (1.7 square miles) occurs around CY 2135, followed by a fairly sharp decrease. By about CY 4000, the area with a concentration above the benchmark begins to level out around 0.5 square kilometers (0.19 square miles). Iodine-129 shows a similar pattern (see Figure 5–321), as both constituents are conservative tracers.

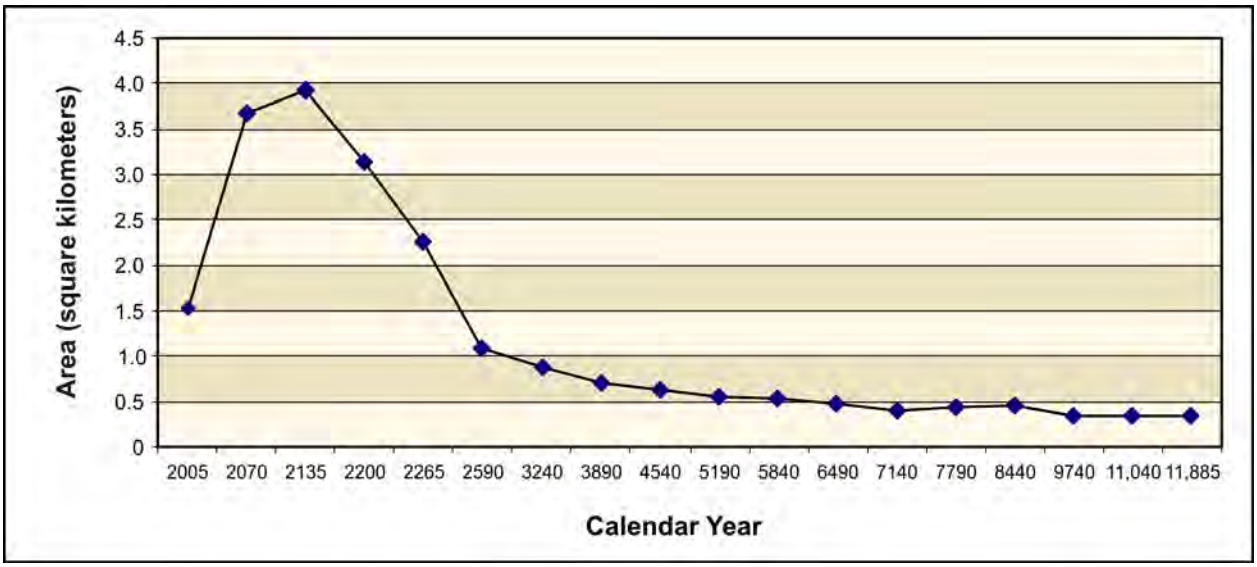


Figure 5–320. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

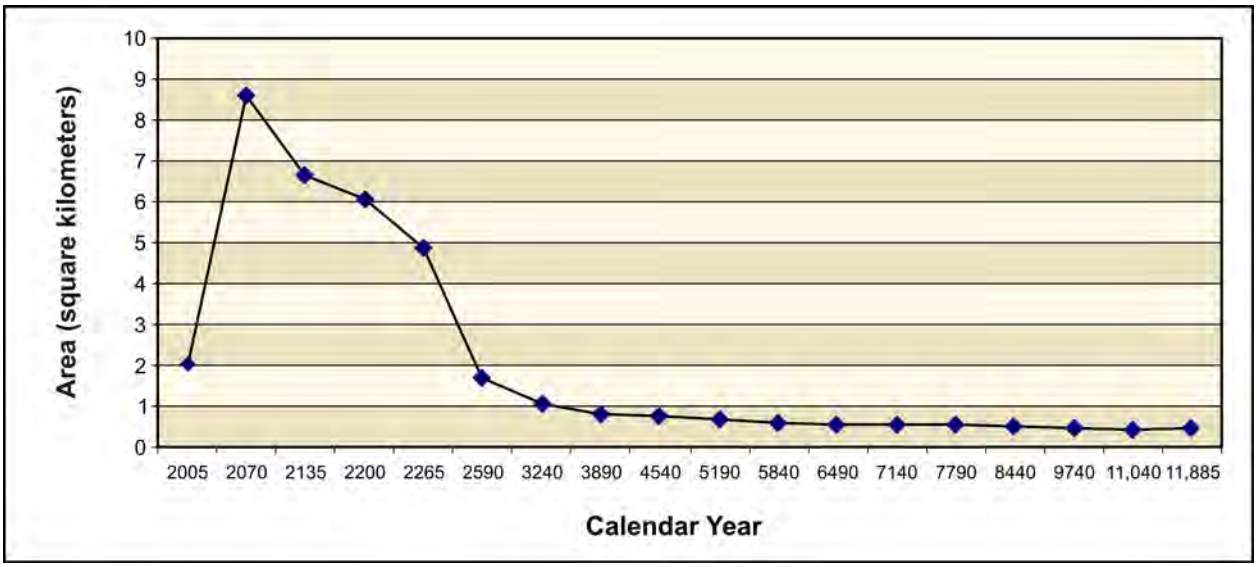


Figure 5–321. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Option Case, the areas with concentrations of technetium-99 and iodine-129 above the benchmarks are essentially identical to those under the Base Case (see Figures 5–322 and 5–323).

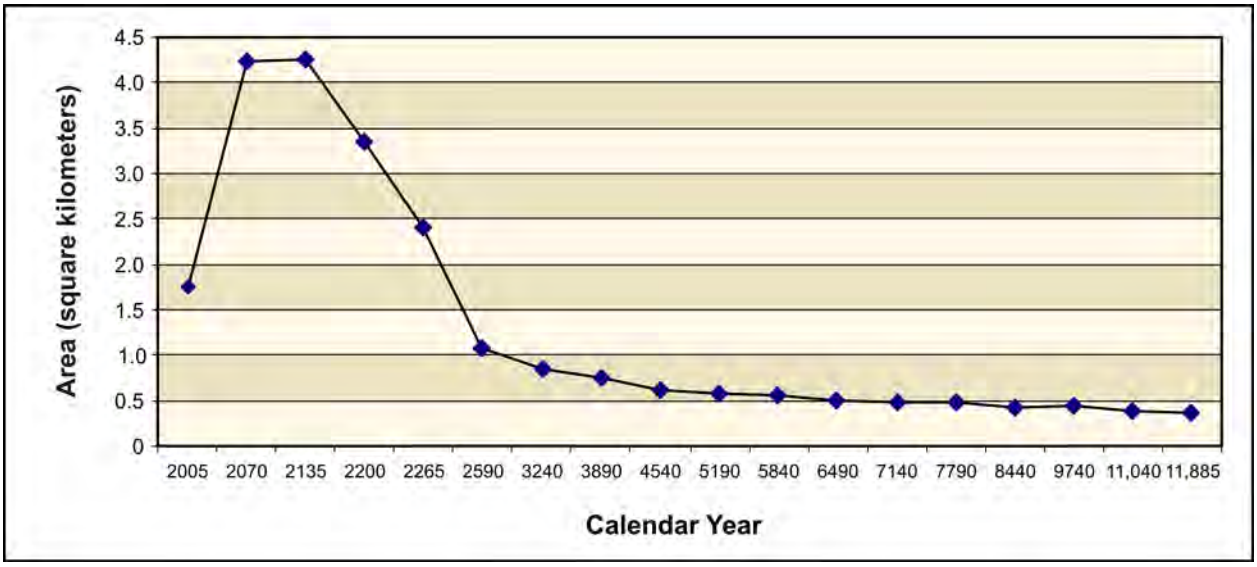


Figure 5–322. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Technetium-99 Concentration Exceeding the Benchmark Concentration as a Function of Time

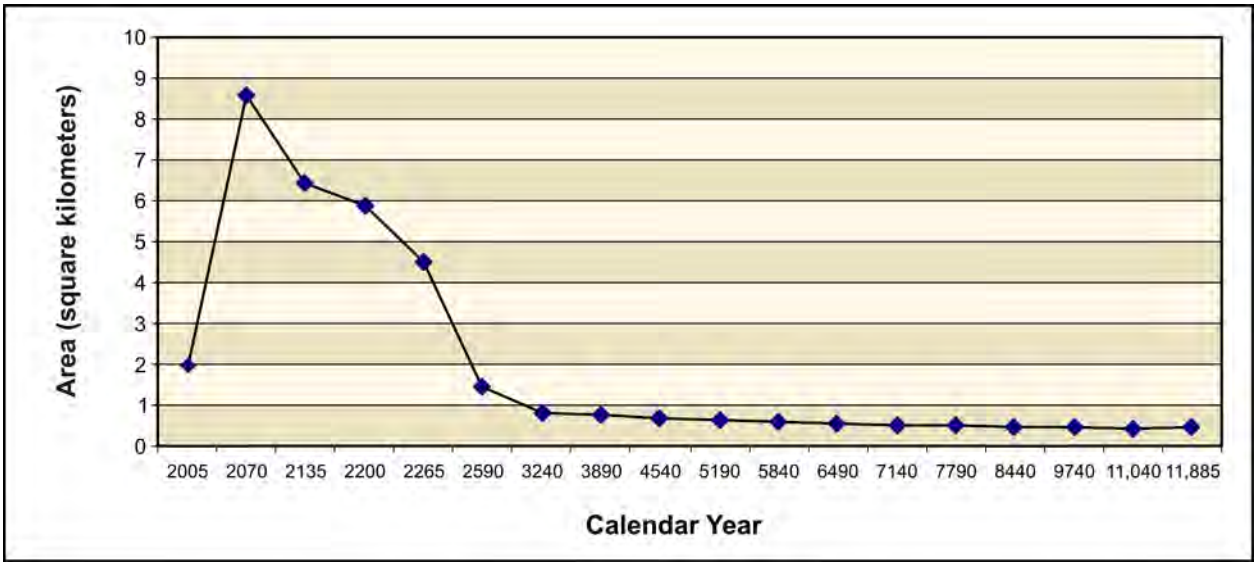


Figure 5–323. Tank Closure Alternative 6B, Option Case, Total Area of Groundwater Iodine-129 Concentration Exceeding the Benchmark Concentration as a Function of Time

Under the Base Case, uranium-238 did not register above the benchmark in any area until after CY 5840 (see Figure 5–324). A sharp increase in area with concentrations above the maximum contaminant level is seen after CY 5840 and continues to rise through the end of the period of analysis (CY 11,940). It is expected that the majority of the uranium-238 would continue to migrate through the vadose zone after the period of analysis is over.

Under the Option Case, uranium-238 did not register above the benchmark in any area during the period of analysis. This is a result of the high retardation rate and the removal and remediation of the cribs and trenches (ditches).

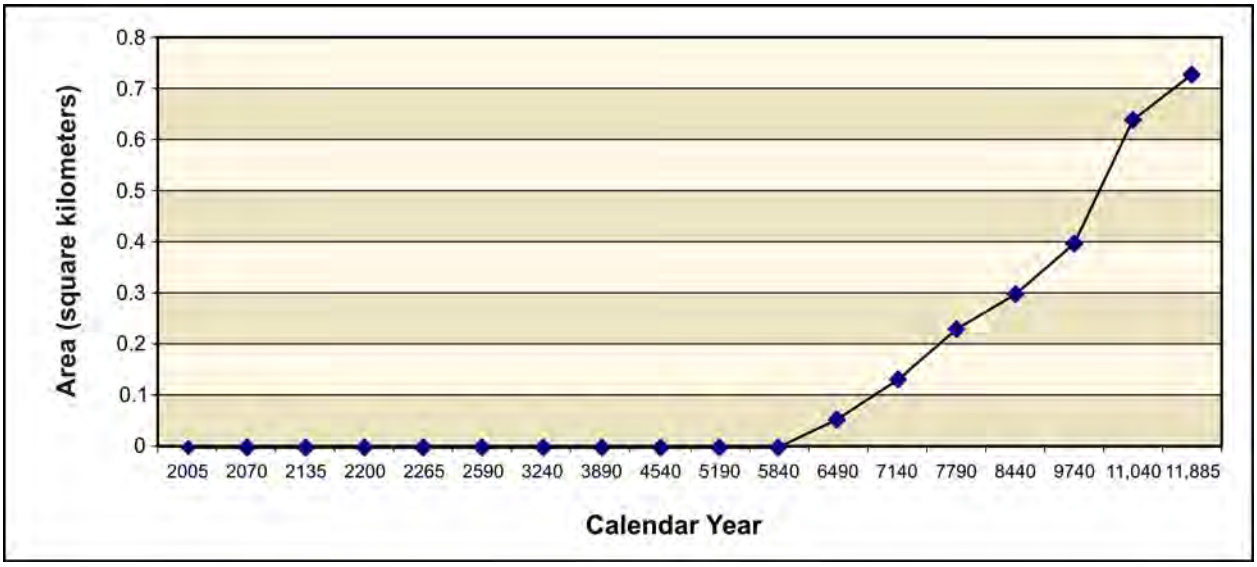


Figure 5–324. Tank Closure Alternative 6B, Base Case, Total Area of Groundwater Uranium-238 Concentration Exceeding the Benchmark Concentration as a Function of Time

5.1.1.10.6 Summary of Impacts

For the conservative tracers under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark standards by about two orders of magnitude during the early part of the period of analysis, around CY 1956. Columbia River nearshore concentrations never reached the benchmark concentration and peaked at about one-half to one order of magnitude below it. The intensities and areas of these groundwater plumes peaked around CY 1956.

The concentrations of iodine-129, technetium-99, chromium, and nitrate (the conservative tracers) under the Option Case are essentially identical to those under the Base Case.

For tritium under the Base Case, concentrations at the Core Zone Boundary exceeded the benchmark by about two orders of magnitude for a short period of time during the early part of the period of analysis, around CY 1956. During the same period of time, the Columbia River nearshore concentrations peaked at about one order of magnitude below the benchmark. Attenuation by radioactive decay is a predominant mechanism that limits the intensity and duration of groundwater impacts of tritium.

The concentrations of tritium under the Option Case are essentially identical to those under the Base Case.

For uranium-238 and total uranium under the Base Case, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species began to approach the benchmark at the Core Zone Boundary toward the latter part of the period of analysis but never reached it. The concentration levels of uranium-238 and total uranium at the Columbia River nearshore never came to within about two orders of magnitude below the benchmark. The intensity and area of the contaminant plumes peaked at the end of the period of analysis.

Under the Option Case, uranium-238 concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark concentration, except for a short spike at the Core Zone Boundary to about one order of magnitude below the benchmark at the beginning of the period of analysis. The Columbia River nearshore concentrations stayed fairly constant at about four orders of magnitude below the benchmark. Total uranium concentrations at the Core Zone Boundary generally stayed about three to four orders of magnitude below the benchmark. The Columbia River nearshore

concentrations remained fairly constant at around four and a half orders of magnitude below the benchmark.

5.1.1.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Activities under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C would be similar in scope and timing. Tank waste would be retrieved to a volume corresponding to 99 percent retrieval, and residual material in tanks would be stabilized in place. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. From the long-term groundwater impact perspective, the results from the analyses of these alternatives are identical. Refer to Section 5.1.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.1 Actions and Timeframes Influencing Groundwater Impacts

Refer to Section 5.1.1.3.1 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.2 COPC Drivers

Refer to Section 5.1.1.3.2 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.3 Analysis of Release and Mass Balance

Refer to Section 5.1.1.3.3 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.4 Analysis of Concentration Versus Time

Refer to Section 5.1.1.3.4 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.5 Analysis of Spatial Distribution of Concentration

Refer to Section 5.1.1.3.5 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.1.11.6 Summary of Impacts

Refer to Section 5.1.1.3.6 for detailed, long-term groundwater analysis results for Tank Closure Alternative 2B, which are identical to those for Tank Closure Alternative 6C.

5.1.2 Human Health Impacts

Potential human health impacts due to release of radionuclides are estimated as dose and as lifetime risk of incidence of cancer. For long-term performance assessment, radiological dose and risk are estimated consistent with the recommendations of *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13 (Eckerman et al. 1999), including use of radionuclide-specific dose factors and risk coefficients. Potential human health effects due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects are estimated as Hazard Quotient, the ratio of the long-term intake of a single chemical to intake that produces no observable effect, and as Hazard Index, the sum of the Hazard Quotients of a group of chemicals. Further information on the nature of human health effects in response to exposure to radiological and chemical constituents is provided in Appendix K. Screening analysis identified 14 radionuclide and 26 chemical constituents as contributing the greatest risk of adverse impacts. Appendix Q provides more information on the screening analysis, including time of occurrence of peak impacts and constituent- and location-specific impacts under each Tank Closure, FFTF Decommissioning, and Waste Management alternative.

Four measures of human health impacts are considered in this analysis—lifetime risks of developing cancer from radiological and chemical constituents, dose from radiological constituents, and Hazard Index from chemical constituents. These measures are calculated for each year for 10,000 years for receptors at eight specific locations (i.e., A, B, S, T, and U Barriers, Core Zone Boundary, Columbia River nearshore, and Columbia River surface water). This is a large amount of information that must be summarized to allow interpretation of results. The method chosen is to present dose for the year of maximum dose, risk for the year of maximum risk, and Hazard Index for the year of maximum Hazard Index. This choice is based on regulation of radiological impacts as dose, and the observation that peak risk and peak noncarcinogenic impacts expressed as Hazard Index may occur at times other than that of peak dose.

Three types of release are considered under the Tank Closure alternatives. The first type of release is the past practice of direct discharge of liquid to cribs and trenches (ditches). The second type of release is due to past leaks from damaged tanks. The third type of release identified in the following text and figures as “other tank farm sources” is due to future activities and includes leaks during retrieval of waste from the tanks, as well as long-term leaching of waste material in tanks and ancillary equipment.

Onsite locations are the boundaries of the tank farms, Core Zone Boundary, and Columbia River nearshore. Offsite locations are access points to Columbia River surface water near the site and at population centers downstream of the site. Estimates of concentration of constituents in the Columbia River surface water are used to calculate impacts for both the offsite location points of analysis. Total offsite population is 5 million people. Four types of receptor are considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield are assumed adequate to produce approximately 25 percent of average requirements of crops and animal products. The third type, an American Indian resident farmer, also uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield are assumed adequate to produce the entirety of average requirements of crops and animal products. The fourth type, an American Indian hunter-gatherer, is impacted by both groundwater and surface water because he uses surface water for drinking-water consumption and consumes both wild plant materials, which use groundwater, and game animals, which use surface water. In Appendix Q, estimates of impacts are presented in two sets of tables, one set for receptors using groundwater and one set for users of surface water. To facilitate presentation, estimates of impacts on the American Indian hunter-gatherer are presented in the set of tables for surface water users in Appendix Q. However, in this section and in subsequent sections, the

impacts on the American Indian hunter-gatherer are presented under the Columbia River nearshore location.

The significance of dose impacts is evaluated by comparison with the 100-millirem-per-year all-exposure-modes standard specified for protection of the public and the environment in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The level of protection provided for the drinking-water pathway is evaluated by comparison with applicable drinking-water standards presented in Section 5.1.1. Population doses are compared with the total effective dose equivalent from background sources of 365 millirem per year for a member of the population of the United States (NCRP 1987). The significance of noncarcinogenic chemical impacts is evaluated by comparison with a guideline value of unity for Hazard Index.

5.1.2.1 Tank Closure Alternative 1: No Action

Under Tank Closure Alternative 1, the tank farms would be maintained in the current condition indefinitely but, for the purpose of analysis, the structural integrity of the tanks is assumed to fail after an administrative control period of 100 years. The salt cake in the SSTs is assumed available at this time for leaching into the vadose zone, and the liquid contents of the DSTs are assumed to be discharged directly to the vadose zone. Potential human health impacts under Tank Closure Alternative 1 are detailed in Appendix Q and summarized in Tables 5–10 through 5–15; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–10 and 5–11; to past leaks after CY 1940 in Tables 5–12 and 5–13; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–14 and 5–15.

Due to the large magnitude of the liquid release in the analysis, transport through the vadose zone is rapid, and impacts exceeding dose standards are estimated for onsite locations. The largest contributors are the cribs and trenches (ditches) and the presence of tritium, technetium-99, iodine-129, uranium-238, chromium, nitrates, and total uranium. Due to large dilution in the Columbia River, offsite impacts on individuals are small. The population dose was estimated as 3.39 person-rem per year for the year of maximum impact. This corresponds to 1.85×10^{-4} percent of the annual population dose due to background exposure.

Table 5–10. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.39×10^{2}	7.88×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.86×10^{2}	3.48×10^{-2}	1.98×10^{-7}	3.48×10^{-2}
T Barrier	1.44×10^{3}	1.23×10^{2}	1.37×10^{-2}	0.00	1.37×10^{-2}	2.30×10^{3}	1.35×10^{2}	2.40×10^{-2}	3.54×10^{-8}	2.40×10^{-2}
Core Zone Boundary	6.39×10^{2}	5.12×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.88×10^{2}	3.48×10^{-2}	1.13×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.51×10^{-1}	4.57×10^{-1}	4.89×10^{-6}	0.00	4.89×10^{-6}	4.40×10^{-1}	5.04×10^{-1}	1.58×10^{-5}	1.28×10^{-10}	1.58×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.93×10^{-4}	1.60×10^{-4}	5.88×10^{-9}	3.39×10^{-14}	5.88×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–11. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.50×10^{3}	7.43×10^{-2}	9.10×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.22×10^{3}	2.22×10^{2}	4.79×10^{-2}	1.62×10^{-3}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.02×10^{3}	7.43×10^{-2}	5.17×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	8.29×10^{-1}	8.33×10^{-1}	3.44×10^{-5}	5.86×10^{-6}	3.44×10^{-5}	5.44×10^{-1}	8.17×10^{-1}	6.69×10^{-6}	2.93×10^{-6}	7.94×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.10×10^{-1}	1.80×10^{-8}	1.56×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–12. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.87×10^{1}	6.34×10^{-1}	8.23×10^{-4}	0.00	8.23×10^{-4}	6.39×10^{1}	6.58×10^{-1}	2.55×10^{-3}	2.30×10^{-10}	2.55×10^{-3}
B Barrier	2.05×10^{1}	1.26	6.00×10^{-4}	0.00	6.00×10^{-4}	4.62×10^{1}	1.35	1.87×10^{-3}	4.04×10^{-10}	1.87×10^{-3}
S Barrier	9.13	4.19	2.64×10^{-4}	0.00	2.64×10^{-4}	2.04×10^{1}	4.26	8.19×10^{-4}	1.65×10^{-9}	8.19×10^{-4}
T Barrier	5.36×10^{1}	5.81	1.54×10^{-3}	0.00	1.54×10^{-3}	1.19×10^{2}	6.03	4.76×10^{-3}	2.12×10^{-9}	4.76×10^{-3}
U Barrier	9.86×10^{-1}	1.39×10^{-1}	1.11×10^{-5}	0.00	1.11×10^{-5}	1.02	1.42×10^{-1}	3.14×10^{-5}	5.29×10^{-11}	3.14×10^{-5}
Core Zone Boundary	1.20×10^{1}	4.55	3.57×10^{-4}	0.00	3.57×10^{-4}	2.74×10^{1}	4.63	1.12×10^{-3}	1.76×10^{-9}	1.12×10^{-3}
Columbia River nearshore	3.14×10^{-1}	4.19×10^{-2}	9.45×10^{-6}	0.00	9.45×10^{-6}	7.24×10^{-1}	4.32×10^{-2}	2.97×10^{-5}	1.60×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.27×10^{-5}	2.15×10^{-6}	1.32×10^{-9}	7.48×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–13. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.01	5.48×10^{-3}	1.05×10^{-5}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.99×10^{1}	2.15	4.02×10^{-3}	1.85×10^{-5}	4.02×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.96×10^{1}	6.36	1.76×10^{-3}	7.55×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.31×10^{2}	9.26	1.02×10^{-2}	9.70×10^{-5}	1.02×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.51	2.15×10^{-1}	6.76×10^{-5}	2.42×10^{-6}	6.76×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	5.36×10^{1}	6.95	2.41×10^{-3}	8.09×10^{-5}	2.41×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.42	6.56×10^{-2}	6.41×10^{-5}	7.34×10^{-7}	6.41×10^{-5}	7.64×10^{-3}	1.86×10^{-2}	9.87×10^{-8}	3.67×10^{-7}	4.44×10^{-7}
Off Site										
Columbia River	1.32×10^{-4}	1.05×10^{-3}	4.72×10^{-9}	3.43×10^{-11}	4.74×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–14. Tank Closure Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.43×10^{2}	4.13	4.45×10^{-3}	2.40×10^{-11}	4.45×10^{-3}	3.39×10^{2}	4.66	1.42×10^{-2}	1.12×10^{-9}	1.42×10^{-2}
B Barrier	3.69×10^{2}	6.95×10^{1}	1.13×10^{-2}	0.00	1.24×10^{-2}	8.60×10^{2}	7.94×10^{1}	3.56×10^{-2}	1.98×10^{-8}	3.56×10^{-2}
S Barrier	8.33×10^{1}	1.73×10^{1}	2.51×10^{-3}	1.36×10^{-11}	2.51×10^{-3}	1.92×10^{2}	1.78×10^{1}	7.89×10^{-3}	6.49×10^{-9}	7.89×10^{-3}
T Barrier	3.52×10^{1}	1.18×10^{1}	1.00×10^{-3}	0.00	1.37×10^{-2}	7.80×10^{1}	1.28×10^{1}	3.10×10^{-3}	3.58×10^{-9}	2.40×10^{-2}
U Barrier	3.43×10^{1}	3.42	9.87×10^{-4}	0.00	9.87×10^{-4}	7.63×10^{1}	3.59	3.06×10^{-3}	1.21×10^{-9}	3.06×10^{-3}
Core Zone Boundary	7.44×10^{2}	1.31×10^{2}	2.26×10^{-2}	2.99×10^{-11}	2.26×10^{-2}	1.73×10^{3}	1.35×10^{2}	7.12×10^{-2}	4.79×10^{-8}	7.12×10^{-2}
Columbia River nearshore	1.19×10^{1}	1.88	3.40×10^{-4}	6.19×10^{-13}	3.40×10^{-4}	2.62×10^{1}	1.98	1.07×10^{-3}	6.47×10^{-10}	1.07×10^{-3}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	6.77×10^{-4}	4.39×10^{-5}	2.76×10^{-8}	1.24×10^{-14}	2.76×10^{-8}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–15. Tank Closure Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	6.72×10^{2}	7.87	3.07×10^{-2}	5.12×10^{-5}	3.07×10^{-2}	N/A	N/A	N/A	N/A	N/A
B Barrier	1.70×10^{3}	1.37×10^{2}	7.70×10^{-2}	9.10×10^{-4}	7.70×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.77×10^{2}	2.71×10^{1}	1.70×10^{-2}	2.97×10^{-4}	1.70×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	2.08×10^{1}	6.66×10^{-3}	1.64×10^{-4}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.48×10^{2}	5.59	6.57×10^{-3}	5.56×10^{-5}	6.57×10^{-3}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	3.40×10^{3}	2.08×10^{2}	1.54×10^{-1}	2.20×10^{-3}	1.54×10^{-1}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	5.11×10^{1}	3.10	2.30×10^{-3}	2.97×10^{-5}	2.30×10^{-3}	7.31×10^{-2}	1.14	3.49×10^{-6}	1.48×10^{-5}	1.77×10^{-5}
Off Site										
Columbia River	2.61×10^{-3}	3.94×10^{-2}	9.42×10^{-8}	5.68×10^{-10}	9.47×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

For releases from the cribs and trenches (ditches), peak impacts at the B and T Barriers are estimated to occur in the past, prior to CY 2000. For past leaks, peak impacts at the tank farm barriers are estimated to occur in the vicinity of, or prior to, CY 2050. As shown in Figure 5–325, peak impacts at the Core Zone Boundary due to all sources are the result primarily of assumed tank failure and occur as a narrow, early peak and as a broad pulse extending between CYs 2500 and 5000. An elevated level of risk due to tank failure extends over the entire period of analysis. At the Core Zone Boundary, peak risk due to tank failure is approximately a factor of 20 greater than peak risk due to cribs and trenches (ditches) and a factor of 100 greater than peak risk due to past leaks.

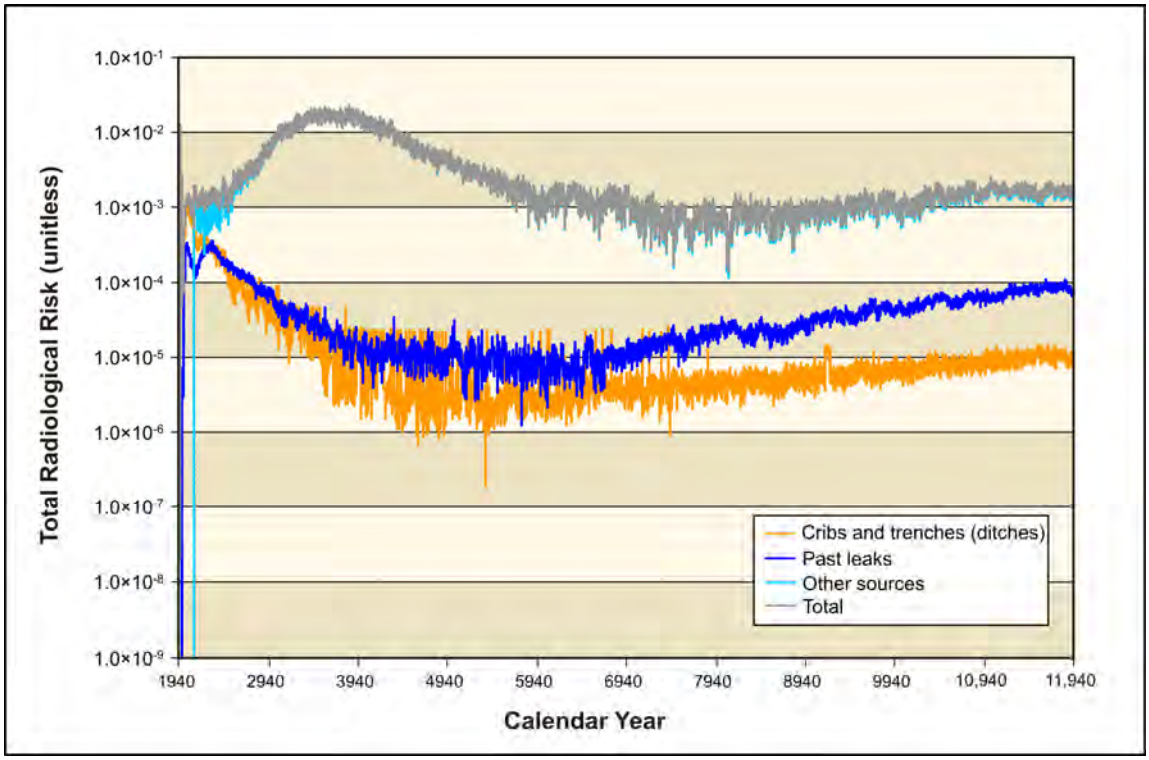


Figure 5–325. Tank Closure Alternative 1 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.2 Tank Closure Alternative 2A: Existing WTP Vitrification; No Closure

Under Tank Closure Alternative 2A, tank waste would be retrieved to a volume corresponding to 99 percent retrieval, but the residual material in tanks would not be stabilized. After an administrative control period of 100 years, salt cake in the tanks was assumed available for dissolution in infiltrating water and the liquid contents of the DSTs are assumed to be discharged directly to the vadose zone. Potential human health impacts under Tank Closure Alternative 2A are detailed in Appendix Q and summarized in Tables 5–16 through 5–21; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–16 and 5–17; to past leaks after CY 1940 in Tables 5–18 and 5–19; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–20 and 5–21.

The dose standard would be exceeded at the B Barrier, T Barrier, and Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129 released from the cribs and trenches (ditches), but would not be exceeded at the other locations. For the drinking-water well user, resident farmer, and American Indian resident farmer, the Hazard Index guideline would be exceeded at the B Barrier, T Barrier, and Core Zone Boundary due primarily to release of chromium and nitrate from the cribs and trenches (ditches).

Table 5–16. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.61×10^{2}	7.60×10^{2}	1.29×10^{-2}	0.00	1.29×10^{-2}	1.28×10^{3}	8.63×10^{2}	3.59×10^{-2}	1.80×10^{-7}	3.59×10^{-2}
T Barrier	1.43×10^{3}	1.25×10^{2}	1.36×10^{-2}	0.00	1.36×10^{-2}	2.28×10^{3}	1.37×10^{2}	2.39×10^{-2}	3.58×10^{-8}	2.39×10^{-2}
Core Zone Boundary	6.61×10^{2}	5.00×10^{2}	1.29×10^{-2}	0.00	1.29×10^{-2}	1.28×10^{3}	5.76×10^{2}	3.59×10^{-2}	1.07×10^{-7}	3.59×10^{-2}
Columbia River nearshore	2.16×10^{-1}	3.97×10^{-1}	4.24×10^{-6}	0.00	4.24×10^{-6}	3.83×10^{-1}	4.39×10^{-1}	1.35×10^{-5}	1.15×10^{-10}	1.35×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.88×10^{-4}	1.60×10^{-4}	5.67×10^{-9}	3.49×10^{-14}	5.67×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–17. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.45×10^{3}	1.47×10^{3}	7.67×10^{-2}	8.27×10^{-3}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.19×10^{3}	2.25×10^{2}	4.76×10^{-2}	1.64×10^{-3}	4.76×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.45×10^{3}	1.00×10^{3}	7.67×10^{-2}	4.89×10^{-3}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	7.20×10^{-1}	7.27×10^{-1}	2.92×10^{-5}	5.29×10^{-6}	2.92×10^{-5}	4.37×10^{-1}	6.78×10^{-1}	5.38×10^{-6}	2.65×10^{-6}	6.85×10^{-6}
Off Site										
Columbia River	5.55×10^{-4}	2.09×10^{-1}	1.77×10^{-8}	1.60×10^{-9}	1.85×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–18. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.79×10^{1}	6.31×10^{-1}	7.95×10^{-4}	0.00	7.95×10^{-4}	6.18×10^{1}	6.55×10^{-1}	2.46×10^{-3}	2.30×10^{-10}	2.46×10^{-3}
B Barrier	2.07×10^{1}	1.55	6.17×10^{-4}	0.00	6.17×10^{-4}	4.74×10^{1}	1.57	1.93×10^{-3}	3.75×10^{-10}	1.93×10^{-3}
S Barrier	9.08	4.08	2.62×10^{-4}	0.00	2.62×10^{-4}	2.03×10^{1}	4.15	8.12×10^{-4}	1.60×10^{-9}	8.12×10^{-4}
T Barrier	5.30×10^{1}	5.73	1.52×10^{-3}	0.00	1.52×10^{-3}	1.18×10^{2}	5.95	4.70×10^{-3}	2.08×10^{-9}	4.70×10^{-3}
U Barrier	1.24	1.44×10^{-1}	1.40×10^{-5}	0.00	1.40×10^{-5}	1.29	1.48×10^{-1}	3.14×10^{-5}	5.48×10^{-11}	3.14×10^{-5}
Core Zone Boundary	1.37×10^{1}	4.95	3.30×10^{-4}	0.00	3.30×10^{-4}	2.54×10^{1}	5.03	1.03×10^{-3}	1.95×10^{-9}	1.03×10^{-3}
Columbia River nearshore	3.08×10^{-1}	4.11×10^{-2}	9.27×10^{-6}	0.00	9.27×10^{-6}	7.10×10^{-1}	4.23×10^{-2}	2.92×10^{-5}	1.61×10^{-11}	2.92×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.29×10^{-5}	2.26×10^{-6}	1.32×10^{-9}	7.74×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–19. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.01	5.28×10^{-3}	1.05×10^{-5}	5.28×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	9.27×10^{1}	2.16	4.17×10^{-3}	1.72×10^{-5}	4.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.93×10^{1}	6.20	1.75×10^{-3}	7.33×10^{-5}	1.75×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.28×10^{2}	9.15	1.01×10^{-2}	9.53×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.51	2.25×10^{-1}	6.77×10^{-5}	2.51×10^{-6}	6.77×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.95×10^{1}	7.49	2.22×10^{-3}	8.95×10^{-5}	2.22×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.39	6.43×10^{-2}	6.30×10^{-5}	7.39×10^{-7}	6.30×10^{-5}	1.06×10^{-2}	1.71×10^{-2}	1.38×10^{-7}	3.70×10^{-7}	4.28×10^{-7}
Off Site										
Columbia River	1.35×10^{-4}	1.08×10^{-3}	4.78×10^{-9}	3.55×10^{-11}	4.81×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–20. Tank Closure Alternative 2A Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.60	3.16×10^{-1}	1.05×10^{-4}	1.16×10^{-13}	7.95×10^{-4}	8.09	3.80×10^{-1}	3.26×10^{-4}	4.73×10^{-11}	2.46×10^{-3}
B Barrier	6.83×10^{1}	6.89×10^{1}	2.05×10^{-3}	0.00	1.29×10^{-2}	1.57×10^{2}	7.78×10^{1}	6.45×10^{-3}	1.67×10^{-8}	3.59×10^{-2}
S Barrier	6.31	2.94	1.85×10^{-4}	0.00	2.62×10^{-4}	1.43×10^{1}	2.99	5.78×10^{-4}	1.14×10^{-9}	8.12×10^{-4}
T Barrier	3.53×10^{1}	9.90	1.01×10^{-3}	0.00	1.36×10^{-2}	7.82×10^{1}	1.06×10^{1}	3.11×10^{-3}	3.14×10^{-9}	2.39×10^{-2}
U Barrier	1.33	2.60×10^{-1}	3.57×10^{-5}	0.00	3.57×10^{-5}	2.74	2.93×10^{-1}	1.12×10^{-4}	6.66×10^{-11}	1.12×10^{-4}
Core Zone Boundary	5.92×10^{1}	3.78×10^{1}	1.80×10^{-3}	4.67×10^{-14}	1.29×10^{-2}	1.37×10^{2}	4.38×10^{1}	5.66×10^{-3}	7.69×10^{-9}	3.59×10^{-2}
Columbia River nearshore	4.39×10^{-1}	4.36×10^{-1}	1.32×10^{-5}	1.53×10^{-15}	1.32×10^{-5}	1.01	4.80×10^{-1}	4.15×10^{-5}	1.26×10^{-10}	4.15×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.37×10^{-5}	2.00×10^{-5}	1.77×10^{-9}	3.91×10^{-15}	5.67×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–21. Tank Closure Alternative 2A American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.57×10^{1}	6.87×10^{-1}	7.02×10^{-4}	2.17×10^{-6}	5.28×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	3.08×10^{2}	1.32×10^{2}	1.39×10^{-2}	7.68×10^{-4}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.78×10^{1}	4.49	1.25×10^{-3}	5.23×10^{-5}	1.75×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	1.70×10^{1}	6.68×10^{-3}	1.44×10^{-4}	4.76×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	5.36	4.96×10^{-1}	2.41×10^{-4}	3.05×10^{-6}	2.41×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.70×10^{2}	7.67×10^{1}	1.22×10^{-2}	3.53×10^{-4}	7.67×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.98	7.91×10^{-1}	8.96×10^{-5}	5.78×10^{-6}	8.96×10^{-5}	4.36×10^{-2}	3.99×10^{-1}	5.66×10^{-7}	2.89×10^{-6}	6.85×10^{-6}
Off Site										
Columbia River	1.72×10^{-4}	2.93×10^{-2}	6.19×10^{-9}	1.79×10^{-10}	1.85×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

The dose standard would be exceeded at the A Barrier for the American Indian resident farmer and at the T Barrier for the resident farmer and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129 released in past leaks. The Hazard Index guideline would be exceeded for the drinking-water well user, resident farmer, and American Indian resident farmer at the B Barrier, S Barrier, T Barrier, and the Core Zone Boundary primarily due to release of chromium and nitrate from past leaks. The Hazard Index guideline would also be exceeded for the resident farmer at the A Barrier primarily due to chromium and nitrate. The Hazard Index guideline would be exceeded for the American Indian resident farmer at the T Barrier primarily due to release of nitrate from past leaks. After CY 2050, the dose standard would be exceeded at the B Barrier and Core Zone Boundary for the resident farmer and American Indian resident farmer due to the presence of tritium, technetium-99, and iodine-129, and the dose standard would be exceeded at the T Barrier for the American Indian resident farmer due to the presence of tritium, technetium-99, iodine-129, and uranium-238. The Hazard Index guideline would be exceeded at the B Barrier, S Barrier, T Barrier, and Core Zone Boundary for the drinking-water well user, resident farmer, and American Indian resident farmer primarily due to chromium, nitrate, and total uranium. The population dose was estimated as 2.18×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.20×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 1. As shown in Figure 5–326, peak impacts at the Core Zone Boundary due to tank salt cake or liquid release are reduced by approximately a factor of 100 due to tank retrieval activity. A substantial peak due to tank failure remains centered on CY 3200, but the major contributor for long-term impacts shifts to past leaks under Tank Closure Alternative 2A.

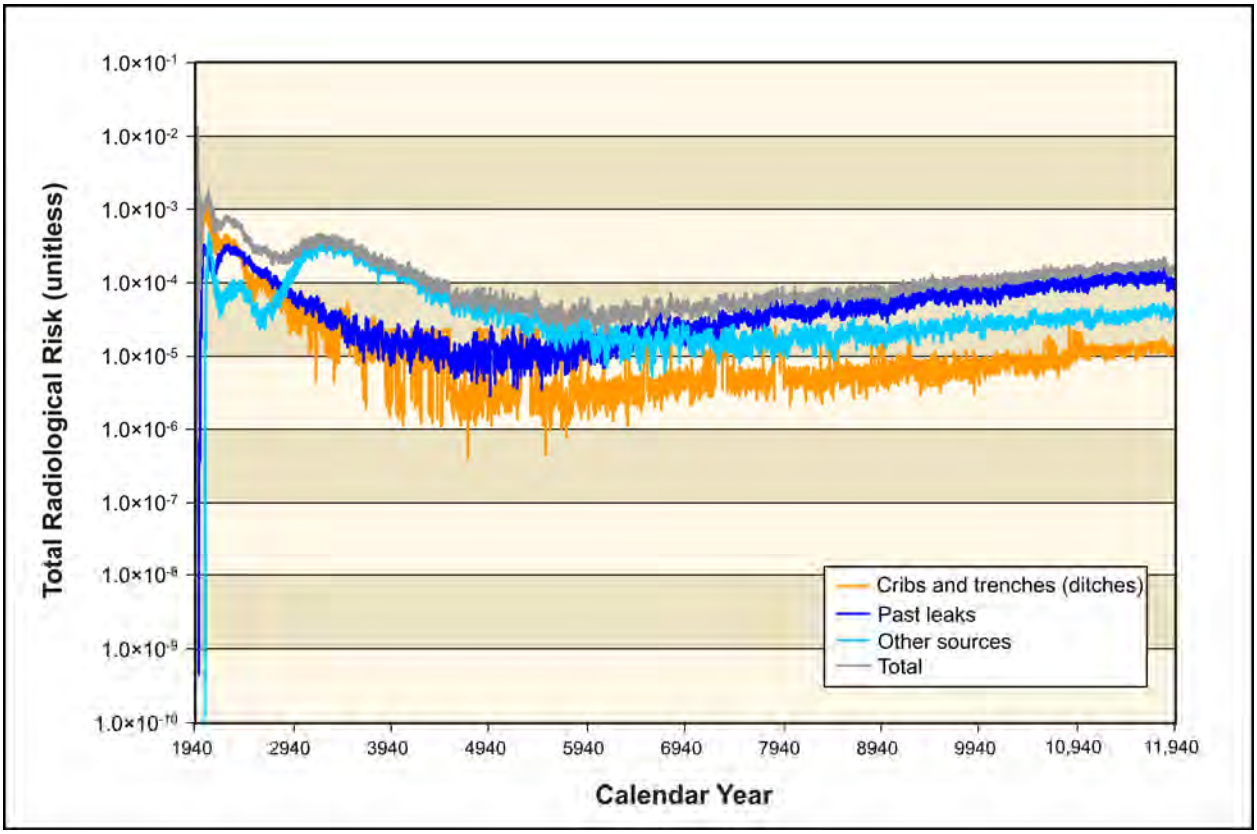


Figure 5–326. Tank Closure Alternative 2A Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.3 Alternative 2B: Expanded WTP Vitrification; Landfill Closure

Activities under Tank Closure Alternative 2B would be similar to those under Tank Closure Alternative 2A, except that residual material in tanks would be stabilized in place. Soil would be removed down to 4.6 meters (15 feet) for the BX and SX tank farms and replaced with clean soils from onsite sources. The tank farms and six sets of adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 2B are detailed in Appendix Q and summarized in Tables 5–22 through 5–27; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–22 and 5–23; to past leaks after CY 1940 in Tables 5–24 and 5–25; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–26 and 5–27.

The risk and hazard drivers are tritium, technetium-99, iodine-129, uranium-238, chromium, nitrate, and total uranium. Impacts would be slightly less than those under Tank Closure Alternative 2A, and standards would be exceeded, as under Alternative 2A. The population dose was estimated as 1.95×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.07×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternatives 1 and 2A. As shown in Figure 5–327, radiological risks at the Core Zone Boundary due to cribs and trenches (ditches) and past leaks prior to CY 3000 are nearly identical to those under Tank Closure Alternative 2A, while long-term risks are reduced slightly due to placement of caps under Tank Closure Alternative 2B. As in the case of Tank Closure Alternative 2A, peak impacts are due to releases from cribs and trenches (ditches) for the early time period, to leaching from other tank farm sources for the intermediate time period, and to past leaks for the long-term time period.

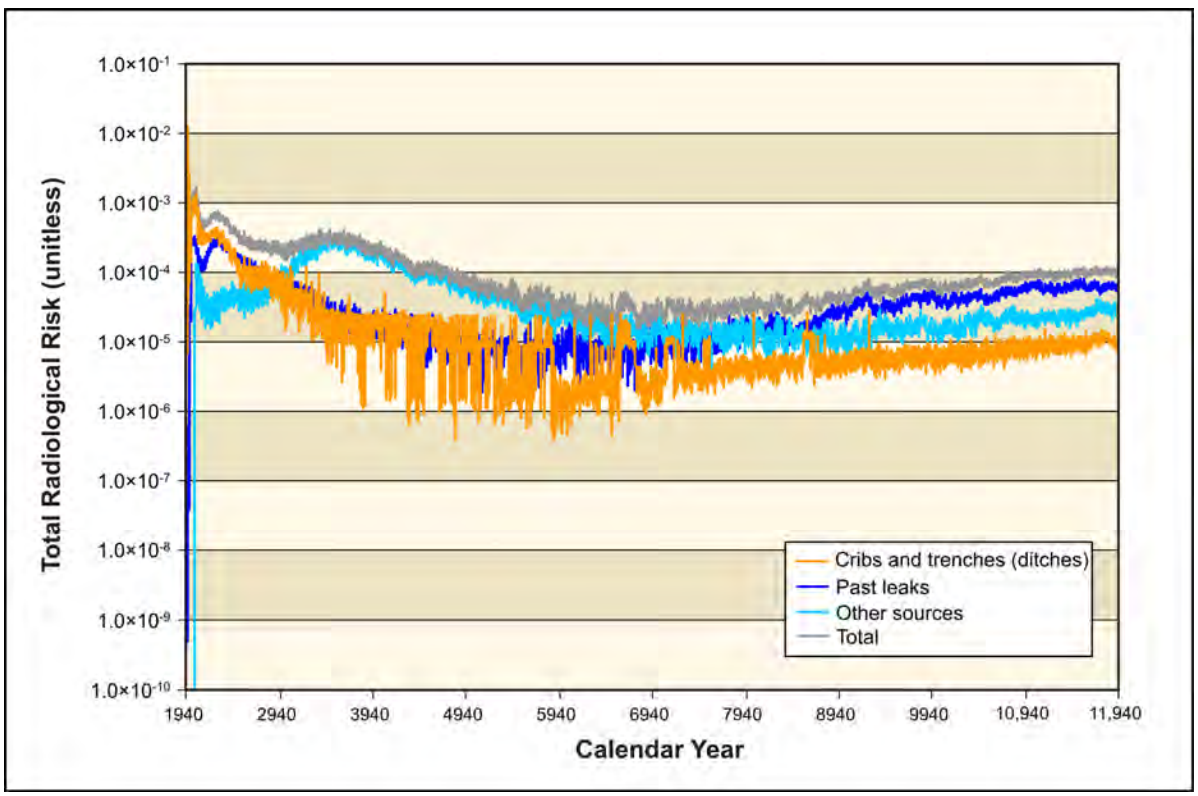


Figure 5–327. Tank Closure Alternative 2B Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

Table 5–22. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–23. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–24. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.75×10^{1}	6.52×10^{-1}	7.79×10^{-4}	0.00	7.79×10^{-4}	6.07×10^{1}	6.76×10^{-1}	2.40×10^{-3}	2.38×10^{-10}	2.40×10^{-3}
B Barrier	1.92×10^{1}	1.22	5.57×10^{-4}	0.00	5.57×10^{-4}	4.30×10^{1}	1.32	1.73×10^{-3}	3.76×10^{-10}	1.73×10^{-3}
S Barrier	9.42	4.15	2.72×10^{-4}	0.00	2.72×10^{-4}	2.10×10^{1}	4.22	8.44×10^{-4}	1.62×10^{-9}	8.44×10^{-4}
T Barrier	5.27×10^{1}	5.75	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	5.98	4.67×10^{-3}	2.07×10^{-9}	4.67×10^{-3}
U Barrier	9.90×10^{-1}	1.40×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.43×10^{-1}	2.97×10^{-5}	5.31×10^{-11}	2.97×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.03	3.21×10^{-4}	0.00	3.21×10^{-4}	2.48×10^{1}	4.10	9.99×10^{-4}	1.58×10^{-9}	9.99×10^{-4}
Columbia River nearshore	2.83×10^{-1}	4.21×10^{-2}	8.87×10^{-6}	0.00	8.87×10^{-6}	6.74×10^{-1}	4.34×10^{-2}	2.83×10^{-5}	1.57×10^{-11}	2.83×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.15×10^{-5}	2.07×10^{-6}	1.28×10^{-9}	7.23×10^{-16}	1.28×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–25. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.17×10^{2}	1.04	5.16×10^{-3}	1.09×10^{-5}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.35×10^{1}	2.14	3.72×10^{-3}	1.72×10^{-5}	3.72×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	4.08×10^{1}	6.31	1.82×10^{-3}	7.44×10^{-5}	1.82×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.21	1.00×10^{-2}	9.52×10^{-5}	1.00×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.44	2.16×10^{-1}	6.38×10^{-5}	2.44×10^{-6}	6.38×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.12	2.15×10^{-3}	7.26×10^{-5}	2.15×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	6.61×10^{-2}	6.13×10^{-5}	7.21×10^{-7}	6.13×10^{-5}	6.74×10^{-3}	1.89×10^{-2}	9.01×10^{-8}	3.61×10^{-7}	4.20×10^{-7}
Off Site										
Columbia River	1.25×10^{-4}	1.02×10^{-3}	4.48×10^{-9}	3.32×10^{-11}	4.51×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–26. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.27	1.84×10^{-1}	9.56×10^{-5}	8.57×10^{-14}	7.79×10^{-4}	7.37	2.16×10^{-1}	2.97×10^{-4}	3.43×10^{-11}	2.40×10^{-3}
B Barrier	6.31×10^{1}	5.79×10^{1}	1.93×10^{-3}	0.00	1.24×10^{-2}	1.47×10^{2}	6.67×10^{1}	6.08×10^{-3}	1.27×10^{-8}	3.48×10^{-2}
S Barrier	6.09	2.74	1.77×10^{-4}	0.00	2.72×10^{-4}	1.36×10^{1}	2.80	5.48×10^{-4}	1.07×10^{-9}	8.44×10^{-4}
T Barrier	3.55×10^{1}	9.63	1.02×10^{-3}	0.00	1.39×10^{-2}	7.89×10^{1}	1.04×10^{1}	3.14×10^{-3}	3.02×10^{-9}	2.43×10^{-2}
U Barrier	1.04	1.18×10^{-1}	1.79×10^{-5}	0.00	1.79×10^{-5}	1.36	1.19×10^{-1}	5.72×10^{-5}	3.91×10^{-11}	5.72×10^{-5}
Core Zone Boundary	5.42×10^{1}	3.39×10^{1}	1.66×10^{-3}	3.26×10^{-14}	1.24×10^{-2}	1.27×10^{2}	3.96×10^{1}	5.25×10^{-3}	6.55×10^{-9}	3.48×10^{-2}
Columbia River nearshore	4.28×10^{-1}	4.35×10^{-1}	1.30×10^{-5}	1.07×10^{-15}	1.30×10^{-5}	9.93×10^{-1}	4.70×10^{-1}	4.14×10^{-5}	1.35×10^{-10}	4.14×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.89×10^{-5}	1.91×10^{-5}	1.57×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–27. Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.43×10^{1}	3.82×10^{-1}	6.40×10^{-4}	1.57×10^{-6}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.90×10^{2}	1.16×10^{2}	1.31×10^{-2}	5.82×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.64×10^{1}	4.19	1.18×10^{-3}	4.89×10^{-5}	1.82×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.67×10^{1}	6.76×10^{-3}	1.38×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	2.71	1.84×10^{-1}	1.24×10^{-4}	1.79×10^{-6}	1.24×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.50×10^{2}	6.98×10^{1}	1.14×10^{-2}	3.00×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.96	7.58×10^{-1}	8.95×10^{-5}	6.17×10^{-6}	8.95×10^{-5}	5.69×10^{-2}	3.84×10^{-1}	7.24×10^{-7}	3.09×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.54×10^{-4}	2.77×10^{-2}	5.55×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); Landfill Closure

Activities under Tank Closure Alternative 3A would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); Landfill Closure

Activities under Tank Closure Alternative 3B would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); Landfill Closure

Activities under Tank Closure Alternative 3C would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.2.7 Tank Closure Alternative 4: Existing WTP Vitrification with Supplemental Treatment Technologies; Selective Clean Closure/Landfill Closure

Under Tank Closure Alternative 4, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval. Except for the BX and SX tank farms, residual material in tanks would be stabilized in place and the tank farms and adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. The BX and SX tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. Potential human health impacts under Tank Closure Alternative 4 are detailed in Appendix Q and summarized in Tables 5–28 through 5–33; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–28 and 5–29; to past leaks after CY 1940 in Tables 5–30 and 5–31; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–32 and 5–33.

Table 5–28. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–29. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–30. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.75×10^{1}	6.52×10^{-1}	7.79×10^{-4}	0.00	7.79×10^{-4}	6.07×10^{1}	6.76×10^{-1}	2.40×10^{-3}	2.38×10^{-10}	2.40×10^{-3}
B Barrier	1.74×10^{1}	1.09	5.07×10^{-4}	0.00	5.07×10^{-4}	3.91×10^{1}	1.18	1.57×10^{-3}	3.39×10^{-10}	1.57×10^{-3}
S Barrier	8.92	3.99	2.55×10^{-4}	0.00	2.55×10^{-4}	1.98×10^{1}	4.06	7.90×10^{-4}	1.56×10^{-9}	7.90×10^{-4}
T Barrier	5.27×10^{1}	5.75	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	5.98	4.67×10^{-3}	2.07×10^{-9}	4.67×10^{-3}
U Barrier	9.90×10^{-1}	1.40×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.43×10^{-1}	2.97×10^{-5}	5.31×10^{-11}	2.97×10^{-5}
Core Zone Boundary	1.12×10^{1}	2.56	3.26×10^{-4}	0.00	3.26×10^{-4}	2.52×10^{1}	2.61	1.02×10^{-3}	1.00×10^{-9}	1.02×10^{-3}
Columbia River nearshore	2.79×10^{-1}	3.45×10^{-2}	8.42×10^{-6}	0.00	8.42×10^{-6}	6.45×10^{-1}	3.55×10^{-2}	2.68×10^{-5}	1.30×10^{-11}	2.68×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.08×10^{-5}	1.85×10^{-6}	1.25×10^{-9}	6.26×10^{-16}	1.25×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–31. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.17×10^{2}	1.04	5.16×10^{-3}	1.09×10^{-5}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	7.60×10^{1}	1.92	3.39×10^{-3}	1.55×10^{-5}	3.39×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.83×10^{1}	6.08	1.70×10^{-3}	7.15×10^{-5}	1.70×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.21	1.00×10^{-2}	9.52×10^{-5}	1.00×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.44	2.16×10^{-1}	6.38×10^{-5}	2.44×10^{-6}	6.38×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.90×10^{1}	3.90	2.19×10^{-3}	4.59×10^{-5}	2.19×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.27	5.38×10^{-2}	5.81×10^{-5}	5.97×10^{-7}	5.81×10^{-5}	6.17×10^{-3}	1.56×10^{-2}	8.89×10^{-8}	2.99×10^{-7}	3.54×10^{-7}
Off Site										
Columbia River	1.23×10^{-4}	9.79×10^{-4}	4.41×10^{-9}	2.87×10^{-11}	4.43×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–32. Tank Closure Alternative 4 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.28	1.79×10^{-1}	9.61×10^{-5}	0.00	7.79×10^{-4}	7.40	2.09×10^{-1}	2.99×10^{-4}	3.47×10^{-11}	2.40×10^{-3}
B Barrier	5.92×10^{1}	5.77×10^{1}	1.81×10^{-3}	0.00	1.24×10^{-2}	1.38×10^{2}	6.64×10^{1}	5.71×10^{-3}	1.26×10^{-8}	3.48×10^{-2}
S Barrier	4.77×10^{-1}	3.61×10^{-1}	1.40×10^{-5}	0.00	2.55×10^{-4}	1.08	3.68×10^{-1}	4.38×10^{-5}	1.40×10^{-10}	7.90×10^{-4}
T Barrier	3.55×10^{1}	9.63	1.02×10^{-3}	0.00	1.39×10^{-2}	7.90×10^{1}	1.04×10^{1}	3.15×10^{-3}	3.02×10^{-9}	2.43×10^{-2}
U Barrier	1.02	1.15×10^{-1}	1.18×10^{-5}	0.00	1.18×10^{-5}	1.06	1.18×10^{-1}	3.68×10^{-5}	3.87×10^{-11}	3.68×10^{-5}
Core Zone Boundary	5.02×10^{1}	3.36×10^{1}	1.54×10^{-3}	0.00	1.24×10^{-2}	1.18×10^{2}	3.93×10^{1}	4.88×10^{-3}	6.47×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.91×10^{-1}	4.31×10^{-1}	1.21×10^{-5}	0.00	1.21×10^{-5}	9.24×10^{-1}	4.65×10^{-1}	3.85×10^{-5}	1.33×10^{-10}	3.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.85×10^{-5}	1.91×10^{-5}	1.55×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–33. Tank Closure Alternative 4 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.44×10^{1}	3.70×10^{-1}	6.44×10^{-4}	1.59×10^{-6}	5.16×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.72×10^{2}	1.15×10^{2}	1.24×10^{-2}	5.80×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.10	5.52×10^{-1}	9.43×10^{-5}	6.41×10^{-6}	1.70×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.67×10^{1}	6.77×10^{-3}	1.38×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.77	1.85×10^{-1}	7.93×10^{-5}	1.78×10^{-6}	7.93×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.32×10^{2}	6.93×10^{1}	1.05×10^{-2}	2.97×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.83	7.51×10^{-1}	8.34×10^{-5}	6.10×10^{-6}	8.34×10^{-5}	5.69×10^{-2}	3.79×10^{-1}	7.24×10^{-7}	3.05×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.52×10^{-4}	2.77×10^{-2}	5.49×10^{-9}	1.81×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Similar to Alternatives 2A, 2B, 3A, 3B, and 3C, the risk and hazard drivers are tritium, technetium-99, iodine-129, uranium-238, chromium, nitrate, and total uranium. The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Alternatives 2A, 2B, 3A, 3B, and 3C for releases from cribs and trenches (ditches). The dose standard would be exceeded at the same locations and for the same receptors as under Alternatives 2A, 2B, 3A, 3B, and 3C for releases from past leaks, with slightly less impacts at the B Barrier, S Barrier, and Core Zone Boundary as a result of clean closure at the two tank farms located within the B and S Barriers. Impacts would be slightly less than those under Alternatives 2B, 3A, 3B, 3C, and 6C as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources, with the exception of the S Barrier, where no exceedances were identified. Overall, the population dose was estimated as 1.92×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.05×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 2B. The time series of radiological risk at the Core Zone Boundary for Tank Closure Alternative 4 is presented in Figure 5–328. Comparison of the time series of risk for other tank farm sources under Tank Closure Alternative 4 with the time series of risk under Tank Closure Alternative 2B (see Figure 5–327) identifies three points of interest. First, for the time period prior to CY 2500, the estimated risks under the two alternatives, presumably due to retrieval leaks, are nearly identical. Second, for the intermediate time between CYs 3000 and 4000, the broad peak is reduced by a factor of approximately 5 under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B. Third, for the long-term period extending out to CY 11,940, risk is reduced by a factor of 10 under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B. The reduction in risk estimate is due to clean closure of the BX and SX tank farms and greater retrieval of tank waste under Tank Closure Alternative 4 relative to that under Tank Closure Alternative 2B.

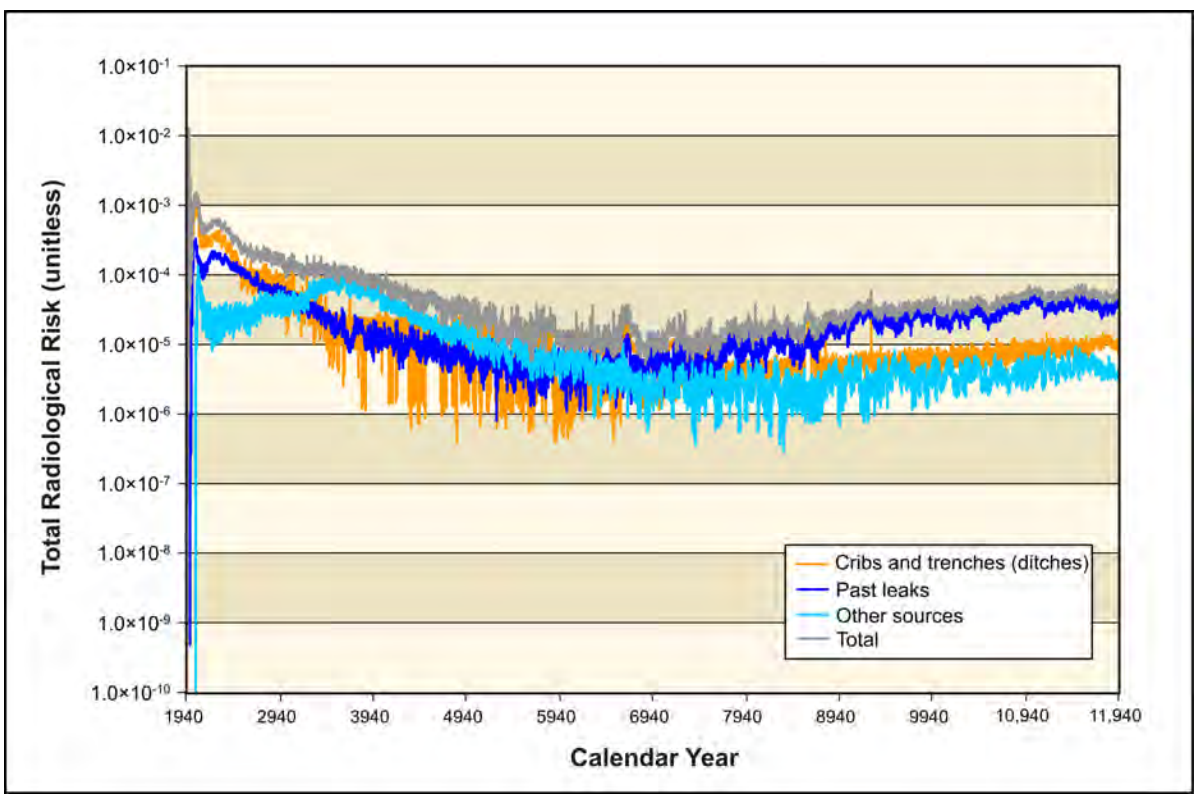


Figure 5–328. Tank Closure Alternative 4 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.8 Tank Closure Alternative 5: Expanded WTP Vitrification with Supplemental Treatment Technologies; Landfill Closure

Under Tank Closure Alternative 5, tank waste would be retrieved to a volume corresponding to 90 percent retrieval, residual material in tanks would be stabilized in place, and the tank farms and adjacent cribs and trenches (ditches) would be covered with a Hanford barrier. Potential human health impacts under Tank Closure Alternative 5 are detailed in Appendix Q and summarized in Tables 5–34 through 5–39; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–34 and 5–35; to past leaks after CY 1940 in Tables 5–36 and 5–37; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–38 and 5–39.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, and 4 for releases from cribs and trenches (ditches). The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, and 3C for releases from past leaks, but would be slightly higher than under these alternatives. Impacts would occur at a later date than under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. This may be due to the Hanford barrier. However, exceedances at the offsite locations are would be higher. The population dose was estimated as 3.39×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.86×10^{-5} percent of the annual population dose due to background exposure.

For releases from cribs and trenches (ditches) and past leaks, estimates of the magnitude and time series of impacts are substantially the same as those reported for Tank Closure Alternative 2B. The time series of radiological risk at the Core Zone Boundary under Tank Closure Alternative 5 is presented in Figure 5–329. Comparison of the time series of risk for other tank farm sources under Tank Closure Alternative 5 with the time series of risk under Tank Closure Alternative 2B (see Figure 5–327) identifies three points of interest. First, for the time period prior to CY 2500, the estimated risks under the two alternatives, presumably due to retrieval leaks, are nearly identical. Second, for the intermediate time between CYs 3000 and 4000, the broad peak is increased by a factor of approximately five under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B. Third, for the long-term period extending out to CY 11,940, risk is increased by a factor of three under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B. The increase in risk estimate is due to less retrieval of tank waste under Tank Closure Alternative 5 relative to that under Tank Closure Alternative 2B.

Table 5–34. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–35. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–36. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.87×10^{1}	6.67×10^{-1}	8.23×10^{-4}	0.00	8.23×10^{-4}	6.39×10^{1}	6.92×10^{-1}	2.55×10^{-3}	2.45×10^{-10}	2.55×10^{-3}
B Barrier	7.95	1.23	1.73×10^{-4}	0.00	1.73×10^{-4}	1.43×10^{1}	1.34	4.71×10^{-4}	3.81×10^{-10}	4.71×10^{-4}
S Barrier	9.29	4.20	2.69×10^{-4}	0.00	2.69×10^{-4}	2.08×10^{1}	4.26	8.34×10^{-4}	1.65×10^{-9}	8.34×10^{-4}
T Barrier	4.76×10^{1}	5.74	1.49×10^{-3}	0.00	1.49×10^{-3}	1.14×10^{2}	5.97	4.76×10^{-3}	2.07×10^{-9}	4.76×10^{-3}
U Barrier	9.89×10^{-1}	1.42×10^{-1}	1.12×10^{-5}	0.00	1.12×10^{-5}	1.03	1.45×10^{-1}	3.00×10^{-5}	5.40×10^{-11}	3.00×10^{-5}
Core Zone Boundary	1.11×10^{1}	4.49	3.28×10^{-4}	0.00	3.28×10^{-4}	2.51×10^{1}	4.56	1.03×10^{-3}	1.77×10^{-9}	1.03×10^{-3}
Columbia River nearshore	2.57×10^{-1}	4.62×10^{-2}	7.81×10^{-6}	0.00	7.81×10^{-6}	5.97×10^{-1}	4.73×10^{-2}	2.46×10^{-5}	1.77×10^{-11}	2.46×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.25×10^{-5}	2.04×10^{-6}	1.32×10^{-9}	7.17×10^{-16}	1.32×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–37. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.06	5.48×10^{-3}	1.12×10^{-5}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.50×10^{1}	2.18	9.78×10^{-4}	1.75×10^{-5}	9.78×10^{-4}	N/A	N/A	N/A	N/A	N/A
S Barrier	4.03×10^{1}	6.36	1.80×10^{-3}	7.59×10^{-5}	1.80×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.26×10^{2}	9.20	1.03×10^{-2}	9.49×10^{-5}	1.03×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.45	2.19×10^{-1}	6.47×10^{-5}	2.48×10^{-6}	6.47×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.93×10^{1}	6.79	2.23×10^{-3}	8.14×10^{-5}	2.23×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.18	7.12×10^{-2}	5.33×10^{-5}	8.13×10^{-7}	5.33×10^{-5}	6.35×10^{-3}	1.89×10^{-2}	8.75×10^{-8}	4.06×10^{-7}	4.62×10^{-7}
Off Site										
Columbia River	1.28×10^{-4}	1.02×10^{-3}	4.62×10^{-9}	3.29×10^{-11}	4.65×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–38. Tank Closure Alternative 5 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	5.46	4.06×10^{-1}	1.84×10^{-4}	4.90×10^{-13}	8.23×10^{-4}	1.38×10^{1}	4.45×10^{-1}	6.02×10^{-4}	1.14×10^{-10}	2.55×10^{-3}
B Barrier	4.96×10^{1}	5.79×10^{1}	1.47×10^{-3}	0.00	1.24×10^{-2}	1.13×10^{2}	6.66×10^{1}	4.61×10^{-3}	1.26×10^{-8}	3.48×10^{-2}
S Barrier	6.04	2.91	2.03×10^{-4}	3.37×10^{-13}	2.69×10^{-4}	1.52×10^{1}	2.96	6.62×10^{-4}	1.14×10^{-9}	8.34×10^{-4}
T Barrier	3.26×10^{1}	9.77	9.86×10^{-4}	0.00	1.39×10^{-2}	7.56×10^{1}	1.05×10^{1}	3.11×10^{-3}	3.07×10^{-9}	2.43×10^{-2}
U Barrier	3.24	4.01×10^{-1}	1.08×10^{-4}	0.00	1.08×10^{-4}	8.13	4.23×10^{-1}	3.53×10^{-4}	1.41×10^{-10}	3.53×10^{-4}
Core Zone Boundary	6.50×10^{1}	3.38×10^{1}	2.18×10^{-3}	4.72×10^{-13}	1.24×10^{-2}	1.64×10^{2}	3.95×10^{1}	7.10×10^{-3}	6.79×10^{-9}	3.48×10^{-2}
Columbia River nearshore	1.37	4.43×10^{-1}	4.47×10^{-5}	7.09×10^{-15}	4.47×10^{-5}	3.37	4.79×10^{-1}	1.45×10^{-4}	1.37×10^{-10}	1.45×10^{-4}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	6.78×10^{-5}	1.92×10^{-5}	2.94×10^{-9}	3.97×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–39. Tank Closure Alternative 5 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	7.28×10^{-1}	1.31×10^{-3}	5.23×10^{-6}	5.48×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.21×10^{2}	1.16×10^{2}	9.93×10^{-3}	5.77×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.09×10^{1}	4.43	1.44×10^{-3}	5.21×10^{-5}	1.80×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.49×10^{2}	1.69×10^{1}	6.73×10^{-3}	1.41×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.65×10^{1}	6.64×10^{-1}	7.68×10^{-4}	6.45×10^{-6}	7.68×10^{-4}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	3.31×10^{2}	6.96×10^{1}	1.55×10^{-2}	3.11×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	6.78	7.74×10^{-1}	3.14×10^{-4}	6.26×10^{-6}	3.14×10^{-4}	5.68×10^{-2}	3.94×10^{-1}	7.20×10^{-7}	3.13×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.72×10^{-4}	2.77×10^{-2}	7.73×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

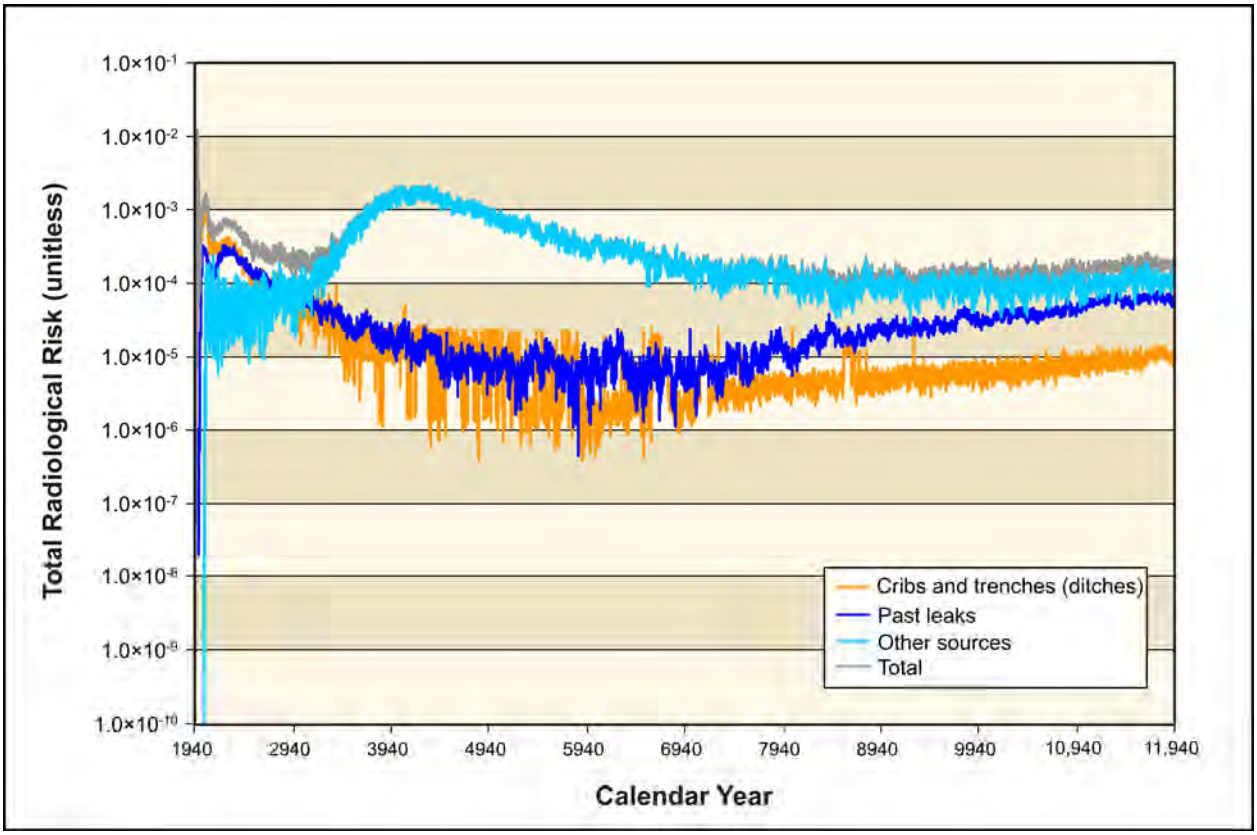


Figure 5–329. Tank Closure Alternative 5 Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure

5.1.2.9.1 Base Case

Under Tank Closure Alternative 6A, Base Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval and all tank farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. The adjacent cribs and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 6A, Base Case, are detailed in Appendix Q and summarized in Tables 5–40 through 5–45; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–40 and 5–41; to past leaks after CY 1940 in Tables 5–42 and 5–43; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–44 and 5–45.

Table 5–40. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–41. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–42. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	6.57×10^{-1}	7.99×10^{-4}	0.00	7.99×10^{-4}	6.21×10^{1}	6.82×10^{-1}	2.47×10^{-3}	2.39×10^{-10}	2.47×10^{-3}
B Barrier	1.94×10^{1}	1.18	5.56×10^{-4}	0.00	5.56×10^{-4}	4.30×10^{1}	1.28	1.72×10^{-3}	3.64×10^{-10}	1.72×10^{-3}
S Barrier	9.24	3.99	2.65×10^{-4}	0.00	2.65×10^{-4}	2.05×10^{1}	4.05	8.18×10^{-4}	1.56×10^{-9}	8.18×10^{-4}
T Barrier	5.25×10^{1}	5.78	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	6.00	4.69×10^{-3}	2.09×10^{-9}	4.69×10^{-3}
U Barrier	3.39×10^{-1}	1.36×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.40×10^{-1}	3.09×10^{-5}	5.15×10^{-11}	3.09×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.04	3.21×10^{-4}	0.00	3.21×10^{-4}	2.46×10^{1}	4.11	1.00×10^{-3}	1.58×10^{-9}	1.00×10^{-3}
Columbia River nearshore	3.04×10^{-1}	4.17×10^{-2}	9.37×10^{-6}	0.00	9.37×10^{-6}	7.15×10^{-1}	4.28×10^{-2}	2.97×10^{-5}	1.59×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.39×10^{-5}	2.22×10^{-6}	1.37×10^{-9}	7.68×10^{-16}	1.37×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–43. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.05	5.31×10^{-3}	1.10×10^{-5}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.32×10^{1}	2.08	3.69×10^{-3}	1.67×10^{-5}	3.69×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.97×10^{1}	6.05	1.76×10^{-3}	7.16×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.27×10^{2}	9.24	1.01×10^{-2}	9.59×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	2.13×10^{-1}	6.64×10^{-5}	2.36×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.15	2.17×10^{-3}	7.23×10^{-5}	2.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.41	6.47×10^{-2}	6.43×10^{-5}	7.27×10^{-7}	6.43×10^{-5}	1.89×10^{-3}	1.62×10^{-2}	9.48×10^{-8}	3.64×10^{-7}	4.11×10^{-7}
Off Site										
Columbia River	1.33×10^{-4}	1.06×10^{-3}	4.83×10^{-9}	3.52×10^{-11}	4.85×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–44. Tank Closure Alternative 6A, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.03	8.36×10^{-2}	8.88×10^{-5}	0.00	7.99×10^{-4}	6.85	8.63×10^{-2}	2.77×10^{-4}	3.11×10^{-11}	2.47×10^{-3}
B Barrier	6.15×10^{1}	5.77×10^{1}	1.87×10^{-3}	0.00	1.24×10^{-2}	1.43×10^{2}	6.65×10^{1}	5.90×10^{-3}	1.25×10^{-8}	3.48×10^{-2}
S Barrier	6.14	2.91	1.78×10^{-4}	0.00	2.65×10^{-4}	1.37×10^{1}	2.96	5.52×10^{-4}	1.14×10^{-9}	8.18×10^{-4}
T Barrier	3.53×10^{1}	9.56	1.01×10^{-3}	0.00	1.39×10^{-2}	7.87×10^{1}	1.03×10^{1}	3.14×10^{-3}	2.99×10^{-9}	2.43×10^{-2}
U Barrier	3.39×10^{-1}	1.03×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.07×10^{-1}	3.09×10^{-5}	3.78×10^{-11}	3.09×10^{-5}
Core Zone Boundary	5.14×10^{1}	3.38×10^{1}	1.58×10^{-3}	0.00	1.24×10^{-2}	1.21×10^{2}	3.95×10^{1}	5.00×10^{-3}	6.52×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.55×10^{-1}	4.20×10^{-1}	1.07×10^{-5}	0.00	1.07×10^{-5}	8.16×10^{-1}	4.54×10^{-1}	3.41×10^{-5}	1.30×10^{-10}	3.41×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.14×10^{-5}	1.92×10^{-5}	1.67×10^{-9}	3.96×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–45. Tank Closure Alternative 6A, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.33×10^{1}	1.32×10^{-1}	5.97×10^{-4}	1.43×10^{-6}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.81×10^{2}	1.15×10^{2}	1.28×10^{-2}	5.72×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.66×10^{1}	4.42	1.19×10^{-3}	5.21×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.53×10^{2}	1.66×10^{1}	6.75×10^{-3}	1.37×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	1.63×10^{-1}	6.64×10^{-5}	1.73×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.38×10^{2}	6.97×10^{1}	1.08×10^{-2}	2.99×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.62	7.33×10^{-1}	7.39×10^{-5}	5.97×10^{-6}	7.39×10^{-5}	5.68×10^{-2}	3.76×10^{-1}	7.22×10^{-7}	2.98×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.60×10^{-4}	2.77×10^{-2}	5.82×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, 4, and 5 for releases from cribs and trenches (ditches). The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 4 for releases from past leaks. Impacts would be slightly higher than those under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. However, after the year 2940, the impacts drop significantly as a result of tank farm removal and clean closure activities. The population dose was estimated as 2.07×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.13×10^{-5} percent of the annual population dose due to background exposure.

The time series of radiological risk under Tank Closure Alternative 6A, Base Case, is presented in Figure 5–330. Because of removal operations, impacts due to retrieval leaks and leaching from other tank farm sources do not occur. For cribs and trenches (ditches), estimated risk is similar to that estimated for Tank Closure Alternative 2B. For past leaks, risk estimated for the period prior to CY 3000 is similar to that estimated for Tank Closure Alternative 2B, while risk estimated for the long-term period is reduced by a factor of 10 relative to that estimated for Tank Closure Alternative 2B.

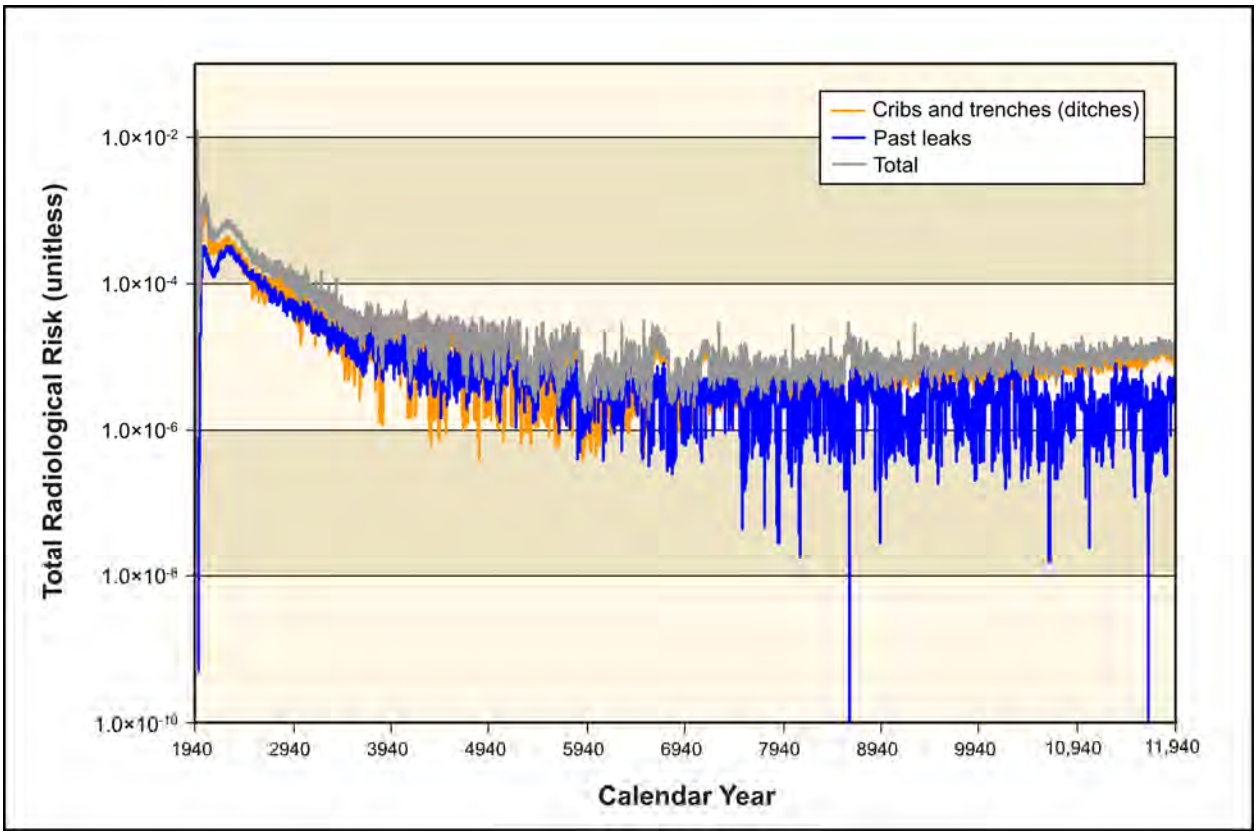


Figure 5–330. Tank Closure Alternative 6A, Base Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

5.1.2.9.2 Option Case

Under Tank Closure Alternative 6A, Option Case, tank waste would be retrieved to a volume corresponding to 99.9 percent retrieval, and all tanks farms would be clean-closed by removing the tanks, ancillary equipment, and soils to a depth of 3 meters (10 feet) below the tank base. Where necessary, deep soil excavation would also be conducted to remove contamination plumes within the soil column. In addition, the adjacent cribs and trenches (ditches) would be clean-closed. Potential human health impacts

under Tank Closure Alternative 6A, Option Case, are detailed in Appendix Q and summarized in Tables 5–46 and 5–51; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–46 and 5–47; to past leaks after CY 1940 in Tables 5–48 and 5–49; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–50 and 5–51.

The dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, 3C, 4, 5, and 6A, Base Case, for releases from cribs and trenches (ditches). Similar to Tank Closure Alternative 6A, Base Case, the dose standard and Hazard Index guideline would be exceeded at the same locations and for the same receptors as under Tank Closure Alternatives 2A, 2B, 3A, 3B, and 3C, but would be slightly higher than under these alternatives. Impacts would be slightly higher than under Tank Closure Alternatives 2B, 3A, 3B, 3C, and 6C for onsite locations as a result of the combination of cribs and trenches (ditches), past leaks, and other tank farm sources. However, after the year 2940, the impacts drop significantly as a result of tank farm removal. The population dose was estimated as 2.05×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.12×10^{-5} percent of the annual population dose due to background exposure.

The time series of radiological risk under Tank Closure Alternative 6A, Option Case, is presented in Figure 5–331. Because of removal operations, impacts due to retrieval leaks and leaching from other tank farm sources do not occur. For cribs and trenches (ditches), estimated risk is similar to that estimated for Tank Closure Alternative 6A, Base Case, prior to CY 5000, but is reduced by a factor of 1,000 for the long-term period. For past leaks, estimates of risk are similar to those estimated for Tank Closure Alternative 6A, Base Case.

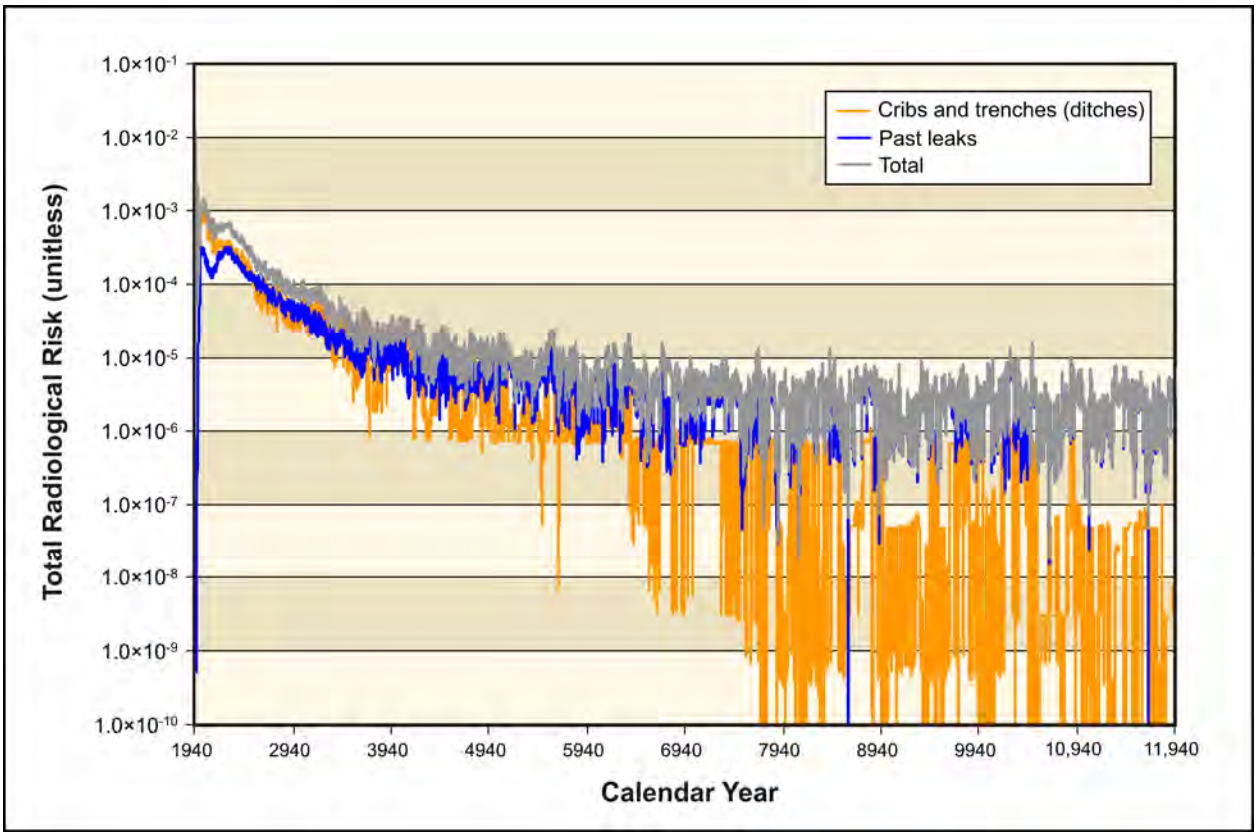


Figure 5–331. Tank Closure Alternative 6A, Option Case, Time Series of Radiological Risk for the Drinking-Water Well User at the Core Zone Boundary

Table 5–46. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.38×10^{2}	7.95×10^{2}	1.25×10^{-2}	0.00	1.25×10^{-2}	1.24×10^{3}	8.93×10^{2}	3.49×10^{-2}	2.00×10^{-7}	3.49×10^{-2}
T Barrier	1.44×10^{3}	1.22×10^{2}	1.37×10^{-2}	0.00	1.37×10^{-2}	2.30×10^{3}	1.34×10^{2}	2.40×10^{-2}	3.48×10^{-8}	2.40×10^{-2}
Core Zone Boundary	6.38×10^{2}	5.09×10^{2}	1.25×10^{-2}	0.00	1.25×10^{-2}	1.24×10^{3}	5.85×10^{2}	3.49×10^{-2}	1.11×10^{-7}	3.49×10^{-2}
Columbia River nearshore	1.99×10^{-1}	3.66×10^{-1}	4.76×10^{-6}	0.00	4.76×10^{-6}	4.20×10^{-1}	4.08×10^{-1}	1.44×10^{-5}	1.02×10^{-10}	1.44×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.89×10^{-4}	1.59×10^{-4}	5.75×10^{-9}	3.41×10^{-14}	5.75×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–47. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.51×10^{3}	7.45×10^{-2}	9.18×10^{-3}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.22×10^{3}	2.20×10^{2}	4.79×10^{-2}	1.60×10^{-3}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.01×10^{3}	7.45×10^{-2}	5.11×10^{-3}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	8.26×10^{-1}	6.84×10^{-1}	3.10×10^{-5}	4.69×10^{-6}	3.10×10^{-5}	4.00×10^{-1}	6.69×10^{-1}	4.92×10^{-6}	2.34×10^{-6}	5.77×10^{-6}
Off Site										
Columbia River	5.54×10^{-4}	2.13×10^{-1}	1.78×10^{-8}	1.56×10^{-9}	1.86×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–48. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.80×10^{1}	6.57×10^{-1}	7.99×10^{-4}	0.00	7.99×10^{-4}	6.21×10^{1}	6.82×10^{-1}	2.47×10^{-3}	2.39×10^{-10}	2.47×10^{-3}
B Barrier	1.94×10^{1}	1.18	5.56×10^{-4}	0.00	5.56×10^{-4}	4.30×10^{1}	1.28	1.72×10^{-3}	3.64×10^{-10}	1.72×10^{-3}
S Barrier	9.24	3.99	2.65×10^{-4}	0.00	2.65×10^{-4}	2.05×10^{1}	4.05	8.18×10^{-4}	1.56×10^{-9}	8.18×10^{-4}
T Barrier	5.25×10^{1}	5.78	1.51×10^{-3}	0.00	1.51×10^{-3}	1.17×10^{2}	6.00	4.69×10^{-3}	2.09×10^{-9}	4.69×10^{-3}
U Barrier	3.39×10^{-1}	1.36×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.40×10^{-1}	3.09×10^{-5}	5.15×10^{-11}	3.09×10^{-5}
Core Zone Boundary	1.10×10^{1}	4.04	3.21×10^{-4}	0.00	3.21×10^{-4}	2.46×10^{1}	4.11×10	1.00×10^{-3}	1.58×10^{-9}	1.00×10^{-3}
Columbia River nearshore	3.04×10^{-1}	4.17×10^{-2}	9.37×10^{-6}	0.00	9.37×10^{-6}	7.15×10^{-1}	4.28×10^{-2}	2.97×10^{-5}	1.59×10^{-11}	2.97×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.39×10^{-5}	2.22×10^{-6}	1.37×10^{-9}	7.68×10^{-16}	1.37×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–49. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.20×10^{2}	1.05	5.31×10^{-3}	1.10×10^{-5}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.32×10^{1}	2.08	3.69×10^{-3}	1.67×10^{-5}	3.69×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.97×10^{1}	6.05	1.76×10^{-3}	7.16×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.27×10^{2}	9.24	1.01×10^{-2}	9.59×10^{-5}	1.01×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	2.13×10^{-1}	6.64×10^{-5}	2.36×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.82×10^{1}	6.15	2.17×10^{-3}	7.23×10^{-5}	2.17×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.41	6.47×10^{-2}	6.43×10^{-5}	7.27×10^{-7}	6.43×10^{-5}	1.89×10^{-3}	1.62×10^{-2}	9.48×10^{-8}	3.64×10^{-7}	4.11×10^{-7}
Off Site										
Columbia River	1.33×10^{-4}	1.06×10^{-3}	4.83×10^{-9}	3.52×10^{-11}	4.85×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–50. Tank Closure Alternative 6A, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.03	8.36×10^{-2}	8.88×10^{-5}	0.00	7.99×10^{-4}	6.85	8.63×10^{-2}	2.77×10^{-4}	3.11×10^{-11}	2.47×10^{-3}
B Barrier	5.61×10^{1}	6.46×10^{1}	1.64×10^{-3}	0.00	1.25×10^{-2}	1.26×10^{2}	7.38×10^{1}	5.09×10^{-3}	1.49×10^{-8}	3.49×10^{-2}
S Barrier	6.14	2.91	1.78×10^{-4}	0.00	2.65×10^{-4}	1.37×10^{1}	2.96	5.52×10^{-4}	1.14×10^{-9}	8.18×10^{-4}
T Barrier	3.54×10^{1}	9.64	1.01×10^{-3}	0.00	1.37×10^{-2}	7.79×10^{1}	1.04×10^{1}	3.13×10^{-3}	3.03×10^{-9}	2.40×10^{-2}
U Barrier	3.39×10^{-1}	1.03×10^{-1}	9.91×10^{-6}	0.00	9.91×10^{-6}	7.64×10^{-1}	1.07×10^{-1}	3.09×10^{-5}	3.78×10^{-11}	3.09×10^{-5}
Core Zone Boundary	4.51×10^{1}	3.67×10^{1}	1.35×10^{-3}	0.00	1.25×10^{-2}	1.04×10^{2}	4.34×10^{1}	4.27×10^{-3}	6.53×10^{-9}	3.49×10^{-2}
Columbia River nearshore	3.73×10^{-1}	3.91×10^{-1}	1.15×10^{-5}	0.00	1.15×10^{-5}	8.80×10^{-1}	4.34×10^{-1}	3.67×10^{-5}	1.13×10^{-10}	3.67×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.09×10^{-5}	2.00×10^{-5}	1.66×10^{-9}	4.17×10^{-15}	5.75×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–51. Tank Closure Alternative 6A, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.33×10^{1}	1.32×10^{-1}	5.97×10^{-4}	1.43×10^{-6}	5.31×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.45×10^{2}	1.27×10^{2}	1.10×10^{-2}	6.82×10^{-4}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.66×10^{1}	4.42	1.19×10^{-3}	5.21×10^{-5}	1.76×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.51×10^{2}	1.67×10^{1}	6.73×10^{-3}	1.39×10^{-4}	4.79×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.49	1.63×10^{-1}	6.64×10^{-5}	1.73×10^{-6}	6.64×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.04×10^{2}	7.74×10^{1}	9.21×10^{-3}	3.00×10^{-4}	7.45×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.74	7.23×10^{-1}	7.94×10^{-5}	5.19×10^{-6}	7.94×10^{-5}	5.42×10^{-2}	3.52×10^{-1}	6.89×10^{-7}	2.60×10^{-6}	5.77×10^{-6}
Off Site										
Columbia River	1.59×10^{-4}	2.70×10^{-2}	5.78×10^{-9}	1.91×10^{-10}	1.86×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure

5.1.2.10.1 Base Case

Tank Closure Alternative 6B, Base Case, resembles Tank Closure Alternative 6A, Base Case, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean-closed, and the adjacent crib and trenches (ditches) would be covered with an engineered modified RCRA Subtitle C barrier. Potential human health impacts under Tank Closure Alternative 6B, Base Case, are detailed in Appendix Q and summarized in Tables 5–52 through 5–57; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–52 and 5–53; to past leaks after CY 1940 in Tables 5–54 and 5–55; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–56 and 5–57.

Impacts would be similar to those under Tank Closure Alternative 6A, Base Case, and standards would be exceeded, as under Tank Closure Alternative 6A, Base Case. The population dose was estimated as 2.04×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.12×10^{-5} percent of the annual population dose due to background exposure.

Table 5–52. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.36×10^{2}	7.95×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	8.94×10^{2}	3.48×10^{-2}	2.00×10^{-7}	3.48×10^{-2}
T Barrier	1.46×10^{3}	1.27×10^{2}	1.39×10^{-2}	0.00	1.39×10^{-2}	2.32×10^{3}	1.39×10^{2}	2.43×10^{-2}	3.66×10^{-8}	2.43×10^{-2}
Core Zone Boundary	6.36×10^{2}	4.97×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.70×10^{2}	3.48×10^{-2}	1.10×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.08×10^{-1}	4.02×10^{-1}	5.89×10^{-6}	0.00	5.89×10^{-6}	4.79×10^{-1}	4.35×10^{-1}	1.85×10^{-5}	1.23×10^{-10}	1.85×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.91×10^{-4}	1.63×10^{-4}	5.83×10^{-9}	3.52×10^{-14}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–53. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.36×10^{3}	1.51×10^{3}	7.43×10^{-2}	9.16×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.27×10^{3}	2.27×10^{2}	4.85×10^{-2}	1.68×10^{-3}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.36×10^{3}	9.85×10^{2}	7.43×10^{-2}	5.05×10^{-3}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	9.53×10^{-1}	7.03×10^{-1}	4.01×10^{-5}	5.66×10^{-6}	4.01×10^{-5}	4.04×10^{-1}	7.14×10^{-1}	4.97×10^{-6}	2.83×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.11×10^{-1}	1.80×10^{-8}	1.61×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–54. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.89×10^{1}	6.75×10^{-1}	8.27×10^{-4}	0.00	8.27×10^{-4}	6.42×10^{1}	7.00×10^{-1}	2.56×10^{-3}	2.48×10^{-10}	2.56×10^{-3}
B Barrier	1.96×10^{1}	1.18	5.68×10^{-4}	0.00	5.68×10^{-4}	4.38×10^{1}	1.28	1.76×10^{-3}	3.57×10^{-10}	1.76×10^{-3}
S Barrier	9.02	4.08	2.60×10^{-4}	0.00	2.60×10^{-4}	2.01×10^{1}	4.14	8.04×10^{-4}	1.60×10^{-9}	8.04×10^{-4}
T Barrier	5.40×10^{1}	5.75	1.56×10^{-3}	0.00	1.56×10^{-3}	1.21×10^{2}	5.97	4.83×10^{-3}	2.09×10^{-9}	4.83×10^{-3}
U Barrier	3.24×10^{-1}	1.40×10^{-1}	9.40×10^{-6}	0.00	9.40×10^{-6}	7.25×10^{-1}	1.44×10^{-1}	2.92×10^{-5}	5.31×10^{-11}	2.92×10^{-5}
Core Zone Boundary	1.03×10^{1}	4.14	3.02×10^{-4}	0.00	3.02×10^{-4}	2.32×10^{1}	4.20	9.41×10^{-4}	1.64×10^{-9}	9.41×10^{-4}
Columbia River nearshore	2.79×10^{-1}	3.64×10^{-2}	8.88×10^{-6}	0.00	8.88×10^{-6}	6.73×10^{-1}	3.73×10^{-2}	2.84×10^{-5}	1.38×10^{-11}	2.84×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.33×10^{-5}	2.07×10^{-6}	1.34×10^{-9}	7.12×10^{-16}	1.34×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–55. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.07	5.50×10^{-3}	1.14×10^{-5}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.50×10^{1}	2.08	3.79×10^{-3}	1.64×10^{-5}	3.79×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.89×10^{1}	6.19	1.73×10^{-3}	7.33×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.34×10^{2}	9.19	1.04×10^{-2}	9.59×10^{-5}	1.04×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.41	2.17×10^{-1}	6.29×10^{-5}	2.44×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.53×10^{1}	6.25	2.03×10^{-3}	7.51×10^{-5}	2.03×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	5.64×10^{-2}	6.17×10^{-5}	6.35×10^{-7}	6.17×10^{-5}	1.90×10^{-3}	1.57×10^{-2}	9.41×10^{-8}	3.18×10^{-7}	3.72×10^{-7}
Off Site										
Columbia River	1.31×10^{-4}	1.00×10^{-3}	4.75×10^{-9}	3.26×10^{-11}	4.77×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–56. Tank Closure Alternative 6B, Base Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.21	7.68×10^{-2}	9.24×10^{-5}	0.00	8.27×10^{-4}	7.15	7.94×10^{-2}	2.86×10^{-4}	2.84×10^{-11}	2.56×10^{-3}
B Barrier	6.17×10^{1}	5.78×10^{1}	1.88×10^{-3}	0.00	1.24×10^{-2}	1.44×10^{2}	6.65×10^{1}	5.94×10^{-3}	1.25×10^{-8}	3.48×10^{-2}
S Barrier	5.86	2.85	1.70×10^{-4}	0.00	2.60×10^{-4}	1.31×10^{1}	2.90	5.27×10^{-4}	1.11×10^{-9}	8.04×10^{-4}
T Barrier	3.61×10^{1}	9.65	1.03×10^{-3}	0.00	1.39×10^{-2}	8.04×10^{1}	1.04×10^{1}	3.20×10^{-3}	3.03×10^{-9}	2.43×10^{-2}
U Barrier	3.23×10^{-1}	9.89×10^{-2}	9.33×10^{-6}	0.00	9.40×10^{-6}	7.22×10^{-1}	1.02×10^{-1}	2.89×10^{-5}	3.63×10^{-11}	2.92×10^{-5}
Core Zone Boundary	5.16×10^{1}	3.38×10^{1}	1.59×10^{-3}	0.00	1.24×10^{-2}	1.21×10^{2}	3.95×10^{1}	5.02×10^{-3}	6.50×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.38×10^{-1}	4.22×10^{-1}	1.06×10^{-5}	0.00	1.06×10^{-5}	8.07×10^{-1}	4.56×10^{-1}	3.39×10^{-5}	1.31×10^{-10}	3.39×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	4.09×10^{-5}	1.91×10^{-5}	1.66×10^{-9}	3.98×10^{-15}	5.83×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–57. Tank Closure Alternative 6B, Base Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.38×10^{1}	1.21×10^{-1}	6.15×10^{-4}	1.30×10^{-6}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.83×10^{2}	1.15×10^{2}	1.28×10^{-2}	5.72×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.55×10^{1}	4.35	1.13×10^{-3}	5.10×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.56×10^{2}	1.67×10^{1}	6.89×10^{-3}	1.39×10^{-4}	4.85×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.40	1.57×10^{-1}	6.22×10^{-5}	1.67×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.39×10^{2}	6.96×10^{1}	1.09×10^{-2}	2.98×10^{-4}	7.43×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.60	7.35×10^{-1}	7.34×10^{-5}	6.00×10^{-6}	7.34×10^{-5}	5.68×10^{-2}	3.77×10^{-1}	7.22×10^{-7}	3.00×10^{-6}	6.40×10^{-6}
Off Site										
Columbia River	1.57×10^{-4}	2.76×10^{-2}	5.73×10^{-9}	1.82×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.10.2 Option Case

Tank Closure Alternative 6B, Option Case, resembles Tank Closure Alternative 6A, Option Case, except that waste retrieval and processing would proceed at a faster rate and closure would occur at an earlier date. All tank farms would be clean-closed, and the adjacent crib and trenches (ditches) would be clean-closed. Potential human health impacts under Tank Closure Alternative 6B, Option Case, are detailed in Appendix Q and summarized in Tables 5–58 through 5–63; those related to cribs and trenches (ditches) after CY 1940 are in Tables 5–58 and 5–59; to past leaks after CY 1940 in Tables 5–60 and 5–61; and to the combination of cribs and trenches (ditches), past leaks, and other tank farm sources after CY 2050 in Tables 5–62 and 5–63.

Impacts would be slightly less than those under Tank Closure Alternative 6B, Base Case, and standards would be exceeded, as under Tank Closure Alternative 6B, Base Case. The population dose was estimated as 2.00×10^{-1} person-rem per year for the year of maximum impact. This corresponds to 1.09×10^{-5} percent of the annual population dose due to background exposure.

Table 5–58. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	6.37×10^{2}	8.06×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	9.07×10^{2}	3.48×10^{-2}	2.01×10^{-7}	3.48×10^{-2}
T Barrier	1.45×10^{3}	1.25×10^{2}	1.38×10^{-2}	0.00	1.38×10^{-2}	2.31×10^{3}	1.37×10^{2}	2.42×10^{-2}	3.59×10^{-8}	2.42×10^{-2}
Core Zone Boundary	6.37×10^{2}	5.15×10^{2}	1.24×10^{-2}	0.00	1.24×10^{-2}	1.24×10^{3}	5.92×10^{2}	3.48×10^{-2}	1.11×10^{-7}	3.48×10^{-2}
Columbia River nearshore	2.13×10^{-1}	3.56×10^{-1}	4.14×10^{-6}	0.00	4.14×10^{-6}	3.54×10^{-1}	3.92×10^{-1}	1.26×10^{-5}	1.01×10^{-10}	1.26×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.92×10^{-4}	1.60×10^{-4}	5.86×10^{-9}	3.50×10^{-14}	5.86×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–59. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Cribs and Trenches (Ditches)

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
B Barrier	2.37×10^{3}	1.54×10^{3}	7.42×10^{-2}	9.23×10^{-3}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
T Barrier	4.25×10^{3}	2.26×10^{2}	4.83×10^{-2}	1.65×10^{-3}	4.83×10^{-2}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.37×10^{3}	1.03×10^{3}	7.42×10^{-2}	5.10×10^{-3}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	6.85×10^{-1}	6.46×10^{-1}	2.71×10^{-5}	4.63×10^{-6}	2.71×10^{-5}	5.07×10^{-1}	6.93×10^{-1}	6.23×10^{-6}	2.31×10^{-6}	7.31×10^{-6}
Off Site										
Columbia River	5.59×10^{-4}	2.06×10^{-1}	1.80×10^{-8}	1.60×10^{-9}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–60. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	2.89×10^{1}	6.75×10^{-1}	8.27×10^{-4}	0.00	8.27×10^{-4}	6.42×10^{1}	7.00×10^{-1}	2.56×10^{-3}	2.48×10^{-10}	2.56×10^{-3}
B Barrier	1.96×10^{1}	1.18	5.68×10^{-4}	0.00	5.68×10^{-4}	4.38×10^{1}	1.28	1.76×10^{-3}	3.57×10^{-10}	1.76×10^{-3}
S Barrier	9.02	4.08	2.60×10^{-4}	0.00	2.60×10^{-4}	2.01×10^{1}	4.14	8.04×10^{-4}	1.60×10^{-9}	8.04×10^{-4}
T Barrier	5.40×10^{1}	5.75	1.56×10^{-3}	0.00	1.56×10^{-3}	1.21×10^{2}	5.97	4.83×10^{-3}	2.09×10^{-9}	4.83×10^{-3}
U Barrier	3.24×10^{-1}	1.40×10^{-1}	9.40×10^{-6}	0.00	9.40×10^{-6}	7.25×10^{-1}	1.44×10^{-1}	2.92×10^{-5}	5.31×10^{-11}	2.92×10^{-5}
Core Zone Boundary	1.03×10^{1}	4.14	3.02×10^{-4}	0.00	3.02×10^{-4}	2.32×10^{1}	4.20	9.41×10^{-4}	1.64×10^{-9}	9.41×10^{-4}
Columbia River nearshore	2.79×10^{-1}	3.64×10^{-2}	8.88×10^{-6}	0.00	8.88×10^{-6}	6.73×10^{-1}	3.73×10^{-2}	2.84×10^{-5}	1.38×10^{-11}	2.84×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.33×10^{-5}	2.07×10^{-6}	1.34×10^{-9}	7.12×10^{-16}	1.34×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–61. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts of Past Leaks

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.24×10^{2}	1.07	5.50×10^{-3}	1.14×10^{-5}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	8.50×10^{1}	2.08	3.79×10^{-3}	1.64×10^{-5}	3.79×10^{-3}	N/A	N/A	N/A	N/A	N/A
S Barrier	3.89×10^{1}	6.19	1.73×10^{-3}	7.33×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	2.34×10^{2}	9.19	1.04×10^{-2}	9.59×10^{-5}	1.04×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.41	2.17×10^{-1}	6.29×10^{-5}	2.44×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	4.53×10^{1}	6.25	2.03×10^{-3}	7.51×10^{-5}	2.03×10^{-3}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.34	5.64×10^{-2}	6.17×10^{-5}	6.35×10^{-7}	6.17×10^{-5}	1.90×10^{-3}	1.57×10^{-2}	9.41×10^{-8}	3.18×10^{-7}	3.72×10^{-7}
Off Site										
Columbia River	1.31×10^{-4}	1.00×10^{-3}	4.75×10^{-9}	3.26×10^{-11}	4.77×10^{-9}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–62. Tank Closure Alternative 6B, Option Case, Drinking-Water Well User and Resident Farmer Long-Term Human Health Impact Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	3.21	7.68×10^{-2}	9.24×10^{-5}	0.00	8.27×10^{-4}	7.15	7.94×10^{-2}	2.86×10^{-4}	2.84×10^{-11}	2.56×10^{-3}
B Barrier	5.79×10^{1}	6.37×10^{1}	1.75×10^{-3}	0.00	1.24×10^{-2}	1.34×10^{2}	7.25×10^{1}	5.50×10^{-3}	1.48×10^{-8}	3.48×10^{-2}
S Barrier	5.86	2.85	1.70×10^{-4}	0.00	2.60×10^{-4}	1.31×10^{1}	2.90	5.27×10^{-4}	1.11×10^{-9}	8.04×10^{-4}
T Barrier	3.61×10^{1}	9.58	1.04×10^{-3}	0.00	1.38×10^{-2}	8.05×10^{1}	1.03×10^{1}	3.20×10^{-3}	3.05×10^{-9}	2.42×10^{-2}
U Barrier	3.23×10^{-1}	9.89×10^{-2}	9.33×10^{-6}	0.00	9.40×10^{-6}	7.22×10^{-1}	1.02×10^{-1}	2.89×10^{-5}	3.63×10^{-11}	2.92×10^{-5}
Core Zone Boundary	4.79×10^{1}	3.52×10^{1}	1.46×10^{-3}	0.00	1.24×10^{-2}	1.12×10^{2}	4.21×10^{1}	4.61×10^{-3}	6.92×10^{-9}	3.48×10^{-2}
Columbia River nearshore	3.38×10^{-1}	3.79×10^{-1}	1.04×10^{-5}	0.00	1.04×10^{-5}	7.91×10^{-1}	4.16×10^{-1}	3.28×10^{-5}	1.09×10^{-10}	3.28×10^{-5}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	3.99×10^{-5}	1.93×10^{-5}	1.62×10^{-9}	4.02×10^{-15}	5.86×10^{-9}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–63. Tank Closure Alternative 6B, Option Case, American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impact Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
A Barrier	1.38×10^{1}	1.21×10^{-1}	6.15×10^{-4}	1.30×10^{-6}	5.50×10^{-3}	N/A	N/A	N/A	N/A	N/A
B Barrier	2.63×10^{2}	1.24×10^{2}	1.19×10^{-2}	6.79×10^{-4}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
S Barrier	2.55×10^{1}	4.35	1.13×10^{-3}	5.10×10^{-5}	1.73×10^{-3}	N/A	N/A	N/A	N/A	N/A
T Barrier	1.56×10^{2}	1.65×10^{1}	6.89×10^{-3}	1.40×10^{-4}	4.83×10^{-2}	N/A	N/A	N/A	N/A	N/A
U Barrier	1.40	1.57×10^{-1}	6.22×10^{-5}	1.67×10^{-6}	6.29×10^{-5}	N/A	N/A	N/A	N/A	N/A
Core Zone Boundary	2.20×10^{2}	7.60×10^{1}	9.96×10^{-3}	3.17×10^{-4}	7.42×10^{-2}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.56	6.83×10^{-1}	7.09×10^{-5}	5.01×10^{-6}	7.09×10^{-5}	5.53×10^{-2}	3.45×10^{-1}	7.10×10^{-7}	2.51×10^{-6}	7.32×10^{-6}
Off Site										
Columbia River	1.54×10^{-4}	2.69×10^{-2}	5.62×10^{-9}	1.84×10^{-10}	1.88×10^{-8}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

5.1.2.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Activities under Tank Closure Alternative 6C would be similar to those under Tank Closure Alternative 2B. Likewise, impacts exceeding dose and risk standards, the estimated population dose for the year of maximum impact, and corresponding percent of the annual population dose due to background exposure would be the same as those under Tank Closure Alternative 2B for cribs and trenches (ditches), past leaks, and other tank farm sources.

5.1.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under Tank Closure alternatives. Risk indices—Hazard Quotient or Hazard Index—were calculated by comparing predicted dose to benchmark dose (see Appendix P of this EIS). Risk indices could not be calculated for some chemical COPCs and some receptors. For each receptor, calculated risk indices are presented for the COPC with the highest Hazard Quotients or Hazard Indices.

Releases to air and groundwater are expected under all Tank Closure alternatives. The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources at the offsite maximum-exposure location (Columbia River). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River.

5.1.3.1 Tank Closure Alternative 1: No Action

Predicted emissions of COPCs in air under Tank Closure Alternative 1, No Action, are unlikely to pose a hazard to ecological receptors. Under Tank Closure Alternative 1, the largest Hazard Quotient (1.16) for any COPC was calculated for the mouse exposed to xylene deposited to soil at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk, but there is uncertainty in the calculated value. The mouse Hazard Quotient for xylene is within the margin of error of the uncertainties in the estimated exposure and toxicity of chemical COPCs and does not indicate that small omnivorous mammals are likely to be adversely impacted (see Appendix P). The largest Hazard Index (0.0098) for radiological COPCs released to air under Tank Closure Alternative 1 (see Appendix P, Table P–3) is predicted for the mourning dove at the onsite maximum-exposure location. This indicates no risk from radiological COPCs released to air under Tank Closure Alternative 1.

Long-term impacts on ecological resources as a result of releases to groundwater from past leaks, residuals, ancillary equipment, and cribs and trenches (ditches) were evaluated at the Columbia River (see Appendix P). The largest risk index (Hazard Quotient is 21) for groundwater releases under Tank Closure Alternative 1 (see Table 5–65) is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River. The uncertainty about the risk it poses to aquatic biota from chromium in groundwater releases under *TC & WM EIS* alternatives is discussed in Appendix P (see Section P.3.2). The next-largest Hazard Quotient (0.82) for any chemical COPC was calculated for the spotted sandpiper exposed to chromium deposited to sediment and taken up by its benthic invertebrate prey. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.02) for radiological COPCs released to groundwater under Tank Closure Alternative 1 (see Appendix P, Table P–12) is predicted for benthic invertebrates. This indicates no risk from radiological COPCs under Tank Closure Alternative 1.

Table 5–64. Tank Closure Alternatives – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

Tank Closure Alternative	Hazard Quotient of Worst-Case Chemical COPC by Receptor								
	Plants	Soil-Dwelling Invertebrate	Side-Blotched Lizard	Great Basin Pocket Mouse	Coyote	Mule Deer	Meadow Lark	Mourning Dove	Burrowing Owl
	Mercury	Mercury	Mercury	Xylene	Xylene	Formaldehyde	Mercury	Mercury	Mercury
1	0.00	0.00	0.00	**1.16**	1.48×10^{-1}	1.63×10^{-1}	0.00	0.00	0.00
2A	6.46	9.02×10^{-1}	**1.52×10^{2}**	1.21×10^{2}	1.54×10^{1}	1.29×10^{1}	9.12×10^{1}	7.53	6.35
2B	7.05	9.85×10^{-1}	**1.66×10^{2}**	9.79×10^{1}	1.24×10^{1}	1.24×10^{1}	9.95×10^{1}	8.22	6.92
3A	1.67×10^{1}	2.33	**3.92×10^{2}**	1.02×10^{2}	1.30×10^{1}	1.24×10^{1}	2.35×10^{2}	1.94×10^{1}	1.64×10^{1}
3B	4.80	6.70×10^{-1}	1.13×10^{2}	**1.23×10^{2}**	1.57×10^{1}	1.39×10^{1}	6.77×10^{1}	5.59	4.71
3C	1.67×10^{1}	2.33	**3.92×10^{2}**	1.07×10^{2}	1.35×10^{1}	1.26×10^{1}	2.35×10^{2}	1.94×10^{1}	1.64×10^{1}
4	6.67	9.31×10^{-1}	**1.57×10^{2}**	9.06×10^{1}	1.15×10^{1}	1.35×10^{1}	9.41×10^{1}	7.77	6.54
5	6.34	8.85×10^{-1}	**1.49×10^{2}**	**1.49×10^{2}**	1.90×10^{1}	1.79×10^{1}	8.94×10^{1}	7.38	6.22
6A, Base	6.56	9.16×10^{-1}	1.54×10^{2}	**2.70×10^{2}**	3.43×10^{1}	3.49×10^{1}	9.25×10^{1}	7.64	6.44
6A, Option	6.51	9.09×10^{-1}	1.53×10^{2}	**2.74×10^{2}**	3.48×10^{1}	4.26×10^{1}	9.18×10^{1}	7.58	6.39
6B, Base	7.33	1.02	**1.72×10^{2}**	1.51×10^{2}	1.92×10^{1}	2.32×10^{1}	1.03×10^{2}	8.54	7.20
6B, Option	7.30	1.02	**1.71×10^{2}**	1.56×10^{2}	1.98×10^{1}	3.09×10^{1}	1.03×10^{2}	8.50	7.16
6C	7.30	1.02	**1.71×10^{2}**	9.70×10^{1}	1.23×10^{1}	1.04×10^{1}	1.03×10^{2}	8.50	7.16

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text.
Key: Base=Base Case; COPC=constituent of potential concern; Option=Option Case.

Table 5–65. Tank Closure Alternatives – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Resources at the Columbia River

Tank Closure Alternative	Hazard Quotient or Hazard Index of Worst-Case Chemical or Radiological COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	Chromium	Chromium	Chromium	Uranium	Nitrate	Chromium	Chromium
1	1.20×10^{-1}	4.71×10^{-3}	8.16×10^{-1}	2.95×10^{-1}	6.31×10^{-1}	2.08×10^{-2}	**2.14×10^{1}**
2A	2.35×10^{-2}	9.17×10^{-4}	1.59×10^{-1}	4.11×10^{-2}	6.25×10^{-1}	1.49×10^{-2}	**2.20×10^{1}**
2B, 3A, 3B, 3C, 6C	2.50×10^{-2}	9.79×10^{-4}	1.70×10^{-1}	2.88×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
4	2.47×10^{-2}	9.67×10^{-4}	1.68×10^{-1}	2.32×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
5	2.54×10^{-2}	9.93×10^{-4}	1.72×10^{-1}	4.12×10^{-2}	6.30×10^{-1}	1.51×10^{-2}	**2.22×10^{1}**
6A, Base	2.42×10^{-2}	9.46×10^{-4}	1.64×10^{-1}	2.72×10^{-3}	6.30×10^{-1}	1.50×10^{-2}	**2.22×10^{1}**
6A, Option	2.11×10^{-2}	8.24×10^{-4}	1.43×10^{-1}	1.01×10^{-4}	6.36×10^{-1}	1.44×10^{-2}	**2.15×10^{1}**
6B, Base	2.43×10^{-2}	9.52×10^{-4}	1.65×10^{-1}	2.72×10^{-3}	6.30×10^{-1}	1.50×10^{-2}	**2.22×10^{1}**
6B, Option	2.03×10^{-2}	7.95×10^{-4}	1.38×10^{-1}	7.41×10^{-5}	6.16×10^{-1}	1.47×10^{-2}	**2.21×10^{1}**

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text.

Key: Base=Base Case; COPC=constituent of potential concern; Option=Option Case.

5.1.3.2 Tank Closure Alternative 2A: Existing WTP Vitrification; No Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 2A pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 2A. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 121) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 152) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 2A. The largest Hazard Index (0.0167) for radiological COPCs released to air under Tank Closure Alternative 2A (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from COPC releases to air under Tank Closure Alternative 2A at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 2A is that calculated for exposure to hexavalent chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0049) for radiological COPCs released to groundwater under Tank Closure Alternative 2A (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 4 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 2A.

5.1.3.3 Tank Closure Alternative 2B: Expanded WTP Vitrification; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 2B pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location, only slightly larger than under Tank Closure Alternative 2A (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 2B. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 98) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 166) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 2B. The largest Hazard Index (0.0091) for radiological COPCs released to air under Tank Closure Alternative 2B (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 2B at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 2B is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 2B (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 2B.

5.1.3.4 Tank Closure Alternative 3A: Existing WTP Vitrification with Thermal Supplemental Treatment (Bulk Vitrification); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3A pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Tank Closure

Alternative 3A (and Tank Closure Alternative 3C) poses the highest risk of all alternatives for soil-dwelling invertebrates and the side-blotched lizard, meadow lark, mourning dove, and owl at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 20 for toluene and mercury under Tank Closure Alternative 3A. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 102) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 392) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3A. The largest Hazard Index (0.0137) for radiological COPCs released to air under Tank Closure Alternative 3A (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3A at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3A is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3A (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3A.

5.1.3.5 Tank Closure Alternative 3B: Existing WTP Vitrification with Nonthermal Supplemental Treatment (Cast Stone); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3B pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 3B. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 123) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 113) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3B. The largest Hazard Index (0.0086) for radiological COPCs released to air under Tank Closure Alternative 3B (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3B at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3B is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3B (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3B.

5.1.3.6 Tank Closure Alternative 3C: Existing WTP Vitrification with Thermal Supplemental Treatment (Steam Reforming); Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 3C pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Tank Closure Alternative 3C risk indices are similar to those under Tank Closure Alternative 3A, posing the highest

risk of all alternatives for soil-dwelling invertebrates and the side-blotched lizard, meadow lark, mourning dove, and owl at the onsite maximum-exposure location (see Table 5–64). Hazard Quotients calculated for plants are between 1 and 20 for toluene and mercury under Tank Closure Alternative 3C. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 107) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 392) at the onsite maximum-exposure location. There would be no risk from radiological COPCs under Tank Closure Alternative 3C. The largest Hazard Index (0.0137) for radiological COPCs released to air under Tank Closure Alternative 3C (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under Tank Closure Alternative 3C at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 3C is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 3C (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 3C.

5.1.3.7 Tank Closure Alternative 4: Existing WTP Vitrification with Supplemental Treatment Technologies; Selective Clean Closure/Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 4 pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 4. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 91) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 157) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 4. The largest Hazard Index (0.01) for radiological COPCs released to air under Tank Closure Alternative 4 (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 4 at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 4 is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0027) for radiological COPCs released to groundwater under Tank Closure Alternative 4 (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7.5 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 4.

5.1.3.8 Tank Closure Alternative 5: Expanded WTP Vitrification with Supplemental Treatment Technologies; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 5 pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 5. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the

mammals (mouse Hazard Quotient is 149) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 149) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 5. The largest Hazard Index (0.0098) for radiological COPCs released to air under Tank Closure Alternative 5 (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 5 at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 5 is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 5 (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 5.

5.1.3.9 Tank Closure Alternative 6A: All Vitrification/No Separations; Clean Closure

5.1.3.9.1 Base Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6A, Base Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6A, Base Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 270) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 154) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6A, Base Case. The largest Hazard Index (0.022) for radiological COPCs released to air under Tank Closure Alternative 6A, Base Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6A, Base Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6A, Base Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0014) for radiological COPCs released to groundwater under Tank Closure Alternative 6A, Base Case (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 15 less than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6A, Base Case.

5.1.3.9.2 Option Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6A, Option Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6A, Option Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 274) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 153) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under

Tank Closure Alternative 6A, Option Case. The largest Hazard Index (0.024) for radiological COPCs released to air under Tank Closure Alternative 6A, Option Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6A, Option Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 21.5) for groundwater releases under Tank Closure Alternative 6A, Option Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0003) for radiological COPCs released to groundwater under Tank Closure Alternative 6A, Option Case (see Appendix P, Table P–12) is predicted for the least weasel, a factor of almost 6 less than that under Tank Closure Alternative 1 (Hazard Index is 0.002) and a factor of 65 less than the maximum Hazard Index under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6A, Option Case.

5.1.3.10 Tank Closure Alternative 6B: All Vitrification with Separations; Clean Closure

5.1.3.10.1 Base Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6B, Base Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6B, Base Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 151) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 172) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6B, Base Case. The largest Hazard Index (0.022) for radiological COPCs released to air under Tank Closure Alternative 6B, Base Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6B, Base Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6B, Base Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0014) for radiological COPCs released to groundwater under Tank Closure Alternative 6B, Base Case (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 15 less than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6B, Base Case.

5.1.3.10.2 Option Case

Predicted emissions of COPCs in air under Tank Closure Alternative 6B, Option Case, pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6B, Option Case. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 156) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 171) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under

Tank Closure Alternative 6B, Option Case. The largest Hazard Index (0.023) for radiological COPCs released to air under Tank Closure Alternative 6B, Option Case (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6B, Option Case, at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6B, Option Case, is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.0003) for radiological COPCs released to groundwater under Tank Closure Alternative 6B, Option Case (see Appendix P, Table P–12) is predicted for the least weasel, a factor of almost 6 less than under Tank Closure Alternative 1 (Hazard Index is 0.002) and a factor of 65 less than the maximum Hazard Index under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6B, Option Case.

5.1.3.11 Tank Closure Alternative 6C: All Vitrification with Separations; Landfill Closure

Predicted emissions of COPCs in air under Tank Closure Alternative 6C pose a small probability of adverse impact on ecological receptors at the onsite maximum-exposure location. Hazard Quotients calculated for plants are between 1 and 10 for toluene and mercury under Tank Closure Alternative 6C. The chemical COPCs with the largest calculated Hazard Quotients for air releases are xylene for the mammals (mouse Hazard Quotient is 97) and mercury for the soil-dwelling invertebrates, lizards, and birds (side-blotched lizard Hazard Quotient is 171) at the onsite maximum-exposure location (see Table 5–64). There would be no risk from radiological COPCs under Tank Closure Alternative 6C. The largest Hazard Index (0.0091) for radiological COPCs released to air under Tank Closure Alternative 6C (see Appendix P, Table P–3) is predicted for the mouse at the onsite maximum-exposure location. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under Tank Closure Alternative 6C at the offsite maximum-exposure location (Columbia River).

The largest risk index (Hazard Quotient is 22) for groundwater releases under Tank Closure Alternative 6C is that calculated for exposure to chromium for aquatic biota, including salmonids, at the Columbia River, only slightly greater than the Hazard Quotient under Tank Closure Alternative 1 (see Table 5–65). No other Hazard Quotients exceed 1.0. Hazard Quotients and Hazard Indices less than or equal to 1 indicate no risk. The largest Hazard Index (0.003) for radiological COPCs released to groundwater under Tank Closure Alternative 6C (see Appendix P, Table P–12) is predicted for benthic invertebrates, a factor of 7 smaller than that under Tank Closure Alternative 1. This indicates no risk from radiological COPCs released to groundwater under Tank Closure Alternative 6C.

5.1.4 Environmental Justice

Sections 5.1.1 and 5.1.2 evaluate groundwater impacts and associated potential long-term human health effects under the Tank Closure alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differs

from that of the American Indian resident farmer. The American Indian hunter-gatherer does not cultivate crops but gathers food from indigenous plants, harvests fish from the Columbia River, and is exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix Q, Section Q.2.1. Long-term human health impacts of tank closure actions would be greatest under Tank Closure Alternative 1. Radiological releases under this alternative would result in the doses at the A and B Barriers and the Core Zone Boundary exceeding regulatory limits for the resident farmer, American Indian resident farmer, and American Indian hunter-gatherer; the dose at the S Barrier would exceed regulatory limits for the American Indian resident farmer and American Indian hunter-gatherer; at the T Barrier, for the American Indian hunter-gatherer. None of the hypothetical receptors at the Columbia River nearshore or surface-water locations would be exposed to a dose in excess of regulatory limits. Nonradiological releases under this alternative would result in exceedance of the Hazard Index for chromium and nitrate at all onsite locations analyzed for the resident farmer, American Indian resident farmer, and American Indian hunter-gatherer. The analysis determined that the greatest impact of any alternative on long-term human health could result in radiological doses in excess of regulatory limits and chemical exposures with a Hazard Index greater than 1 for receptors located on site at the A, B, S, T, or U Barriers, Core Zone Boundary, or Columbia River nearshore. There are no such onsite receptors currently at Hanford. The onsite exposure scenarios do not currently exist and have never existed during Hanford operations. Therefore, the estimated high health risks for past years are hypothetical risks only; no persons were ever exposed at these levels. While it is possible for these receptor scenarios to develop in the future, none are expected for the foreseeable future because the Core Zone is designated for Industrial-Exclusive land use, the Columbia River nearshore is designated for Preservation (Hanford Reach National Monument), and the area between them is designated for Conservation (Mining) (DOE 1999). It is unlikely, therefore, that any of the Tank Closure alternatives would pose a disproportionately high and adverse long-term human health risk to the offsite American Indian population. The greatest risk would be to the American Indian resident farmer at the Core Zone Boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.4 rem. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index greater than 1. The adverse impacts would also be applicable to non–American Indian receptors at the same locations, but to a lesser extent.

5.2 FFTF DECOMMISSIONING ALTERNATIVES

This section describes the potential long-term environmental and human health impacts associated with the implementation of alternatives considered to decommission the Fast Flux Test Facility (FFTF) and auxiliary facilities at Hanford; manage waste from the decommissioning process, including waste designated as remote-handled special components (RH-SCs); and disposition the Hanford inventory of radioactively contaminated bulk sodium from FFTF, as well as other facilities on site. Three FFTF Decommissioning alternatives are considered and analyzed: (1) FFTF Decommissioning Alternative 1, No Action, in which only certain deactivation activities at FFTF would be conducted, consistent with previous DOE National Environmental Policy Act actions and two action alternatives; (2) FFTF Decommissioning Alternative 2, Entombment; and (3) FFTF Decommissioning Alternative 3, Removal. FFTF Decommissioning Alternative 2 would involve removing all aboveground structures within the 400 Area Property Protected Area (PPA), with minimal removal of below-grade structures, equipment, and materials as necessary to comply with regulatory standards. The FFTF reactor vessel and other equipment below grade would remain. FFTF Decommissioning Alternative 3 would consist of removing all above-grade structures within the 400 Area PPA and the additional removal of contaminated below-grade structures, including the FFTF reactor vessel, equipment, and materials. Associated construction, operations, deactivation, closure, and decommissioning activities are assessed, as applicable, for each alternative.

For each action alternative (i.e., FFTF Decommissioning Alternatives 2 and 3), two options (Hanford and Idaho Options) are evaluated for disposition of RH-SCs and two (Hanford Reuse and Idaho Reuse Options) for disposition of bulk sodium. For RH-SCs, the Hanford Option would involve treating the waste in a new, onsite treatment facility, followed by disposal of the treated components and residuals along with other Hanford waste in the 200 Areas. Under the Idaho Option, RH-SCs would be shipped to the proposed Remote Treatment Project (RTP) at the Idaho National Laboratory (INL) Materials and Fuels Complex (MFC). Following treatment at the RTP, the FFTF components and residuals would be disposed of with other INL waste at an offsite facility or returned to Hanford for disposal. For disposition of bulk sodium under the Hanford Reuse Option, the bulk sodium would be stored in its current locations until it is shipped to a new onsite facility for processing. The caustic would then be transferred to the WTP for reuse. Under the Idaho Reuse Option, the bulk sodium would be stored in its current locations until it is shipped to the INL MFC for processing in the existing Sodium Processing Facility (SPF). Following processing, the caustic would be returned to Hanford for use in the WTP. These alternatives and options are described further in Chapter 2, Section 2.5.

5.2.1 Groundwater

The focus is on the impacts of FFTF disposition (sodium processing and remote-handled treatment should not have a groundwater impact); the waste removed from FFTF or resulting from removal will be discussed under the Waste Management alternatives.

5.2.1.1 FFTF Decommissioning Alternative 1: No Action

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 1: No Action, including long-term groundwater impacts of contaminant sources within the FFTF Barrier (for analysis purposes, the FFTF Barrier is represented by a rectangle surrounding FFTF). Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 1, after a period of administrative control, no further actions would be taken to remove radionuclides or chemicals from within the FFTF Barrier. Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 1, as follows:

- The administrative control period was assumed to start in 2008 and end in CY 2107 (100-year duration). It was assumed that during this administrative control period, corrective action or emergency response measures would preclude releases of contaminants from FFTF to the environment.

- The post–administrative control period was assumed to start in CY 2108 and continue through the 10,000-year period of analysis until CY 11,940. During this post–administrative control period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.1.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 1. Complete results for all 40 COPCs are provided in Appendices M, N, and O. The discussion in this section of long-term impacts associated with FFTF Decommissioning Alternative 1 is focused on the following COPC drivers:

- Radiological risk drivers: tritium and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: none

The COPC drivers for FFTF Decommissioning Alternative 1 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the FFTF Barrier during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers account for essentially all of the radiological risk. The peak chemical hazard to a drinking-water well user at the FFTF Barrier is essentially negligible.

The COPC drivers that are discussed in detail in this section fall into two categories. Technetium-99 is mobile (i.e., moves with groundwater) and long-lived (relative to the 10,000-year period of analysis). It is essentially a conservative tracer. Tritium is also mobile, but short-lived. The half-life of tritium is about 13 years, and tritium concentrations are strongly attenuated by radioactive decay during travel through the vadose zone and groundwater systems. The other COPCs that were analyzed do not significantly contribute to drinking water risk or hazard at the FFTF Barrier during the period of analysis because of low inventories, low release rates, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.2.1.1.3 Analysis of Release and Mass Balance

This section presents the impacts of FFTF Decommissioning Alternative 1 in terms of total amount of radiological COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies (see Figures 5–332 through 5–334). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over four orders of magnitude.

Figure 5–332 shows the estimated release to the vadose zone for the radiological risk drivers. The total release to the vadose zone is controlled only by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). About 2 curies of tritium and about 27 curies of technetium-99 were released to the vadose zone in the analysis. Figure 5–333 shows the release to groundwater for the radiological risk drivers. In addition to the inventory considerations, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For technetium-99, the amount released to groundwater is essentially equal to the amount released to the vadose zone. For tritium, the amount released to groundwater is strongly attenuated by radioactive decay. Less than 1 percent of the tritium that was released in the analysis into the vadose zone reached the groundwater. Figure 5–334 shows the release to the Columbia River for the radiological risk drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99, the amount released to the Columbia River is essentially equal to the amount released to groundwater. For tritium, the amount released to the Columbia River is strongly attenuated by radioactive decay. Overall, only about 6 percent of the tritium released to groundwater reaches the Columbia River in the analysis.

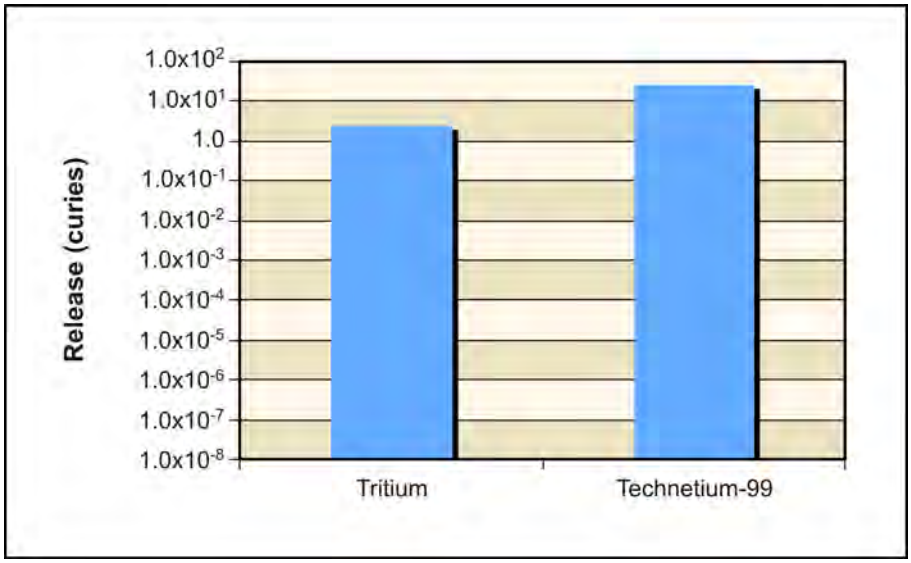


Figure 5–332. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

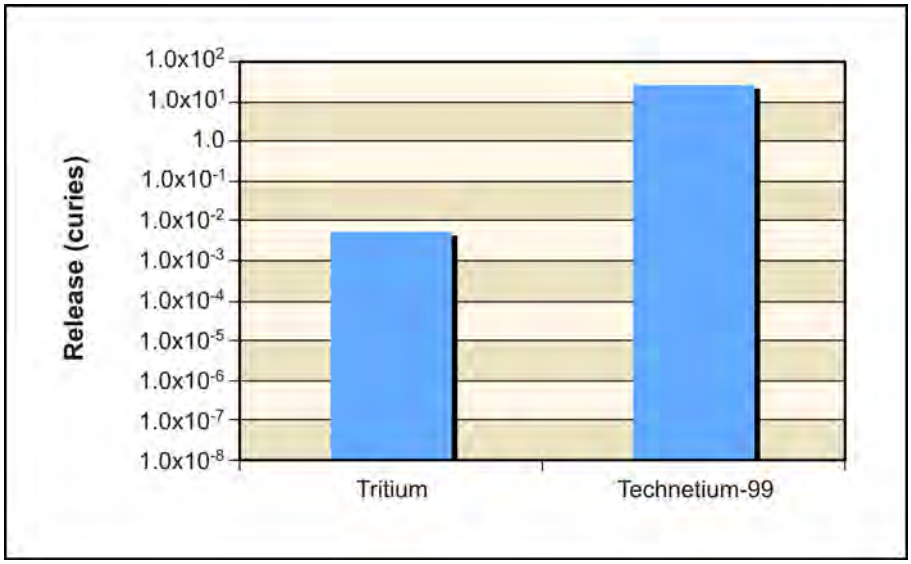


Figure 5–333. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

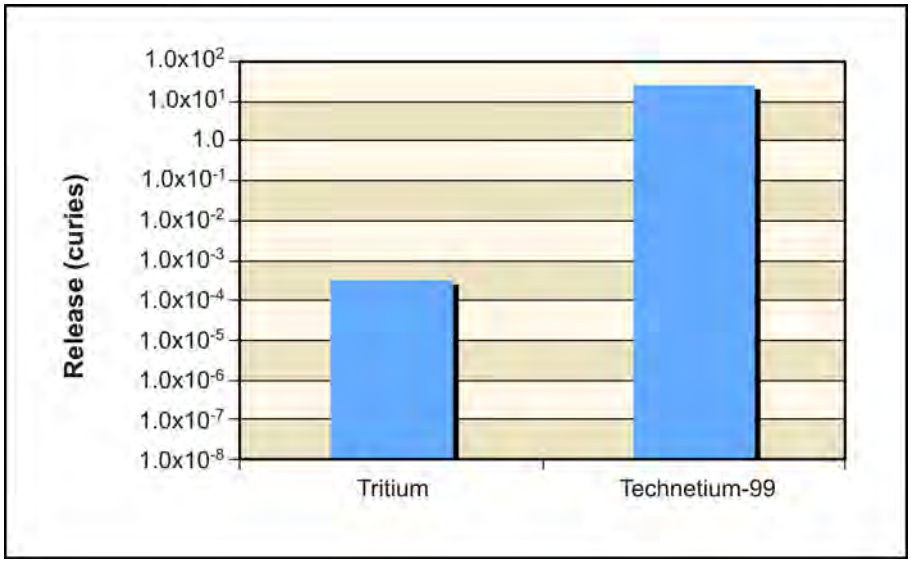


Figure 5–334. FFTF Decommissioning Alternative 1 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

5.2.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of FFTF Decommissioning Alternative 1 impacts in terms of groundwater concentration versus time at the FFTF Barrier and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter (see Figures 5–335 and 5–336). The benchmark concentration for each radionuclide is also shown (900 and 20,000 picocuries per liter for technetium-99 and tritium, respectively). Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over two orders of magnitude.

Figure 5–335 shows concentration versus time for technetium-99. The concentration of technetium-99 at the FFTF Barrier peaks at about 40 percent of the benchmark around CY 2550. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude below the benchmark concentration. Technetium-99 is essentially not a factor at times later than CY 5800.

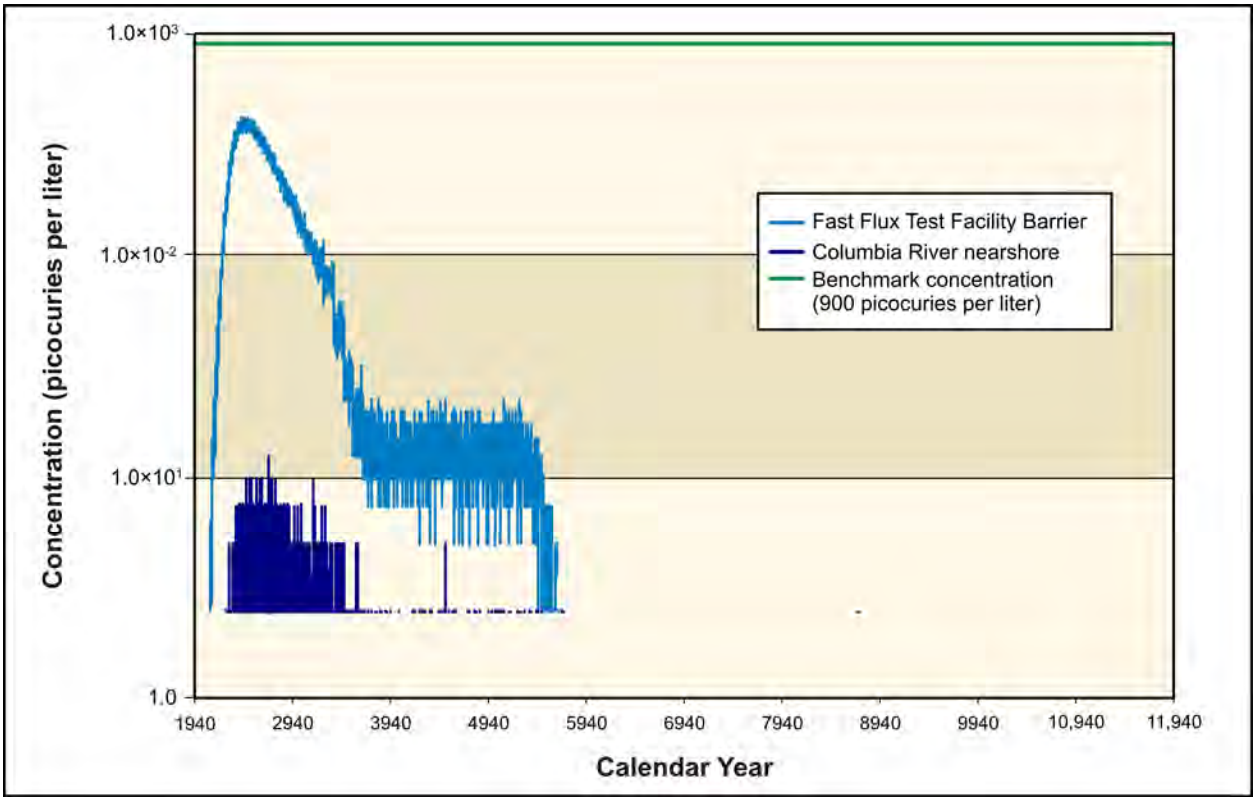


Figure 5–335. FFTF Decommissioning Alternative 1 Technetium-99 Concentration Versus Time

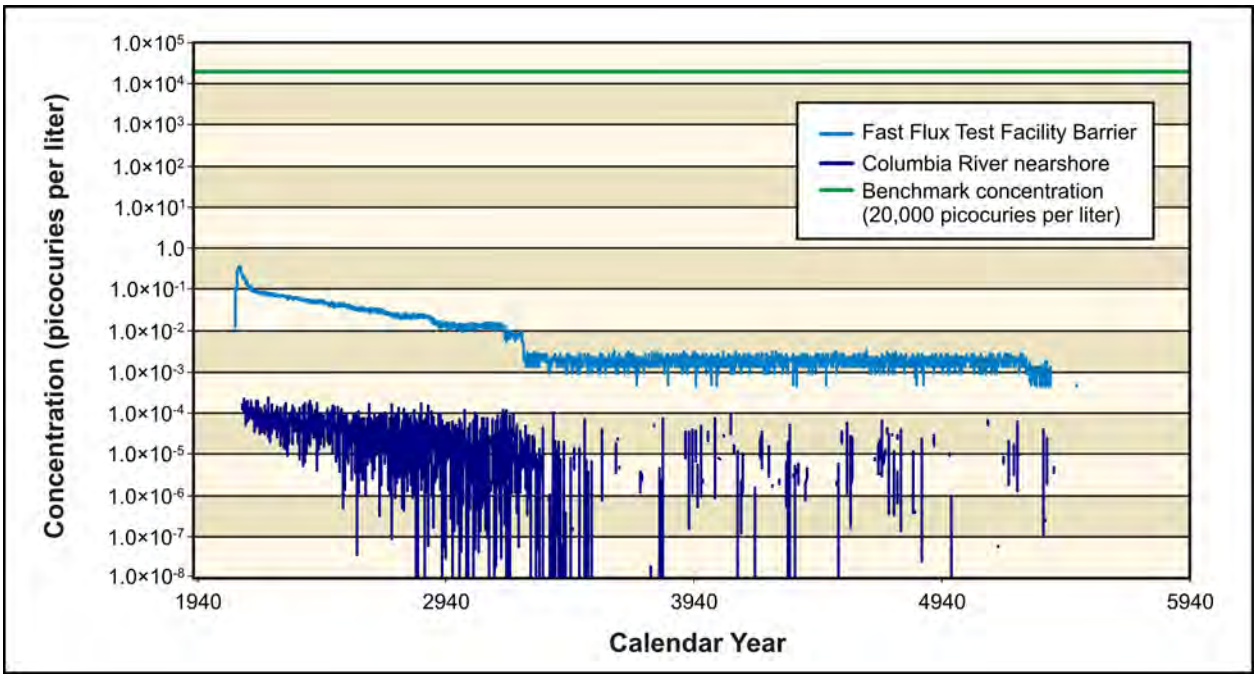


Figure 5–336. FFTF Decommissioning Alternative 1 Hydrogen-3 (Tritium) Concentration Versus Time

Figure 5–336 shows concentration versus time for tritium. Because the half-life of tritium is less than 13 years, radioactive decay rapidly attenuates groundwater concentration. Releases from FFTF did not cause groundwater concentrations to exceed the benchmark throughout the period of analysis. The concentrations at the FFTF Barrier peak at about five orders of magnitude below the benchmark. During this time, groundwater concentrations at the Columbia River nearshore peak at about eight orders of magnitude below the benchmark. Table 5–66 lists the estimated maximum concentrations of tritium and technetium-99 in the peak year at the FFTF Barrier and the Columbia River nearshore.

Table 5–66. FFTF Decommissioning Alternative 1 Maximum COPC Concentrations in the Peak Year at the FFTF Barrier and Columbia River Nearshore

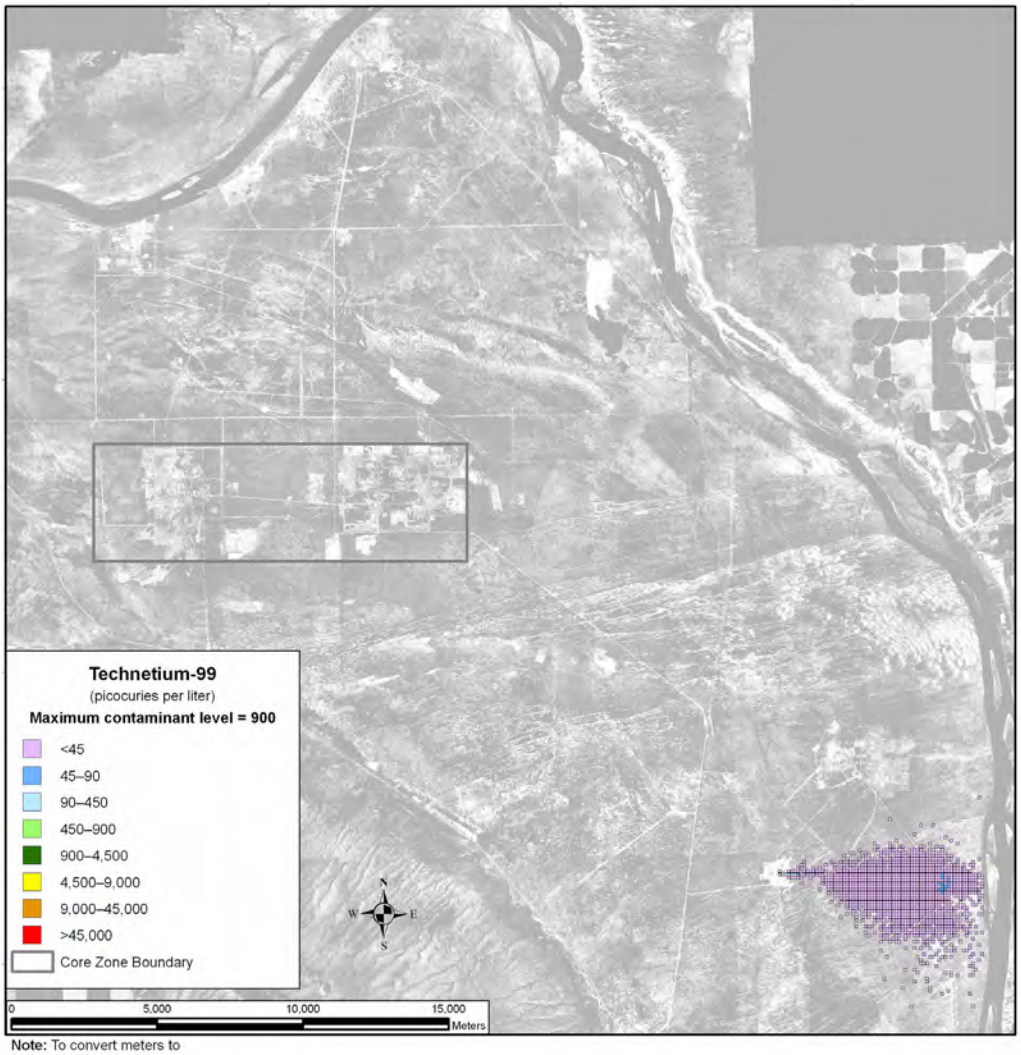
Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter			
Hydrogen-3 (tritium)	0.36	0.00024	20,000
	(2122)	(2243)	
Technetium-99	416	12	900
	(2425)	(2702)	

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

5.2.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of FFTF Decommissioning Alternative 1 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter (see Figures 5–337 and 5–338). Concentrations for each radionuclide are indicated by a color scale that is relative to the benchmark concentration (900 and 20,000 picocuries per liter for technetium-99 and tritium, respectively). Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–337 shows the spatial distribution of groundwater concentration for technetium-99 during CY 2590, roughly the time of greatest development of the groundwater plume. Analysis releases from FFTF result in a groundwater concentration plume that extends easterly from the facility to the Columbia River nearshore. Peak concentrations in this plume are less than a tenth of the benchmark during CY 2590.



Note: To convert meters to feet, multiply by 3.281

Figure 5–337. FFTF Decommissioning Alternatives 1 and 2 Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 2590

Figure 5–338 shows the spatial distribution of groundwater concentration for tritium during CY 2135. Analysis releases from FFTF result in a groundwater concentration plume that extends from the facility easterly to the Columbia River nearshore. Peak concentrations in this plume are about 20 times less than the benchmark.

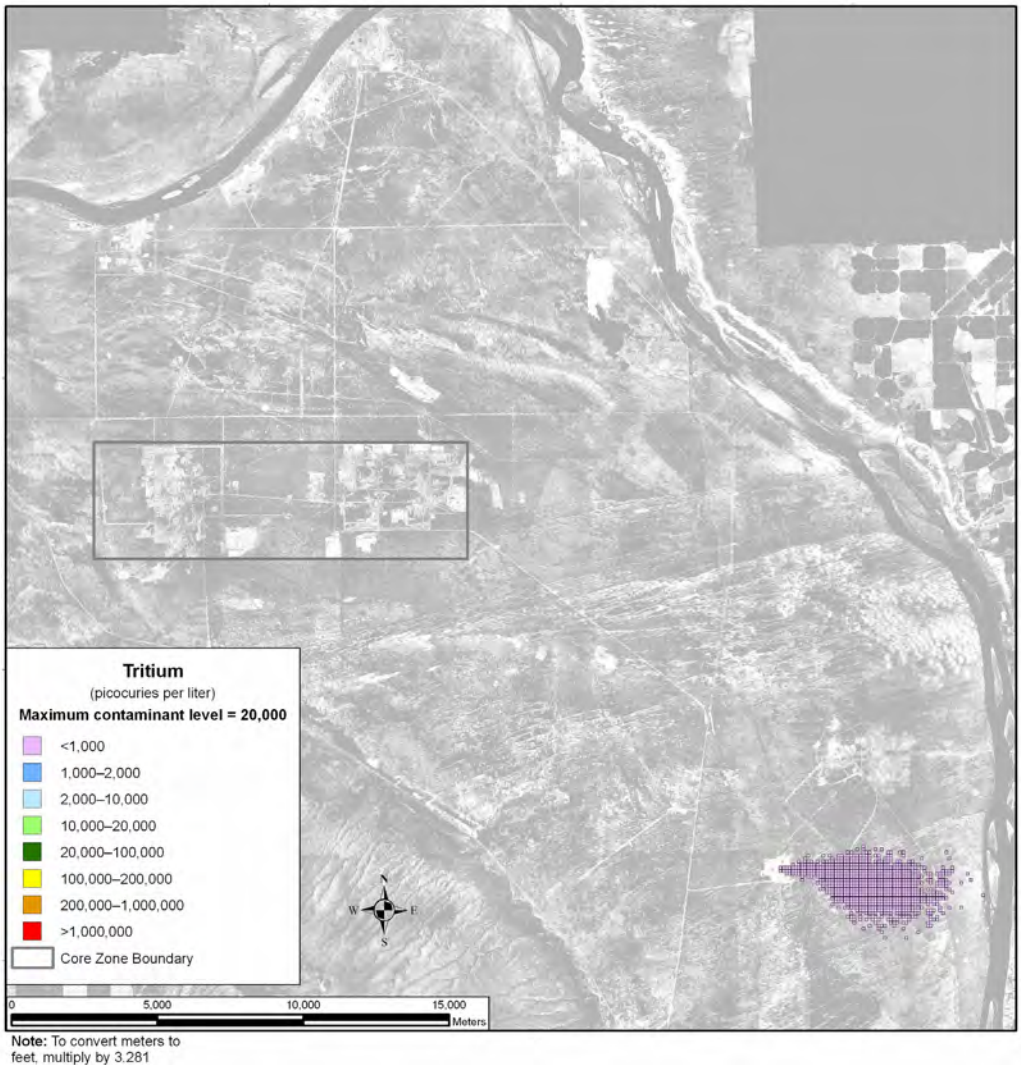


Figure 5–338. FFTF Decommissioning Alternative 1 Spatial Distribution of Groundwater Hydrogen-3 (Tritium) Concentration During Calendar Year 2135

5.2.1.1.6 Summary of Impacts

Under FFTF Decommissioning Alternative 1, technetium-99 and tritium are the COPC drivers in the analysis. Neither COPC exceeds benchmark standards at the FFTF Barrier or the Columbia River nearshore during the 10,000-year period of analysis. Tritium concentrations are strongly attenuated by radioactive decay, and the impacts are dominated by technetium-99. The impacts are greatest around CY 2500.

5.2.1.2 FFTF Decommissioning Alternative 2: Entombment

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 2, Entombment, including long-term groundwater impacts of contaminant sources within the FFTF Barrier. Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.2.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 2, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures (including the reactor vessel). Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 2, as follows:

- The entombment period was assumed to start in CY 2013 when decommissioning activities begin and to end in CY 2121, following the completion of decommissioning and entombment activities and a 100-year postclosure period. It was assumed that during this entombment period, there would be no releases from FFTF.

- The post-entombment period was assumed to start in CY 2122 and continue through the 10,000-year period of analysis until CY 11,940. During this post-entombment period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.2.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 2. Complete results for all 40 COPCs are provided in Appendices M, N, and O. The discussion in this section of long-term impacts associated with FFTF Decommissioning Alternative 2 is focused on the following COPC drivers:

- Radiological risk drivers: technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: none

The COPC drivers for FFTF Decommissioning Alternative 2 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the FFTF Barrier during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers account for essentially all of the radiological risk. The peak chemical hazard to a drinking-water well user at the FFTF Barrier is essentially negligible.

The COPC driver that is discussed in detail in this section is technetium-99. Technetium-99 is mobile (i.e., moves with groundwater) and long-lived (relative to the 10,000-year period of analysis). It is essentially a conservative tracer. The other COPCs that were analyzed do not significantly contribute to drinking water risk or hazard at the FFTF Barrier during the period of analysis because of low inventories, low release rates, high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of these factors.

5.2.1.2.3 Analysis of Release and Mass Balance

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of total amount of radiological COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies (see Figures 5–339 through 5–341). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over seven orders of magnitude.

Figure 5–339 shows the estimated release to the vadose zone for technetium-99, about 27 curies. Figure 5–340 shows the release to groundwater, which is essentially the same as that released to the vadose zone. This is due to technetium-99's lack of retardation and long half-life. Figure 5–341 shows the release to the Columbia River for technetium-99, which also is about 27 curies.

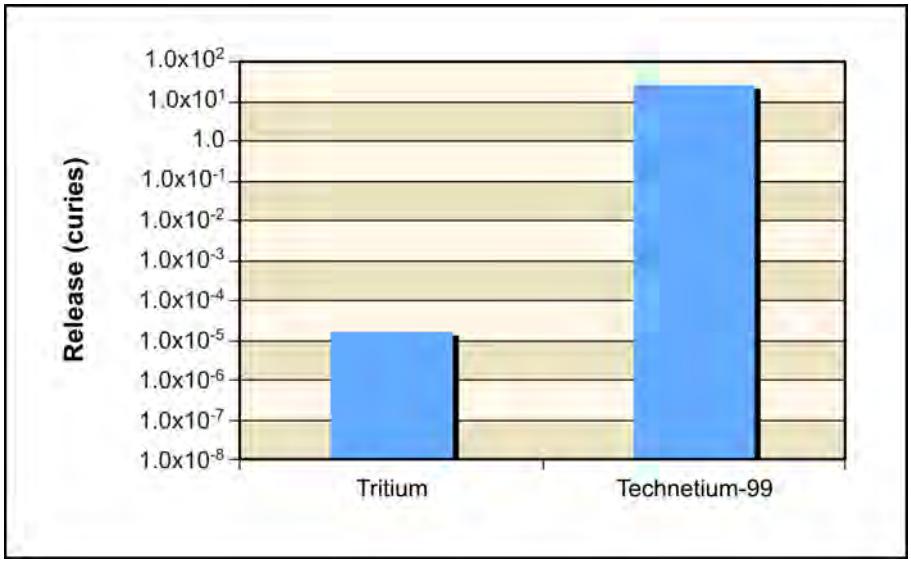


Figure 5–339. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Vadose Zone from Sources Inside the Fast Flux Test Facility Barrier

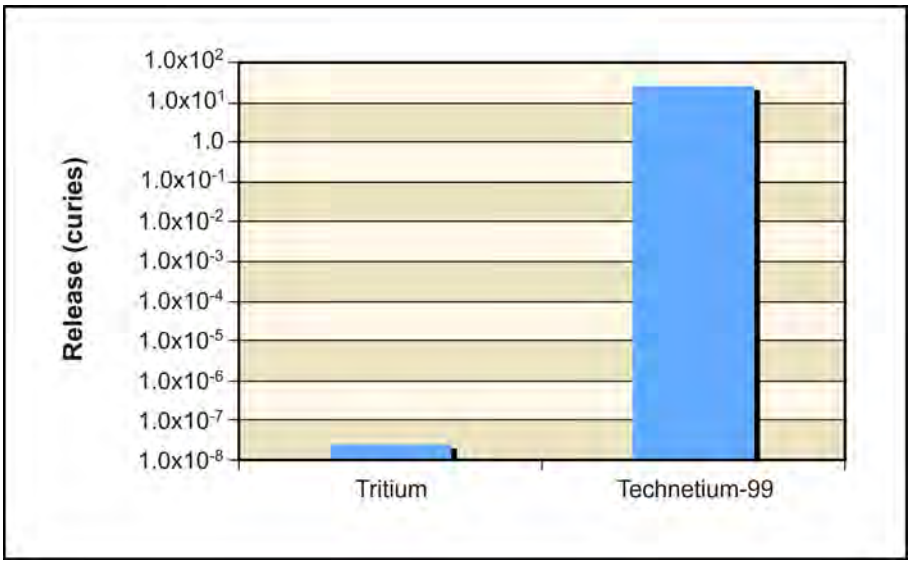


Figure 5–340. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Groundwater from Sources Inside the Fast Flux Test Facility Barrier

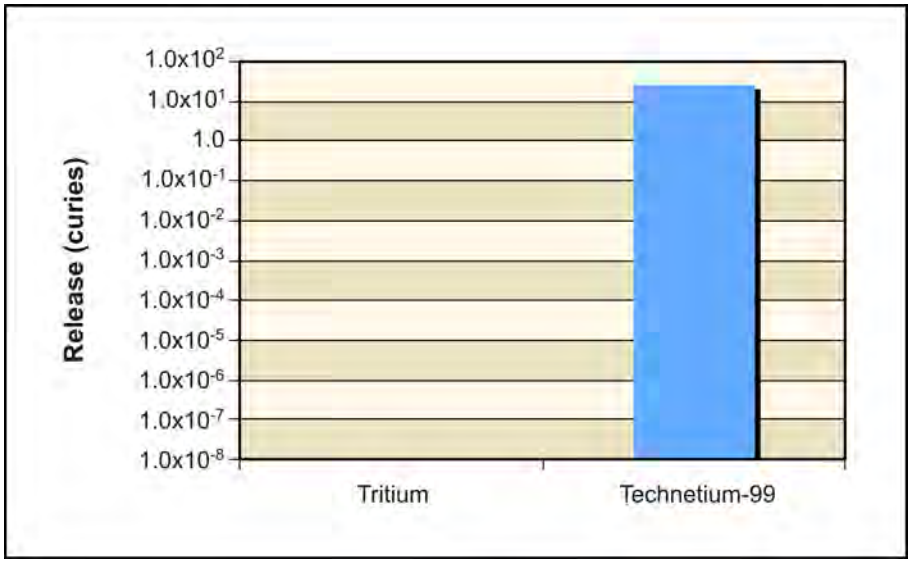


Figure 5–341. FFTF Decommissioning Alternative 2 Releases of Radiological Constituent of Potential Concern to Columbia River from Sources Inside the Fast Flux Test Facility Barrier

5.2.1.2.4 Analysis of Concentration Versus Time

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of groundwater concentration versus time at the FFTF Barrier and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter (see Figure 5–342). The benchmark concentration for technetium-99 is also shown (900 picocuries per liter). Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over two to three orders of magnitude.

Figure 5–342 shows concentration versus time for technetium-99. The concentration of technetium-99 at the FFTF Barrier peaks at about 40 percent of the benchmark around CY 2550. During this time, groundwater concentrations at the Columbia River nearshore peak at about two orders of magnitude below the benchmark concentration. Technetium-99 is essentially not a factor at times later than CY 5800. Table 5–67 lists the estimated maximum concentrations of technetium-99 in the peak year at the FFTF Barrier and the Columbia River nearshore.

Table 5–67. FFTF Decommissioning Alternative 2 Maximum COPC Concentrations in the Peak Year at the FFTF Barrier and Columbia River Nearshore

Contaminant	FFTF Barrier	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter			
Hydrogen-3 (tritium)	0	0	20,000
	N/A	N/A	
Technetium-99	407	12	900
	(2819)	(2965)	

Note: Corresponding calendar years shown in parentheses.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility; N/A=not applicable.

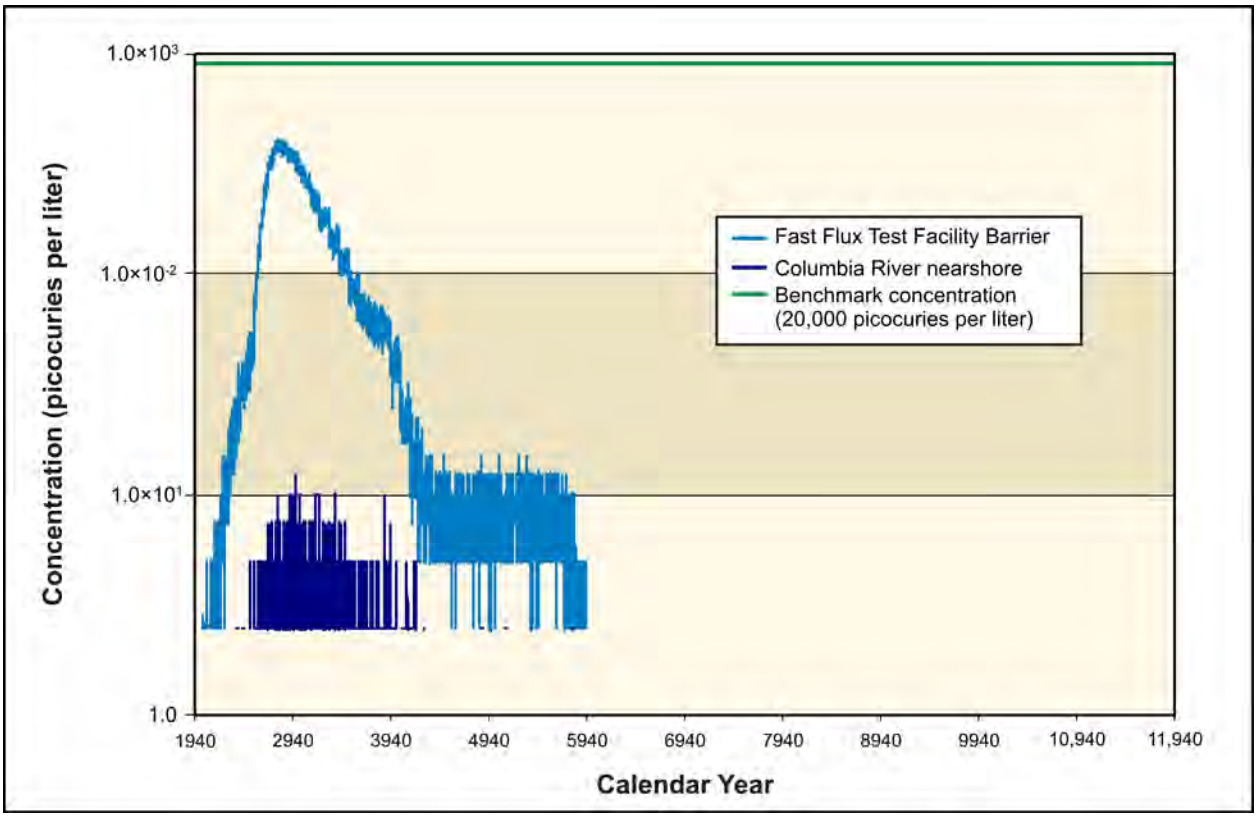


Figure 5–342. FFTF Decommissioning Alternative 2 Technetium-99 Concentration Versus Time

5.2.1.2.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of FFTF Decommissioning Alternative 2 in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter (see Figure 5–337). Concentrations of technetium-99 are indicated by a color scale that is relative to the benchmark concentration (900 picocuries per liter). Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

The results of the analyses of release and mass balance and of concentration versus time show that the plume development for technetium-99 is identical under FFTF Decommissioning Alternatives 1 and 2. Figure 5–337 shows the spatial distribution of the technetium plume during CY 2590, roughly the time of greatest development of the groundwater plume. Analysis releases from FFTF result in a groundwater concentration plume that extends easterly from the facility to the Columbia River nearshore. Peak concentrations in this plume are less than a tenth of the benchmark during CY 2590.

5.2.1.2.6 Summary of Impacts

Under FFTF Decommissioning Alternative 2, technetium-99 is the COPC driver in the analysis. Groundwater impacts of technetium-99 are similar to those under FFTF Decommissioning Alternative 1. Technetium-99 concentrations do not exceed benchmark standards at the FFTF Barrier or the Columbia River nearshore during the 10,000-year period of analysis. The impacts are greatest around CY 2500.

5.2.1.3 FFTF Decommissioning Alternative 3: Removal

This section describes the groundwater analysis results for FFTF Decommissioning Alternative 3, Removal, including long-term groundwater impacts of contaminant sources within the FFTF Barrier. Impacts of sources removed from within the FFTF Barrier and disposed of in an IDF are presented in Section 5.3, which discusses waste management impacts.

5.2.1.3.1 Actions and Timeframes Influencing Groundwater Impacts

Under FFTF Decommissioning Alternative 3, all above-grade structures within the 400 Area PPA would be removed; additionally, contaminated below-grade structures, equipment, and materials would be removed. Summaries of the proposed actions and timelines for this alternative are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for FFTF Decommissioning Alternative 3, as follows:

- The removal period was assumed to start in CY 2013 when decommissioning activities begin and to end in CY 2121, following the completion of decommissioning and removal activities and a 100-year postclosure period. It was assumed that during this removal period, there would be no releases from FFTF.

- The post-removal period was assumed to start in CY 2122 and continue through the 10,000-year period of analysis until CY 11,940. During this post-removal period, all remaining constituents at FFTF would be available for release to the environment.

5.2.1.3.2 COPC Drivers

A total of 40 COPCs were analyzed for FFTF Decommissioning Alternative 3. These COPCs become available for release to the environment at the end of the post-removal period in 2121. The total amount of each COPC released to the aquifer is limited first by the inventory remaining after removal. The removal activities limit the residual inventories to a much greater extent under FFTF Decommissioning Alternative 3 than under FFTF Decommissioning Alternatives 1 and 2. The maximum residual inventory calculated under FFTF Decommissioning Alternative 3 is for carbon-14, which is approximately 4×10^{-4} curies. The second factor that limits release to the aquifer is attenuation by retardation and/or radioactive decay. Accounting for both factors, the calculated maximum total release to the aquifer of all COPCs is for technetium-99, which is 4×10^{-6} curies. For all COPCs, the calculated peak rate of release to the aquifer is less than 10^{-8} curies per year, the threshold for evaluating long-term groundwater impacts (see Appendix O). Thus, the analysis predicts no long-term groundwater impacts associated with FFTF Decommissioning Alternative 3 above *de minimis* values.

5.2.2 Human Health Impacts

Potential human health impacts due to release of radionuclides are estimated as dose and as lifetime risk of incidence of cancer. For long-term performance assessment, radiological dose and risk are estimated consistent with the recommendations of *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13 (Eckerman et al. 1999), including use of radionuclide-specific dose factors and risk coefficients. Potential human health effects due to release of chemical constituents include both carcinogenic effects and other forms of toxicity. Impacts of carcinogenic chemicals are estimated as lifetime risk of incidence of cancer. Noncarcinogenic effects were estimated as a Hazard Quotient, the ratio of the long-term intake of a single chemical to intake that produces no observable effect, and as a Hazard Index, the sum of the Hazard Quotients of a group of chemicals. Further information on the nature of human health effects in response to exposure to radiological and chemical constituents is provided in Appendix K. Screening analysis identified 14 radionuclide and 26 chemical constituents as contributing the greatest risk of adverse impacts. Appendix Q provides more

information on the screening analysis, including time of occurrence of peak impacts and constituent- and location-specific impacts under each Tank Closure, FFTF Decommissioning, and Waste Management alternative.

Four measures of human health impacts were considered in this analysis: lifetime risks of developing cancer from both radiological and chemical constituents, dose from radiological constituents, and Hazard Index from chemical constituents. These measures were calculated for each year for 10,000 years for each receptor at three locations: the FFTF Barrier, Columbia River nearshore, and surface water of the Columbia River. This large amount of information must be summarized to allow an interpretation of results. The method chosen was to present the dose for the year of maximum dose, the risk for the year of maximum risk, and the Hazard Index for the year of maximum Hazard Index. This choice was based on regulation of radiological impacts as dose and observations from the analysis results that (1) risk due to exposure to chemical constituents would be small relative to risk due to exposure to radiological constituents and (2) peak noncarcinogenic impacts expressed as a Hazard Index may occur at times other than that of peak dose.

Impacts on human health over the long period following decommissioning of the FFTF would be due primarily to the materials left in place following no action, entombment, or removal. Onsite analysis locations included the FFTF boundary and the Columbia River nearshore. Offsite analysis locations included access points to Columbia River surface water near the site and at population centers downstream of the site. Estimates of constituent concentrations in Columbia River surface water were used to calculate the impacts for both offsite location points of analysis. The total offsite population is 5 million people. Four types of receptor were considered. The first type, a drinking-water well user, uses groundwater as a source of drinking water. The second type, a resident farmer, uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield were assumed to be adequate to produce approximately 25 percent of average requirements for crops and animal products. The third type, an American Indian resident farmer, also uses groundwater for drinking-water consumption and irrigation of crops. Garden size and crop yield were assumed to be adequate to produce the entirety of average requirements for crops and animal products. The fourth type, an American Indian hunter-gatherer, uses both groundwater and surface water because surface water is used for drinking-water consumption and both wild plant materials, which use groundwater, and game, which use surface water, are consumed.

The significance of the dose impacts was evaluated by comparison with the 100-millirem-per-year all-exposure modes standard specified for protection of the public and the environment in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The level of protection provided for the drinking-water pathway was evaluated by comparison with the applicable drinking-water standards presented in Section 5.2.1. The population doses were compared with the total effective dose equivalent from background sources of 365 millirem per year for a member of the population of the United States (NCRP 1987). The significance of noncarcinogenic chemical impacts was evaluated by comparison with a guideline value of unity for Hazard Index.

5.2.2.1 FFTF Decommissioning Alternative 1: No Action

This section contains the results for FFTF Decommissioning Alternative 1, No Action. The section includes analysis of long-term human health impacts from sources within the FFTF Barrier. Impacts from sources removed from the FFTF Barrier and disposed of in an IDF are discussed in Section 5.3, which deals with waste management issues.

Under FFTF Decommissioning Alternative 1, only those actions consistent with previous DOE National Environmental Policy Act actions would be completed. Final decommissioning of FFTF would not occur. For analysis purposes, the remaining waste would be available for release to the environment after an institutional control period of 100 years.

The potential human health impacts of this alternative are summarized in Tables 5–68 and 5–69 and are detailed in Appendix Q. The key constituent contributors to human health risk would be tritium and technetium-99 for radionuclides. The chemical risk and hazard drivers were essentially negligible. Neither the dose standards nor the Hazard Index guideline would be exceeded at any location. The population dose was estimated as 9.80×10^{-3} person-rem per year for the year of peak dose. This corresponds to 5.27×10^{-7} percent of the annual population dose due to background exposure. The time series of radiological risk for the drinking-water well user at the FFTF Barrier is presented in Figure 5–343.

Table 5–68. FFTF Decommissioning Alternative 1 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	7.29×10^{-1}	3.19×10^{-6}	2.51×10^{-5}	0.00	2.51×10^{-5}	1.87	3.22×10^{-6}	8.23×10^{-5}	3.48×10^{-16}	8.23×10^{-5}
Columbia River nearshore	2.16×10^{-2}	1.01×10^{-7}	7.42×10^{-7}	0.00	7.42×10^{-7}	5.54×10^{-2}	1.02×10^{-7}	2.43×10^{-6}	1.02×10^{-17}	2.43×10^{-6}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.96×10^{-6}	8.56×10^{-13}	8.60×10^{-11}	3.49×10^{-22}	8.60×10^{-11}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–69. FFTF Decommissioning Alternative 1 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	3.82	3.33×10^{-6}	1.79×10^{-4}	1.60×10^{-11}	1.79×10^{-4}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.13×10^{-1}	1.06×10^{-7}	5.31×10^{-6}	4.67×10^{-13}	5.31×10^{-6}	1.36×10^{-4}	5.74×10^{-9}	7.43×10^{-9}	2.34×10^{-13}	7.43×10^{-9}
Off Site										
Columbia River	4.53×10^{-6}	1.37×10^{-12}	2.14×10^{-10}	1.60×10^{-17}	2.14×10^{-10}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

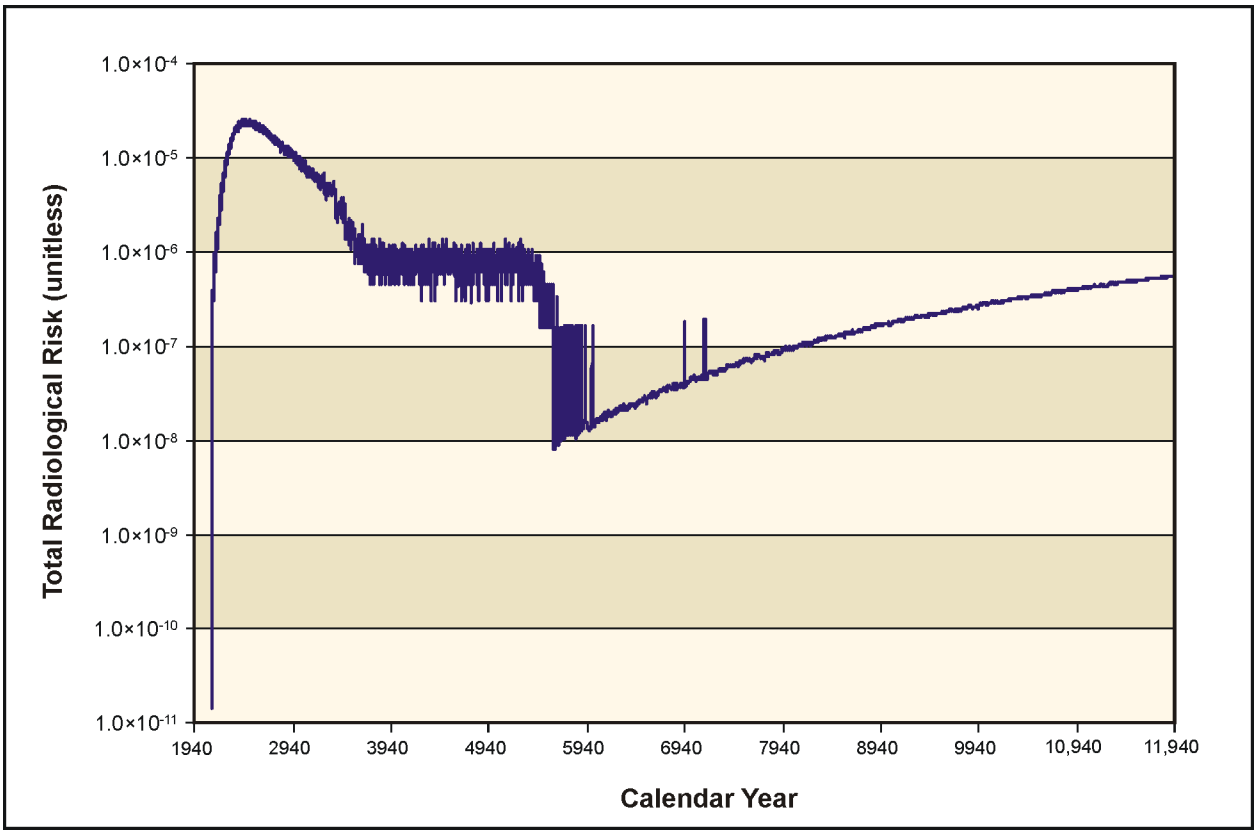


Figure 5–343. FFTF Decommissioning Alternative 1 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

5.2.2.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, Entombment, all aboveground structures and minimal below-grade structures, equipment, and materials would be removed. An RCRA-compliant barrier would be constructed over the Reactor Containment Building and any other remaining below-grade structures, including the reactor vessel. Impacts from sources removed from the FFTF Barrier and disposed of in an IDF are discussed in Section 5.3, which discusses waste management issues.

The potential human health impacts of this alternative are summarized in Tables 5–70 and 5–71 and are detailed in Appendix Q. The key constituent contributor to human health risk would be technetium-99 for radionuclides. The chemical risk and hazard drivers would be essentially negligible. Neither dose standards nor the Hazard Index guideline would be exceeded at any location. The population dose was estimated as 8.90×10^{-3} person-rem per year for the year of peak dose. This corresponds to 4.87×10^{-7} percent of the annual population dose due to background exposure. The time series of radiological risk for the drinking-water well user at the FFTF Barrier is presented in Figure 5–344.

Table 5–70. FFTF Decommissioning Alternative 2 Drinking-Water Well User and Resident Farmer Long-Term Human Health Impacts Summary

Location	Receptor									
	Drinking-Water Well User					Resident Farmer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	7.13×10^{-1}	0.00	2.45×10^{-5}	0.00	2.45×10^{-5}	1.83	0.00	8.04×10^{-5}	0.00	8.04×10^{-5}
Columbia River nearshore	2.16×10^{-2}	0.00	7.42×10^{-7}	0.00	7.42×10^{-7}	5.55×10^{-2}	0.00	2.44×10^{-6}	0.00	2.44×10^{-6}
Off Site										
Columbia River	N/A	N/A	N/A	N/A	N/A	1.78×10^{-6}	0.00	7.81×10^{-11}	0.00	7.81×10^{-11}

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

Table 5–71. FFTF Decommissioning Alternative 2 American Indian Resident Farmer and American Indian Hunter-Gatherer Long-Term Human Health Impacts Summary

Location	Receptor									
	American Indian Resident Farmer					American Indian Hunter-Gatherer				
	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)	Dose at Year of Peak Dose (mrem/yr)	Hazard Index at Year of Peak Hazard Index (unitless)	Rad. Risk at Year of Peak Rad. Risk (unitless)	Nonrad. Risk at Year of Peak Nonrad. Risk (unitless)	Total Risk at Year of Peak Total Risk (unitless)
On Site										
Fast Flux Test Facility	3.73	0.00	1.75×10^{-4}	0.00	1.75×10^{-4}	N/A	N/A	N/A	N/A	N/A
Columbia River nearshore	1.13×10^{-1}	0.00	5.31×10^{-6}	0.00	5.31×10^{-6}	1.36×10^{-4}	0.00	7.46×10^{-9}	0.00	7.46×10^{-9}
Off Site										
Columbia River	4.11×10^{-6}	0.00	1.95×10^{-10}	0.00	1.95×10^{-10}	N/A	N/A	N/A	N/A	N/A

Key: mrem=millirem; N/A=not applicable; Nonrad.=nonradiological; Rad.=radiological; yr=year.

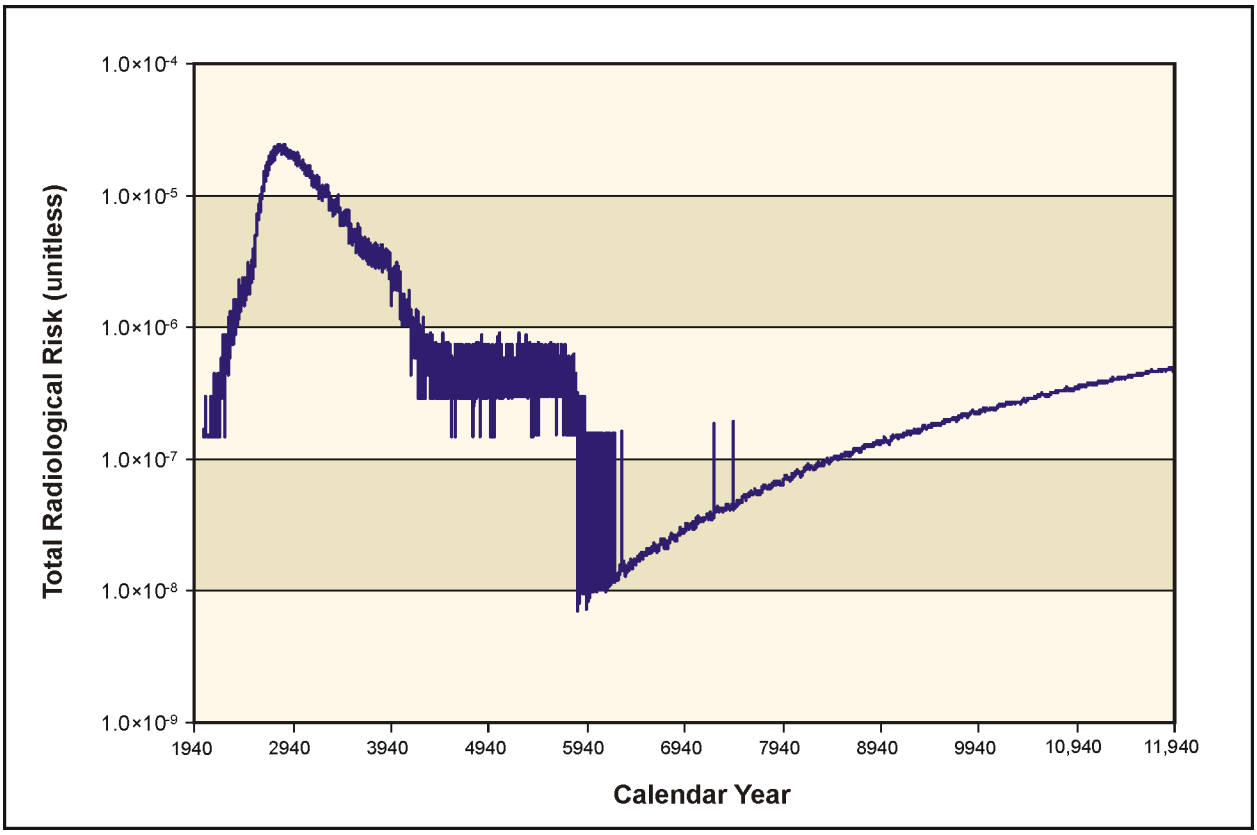


Figure 5–344. FFTF Decommissioning Alternative 2 Total Radiological Risk for Fast Flux Test Facility Barrier Drinking-Water Well User Versus Time

5.2.2.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, all aboveground structures, as well as contaminated below-grade structures, equipment, and materials would be removed. As a result of the removal of all contaminated material, there would be no impacts on groundwater, surface water, or human health.

5.2.3 Ecological Risk

This section presents the results of the evaluation of long-term impacts on ecological resources of releases to air and groundwater under the FFTF Decommissioning alternatives. Risk indices—Hazard Quotient or Hazard Index—were calculated by comparing predicted dose to benchmark dose (see Appendix P). Risk indices could not be calculated for lizards, toads, or birds for COPCs (organic compounds only) released under the FFTF Decommissioning alternatives because there are no toxicity reference values for such receptors for these COPCs. Risk indices for air emissions were calculated for the three FFTF Decommissioning alternatives and the Hanford and Idaho Options and Reuse Options for FFTF Decommissioning Alternatives 2 and 3. Separate risk indices for air releases were not calculated for the three components of each alternative: disposition of facilities, RH-SCs, and bulk sodium. Calculated risk indices for the COPC with the highest Hazard Quotient or Hazard Index are presented for each receptor.

Releases to air are expected for Environmental Assessment-associated activities under the No Action Alternative (FFTF Decommissioning Alternative 1) and facility disposition under FFTF Decommissioning Alternatives 2 and 3. Releases to air associated with the disposition of RH-SCs and bulk sodium are expected under all FFTF Decommissioning alternatives at Hanford under the Hanford Option and Hanford Reuse Option and, under FFTF Decommissioning Alternatives 2 and 3, at both Hanford and INL under the Idaho Option and Idaho Reuse Option. The impacts on ecological resources

of releases to air were evaluated together for the disposition of RH-SCs and bulk sodium. The estimated impacts are identical under FFTF Decommissioning Alternatives 2 and 3 because the options for RH-SC disposition and bulk sodium disposition are identical under the two alternatives. There would be impacts of releases to groundwater associated with the FFTF Decommissioning Alternatives—No Action, Entombment, and Removal.

The long-term impacts on terrestrial ecological resources of releases to air at Hanford were evaluated at the onsite maximum-exposure location (Core Zone Boundary) and on terrestrial, riparian, and aquatic resources at the offsite maximum-exposure location (Columbia River). Impacts on ecological resources of releases to groundwater were evaluated at the Columbia River.

5.2.3.1 FFTF Decommissioning Alternative 1: No Action

The FFTF Decommissioning No Action Alternative is not expected to result in releases of radionuclides to air. Releases of chemicals to air are expected due to activities associated with the Environmental Assessment (see Section 5.2 and Chapter 2, Section 2.3). The calculated risks to plants, the Great Basin pocket mouse, and the coyote from air releases under FFTF Decommissioning Alternative 1 are the highest of all Tank Closure, FFTF Decommissioning, and Waste Management alternatives. Predicted emissions of COPCs in air under FFTF Decommissioning Alternative 1 pose a small risk to plants (Hazard Quotient is 47) and a moderate risk to mammals at the onsite maximum-exposure location (see Table 5–72). The chemical COPCs released to air with the largest calculated Hazard Quotients for the Great Basin pocket mouse are xylene (2120), toluene (338), formaldehyde (79), and benzene (17) at the onsite maximum-exposure location. The coyote has the next-largest calculated chemical COPC with the Hazard Quotient for xylene (269).

Table 5–72. FFTF Decommissioning Alternatives – Long-Term Impacts of Chemical COPC Releases to Air on Terrestrial Resources at the Onsite Maximum-Exposure Location

FFTF Decommissioning Alternative	Hazard Quotient of Worst-Case Chemical COPC by Receptor			
	Plants	**Great Basin Pocket Mouse**	**Coyote**	**Mule Deer**
	Toluene	**Xylene**	**Xylene**	**Formaldehyde**
1	4.68×10^{1}	$\mathbf{2.12\times10^{3}}$	2.69×10^{2}	4.79×10^{1}
2	1.63×10^{-1}	**7.60**	9.65×10^{-1}	6.09×10^{-1}
3	1.64×10^{-1}	**7.65**	9.71×10^{-1}	5.79×10^{-1}

Note: The maximum Hazard Quotient under each alternative is indicated by **bold** text. Results are not available for other terrestrial receptors: side-blotched lizard, mourning dove, western meadowlark, and burrowing owl.
Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility.

There would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under FFTF Decommissioning Alternative 1 at the offsite maximum-exposure location (Columbia River). The only estimated Hazard Quotient exceeding 1 is xylene for the mouse (2.4). This value is well within the margin of error of the uncertainties in the estimated exposure and toxicity.

Predicted emissions of chemical and radiological COPCs in groundwater discharging at the Columbia River do not pose a risk to ecological receptors. The largest risk index (Hazard Index is 0.00001) for groundwater releases under FFTF Decommissioning Alternative 1 (see Table 5–73) is that calculated for total internal and external exposure to all radiological COPCs for birds eating benthic invertebrates (the spotted sandpiper) at the Columbia River. This indicates no risk to ecological receptors from chemical or radiological COPCs released to groundwater at Hanford under FTFF Decommissioning Alternative 1.

Table 5–73. FFTF Decommissioning Alternatives – Long-Term Impacts of Contaminant Releases to Groundwater on Aquatic and Riparian Resources at the Columbia River

FFTF Decommissioning Alternative	Hazard Quotient or Hazard Index of Worst-Case Chemical or Radiological COPC by Receptor						
	Benthic Invertebrate	Muskrat	Spotted Sandpiper	Raccoon	Least Weasel	Bald Eagle	Aquatic Biota/Salmonids
	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs	All Rad. COPCs
1	1.05×10^{-6}	9.76×10^{-6}	1.07×10^{-5}	1.01×10^{-5}	5.60×10^{-6}	1.98×10^{-6}	9.42×10^{-7}
2	7.43×10^{-7}	6.69×10^{-6}	7.65×10^{-6}	7.06×10^{-6}	5.10×10^{-6}	1.80×10^{-6}	8.56×10^{-7}
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Key: COPC=constituent of potential concern; FFTF=Fast Flux Test Facility; N/A=not applicable; Rad.=radiological.

5.2.3.2 FFTF Decommissioning Alternative 2: Entombment

Under FFTF Decommissioning Alternative 2, long-term impacts on ecological resources were evaluated for releases to air and groundwater at Hanford (Hanford and Hanford Reuse Options) and releases to air at Idaho (Idaho and Idaho Reuse Options) associated with the disposition of FFTF and associated facilities, RH-SCs, and bulk sodium.

Predicted emissions of COPCs in the air at Hanford under FFTF Decommissioning Alternative 2 (Hanford and Idaho Options) do not pose a risk to ecological receptors. The chemical COPC with the largest calculated Hazard Quotient for air releases is xylene for the mouse (7.6) at the onsite maximum-exposure location under the Hanford Option (see Table 5–72). This is within the margin of error of the uncertainties in the estimated exposure and toxicity of COPCs. Hazard Quotients calculated for chemical COPCs released to air under FFTF Decommissioning Alternative 2, Idaho Option, are about half as large as those under the Hanford Option. The largest Hazard Index (6.6×10^{-6}) for radiological COPCs released to air under FFTF Decommissioning Alternative 2, Hanford Option (see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location, with tritium as the primary contributor. This Hazard Index, much smaller than 1, indicates no risk from radiological COPCs released to air at Hanford under FFTF Decommissioning Alternative 2, either Hanford or Idaho Option. Also, there would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases to air under FFTF Decommissioning Alternative 2 at the offsite maximum-exposure location (Columbia River) under both Hanford and Idaho Options.

Although risk indices were not calculated for ecological receptors at INL, the relative magnitude of emissions there suggests little to no risk. For the disposition of RH-SCs and bulk sodium under FFTF Decommissioning Alternative 2, Idaho and Idaho Reuse Options, the predicted peak annual emissions of tritium (5.72 curies per year) and cesium-137 (3.3×10^{-4} curies per year) at INL are orders of magnitude smaller than the maximum emissions at Hanford under any *TC & WM EIS* alternative (1.22×10^{3} curies per year for tritium, 2.5×10^{2} curies per year for cesium-137). The emissions of COPCs at INL would be smaller than emissions at Hanford under at least one of the Tank Closure, FFTF Decommissioning, or Waste Management alternatives (see Table 5–74). There would be no releases of mercury at INL. Because predicted emissions of COPCs do not pose a risk to ecological receptors at Hanford, the smaller rates at INL are unlikely to pose a risk to similar ecological receptors with similar exposure pathways.

Predicted emissions of chemical and radiological COPCs in groundwater discharging at the Columbia River do not pose a risk to ecological receptors. The largest risk index (Hazard Index is 0.000008) for groundwater releases under FFTF Decommissioning Alternative 2 (Table 5–73) is that calculated for total internal and external exposure to all radiological COPCs for birds eating benthic invertebrates (the spotted sandpiper) at the Columbia River. This indicates no risk to ecological receptors from chemical or radiological COPCs released to groundwater at Hanford under FTFF Decommissioning Alternative 2.

5.2.3.3 FFTF Decommissioning Alternative 3: Removal

Under FFTF Decommissioning Alternative 3, long-term impacts on ecological resources were evaluated for releases to air and groundwater at Hanford (Hanford Option) and releases to air at Idaho (Idaho Option).

Predicted emissions of COPCs in air at Hanford under FFTF Decommissioning Alternative 3 (Hanford and Idaho Options) are similar to those under FFTF Decommissioning Alternative 2 and do not pose a risk to ecological receptors. The chemical COPC with the largest calculated Hazard Quotient (xylene, 7.65) is for the mouse at the onsite maximum-exposure location (see Table 5–72). Hazard Quotients calculated for chemical COPCs released to air under FFTF Decommissioning Alternative 3, Idaho Option, are about half as large as those under the Hanford Option. The largest Hazard Index (6.6×10^{-6}) for radiological COPCs released to air under FFTF Decommissioning Alternative 3, Hanford Option

(see Appendix P, Table P–3), is predicted for the mouse at the onsite maximum-exposure location, primarily from tritium. This indicates no risk from radiological COPCs released to air at Hanford under FFTF Decommissioning Alternative 3, either Hanford or Idaho Option. There also would be no risk to terrestrial, riparian, or aquatic ecological receptors from releases of COPCs to air under FFTF Decommissioning Alternative 3 at the offsite maximum-exposure location (Columbia River).

Although risk indices were not calculated for ecological receptors at INL, the relative magnitude of emissions there suggests little to no risk. For the disposition of RH-SCs and bulk sodium under FFTF Decommissioning Alternative 3, Idaho and Idaho Reuse Options, the predicted peak annual emissions of tritium (5.72 curies per year) and cesium-137 (3.30×10^{-4} curies per year) at INL are orders of magnitude smaller than the maximum emissions at Hanford under any *TC & WM EIS* alternative (1.22×10^{3} curies per year for tritium, 2.50×10^{2} curies per year for cesium-137). The emissions of COPCs at INL would be smaller than emissions at Hanford under at least one of the Tank Closure, FFTF Decommissioning, or Waste Management alternatives (see Table 5–74). There would be no releases of mercury at INL. Because predicted emissions of COPCs under FFTF Decommissioning Alternative 3 do not pose a risk to ecological receptors at Hanford, the smaller rates at INL are unlikely to pose a risk to similar ecological receptors with similar exposure pathways.

Table 5–74. Comparison of Peak Annual Emission Rates at INL Under FFTF Decommissioning Alternatives 2 and 3 and at the Hanford Site Under Tank Closure Alternatives

Constituent of Potential Concern	INL	Hanford	Alternative
Radionuclide (curies per year)			
Hydrogen-3 (tritium)	5.72	1.22×10^{3}	Tank Closure 2A
Carbon-14	0	N/A	N/A
Cobalt-60	0	N/A	N/A
Strontium-90	0	N/A	N/A
Technetium-99	0	N/A	N/A
Iodine-129	0	N/A	N/A
Cesium-137	3.30×10^{-4}	2.50×10^{2}	Tank Closure 6B
Uranium (all isotopes)	0	N/A	N/A
Plutonium-238	0	N/A	N/A
Plutonium-239, -240	0	N/A	N/A
Plutonium-241	0	N/A	N/A
Americium-241	0	N/A	N/A
Chemical (grams per year)			
Nitrogen dioxide	0	N/A	N/A
Sulfur dioxide	2.26×10^{3}	5.60×10^{7}	Tank Closure 2B
Ammonia	0	N/A	N/A
Benzene	0	N/A	N/A
Toluene	1.71×10^{4}	5.50×10^{6}	Tank Closure 5
Xylene	4.87×10^{3}	1.60×10^{6}	Tank Closure 5
1,3-Butadiene	1.55×10^{1}	2.58×10^{4}	Waste Management 3 (Disposal Group 2)
Mercury	0	N/A	N/A
Formaldehyde	0	N/A	N/A

Note: To convert grams to ounces, multiply by 0.03527.

Key: FFTF=Fast Flux Test Facility; INL=Idaho National Laboratory; N/A=not applicable because constituent not released at INL.

Under FFTF Decommissioning Alternative 3, all aboveground structures, as well as contaminated below grade structures, equipment, and materials would be removed. As a result of the removal of all contaminated material, there would be no impacts on ecological receptors resulting from releases to groundwater.

5.2.4 Environmental Justice

Sections 5.2.1 and 5.2.2 evaluate groundwater impacts and associated potential long-term human health effects under the FFTF Decommissioning alternatives. Receptors analyzed with a potential for environmental justice concerns include a resident farmer, an American Indian resident farmer, and an American Indian hunter-gatherer. The hypothetical resident farmer, which could represent a low-income population, and American Indian resident farmer were both assumed to use only groundwater for drinking water ingestion and crop irrigation. While only a portion of the food consumed by the resident farmer was assumed to come from crops and animal products exposed to contaminated groundwater, all of the food consumed by the American Indian resident farmer was assumed to be exposed to contaminated groundwater. The American Indian hunter-gatherer was assumed to have a subsistence consumption pattern that differing from that of the American Indian resident farmer. The American Indian hunter gatherer does not cultivate crops but gathers food from indigenous plants, harvests fish from the Columbia River, and is exposed to a combination of surface water and groundwater. Given these assumptions, the two American Indian receptors would be most at risk from contaminated groundwater. These receptors were used to develop exposure scenarios at several on- and offsite locations identified in Appendix Q, Section Q.2.1. Long-term human health impacts of FFTF decommissioning actions would be greatest under FFTF Decommissioning Alternative 1. Under this alternative, none of the hypothetical receptors at any of the assessment boundaries would be exposed to radiological doses in excess of regulatory limits or to chemicals with a Hazard Index greater than 1. The greatest risk would be to the American Indian resident farmer at the FFTF boundary. During the year of peak dose, this receptor would receive a radiological dose of 3.8 millirem, compared to the regulatory limit of 100 millirem from all sources. During the year of peak Hazard Index, this receptor would be exposed to chemicals resulting in a Hazard Index less than 1. Therefore, none of the FFTF Decommissioning alternatives would pose a disproportionately high and adverse long-term human health risk to the American Indian population at offsite locations.

5.3 WASTE MANAGEMENT ALTERNATIVES

This section describes the potential long-term environmental impacts associated with the implementation of alternatives for administering ongoing solid waste management operations and proposed disposal of low-level radioactive waste (LLW) and mixed low-level radioactive waste (MLLW) from Hanford and a limited volume of offsite LLW and MLLW in an IDF located at Hanford. Specifically, this includes the management and disposal of LLW and MLLW from tank closure activities as described in Chapter 4, Section 4.1.14, as well as other non–Comprehensive Environmental Response, Compensation, and Liability Act (non-CERCLA) LLW and MLLW from Hanford, including the waste from FFTF decommissioning described in Chapter 4, Section 4.2.14, and waste from other DOE sites (i.e., offsite waste). This section analyzes the impacts of expanding Hanford's waste disposal capacity to provide space for on- and offsite waste; this section also includes an analysis of associated storage, disposal, and closure activities, as well as facility-specific construction, operations, deactivation, and closure activities.

Three Waste Management alternatives are considered and analyzed, including (1) Waste Management Alternative 1: No Action; (2) Waste Management Alternative 2: Disposal in IDF, 200-East Area Only; and (3) Waste Management Alternative 3: Disposal in IDF, 200-East and 200-West Areas.

Waste Management Alternative 1 would include storing and disposing of LLW and MLLW in trenches 31 and 34 of existing low-level radioactive waste burial ground (LLBG) 218-W-5 and storing and disposing of transuranic (TRU) waste in the Waste Isolation Project Plant (WIPP) near Carlsbad, New Mexico. No offsite waste would be received; construction/use of the IDF located in the 200-East Area (IDF-East) would be discontinued; and IDF-East would be deactivated.

Waste Management Alternative 2 would include storing LLW, MLLW, and TRU waste in the Central Waste Complex (CWC) prior to disposal and processing waste prior to disposal at new facilities or existing-facility expansions at the CWC, Waste Receiving and Processing Facility, and the T Plant. A total volume of 62,000 cubic meters (2.2 million cubic feet) of LLW and 20,000 cubic meters (706,300 cubic feet) of MLLW from other DOE sites would be received for disposal under this alternative. Waste from tank closure and treatment operations, onsite non-CERCLA sources, FFTF decommissioning, and waste management, as well as offsite waste from other DOE sites would be disposed of in IDF-East. A new RPPDF would be constructed for disposal of lightly contaminated equipment and soils as a result of tank farm clean closure activities.

Waste Management Alternative 3 would involve the same waste storage and processing provisions as Waste Management Alternative 2 and the same volume of offsite waste accepted for disposal; a new RPPDF would also be constructed. However, an additional IDF would be constructed in the 200-West Area (IDF-West). Waste from tank closure and treatment operations would be disposed of in IDF-East, while onsite non-CERCLA waste, FFTF decommissioning waste, waste management, and offsite waste from other DOE sites would be disposed of in IDF-West.

In addition, under each Waste Management action alternative (i.e., Alternatives 2 and 3), three disposal groupings are analyzed: Disposal Groups 1, 2, and 3. These disposal groupings encompass the sizing requirements and associated construction, operations, and closure requirements for the IDF(s) and RPPDF necessary to accommodate the varying waste volumes considered under each disposal configuration. These alternatives and options are described further in Chapter 2, Section 2.5, of this EIS.

These disposal groupings are further divided into subgroupings for the consideration of the different types and volumes of waste generated from the 10 Tank Closure action alternatives and the 2 FFTF Decommissioning action alternatives to analyze the long-term impacts associated with disposal of the various waste types and volumes. These subgroupings are described in Table 5–75.

Table 5–75. Waste Management Action Alternative Subgroupings

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
1	N/A	LLBG, trenches 31 and 34	N/A	Non-CERCLA waste
2	Disposal Group 1, Subgroup 1-A	IDF-East	Tank Closure Alternative 2B • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 2B • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-B	IDF-East	Tank Closure Alternative 3A • ILAW glass • Bulk vitrification glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3A • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-C	IDF-East	Tank Closure Alternative 3B • ILAW glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3B • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-D	IDF-East	Tank Closure Alternative 3C • ILAW glass • Steam reforming waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3C • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 1, Subgroup 1-E	IDF-East	Tank Closure Alternative 4 • ILAW glass • Bulk vitrification glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 4 • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
2	Disposal Group 1, Subgroup 1-F	IDF-East	Tank Closure Alternative 5 • ILAW glass • Bulk vitrification glass • Cast stone waste • Sulfate grout • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
2	Disposal Group 1, Subgroup 1-G	IDF-East	Tank Closure Alternative 6C • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6C • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 2, Subgroup 2-A	IDF-East	Tank Closure Alternative 2A • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
2	Disposal Group 2, Subgroup 2-B	IDF-East	Tank Closure Alternative 6B, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6B, Base and Option Cases • Closure waste (LLW and MLLW)	N/A
2	Disposal Group 3	IDF-East	Tank Closure Alternative 6A, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6A, Base and Option Cases • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 1, Subgroup 1-A	IDF-East	Tank Closure Alternative 2B • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 2B • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-B	IDF-East	Tank Closure Alternative 3A • ILAW glass • Bulk vitrification glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3A • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-C	IDF-East	Tank Closure Alternative 3B • ILAW glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3B • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-D	IDF-East	Tank Closure Alternative 3C • ILAW glass • Steam reforming waste • LAW melters • Secondary Waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 3C • Closure waste (LLW and MLLW)	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 1, Subgroup 1-E	IDF-East	Tank Closure Alternative 4 • ILAW glass • Bulk vitrification glass • Cast stone waste • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 4 • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 1, Subgroup 1-F	IDF-East	Tank Closure Alternative 5 • ILAW glass • Bulk vitrification glass • Cast stone waste • Sulfate grout • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A
3	Disposal Group 1, Subgroup 1-G	IDF-East	Tank Closure Alternative 6C • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6C • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 2, Subgroup 2-A	IDF-East	Tank Closure Alternative 2A • ILAW glass • LAW melters • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	N/A	N/A

Table 5-75. Waste Management Action Alternative Subgroupings *(continued)*

Waste Management Alternative	Disposal Group and Subgroup	Disposal Location	Tank Closure Alternative Waste	Other DOE Waste
3	Disposal Group 2, Subgroup 2-B	IDF-East	Tank Closure Alternative 6B, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6B, Base and Option Cases • Closure waste (LLW and MLLW)	N/A
3	Disposal Group 3	IDF-East	Tank Closure Alternative 6A, Base and Option Cases • PPF melters • PPF glass • Secondary waste (LLW and MLLW)	N/A
		IDF-West	N/A	FFTF decommissioning waste Onsite secondary waste Non-CERCLA waste Offsite waste
		RPPDF	Tank Closure Alternative 6A, Base and Option Cases • Closure waste (LLW and MLLW)	N/A

Key: CERCLA=Comprehensive Environmental Response, Compensation, and Liability Act; DOE= U.S. Department of Energy; FFTF=Fast Flux Test Facility; IDF-East=200-East Area Integrated Disposal Facility; IDF-West=200-West Area Integrated Disposal Facility; ILAW=immobilized low-activity waste; LAW=low-activity waste; LLBG=low-level radioactive waste burial ground; LLW=low-level radioactive waste; MLLW=mixed low-level radioactive waste; N/A=not applicable; PPF=Preprocessing Facility; RPPDF=River Protection Project Disposal Facility.

5.3.1 Groundwater

5.3.1.1 Waste Management Alternative 1: No Action

This section describes the groundwater analysis results for Waste Management Alternative 1, including long-term groundwater impacts of contaminant sources within the Trenches 31 and 34 Barrier. Impacts of sources remaining within the tank farm barriers are presented in Section 5.1, which discusses tank closure impacts. Impacts of sources remaining within the FFTF Barrier are presented in Section 5.2, which discusses FFTF decommissioning impacts.

5.3.1.1.1 Actions and Timeframes Influencing Groundwater Impacts

Summaries of the proposed actions and timelines for Waste Management Alternative 1 are provided in Chapter 2, Section 2.5. For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 1, as follows:

- The disposal period was assumed to start with the onset of disposal operations in LLBG 218-W-5, trenches 31 and 34, in CY 2008 and continue through CY 2035, when the trenches would be operationally closed. During this time, these trenches have accepted, and would continue to

accept, onsite non-CERCLA LLW and MLLW. During the disposal period, the materials in this permitted, operational facility would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2036 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the trenches become available for release to the environment. Waste Management Alternative 1 does not include construction of barriers over trenches 31 and 34. However, the surrounding LLBG 218-W-5, which is included in the cumulative impact analysis, would have a barrier emplaced consistent with the cumulative impact analysis end-state methodology (see Appendix S). For the purpose of analyzing long-term groundwater impacts under Waste Management Alternative 1, trenches 31 and 34 are assumed to be covered by a barrier that limits infiltration for the first 500 years of the post-disposal period.

5.3.1.1.2 COPC Drivers

A total of 40 COPCs were analyzed for Waste Management Alternative 1. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 1 is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 1 were selected by evaluating the risk or hazard associated with all 40 COPCs in the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 1.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

5.3.1.1.3 Analysis of Release and Mass Balance

This section presents the impacts of Waste Management Alternative 1 in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–345 through 5–350). Two subtotals are plotted representing releases from trenches 31 and 34. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over three orders of magnitude.

Figure 5–345 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–346, the chemical hazard drivers. For both sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). Trenches 31 and 34 are equal sources for all COPCs.

Figure 5–347 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–348, the chemical hazard drivers. In addition to the inventory considerations discussed in the

previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All COPCs act as conservative tracers, and essentially all of the release to the vadose zone reached groundwater in the analysis.

Figure 5–349 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–350, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. In all cases, nearly 100 percent of the amount released to groundwater reached the Columbia River in the analysis.

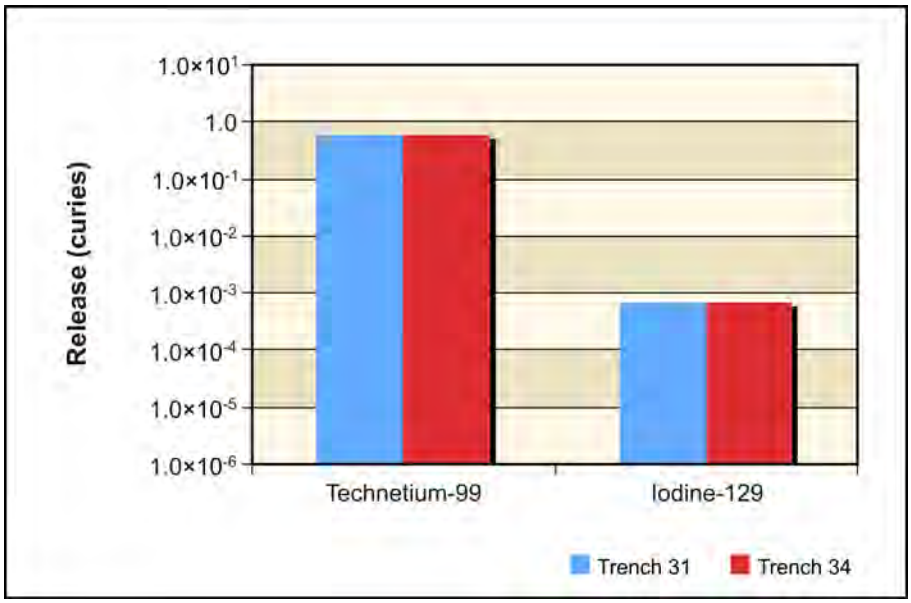


Figure 5–345. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

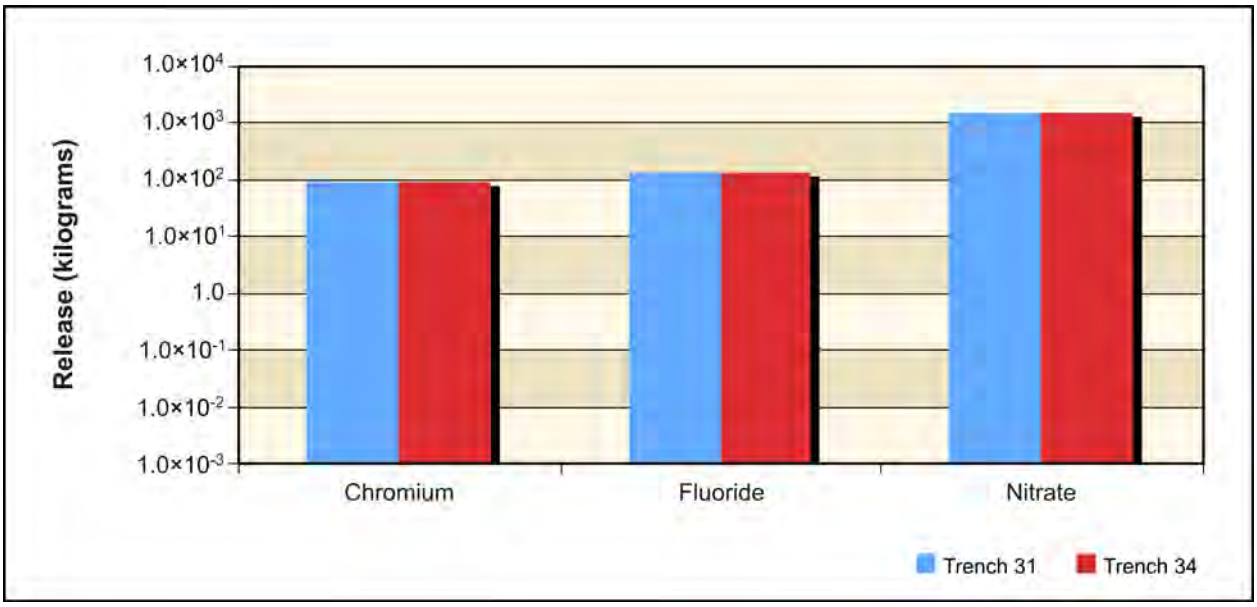


Figure 5–346. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

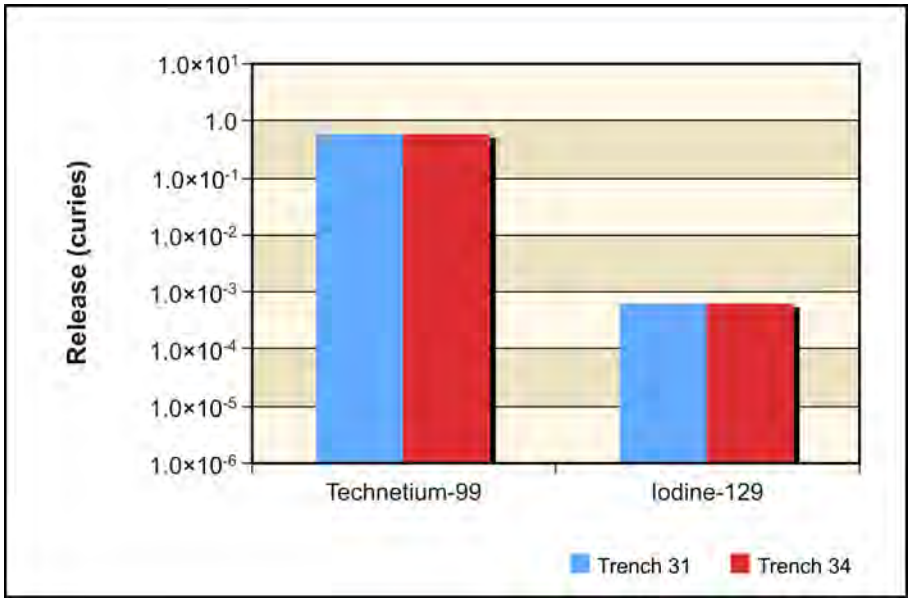


Figure 5–347. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

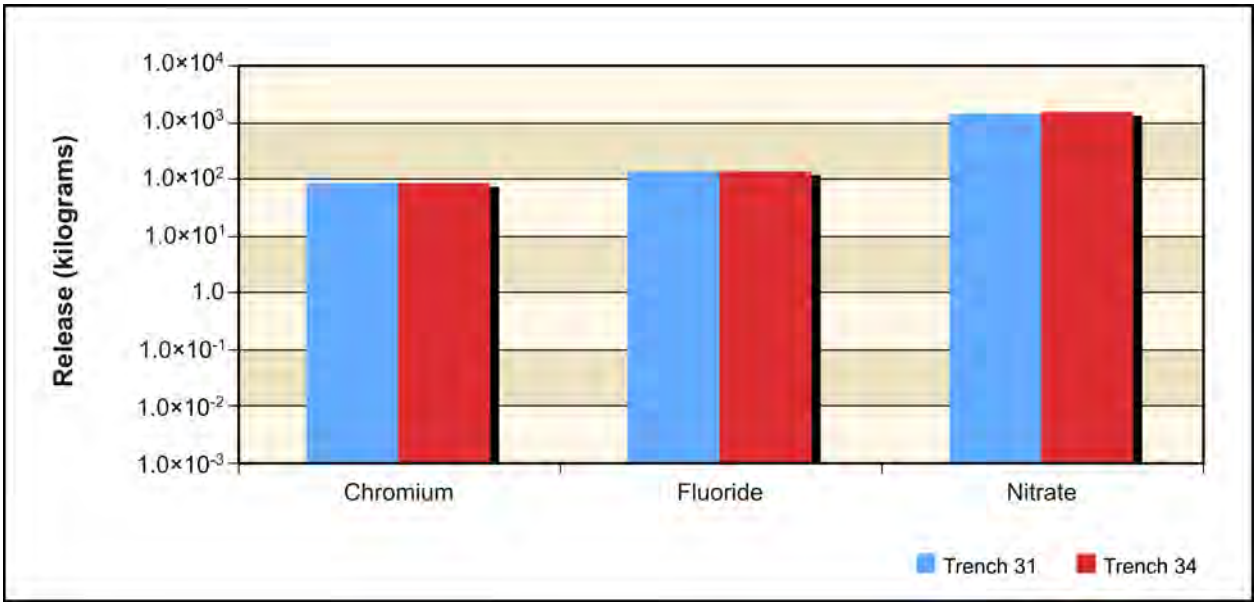


Figure 5–348. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility Groundwater

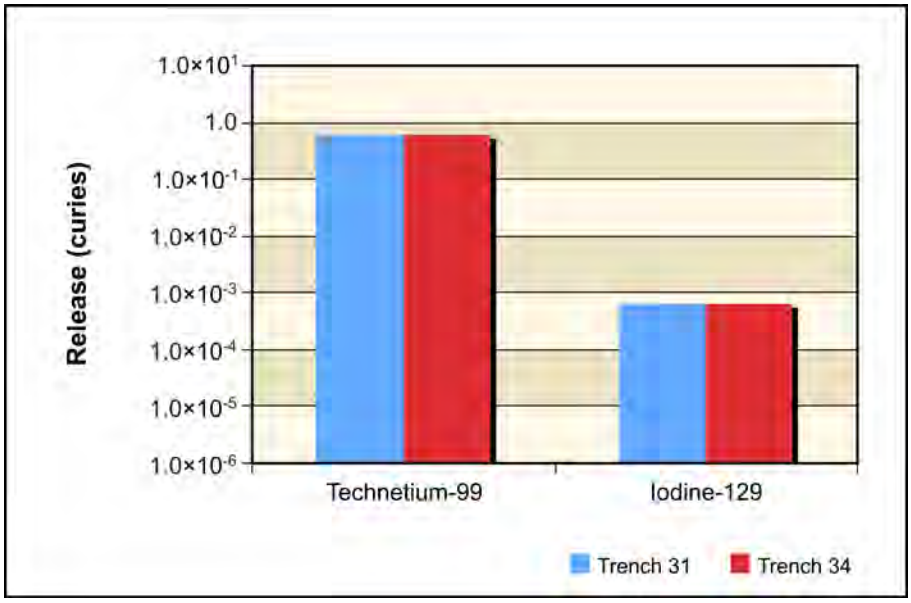


Figure 5–349. Waste Management Alternative 1, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

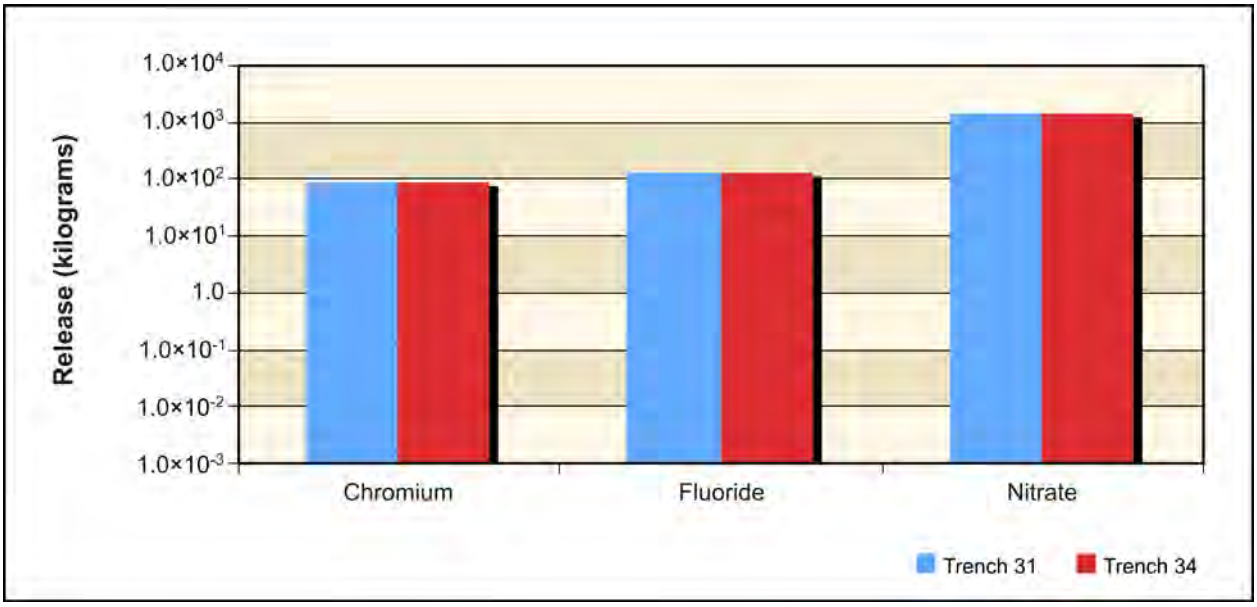


Figure 5–350. Waste Management Alternative 1, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

5.3.1.1.4 Analysis of Concentration Versus Time

This section presents the analysis of Waste Management Alternative 1 impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–351 through 5–356). The benchmark concentration for each radionuclide and chemical is also shown. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude. Table 5–76 lists the maximum concentrations of the COPCs in the peak year at trenches 31 and 34 and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–351 through 5–354 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). For technetium-99, concentrations at the Core Zone Boundary rise early in the simulation, reaching a peak of about two orders of magnitude below the benchmark between CYs 2940 and 3940. After the peak, concentrations decline for the remainder of the simulation. Iodine-129, chromium, and nitrate all follow similar patterns, although the peak concentration for nitrate at the Core Zone Boundary is over three orders of magnitude below the benchmark.

Figures 5–355 and 5–356 show concentration versus time for uranium-238 and total uranium. Because of the high retardation of uranium, no contamination appears until CY 8940, when uranium-238 concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Uranium-238 remains over four orders of magnitude below the benchmark throughout the simulation. Total uranium remains over seven orders of magnitude below the benchmark concentration at the Core Zone Boundary throughout the simulation.

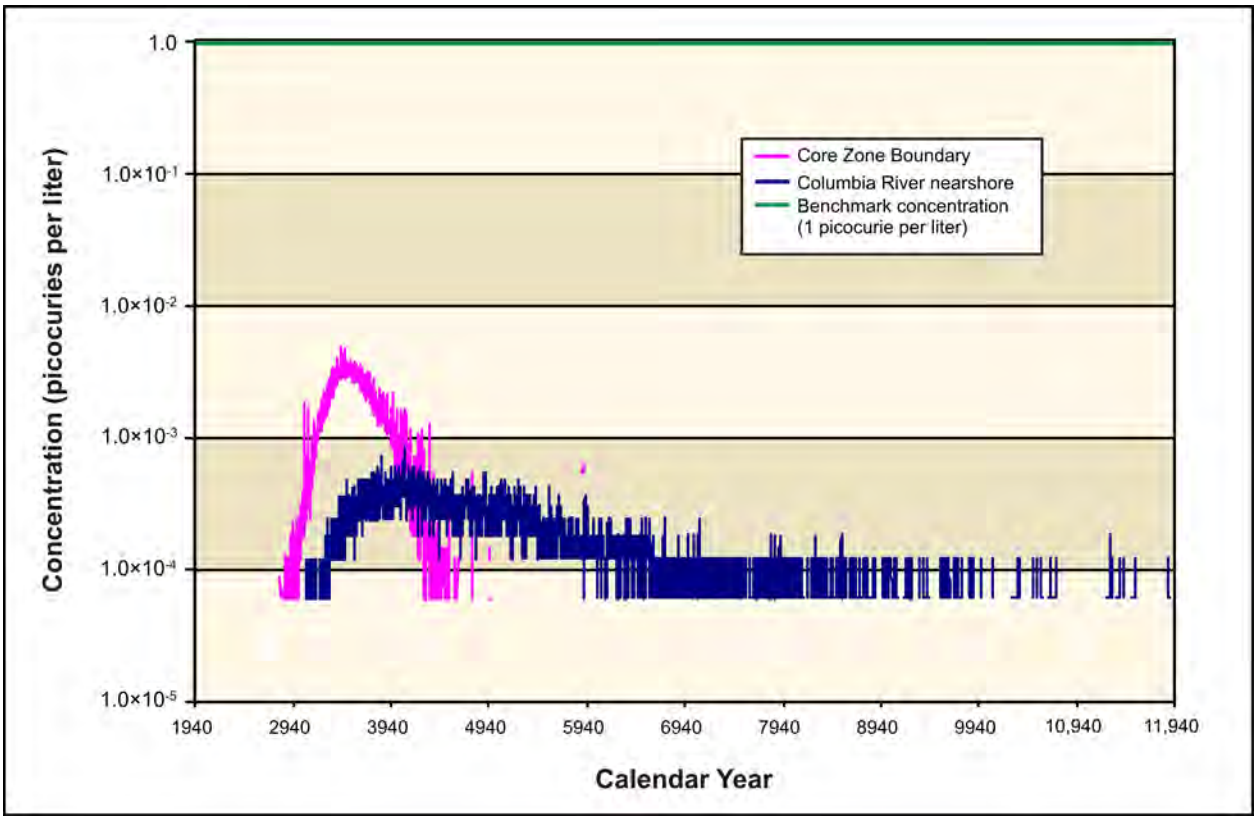


Figure 5–351. Waste Management Alternative 1, Iodine-129 Concentration Versus Time

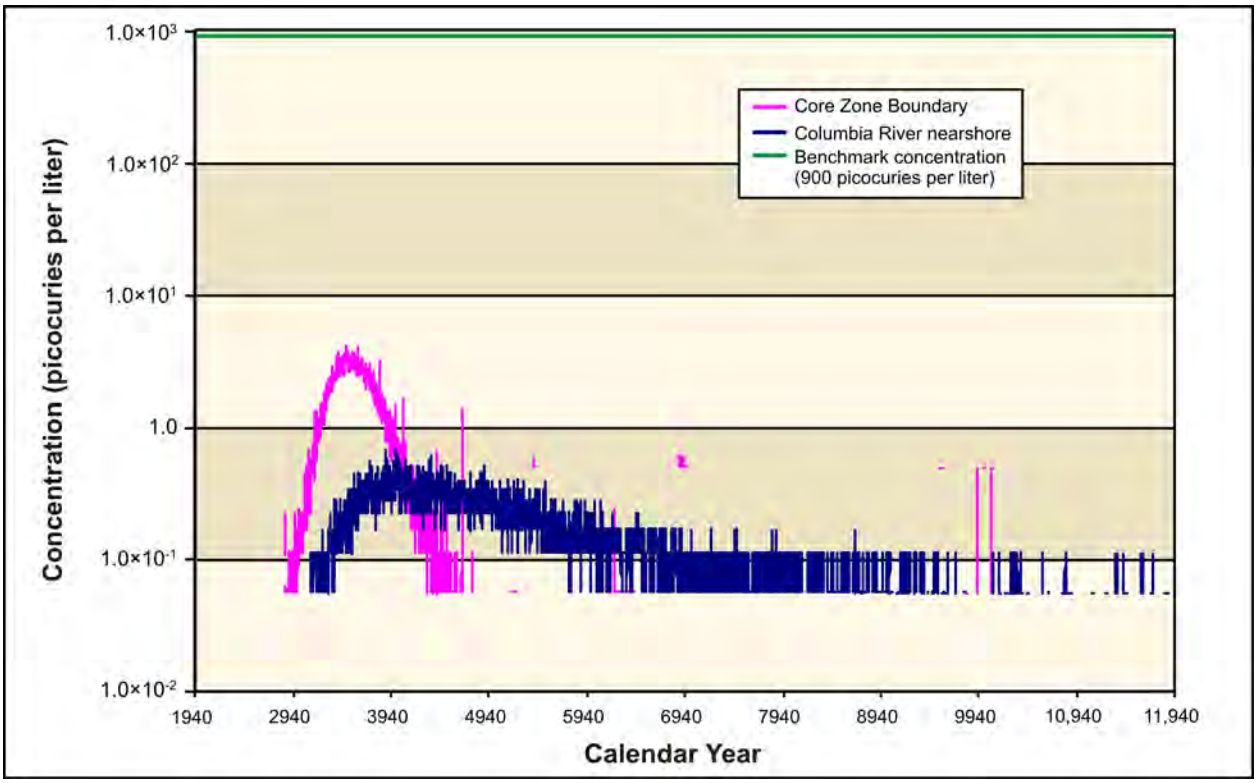


Figure 5–352. Waste Management Alternative 1, Technetium-99 Concentration Versus Time

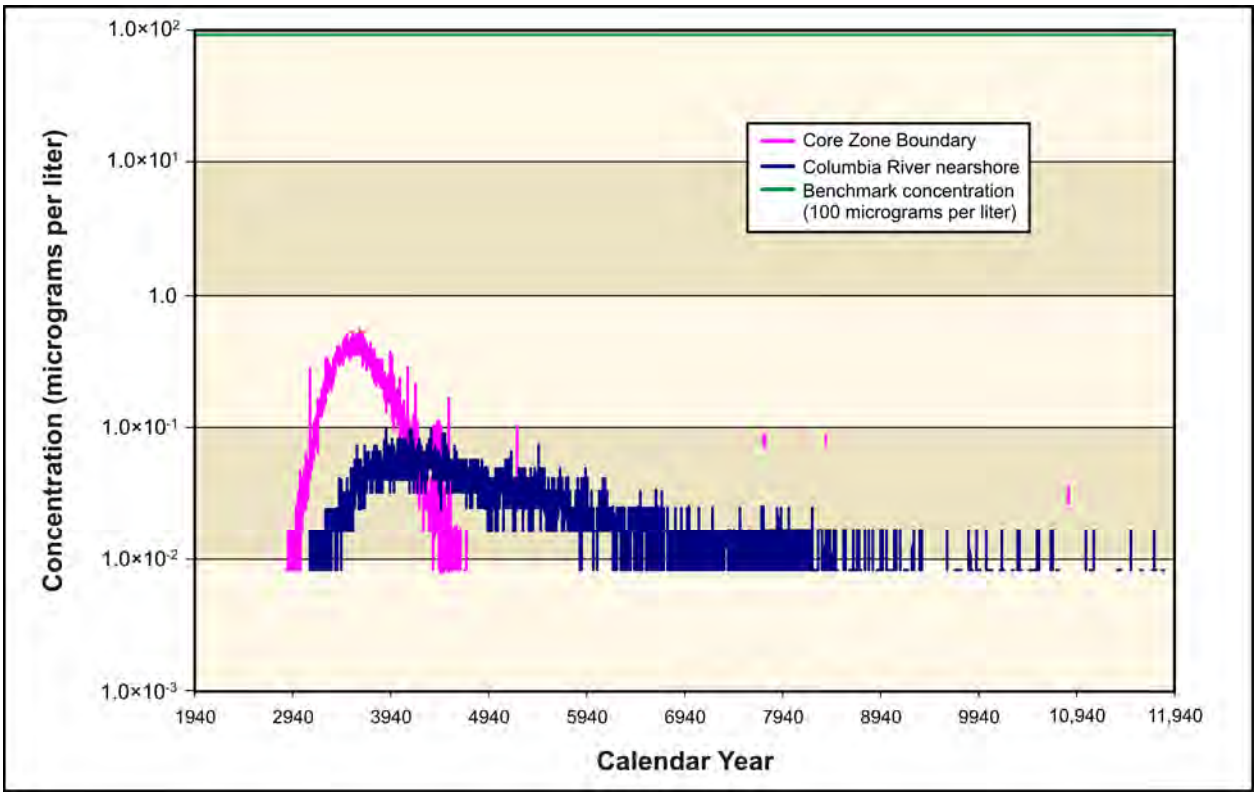


Figure 5–353. Waste Management Alternative 1, Chromium Concentration Versus Time

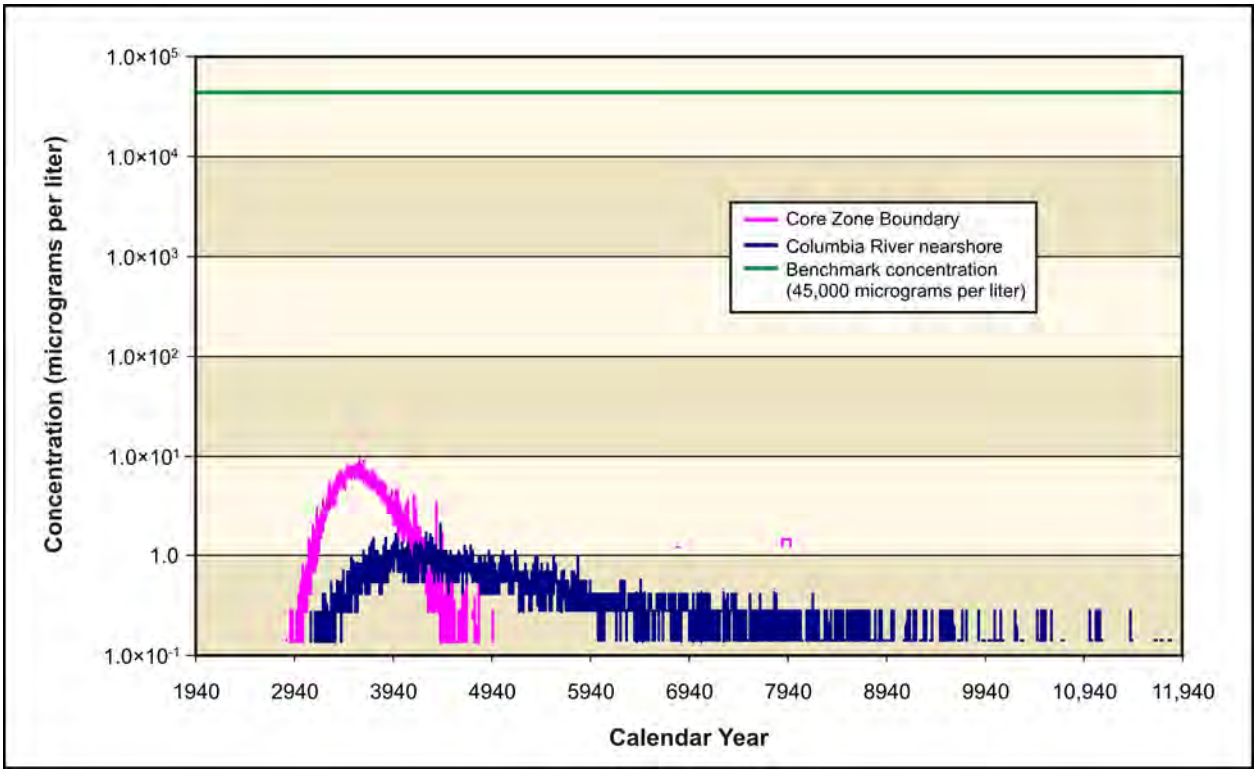


Figure 5–354. Waste Management Alternative 1, Nitrate Concentration Versus Time

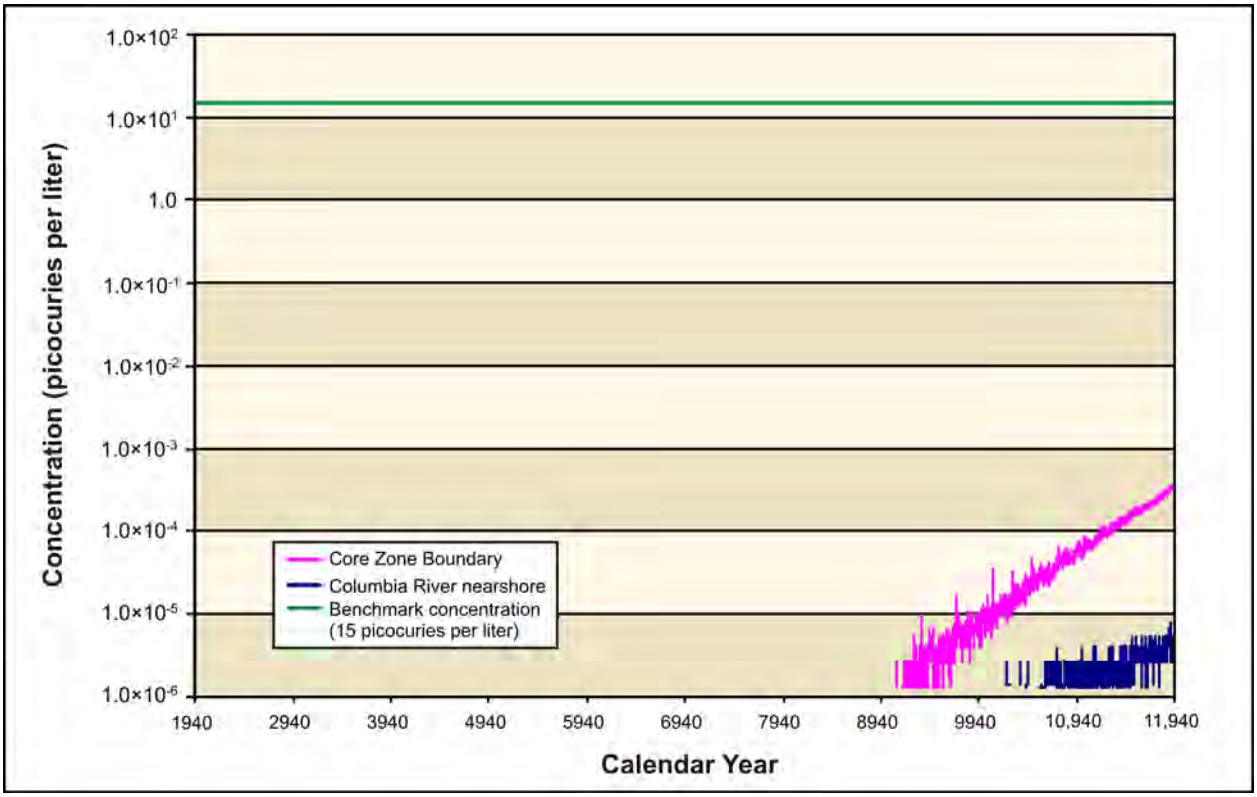


Figure 5–355. Waste Management Alternative 1, Uranium-238 Concentration Versus Time

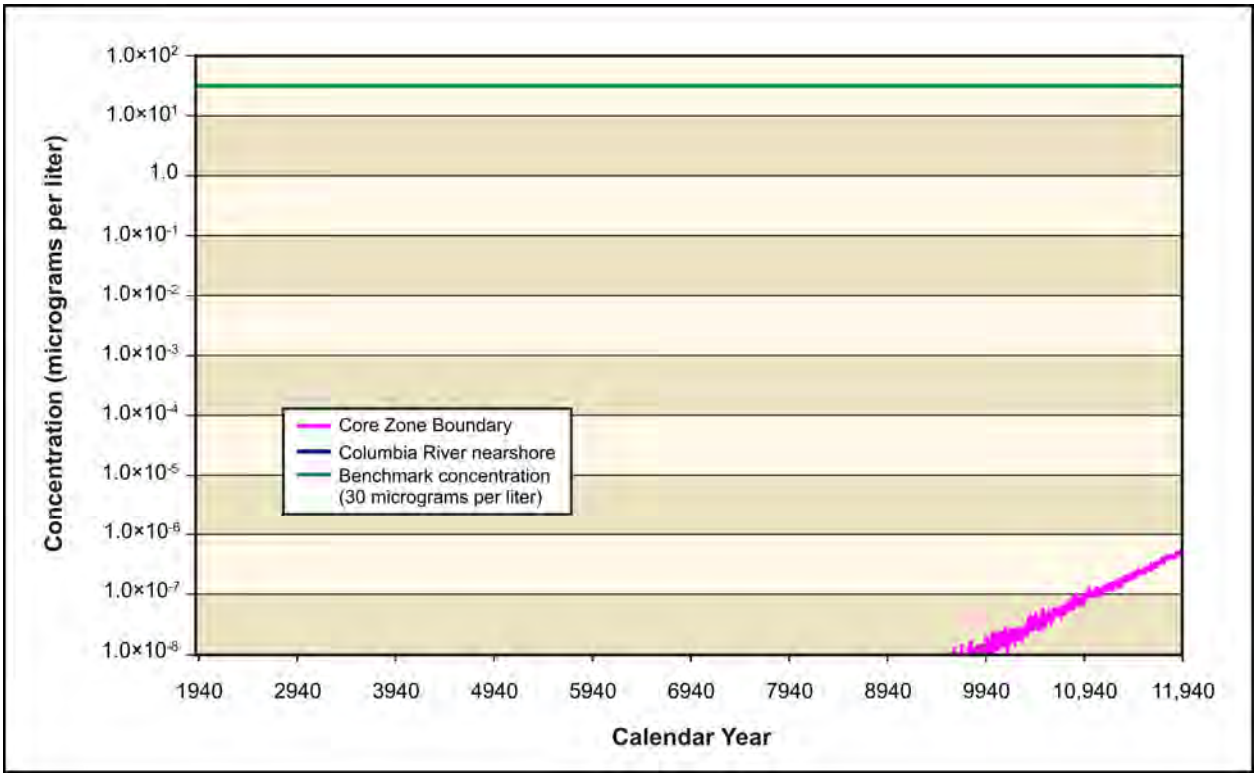


Figure 5–356. Waste Management Alternative 1, Total Uranium Concentration Versus Time

Table 5–76. Waste Management Alternative 1 Maximum COPC Concentrations in the Peak Year at Trenches 31 and 34, and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	Trenches 31 and 34	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	22 (3499)	N/A	4 (3474)	1 (3974)	900
Chemical in micrograms per liter					
Chromium	3 (3526)	N/A	1 (3615)	0 (4353)	100
Fluoride	4 (3545)	N/A	1 (3661)	0 (4592)	4,000
Nitrate	47 (3534)	N/A	9 (3600)	2 (4417)	45,000

Note: Corresponding calendar year shown in parentheses.
Key: COPC=constituent of potential concern; N/A=not applicable; RPPDF=River Protection Project Disposal Facility.

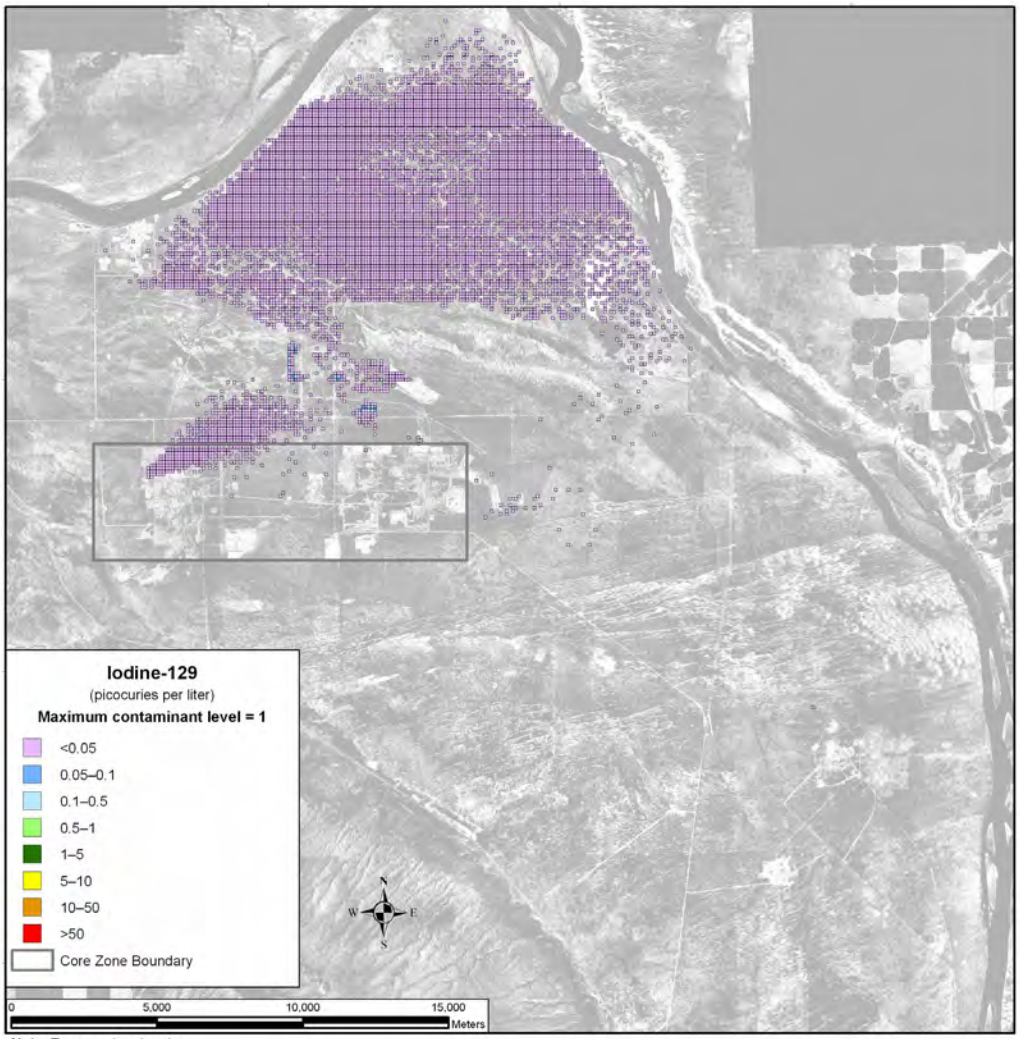
5.3.1.1.5 Analysis of Spatial Distribution of Concentration

This section presents the impacts of Waste Management Alternative 1 in terms of the spatial distribution of groundwater concentrations at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–357 through 5–366). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing

concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

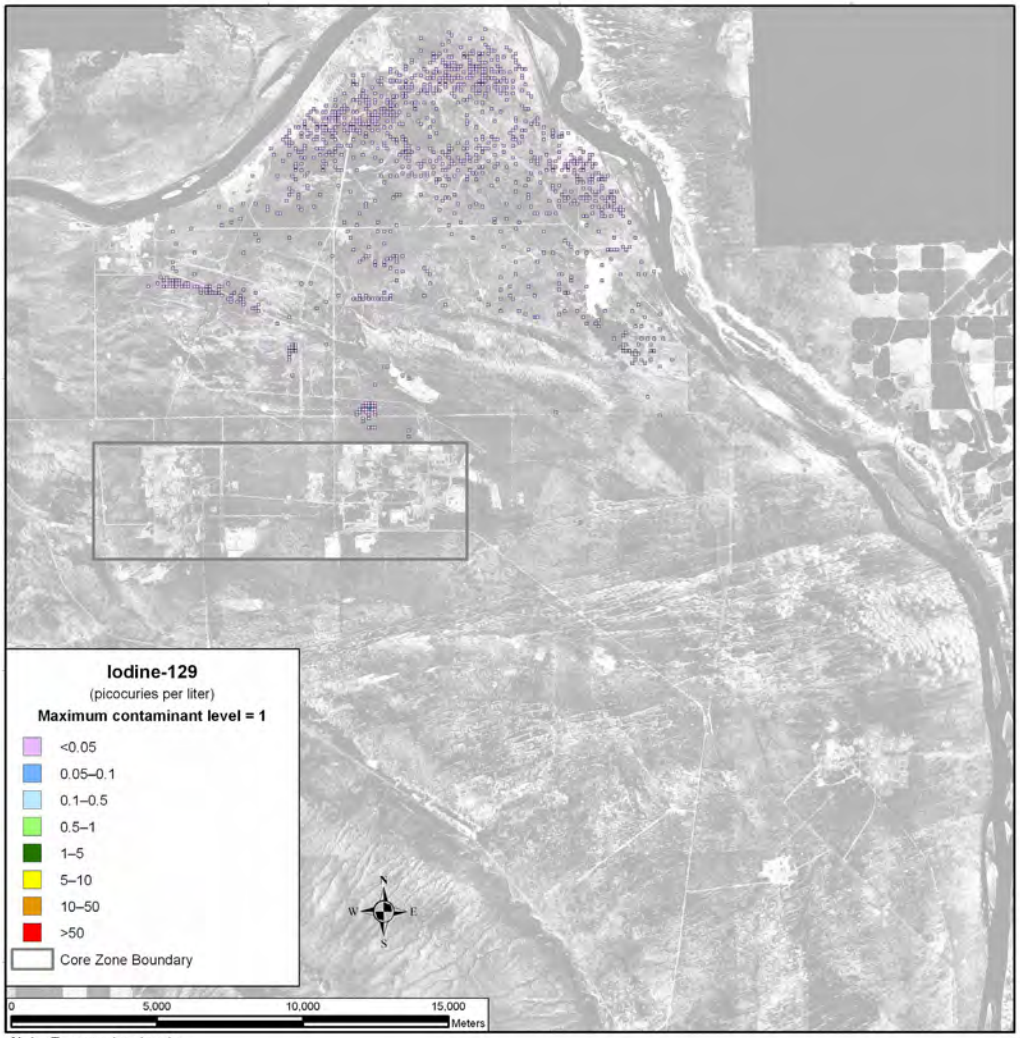
At CY 3890 (see Figure 5–357), there is a very low-concentration plume of iodine-129 stretching northeast of trenches 31 and 34 and through Gable Gap. By CY 7140 (Figure 5–358), the plume has almost completely dissipated. Technetium-99 (see Figures 5–359 and 5–360), nitrate (see Figures 5–361 and 5–362), and chromium (see Figures 5–363 and 5–364) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium and uranium-238 show a different spatial distribution over time. They are not as mobile as the COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. By CY 11,885, there are total uranium and uranium-238 plumes (see Figures 5–365 and 5–366, respectively) extending through Gable Gap from trenches 31 and 34. Concentrations in all areas of the plumes remain below one-twentieth of the benchmark.



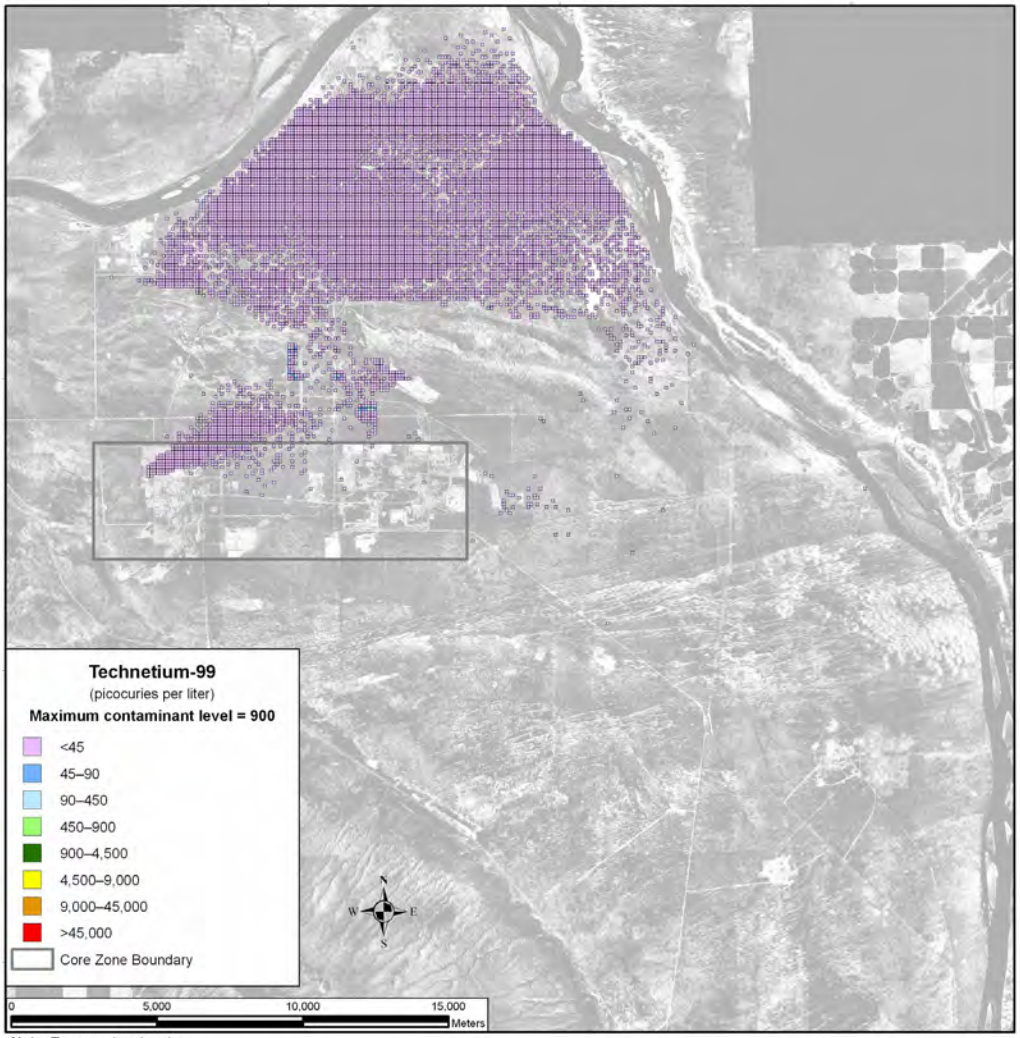
Note: To convert meters to feet, multiply by 3.281

Figure 5–357. Waste Management Alternative 1, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



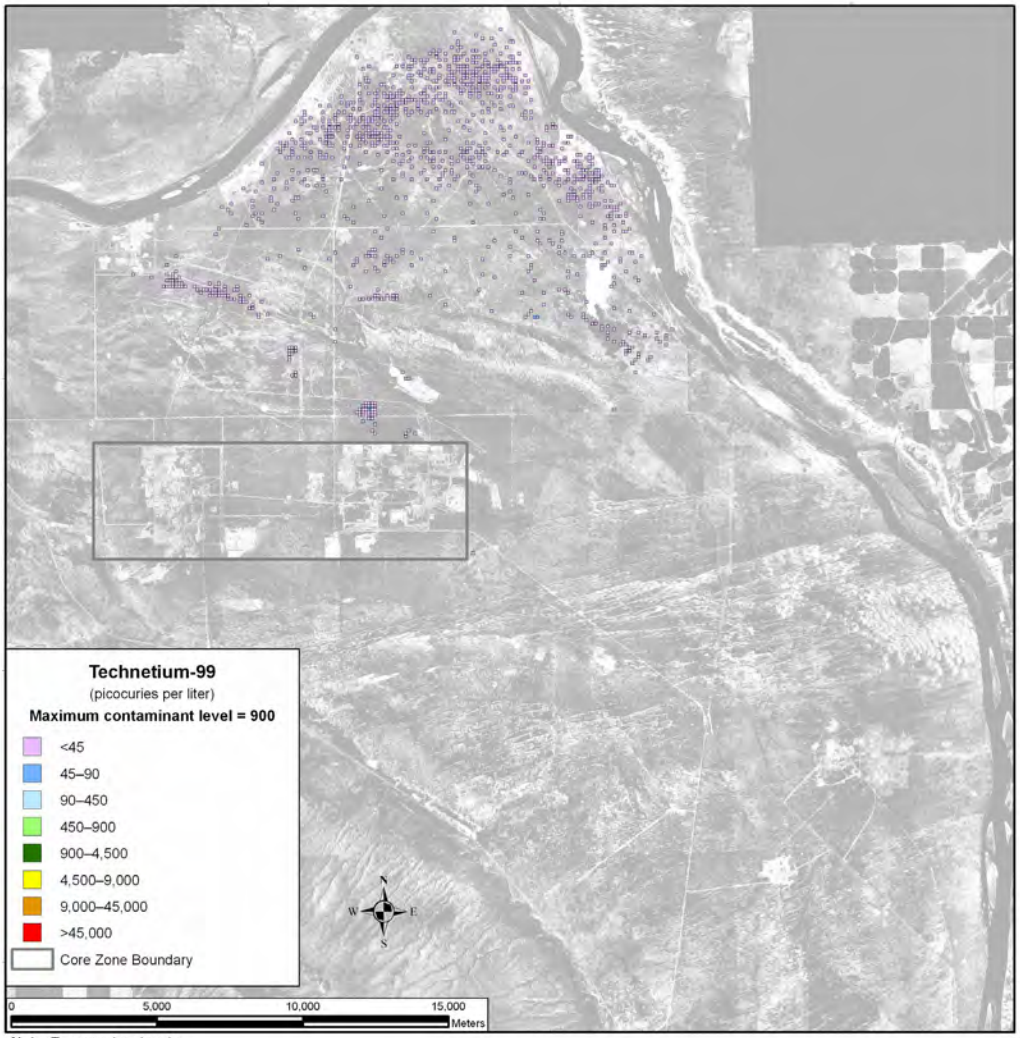
Note: To convert meters to feet, multiply by 3.281

Figure 5–358. Waste Management Alternative 1, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



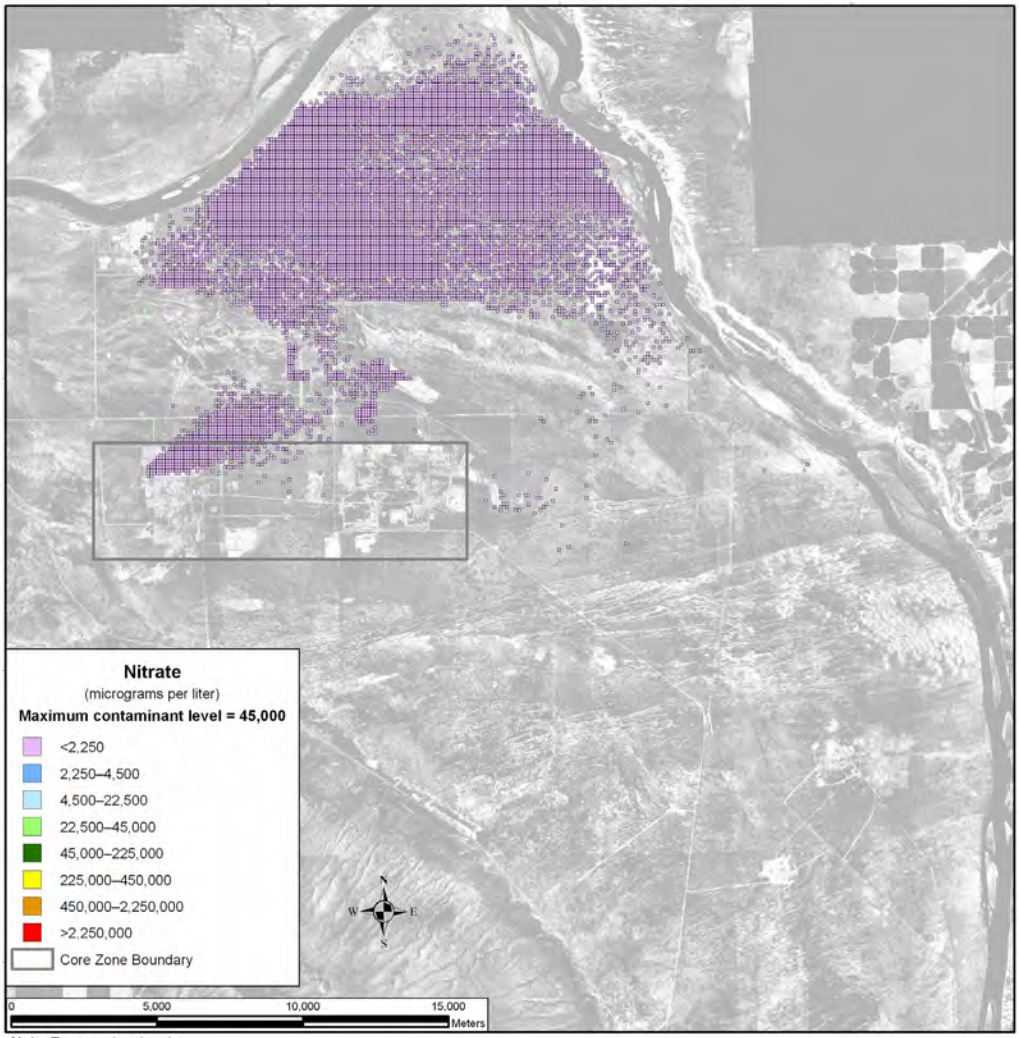
Note: To convert meters to feet, multiply by 3.281

Figure 5–359. Waste Management Alternative 1, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



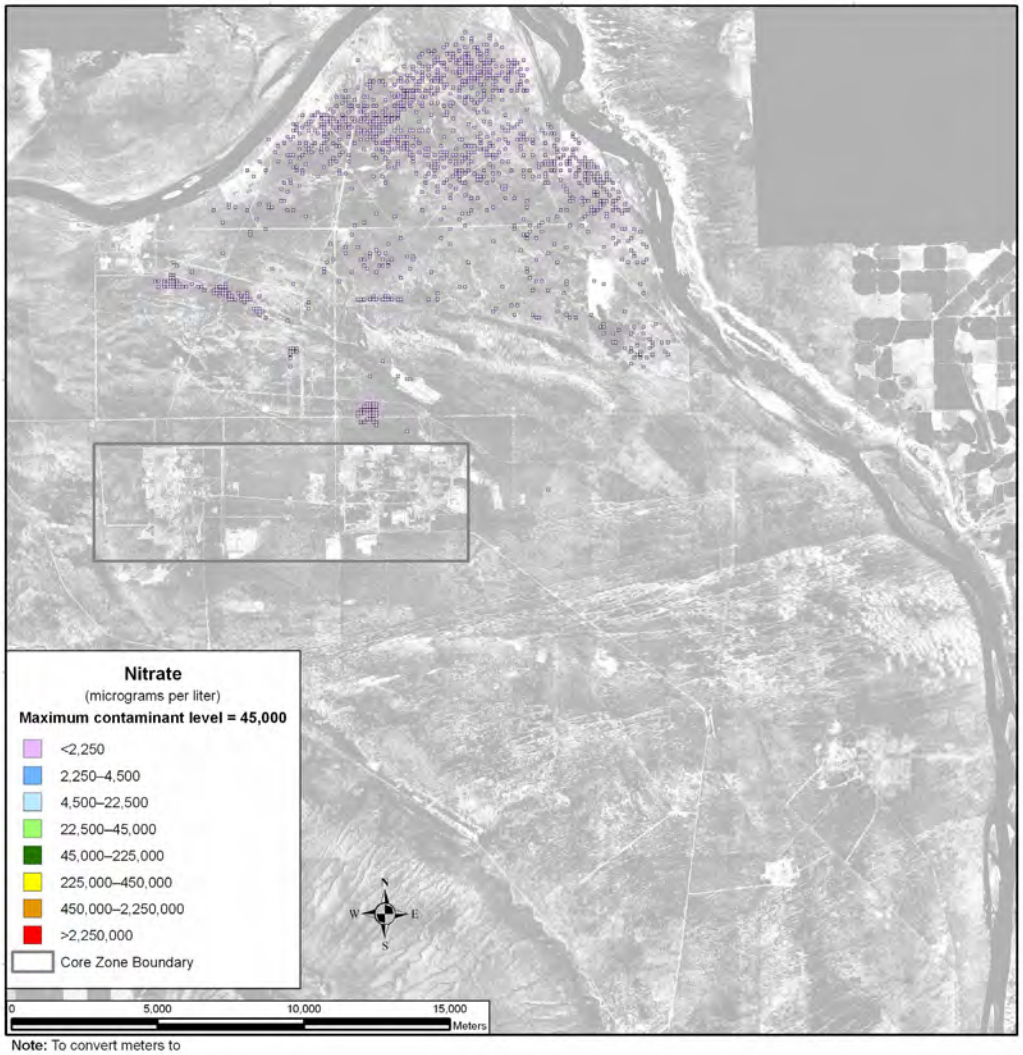
Note: To convert meters to feet, multiply by 3.281

Figure 5–360. Waste Management Alternative 1, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



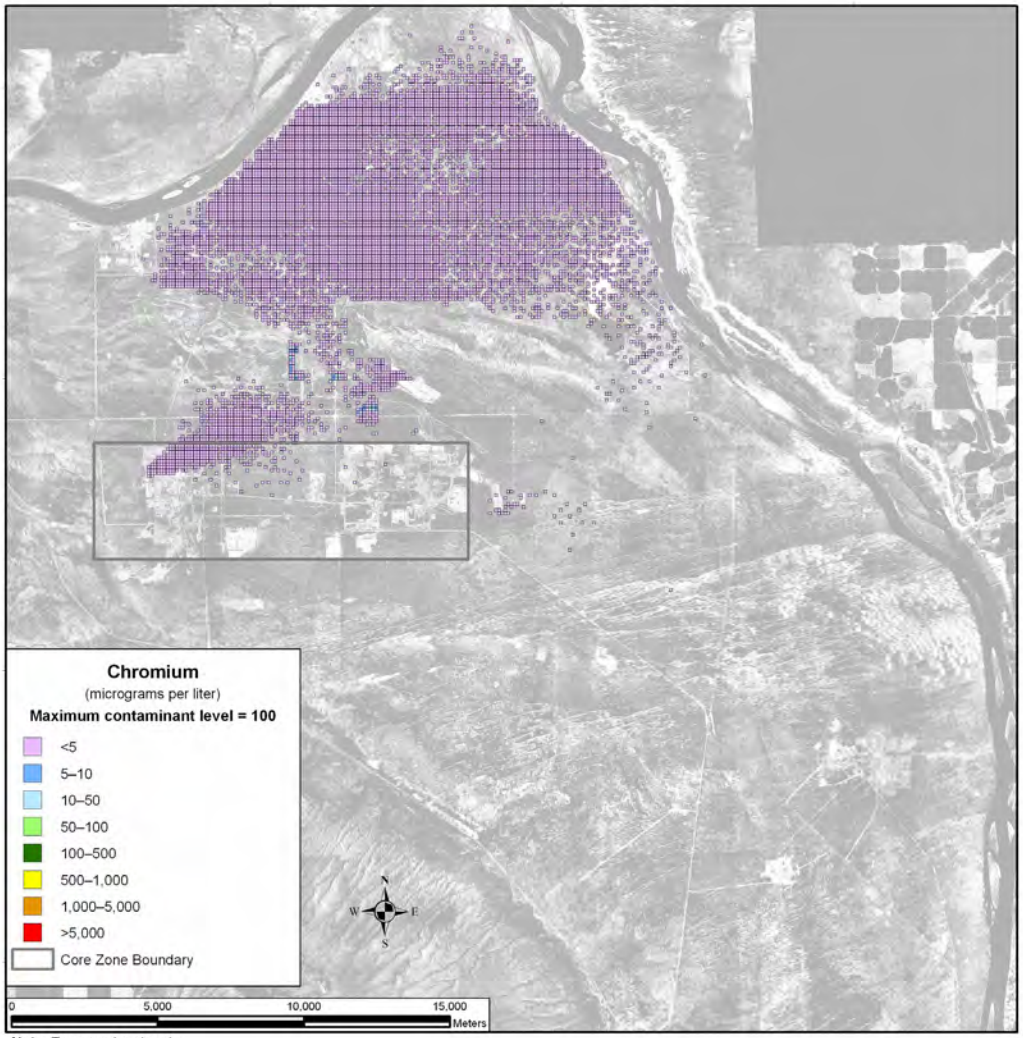
Note: To convert meters to feet, multiply by 3.281

Figure 5–361. Waste Management Alternative 1, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



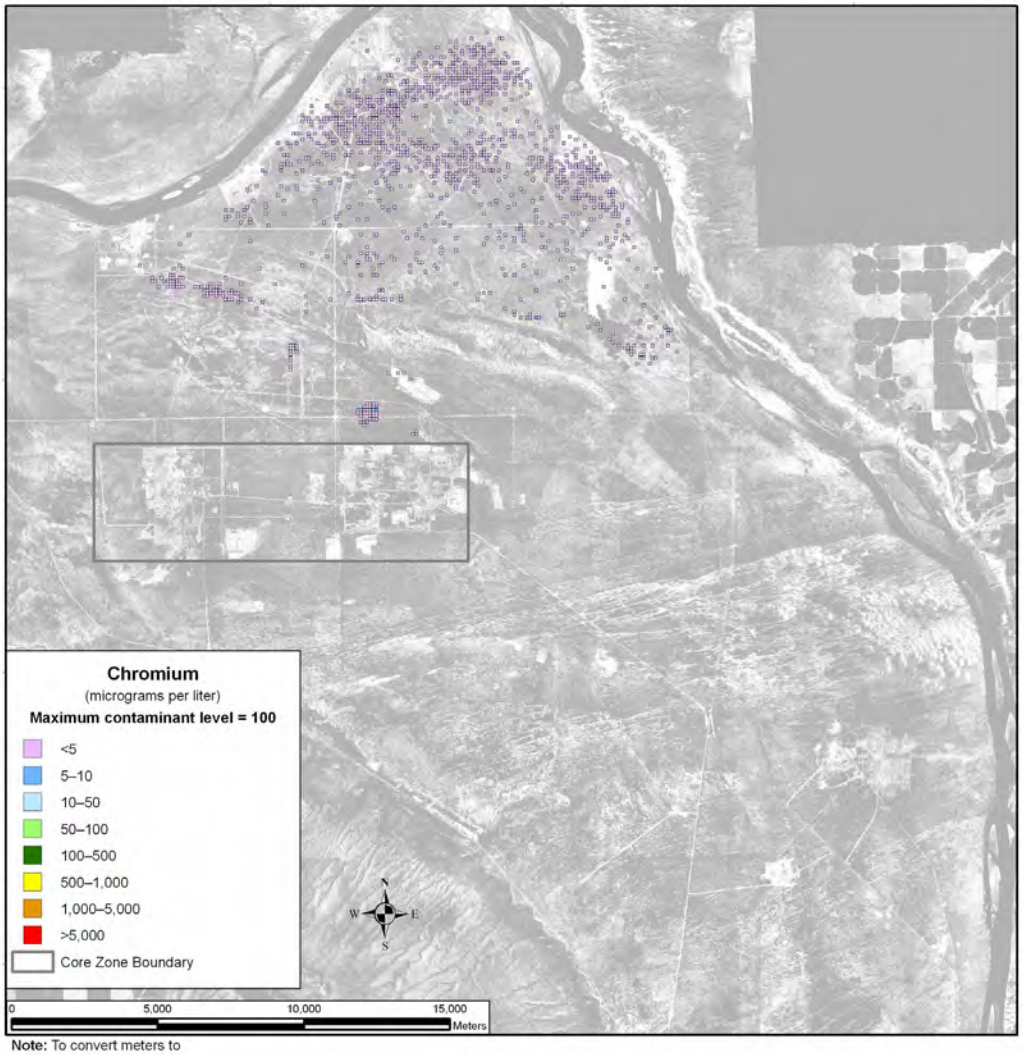
Note: To convert meters to feet, multiply by 3.281

Figure 5–362. Waste Management Alternative 1, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



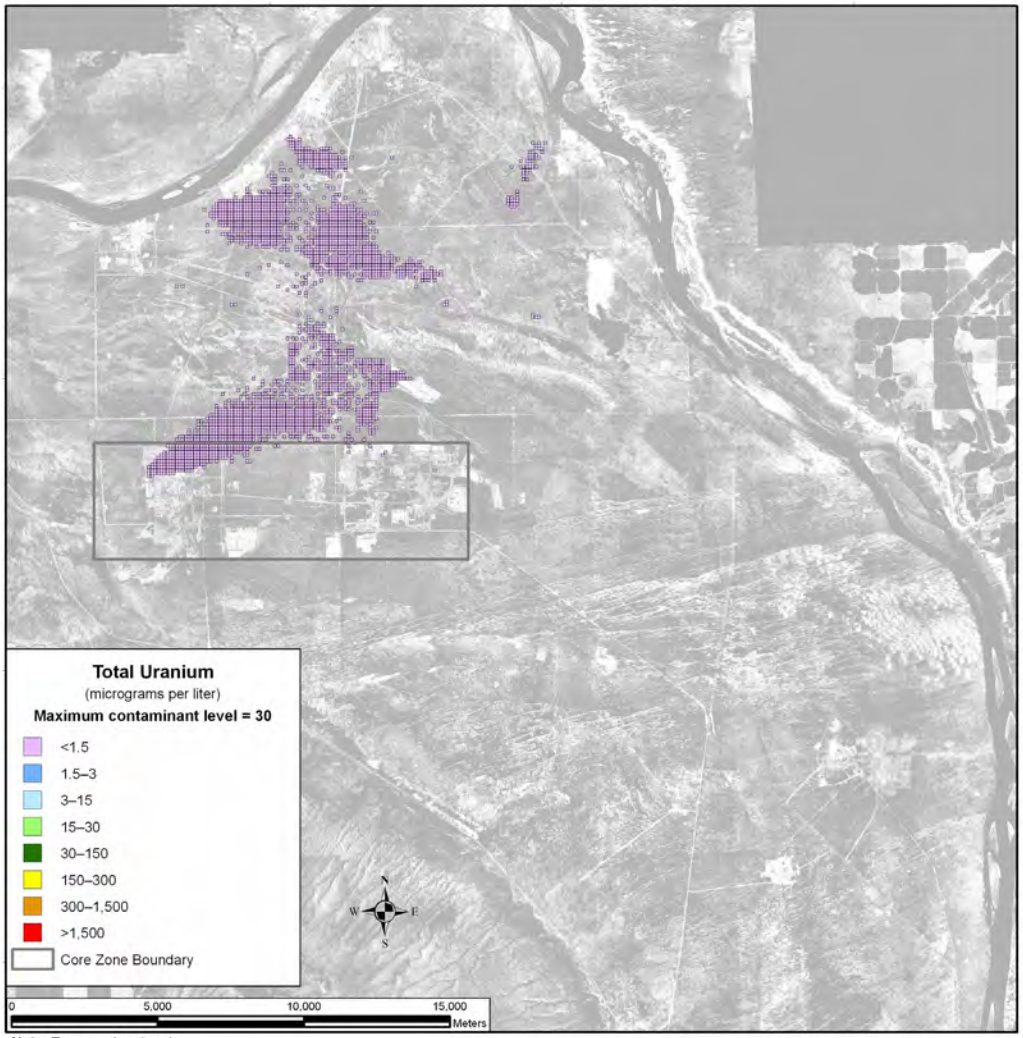
Note: To convert meters to feet, multiply by 3.281

Figure 5–363. Waste Management Alternative 1, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



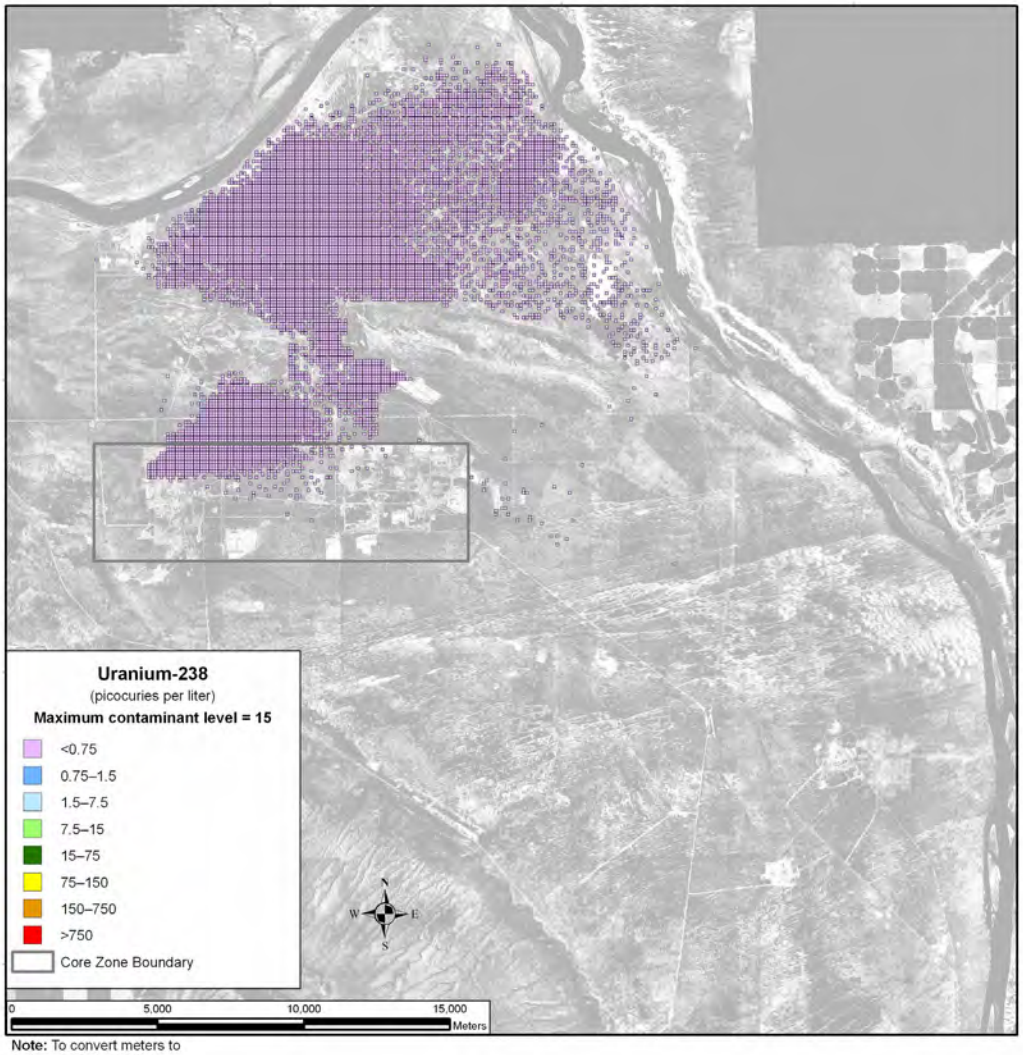
Note: To convert meters to feet, multiply by 3.281

Figure 5–364. Waste Management Alternative 1, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–365. Waste Management Alternative 1, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–366. Waste Management Alternative 1, Spatial Distribution of Groundwater Uranium-238 Concentration During Calendar Year 11,885

5.3.1.1.6 Summary of Impacts

Under Waste Management Alternative 1, all discharges originate in trenches 31 and 34.

No COPCs reached a concentration exceeding the benchmark concentration at the Core Zone Boundary or Columbia River during the course of the simulation.

5.3.1.2 Waste Management Alternative 2: Disposal in IDF, 200-East Area Only

This section describes the groundwater analysis results for Waste Management Alternative 2, including long-term groundwater impacts of contaminant sources within the IDF-East and RPPDF Barriers. Impacts of sources remaining within the tank farm barriers are presented in Section 5.1, which discusses tank closure impacts. Impacts of sources remaining within the FFTF Barrier are presented in Section 5.2, which discusses FFTF decommissioning impacts.

Summaries of the proposed actions and timelines for Waste Management Alternative 2 are provided in Chapter 2, Section 2.5. There are three disposal facilities, as follows:

- LLBG 218-W-5 trenches 31 and 34, which receive LLW and MLLW. For the purposes of this analysis, the waste inventories associated with these trenches are included with the IDF-East inventory.

- IDF-East, located in the south-central part of the 200-East Area, which receives tank waste, FFTF decommissioning waste, onsite-generated non-CERCLA waste, and offsite-received LLW and MLLW. The LLW and MLLW inventories for trenches 31 and 34 are also included at IDF-East in this analysis.

- The RPPDF, located in the Core Zone between the 200-East and 200-West Areas, which receives lightly contaminated equipment and soils resulting from tank farm closure activities.

Three disposal groups were analyzed. Each has a different configuration and timeline for IDF-East and the RPPDF. The three disposal groups are discussed in detail in the following subsections.

5.3.1.2.1 Disposal Group 1

Disposal Group 1 is characterized by an operational completion date of CY 2050 for both IDF-East and the RPPDF. Under Disposal Group 1, IDF-East has a large capacity (1,200,000 cubic meters [1,570,000 cubic yards]) and the RPPDF has a smaller capacity (1,030,000 cubic meters [1,350,000 cubic yards]). These capacities were designed to meet the waste generation volumes associated with Tank Closure Alternatives 2B, 3A, 3B, 3C, 4, 5, and 6C; either FFTF Decommissioning Alternative 2 or 3; and waste management activities.

5.3.1.2.1.1 Disposal Group 1, Subgroup 1-A

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-A covers disposal of waste generated under Tank Closure Alternative 2B and either FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW and ILAW glass. IHLW would be stored on site, while ILAW glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2008 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A (Tank Closure Alternative 2B, FFTF Decommissioning Alternative 3, and onsite- and offsite-generated waste), is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–367 through 5–378). Three subtotals are plotted, representing releases from the RPPDF and IDF-East, which include ILAW glass, Effluent Treatment Facility (ETF)-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over more than 10 orders of magnitude.

Figure 5–367 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers representing the individual waste form release and Figure 5–368, the chemical hazard drivers. The release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period in the analysis). For the radiological COPCs (technetium-99 and iodine-129), the releases range over seven orders of magnitude, depending on the source. The chemical COPCs (boron, chromium, fluoride, and nitrate) in IDF-East all have releases associated with waste management secondary waste and onsite-generated waste. Other sources include 99 percent of the nitrate release from ETF-generated secondary waste and 81 percent of the chromium release from tank closure secondary waste; the other chromium releases are dispersed in the other waste forms.

Figure 5–369 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–370, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers

and by the rate of moisture movement through the vadose zone. For the conservative tracers (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone. The exception to this is the release associated with retired melters, which decreases at groundwater for both technetium-99 and iodine-129 by more than 40 percent. These results suggest that melters as a source do not continue to release after the initial exposure.

Figure 5–371 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–372, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to the Columbia River is essentially equal to the amount released to groundwater. The exception to this is the *de minimis* release associated with the retired melters.

Figure 5–373 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–374, the chemical hazard drivers. The release of technetium-99 is more than two orders of magnitude greater than the release of iodine-129 at the RPPDF. The chemical constituents show nitrate as the predominant COPC, about two orders of magnitude greater than the release of chromium at the RPPDF.

Figure 5–375 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–376, the chemical hazard drivers. For the conservative tracers (iodine-129, technetium-99, chromium, and nitrate), the amount released to groundwater is essentially equal to the amount released to the vadose zone.

Figure 5–377 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–378, the chemical hazard drivers. Both figures show trends similar to those discussed in the previous paragraph for the release to the Columbia River for all COPC drivers at the RPPDF.

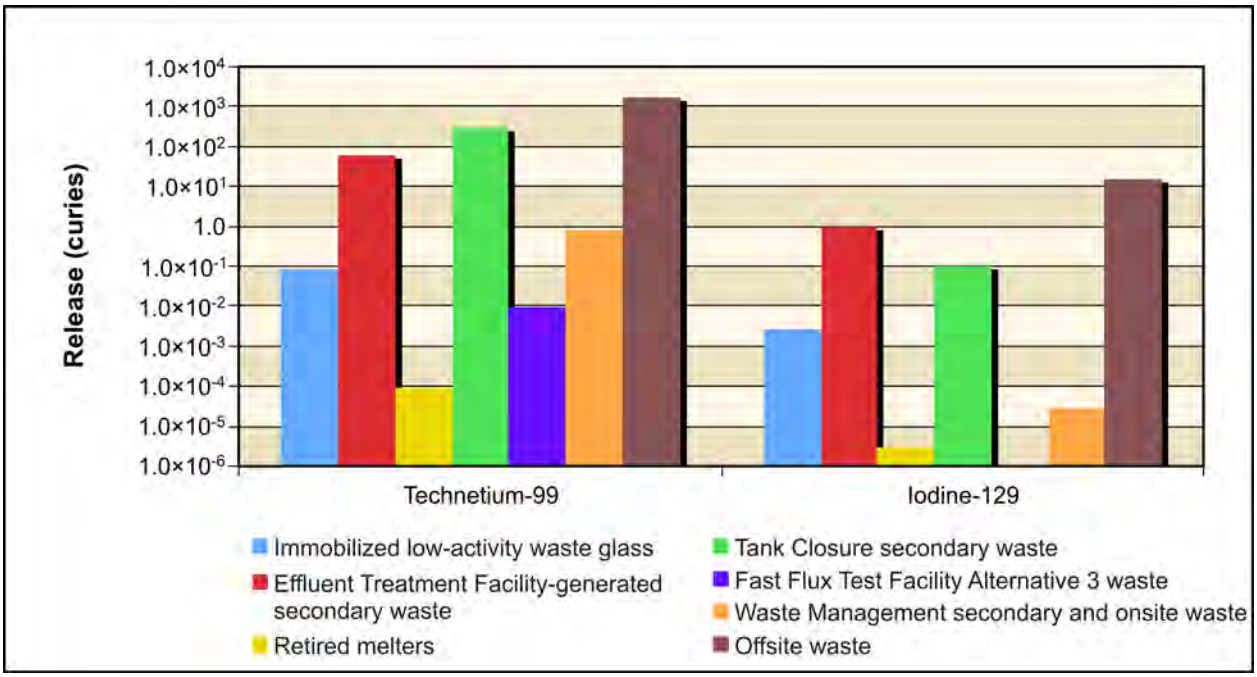


Figure 5–367. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

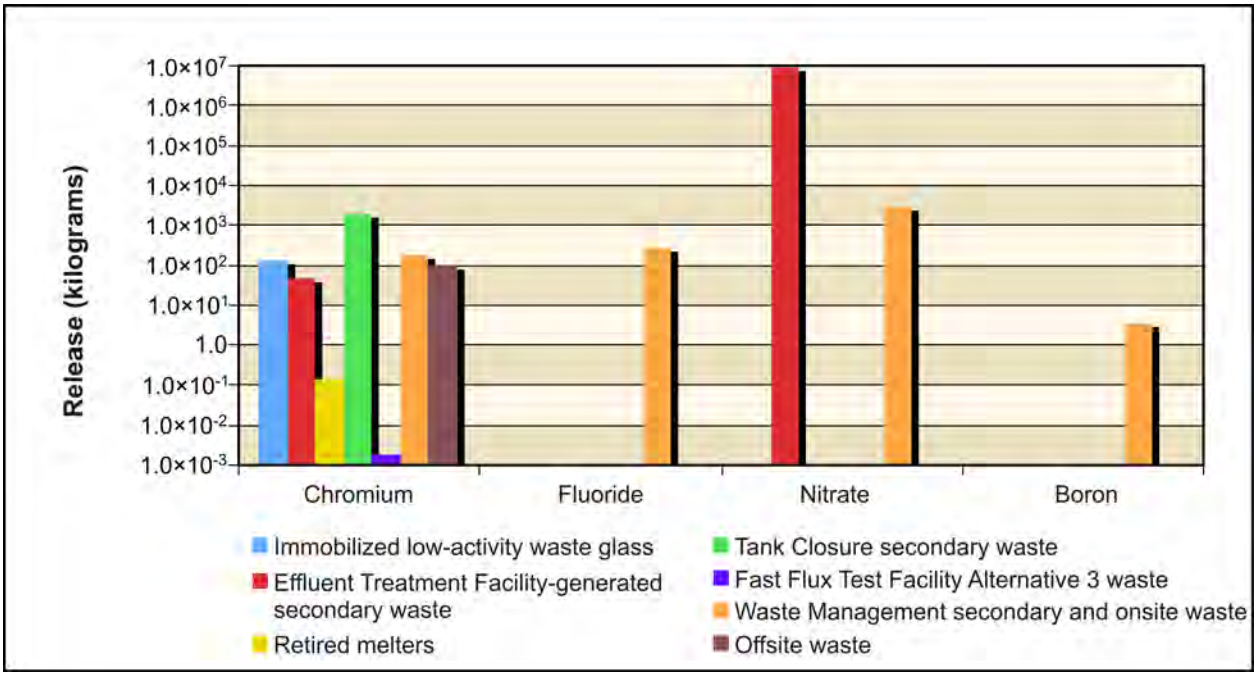


Figure 5–368. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

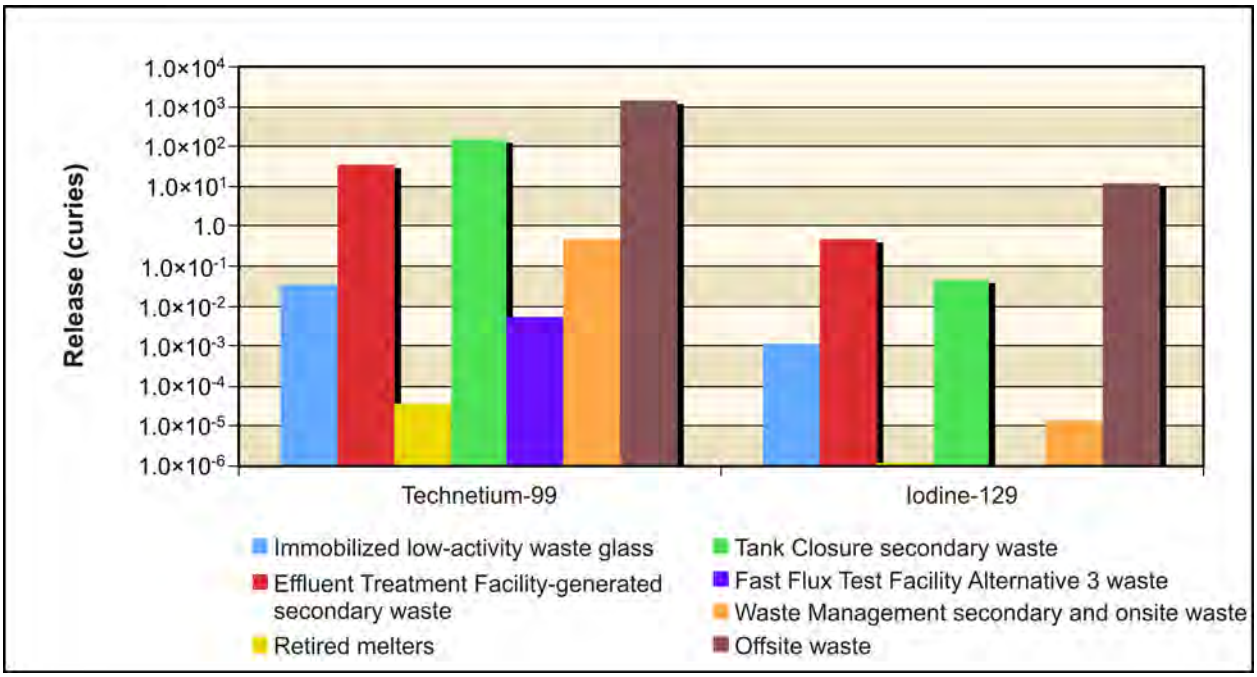


Figure 5–369. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

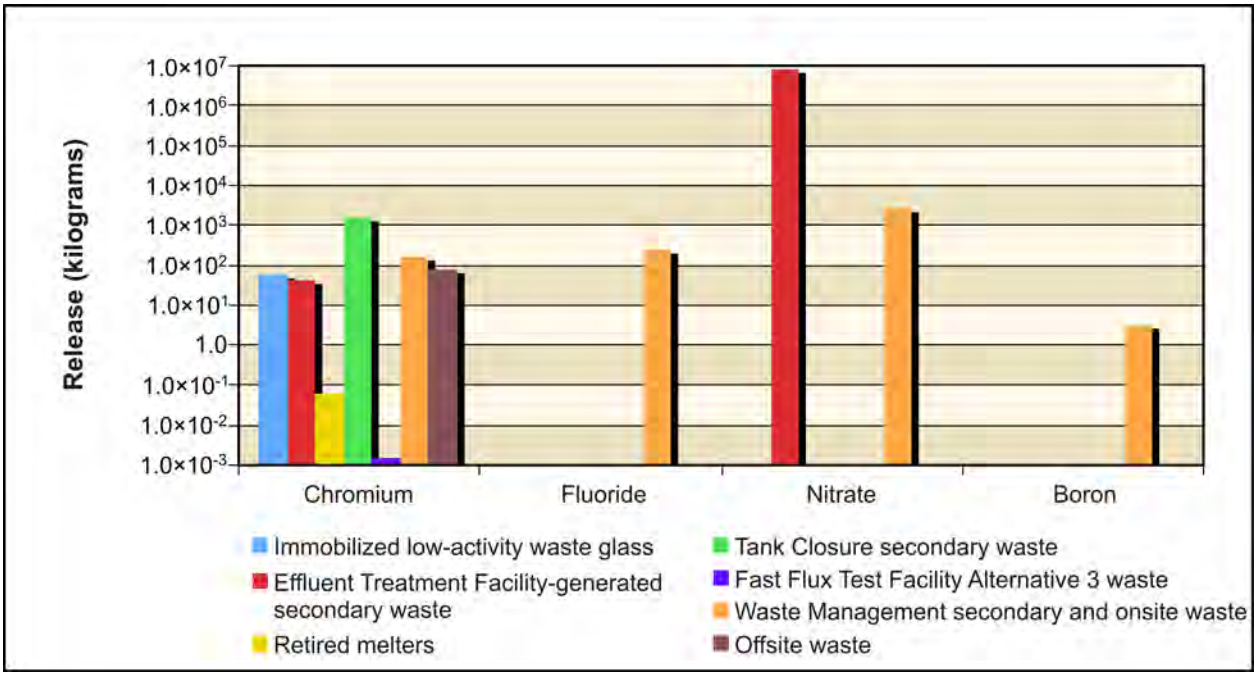


Figure 5–370. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

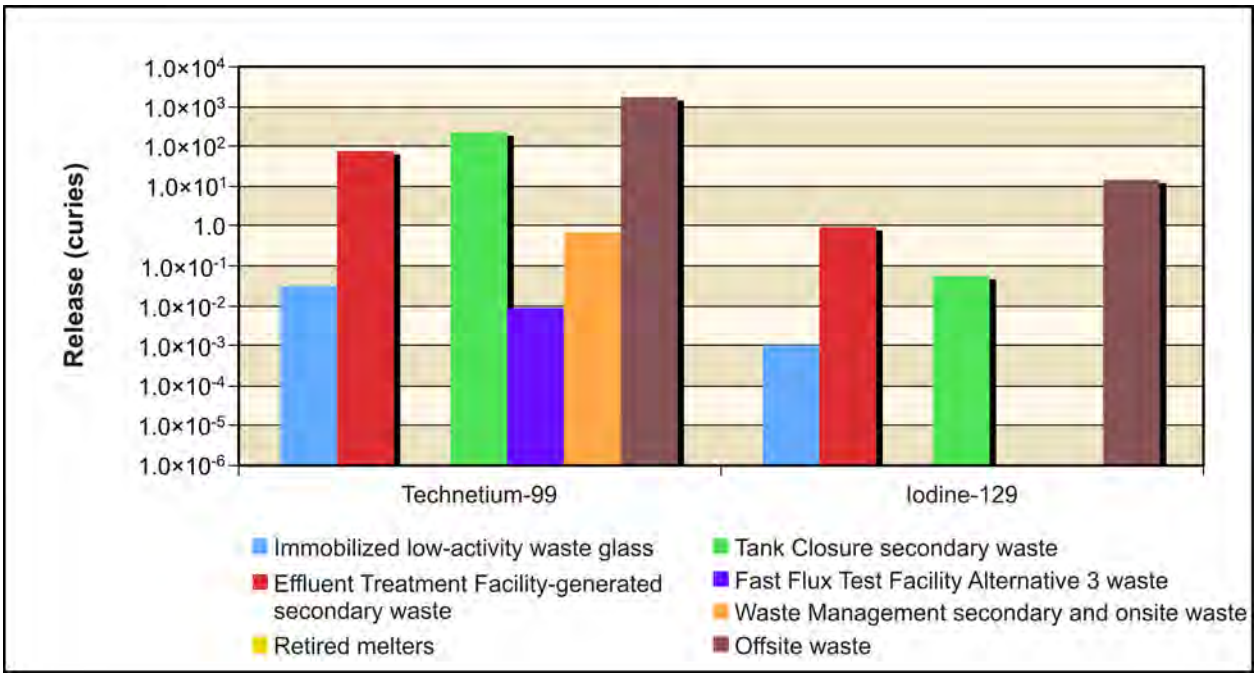


Figure 5–371. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

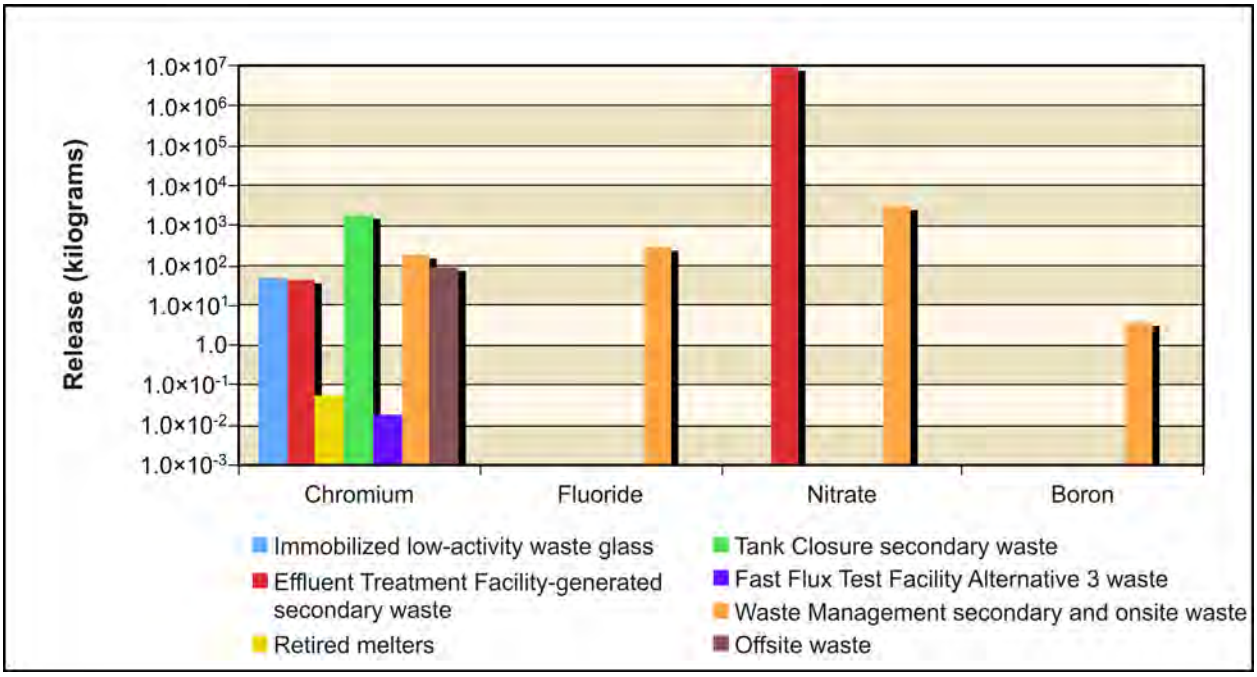


Figure 5–372. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

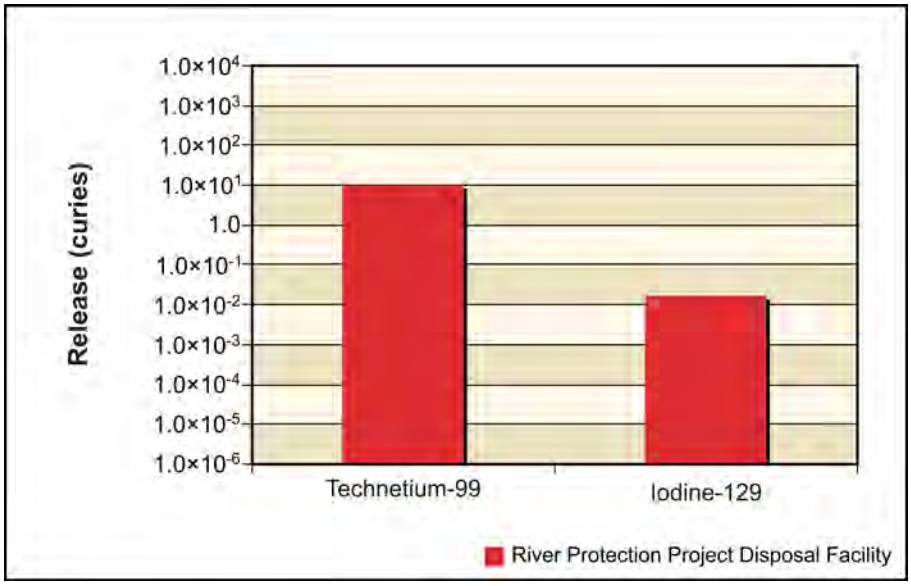


Figure 5–373. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

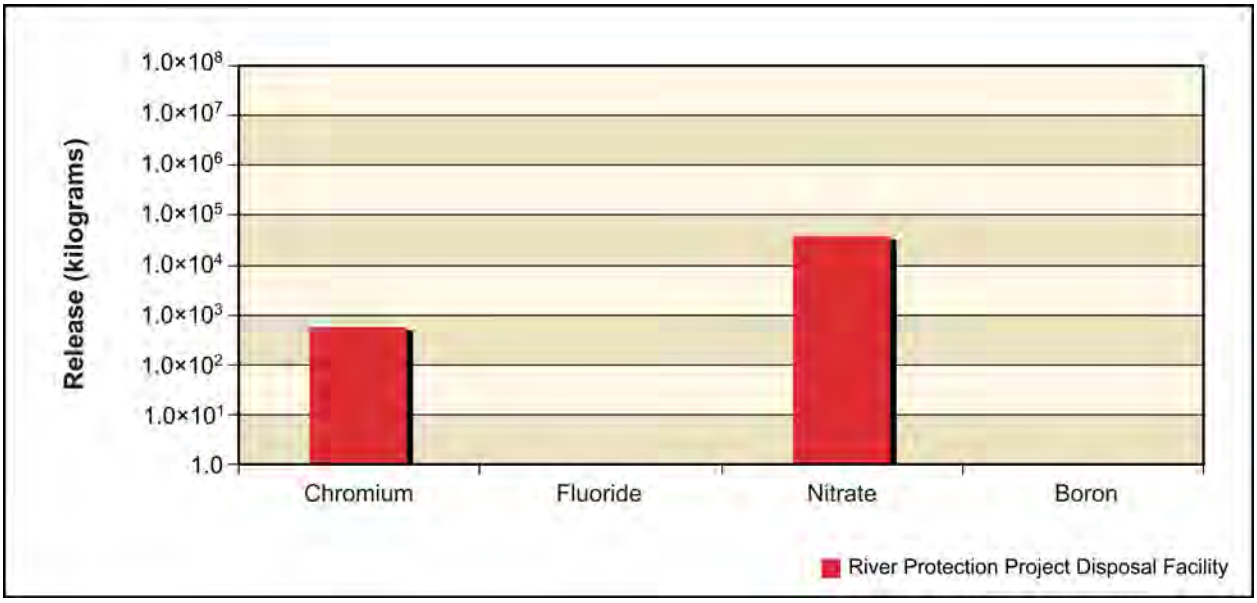


Figure 5–374. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

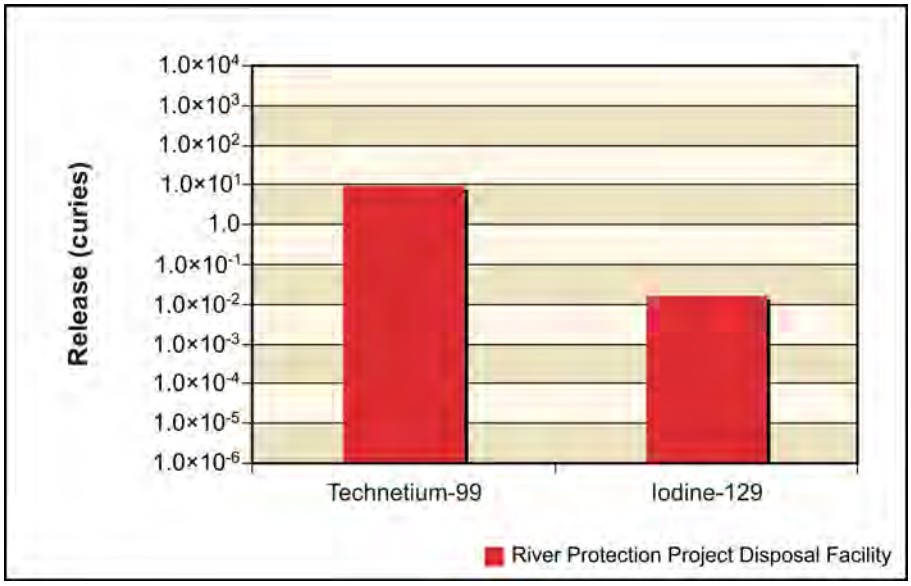


Figure 5–375. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Groundwater

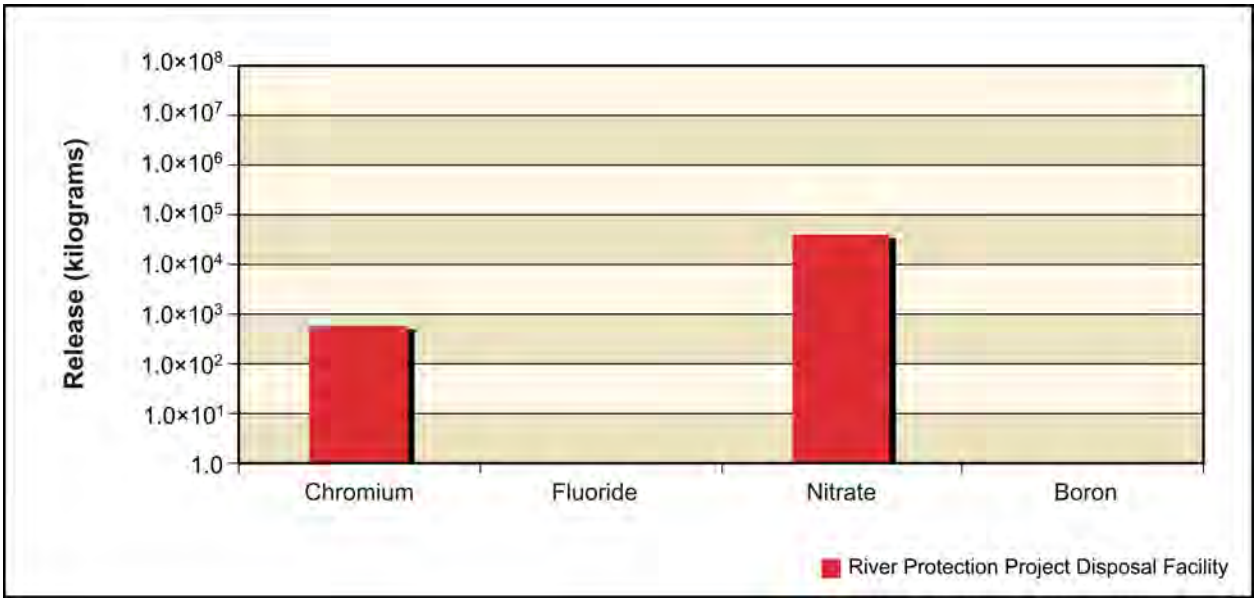


Figure 5–376. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Groundwater

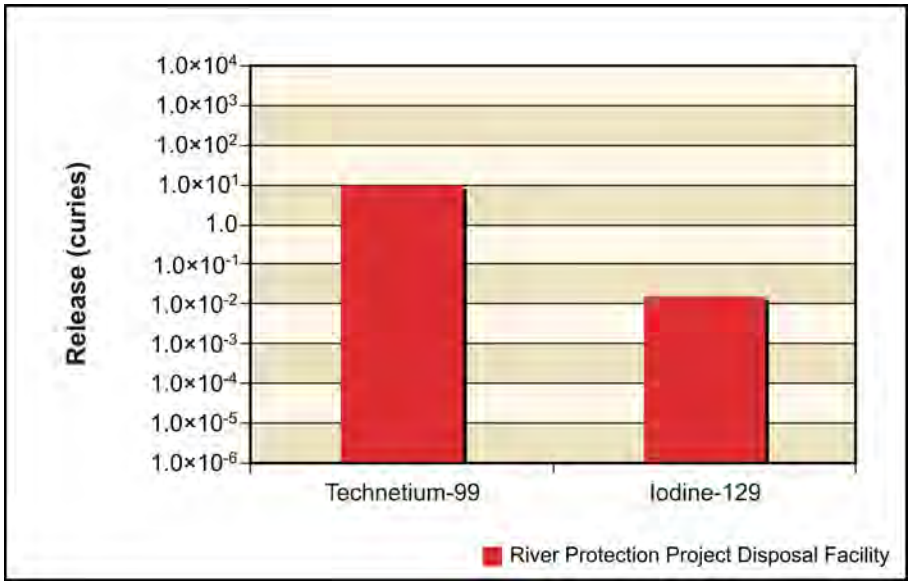


Figure 5–377. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Radiological Releases at River Protection Project Disposal Facility to Columbia River

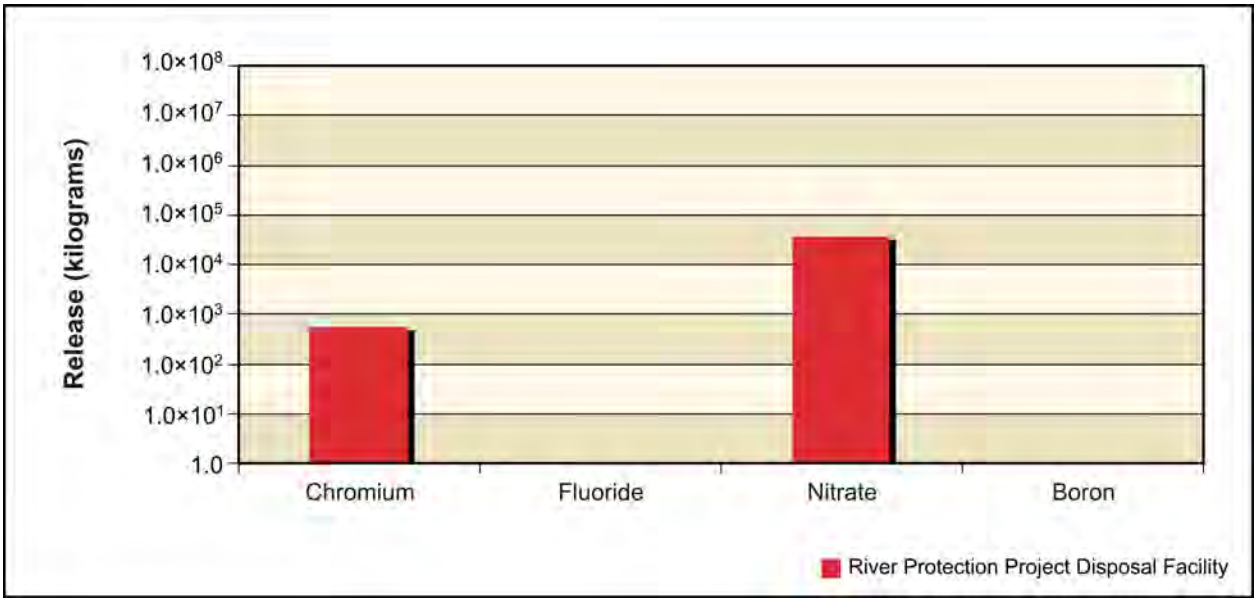


Figure 5–378. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Disposal Group 1, Subgroup 1-A, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–379 through 5–383). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–77 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–379 through 5–382 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). Releases from IDF-East and the RPPDF at the Core Zone Boundary cause groundwater concentrations to exceed the benchmark concentration for iodine-129 in CY 5500; using the confidence interval, the concentrations appear slightly below the benchmark for both the Core Zone Boundary and the Columbia River nearshore. The same trend is applicable to technetium-99 concentrations during the period of analysis. Chromium and nitrate measurements at the Core Zone Boundary and the Columbia River nearshore are below the benchmark concentrations by one to three orders of magnitude, showing a trend similar to iodine-129 and technetium-99.

Figure 5–383 shows concentration versus time for total uranium. Because of the high retardation of uranium, no contamination appears until CY 9800, when total uranium concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Uranium-238 does not surpass 1.0×10^{-8} picocuries per liter during the simulation, but total uranium continues to rise near the end of the 10,000-year period of analysis, still well below the benchmark for both the Core Zone Boundary and Columbia River nearshore by eight to nine orders of magnitude at the end of the period of analysis.

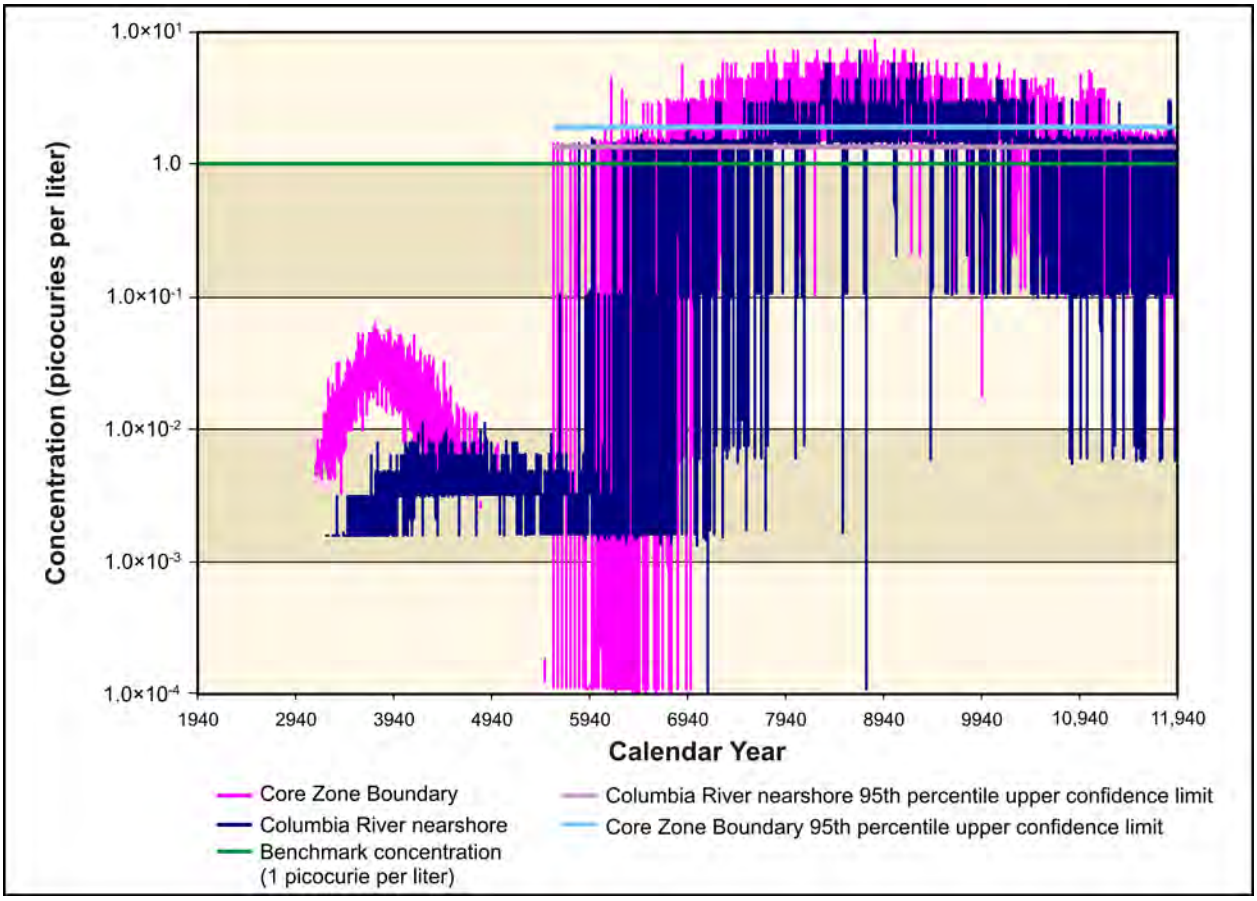


Figure 5–379. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Iodine-129 Concentration Versus Time

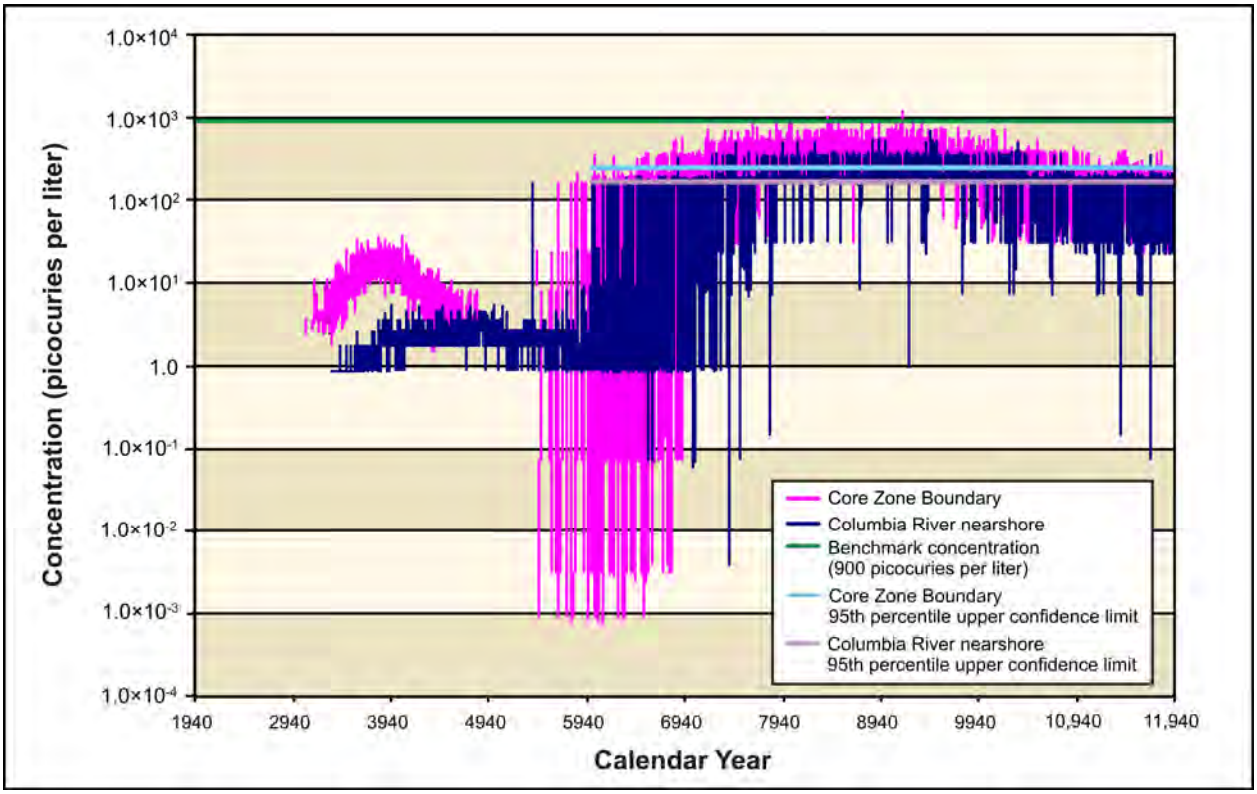


Figure 5–380. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Technetium-99 Concentration Versus Time

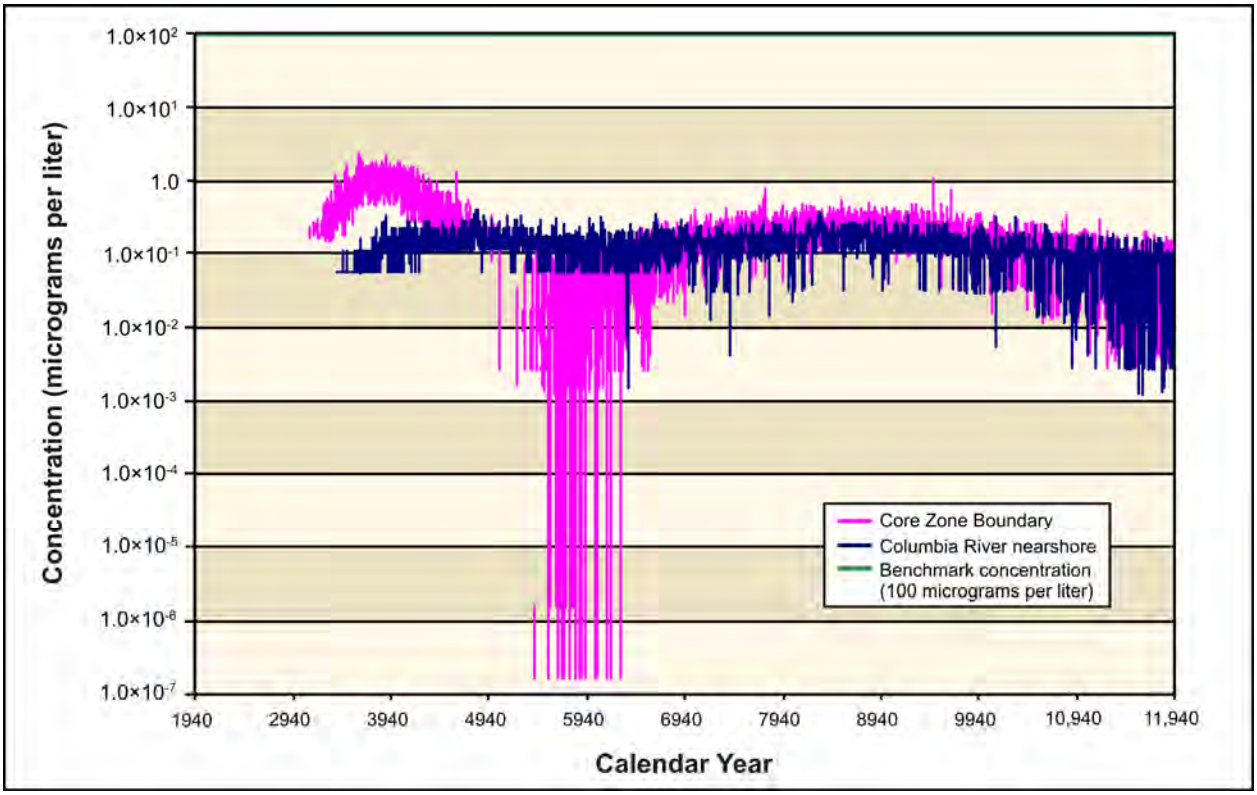


Figure 5–381. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Chromium Concentration Versus Time

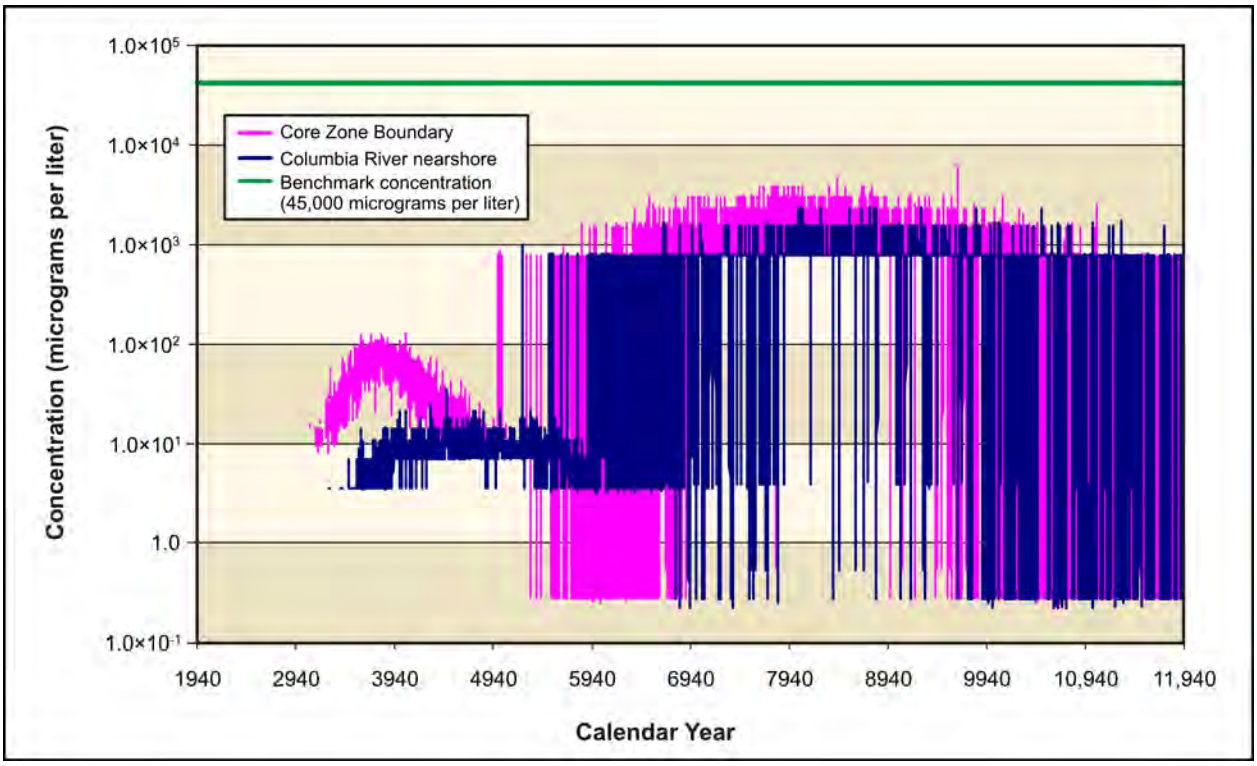


Figure 5–382. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Nitrate Concentration Versus Time

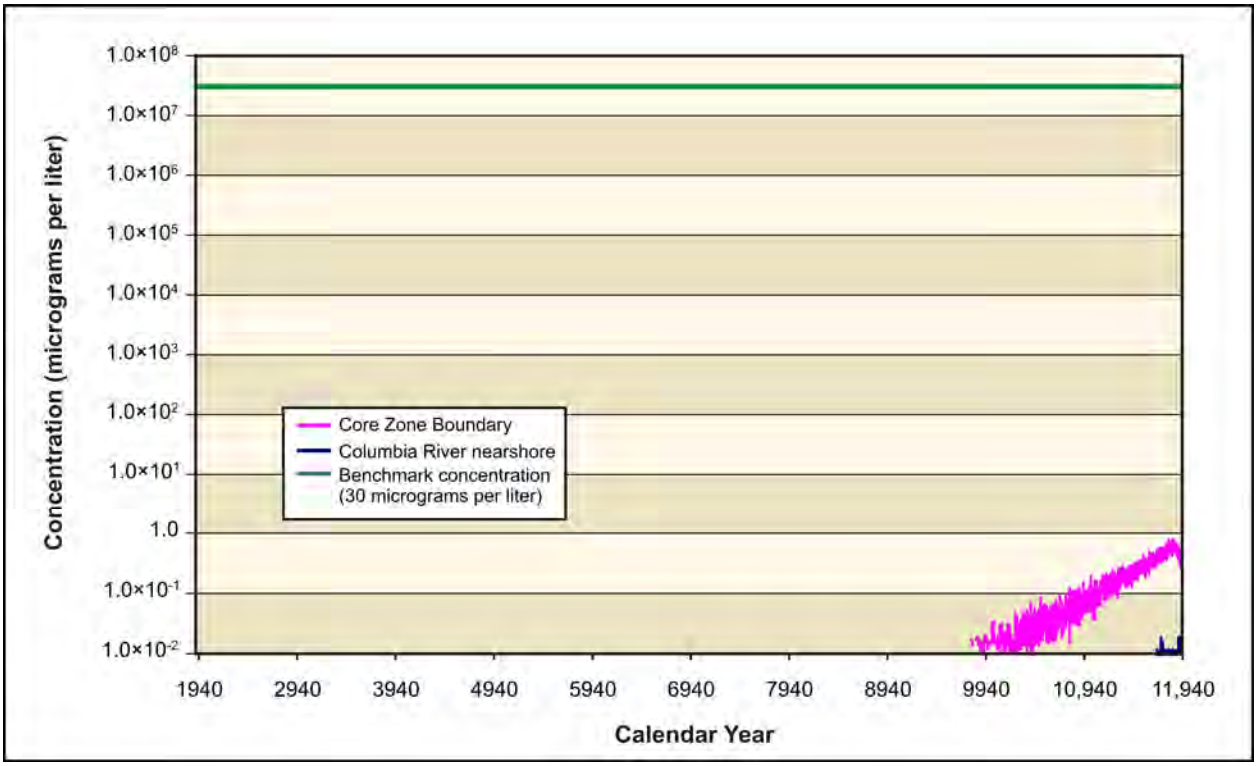


Figure 5–383. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Total Uranium Concentration Versus Time

Table 5–77. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,040**	33	**1,180**	675	900
	(9004)	(3825)	(9155)	(9451)	
Iodine-129	**19**	0.1	**9**	**7**	1
	(8739)	(3772)	(8858)	(8700)	
Chemical in micrograms per liter					
Chromium	4	2	2	1	100
	(8511)	(3856)	(3889)	(8898)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,200	149	5,630	2,440	45,000
	(8522)	(3811)	(9653)	(8827)	

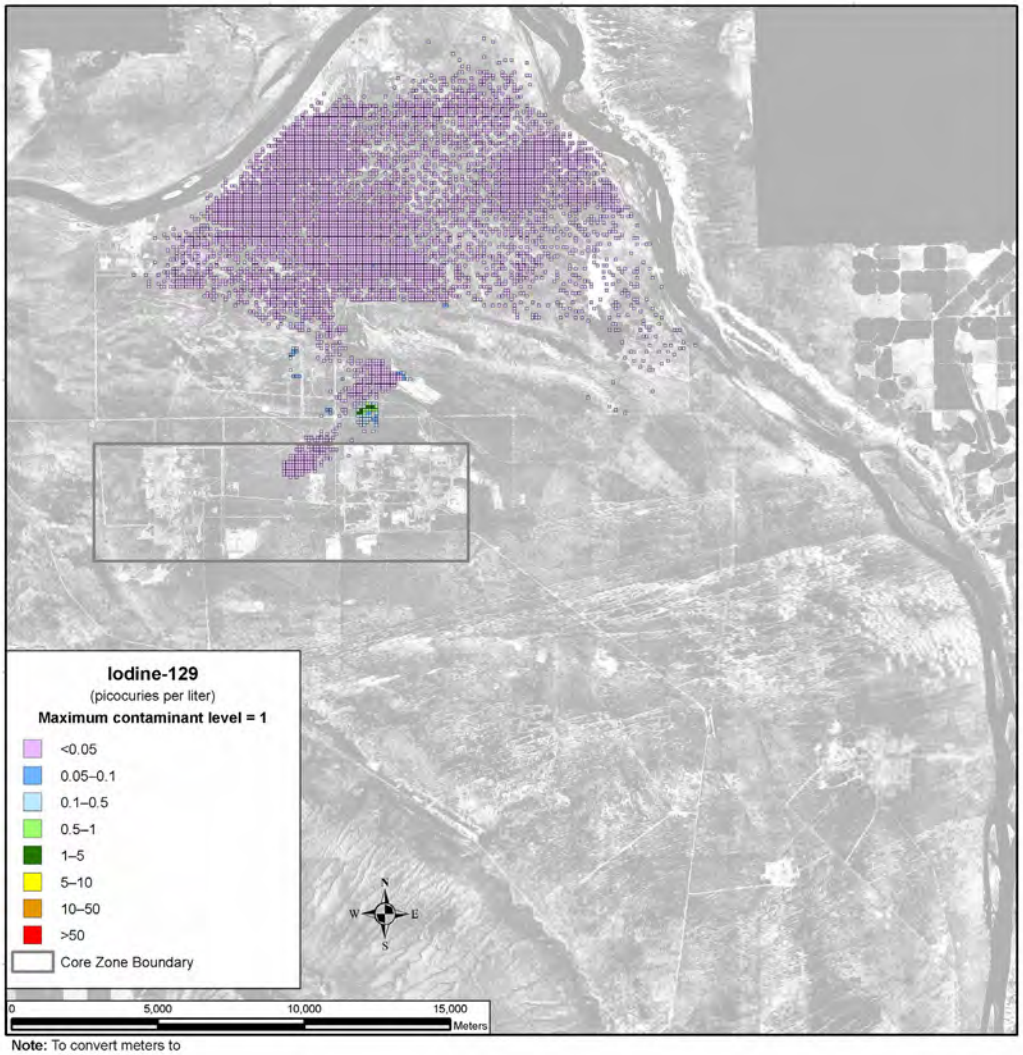
Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

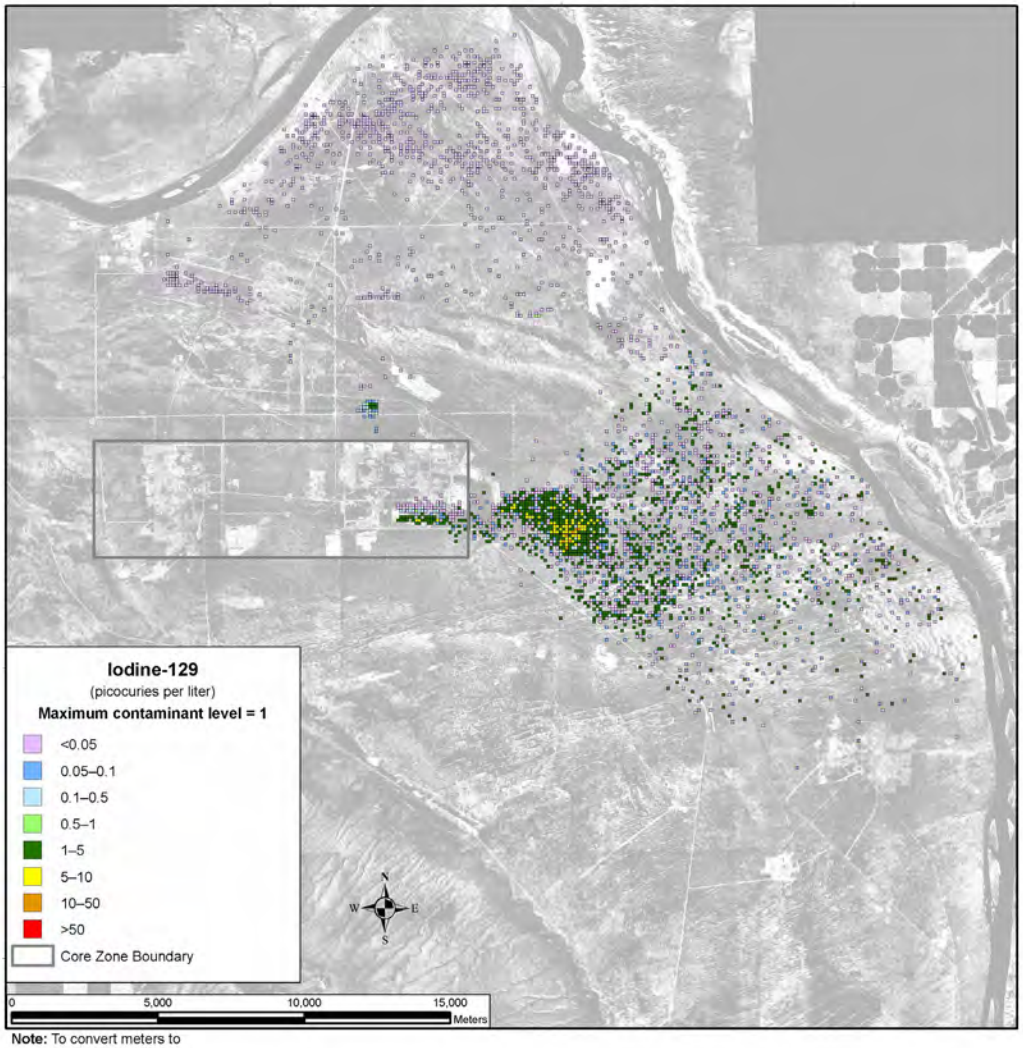
This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–384 through 5–396). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figures 5–384 through 5–386 show the spatial distribution of groundwater concentration for iodine-129. During CY 3890, there is a low-concentration plume that stretches north from the RPPDF and through Gable Gap. By CY 7140, the plume from the RPPDF is gone, but a new plume has formed, traveling east from IDF-East. The peak concentrations in this plume are greater than the benchmark. By CY 11,885, the plume continues to spread toward the river and the concentrations within remain relatively the same. Technetium-99 (see Figures 5–387 through 5–389), chromium (see Figures 5–390 through 5–392), and nitrate (see Figures 5–393 through 5–395) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).



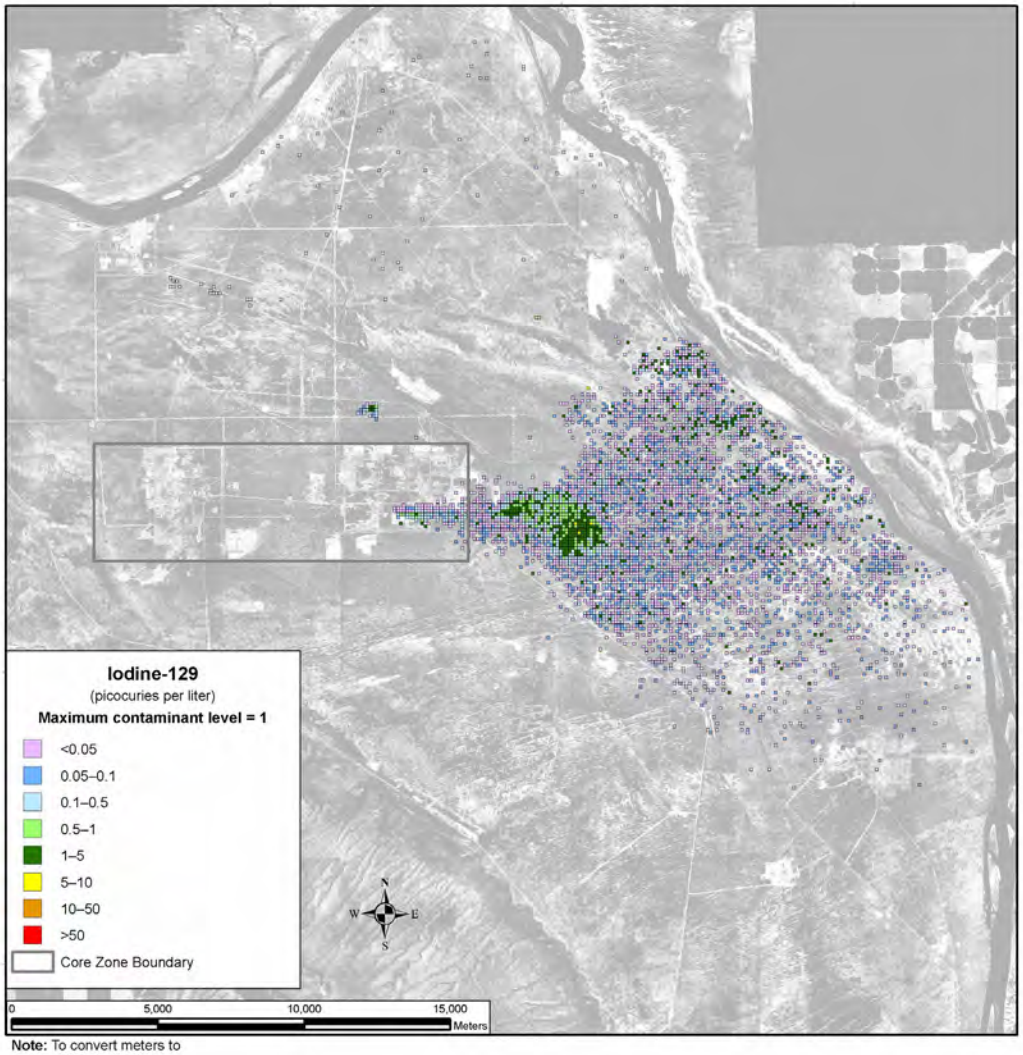
Note: To convert meters to feet, multiply by 3.281

Figure 5–384. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



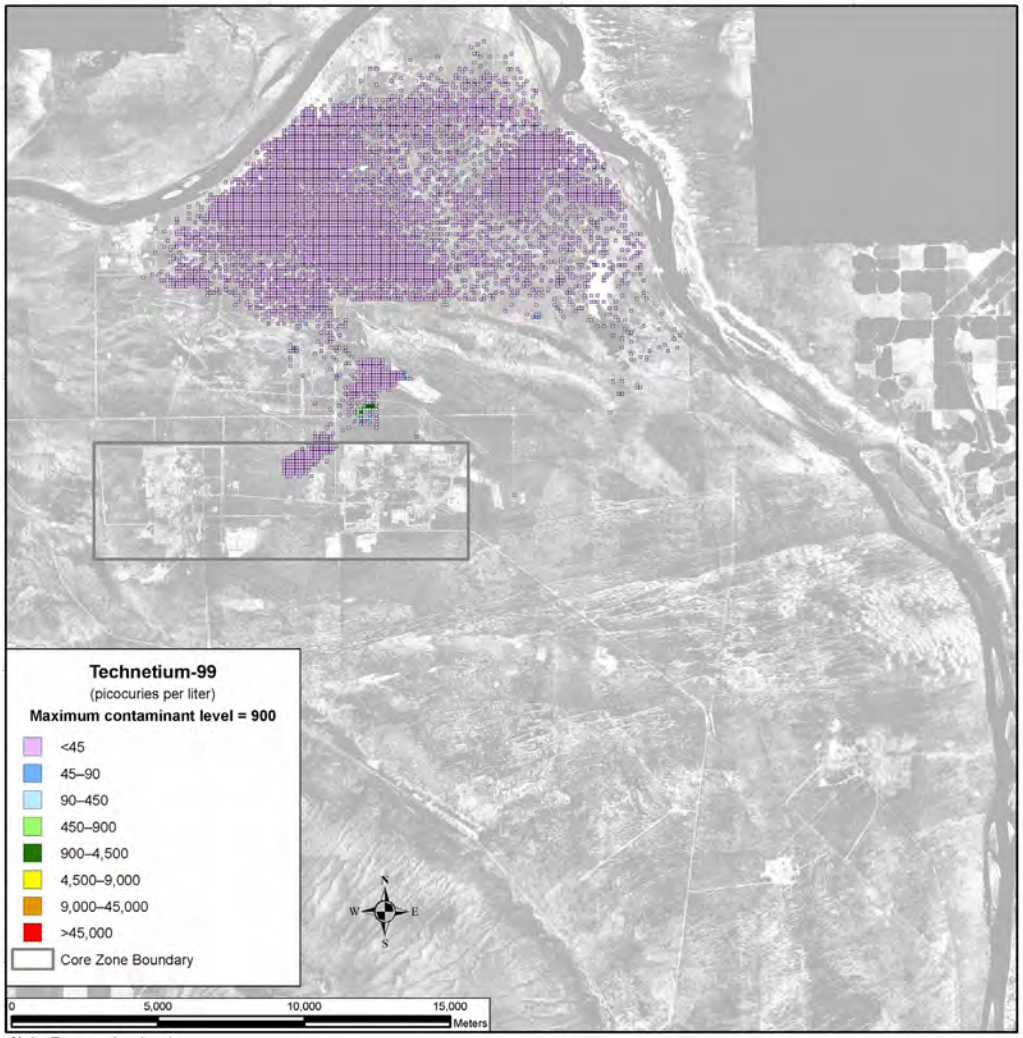
Note: To convert meters to feet, multiply by 3.281

Figure 5–385. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



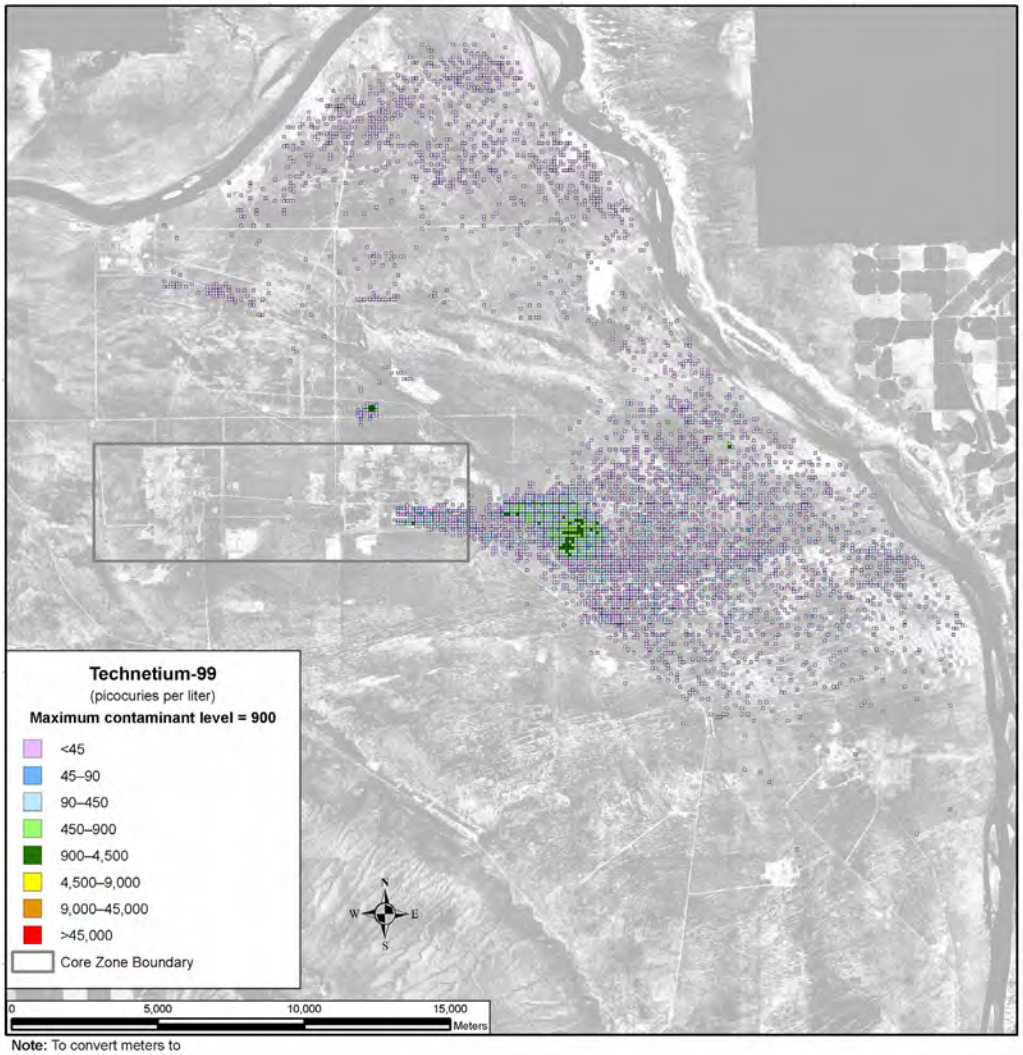
Note: To convert meters to feet, multiply by 3.281

Figure 5–386. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



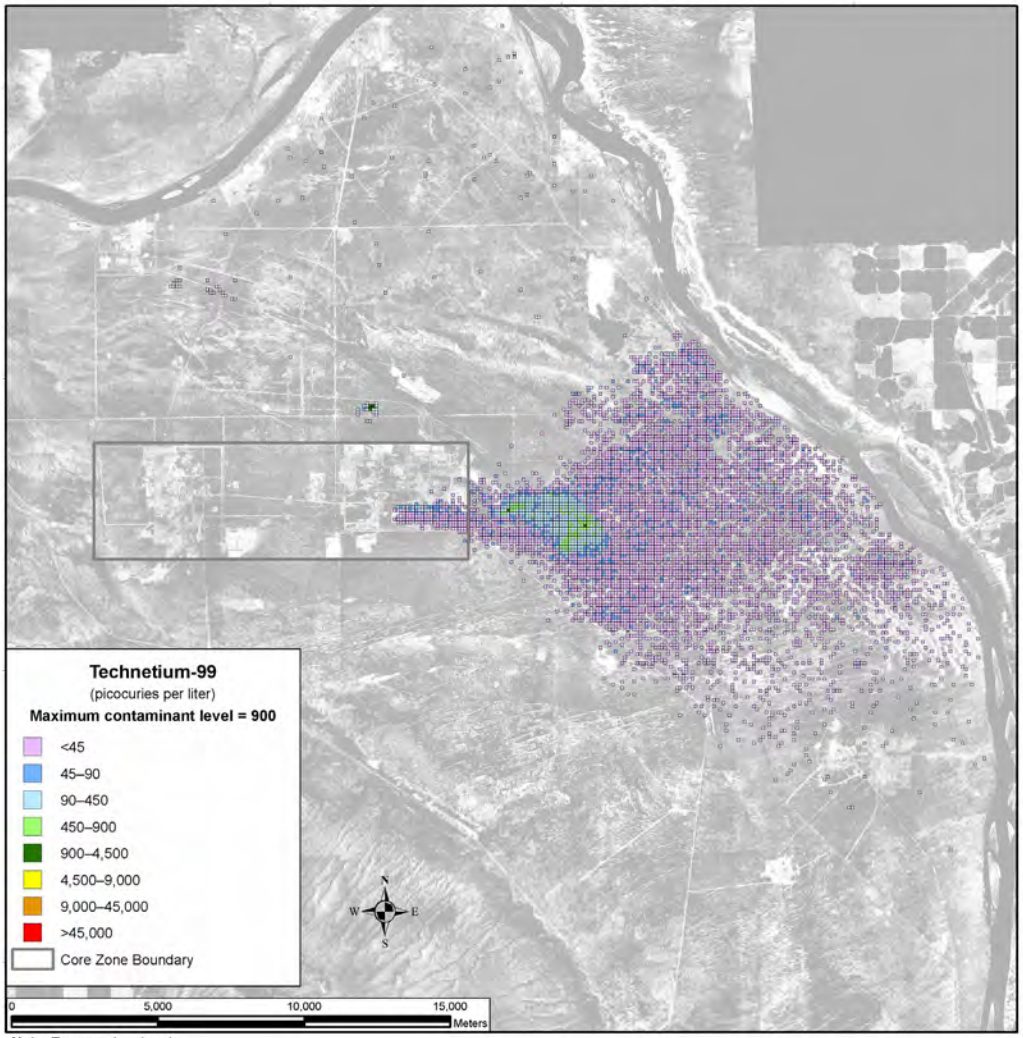
Note: To convert meters to feet, multiply by 3.281

Figure 5–387. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



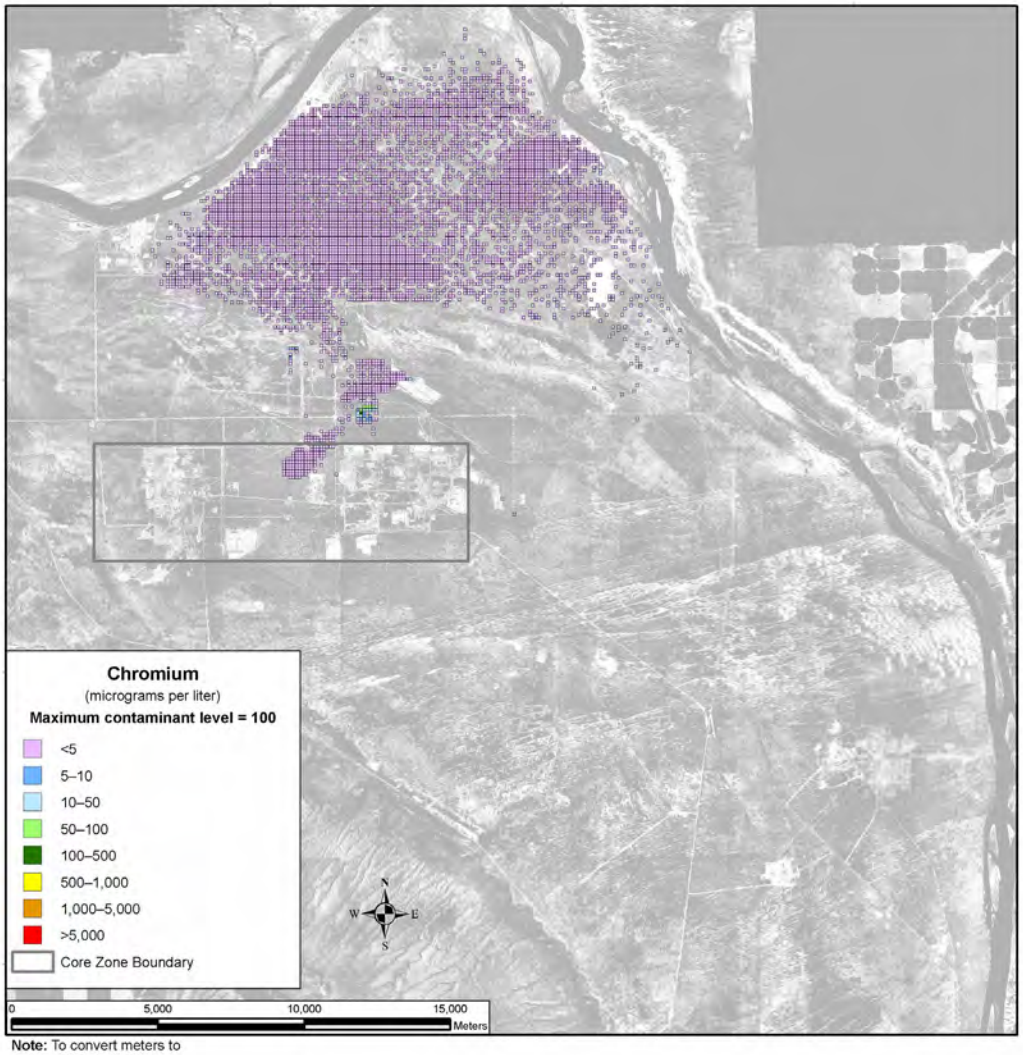
Note: To convert meters to feet, multiply by 3.281

Figure 5–388. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



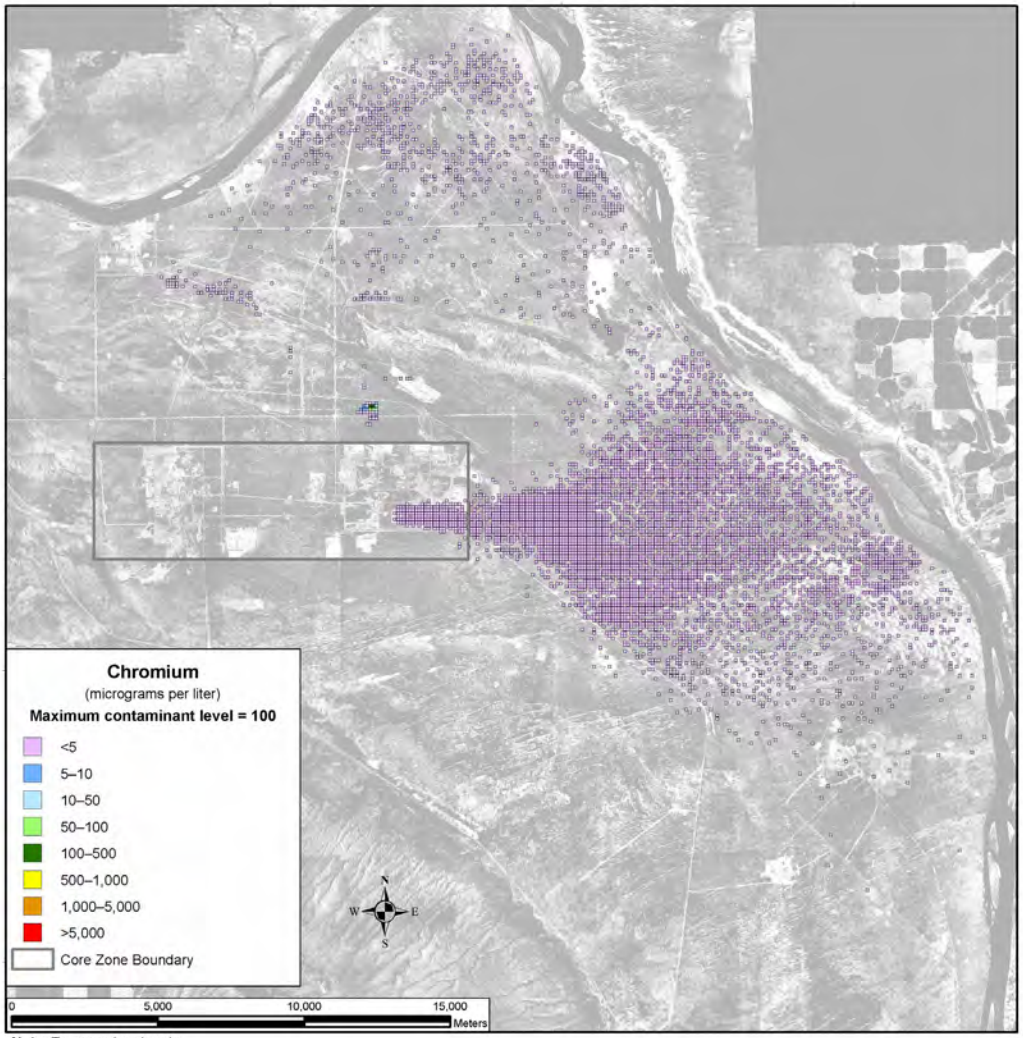
Note: To convert meters to feet, multiply by 3.281

Figure 5–389. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



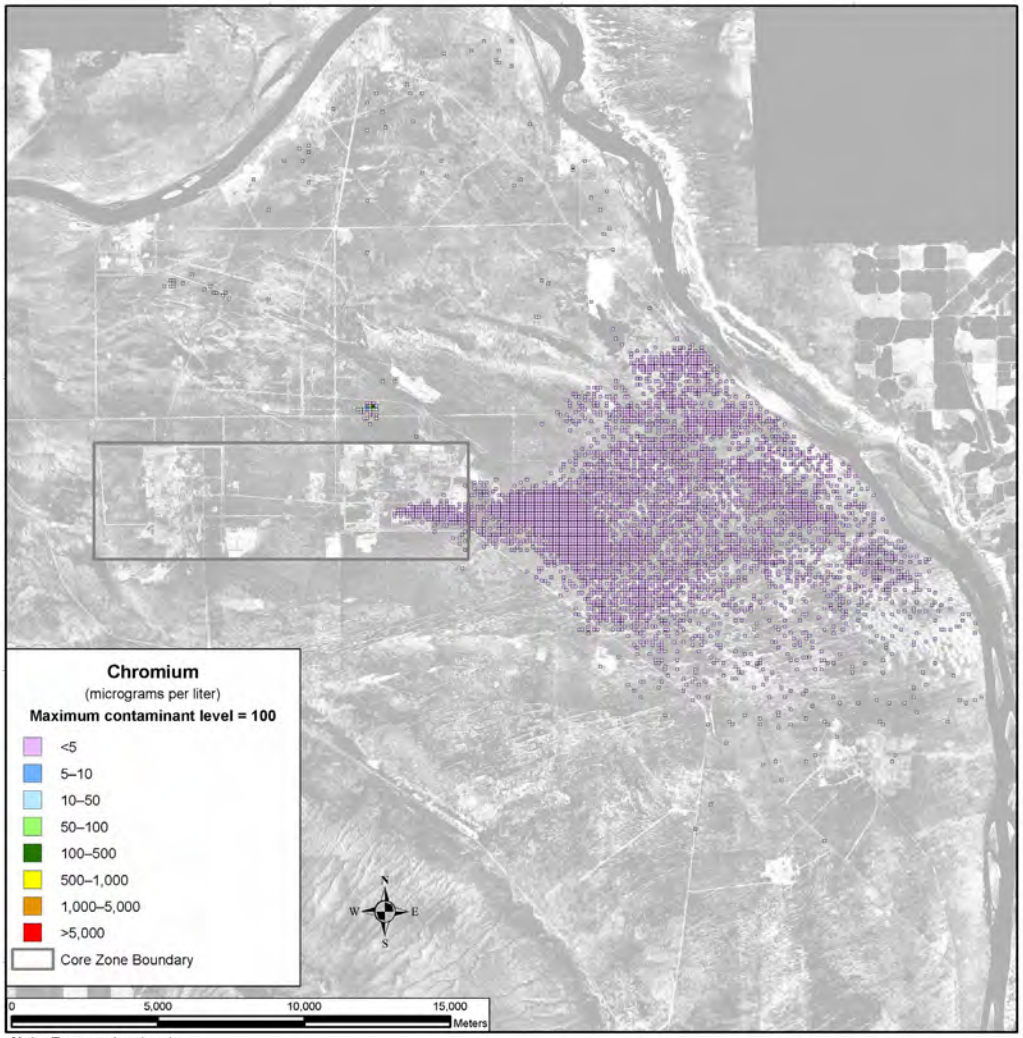
Note: To convert meters to feet, multiply by 3.281

Figure 5–390. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



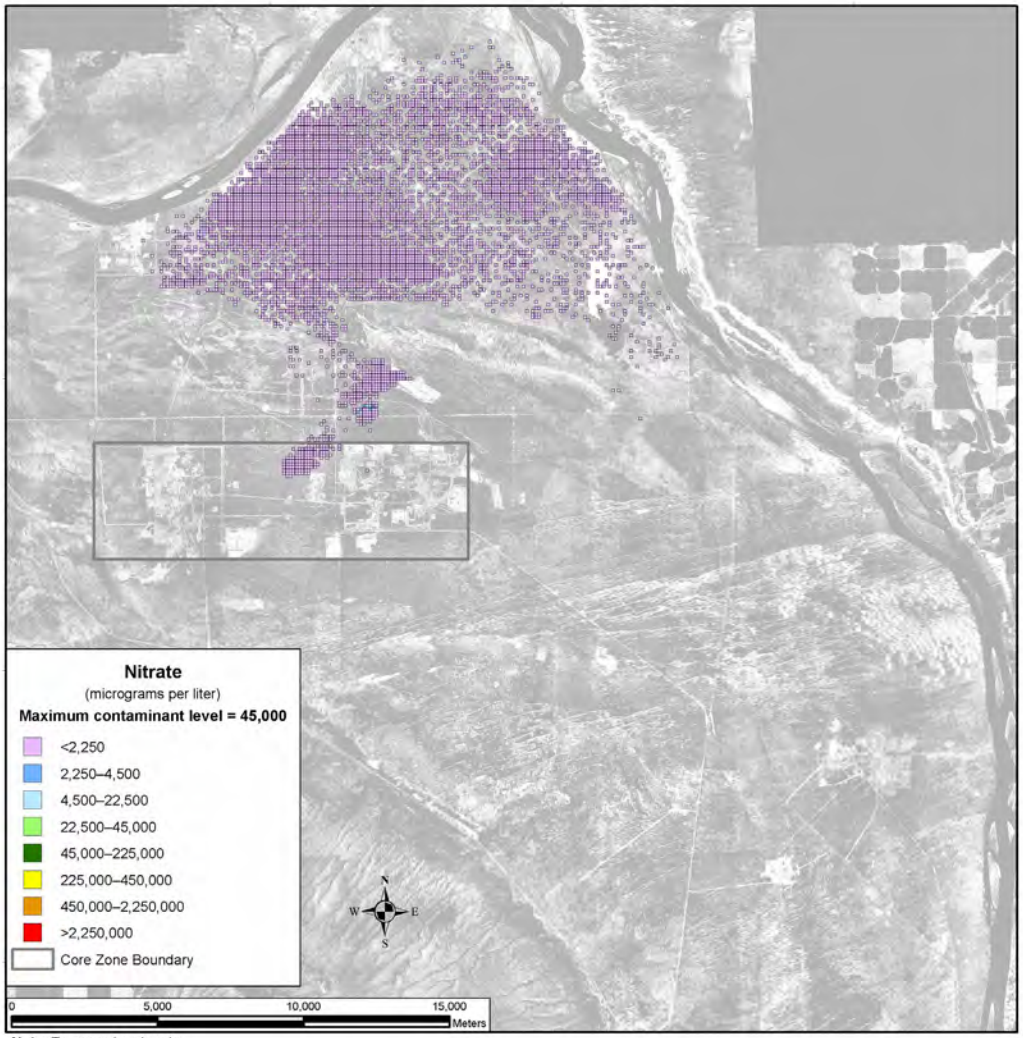
Note: To convert meters to feet, multiply by 3.281

Figure 5–391. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



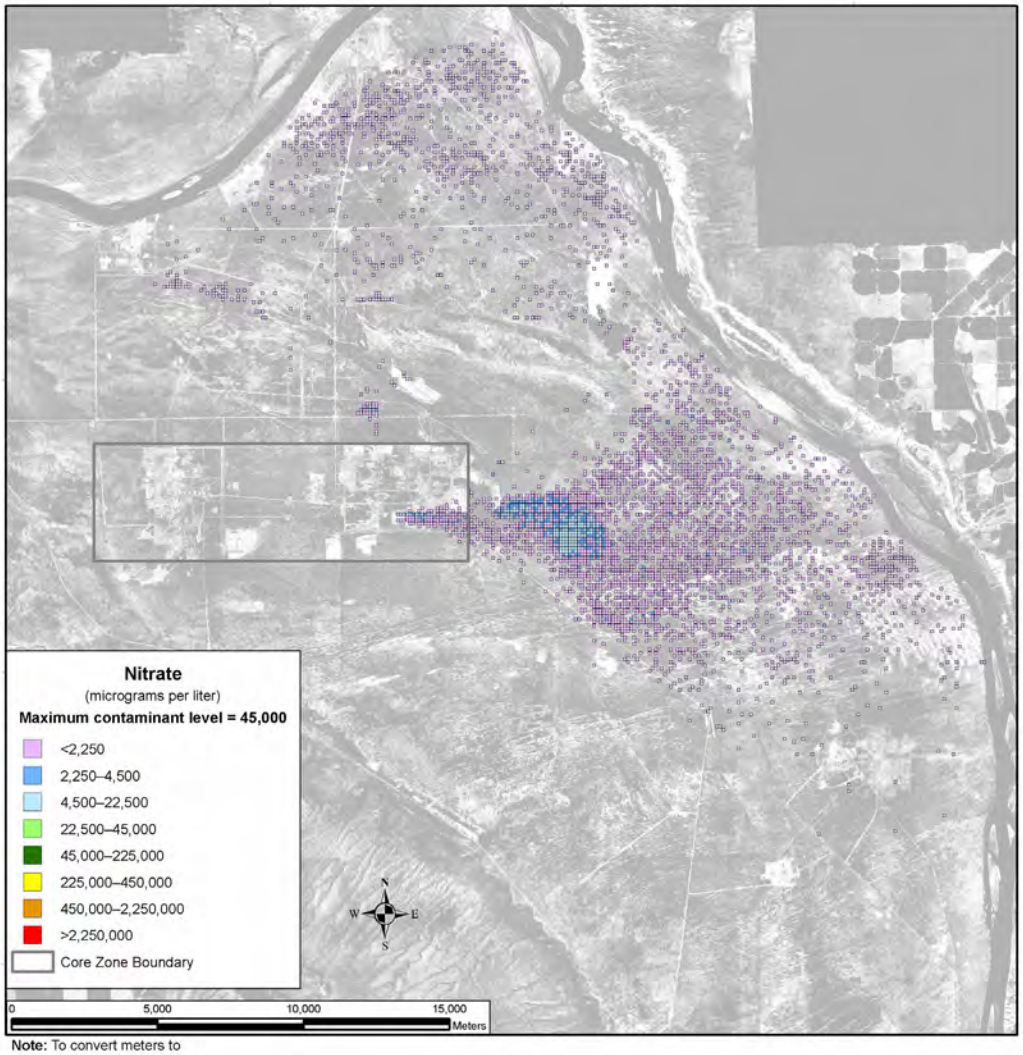
Note: To convert meters to feet, multiply by 3.281

Figure 5–392. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



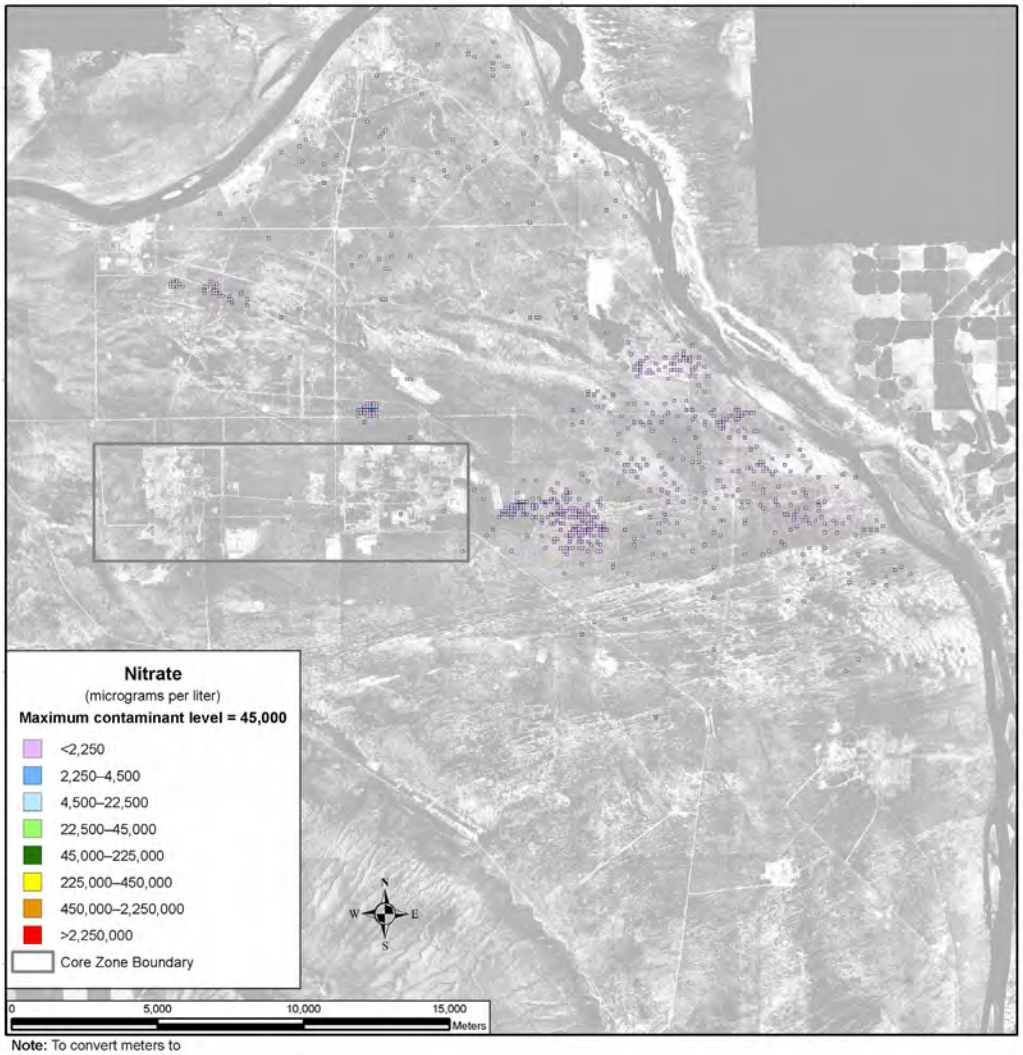
Note: To convert meters to feet, multiply by 3.281

Figure 5–393. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

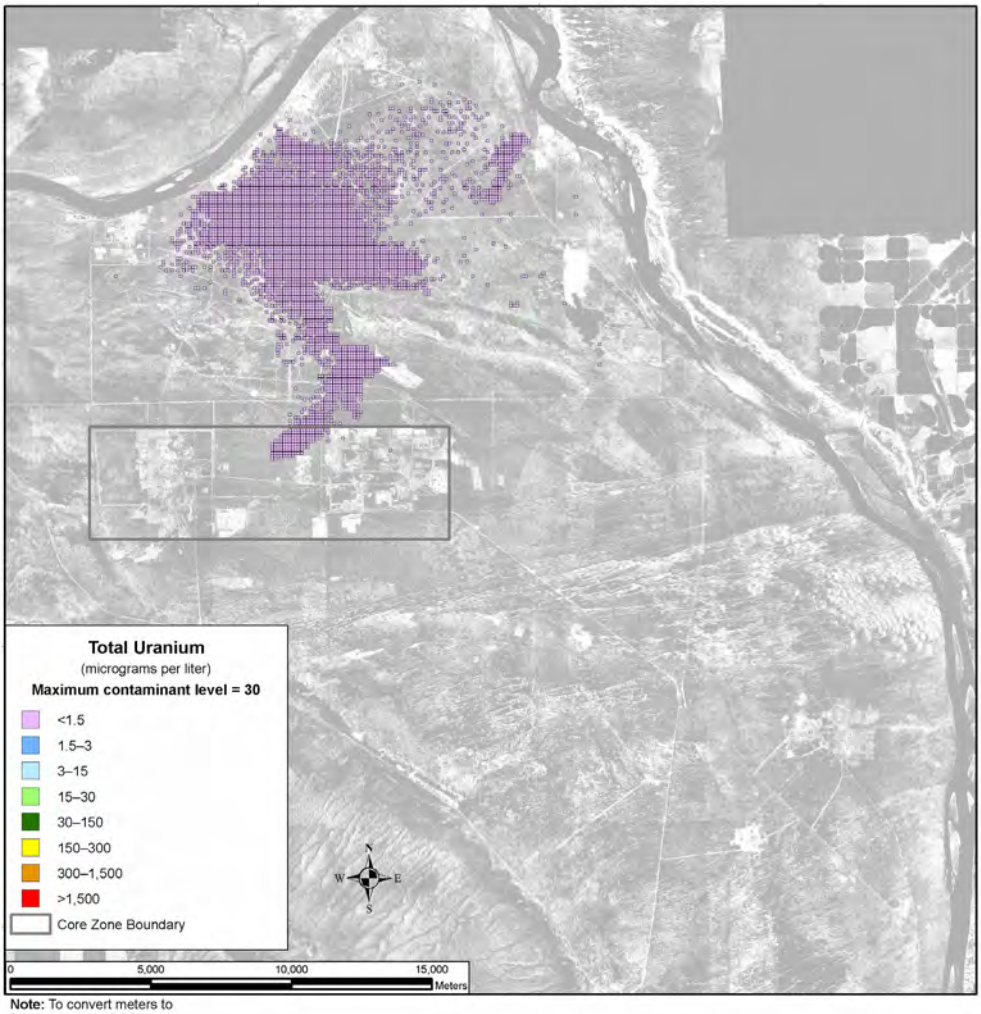
Figure 5–394. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–395. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

Total uranium shows a different spatial distribution over time. This COPC is not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–396 shows the distribution of total uranium at CY 11,885. There is a low-concentration plume that stretches north from the RPPDF and Gable Gap. Concentrations in all areas of the plume remain below one-tenth of the benchmark.



Note: To convert meters to feet, multiply by 3.281

Figure 5–396. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-A, in general, the inventory remaining in IDF-East, available for release to the environment at the start of the post-disposal period, is the predominant contributor. The inventory available for release from the RPPDF during the post-disposal period is a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary approach or exceed benchmark standards by less than one order of magnitude during most of the period of analysis. Concentrations at the Columbia River nearshore are similar to or slightly lower than the concentrations at the Core Zone Boundary. The intensities and areas of these groundwater plumes peak between CYs 8000 and 9000.

For total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species are increasing, but are well below the benchmark at the Core Zone Boundary beyond CY 9940, and remain eight orders of magnitude below the benchmark at the Columbia River after CY 11,940. The peak intensity and area of the contamination plume are largest near the end of the period of analysis.

5.3.1.2.1.2 Disposal Group 1, Subgroup 1-B

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-B covers disposal of waste generated under Tank Closure Alternative 3A and FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW, ILAW glass, and bulk vitrification glass. IHLW would be stored on site, while ILAW glass and bulk vitrification glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.
- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–397 through 5–408). Three subtotals are plotted representing releases from ILAW glass, bulk vitrification glass, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over eight orders of magnitude.

Figure 5–397 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–398, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). The predominant sources of technetium-99 are bulk vitrification glass and offsite-generated waste; of iodine-129 is offsite-generated waste; and of boron is waste management secondary waste. The predominant sources for chromium are tank closure secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. The predominant sources for fluoride are waste management secondary waste and onsite-generated waste. The predominant source for nitrate is ETF-generated secondary waste.

Figure 5–399 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–400, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Nearly all of the technetium-99 and iodine-129 released to the vadose zone reached groundwater in the analysis, as well as nearly all of the chromium, fluoride, nitrate, and boron.

Figure 5–401 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–402, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99 and iodine-129, about 90 percent of the total amounts released from the vadose zone reached the Columbia River in the analysis; for chromium, about 93 percent; and for fluoride, nitrate, and boron, about 98 percent.

Figure 5–403 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–404, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e. 100 percent of the inventory was released during the period of analysis). Technetium-99, iodine-129, chromium, and nitrate are all present at the RPPDF in the analysis (fluoride and boron are not).

Figure 5–405 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–406, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All of the COPC drivers present at the RPPDF behave as conservative tracers, with essentially all of the mass released to the vadose zone reaching groundwater.

Figure 5–407 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–408, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For technetium-99, iodine-129, chromium, and nitrate, approximately 100 percent of the total amounts released to the vadose zone at the RPPDF reached the Columbia River in the analysis.

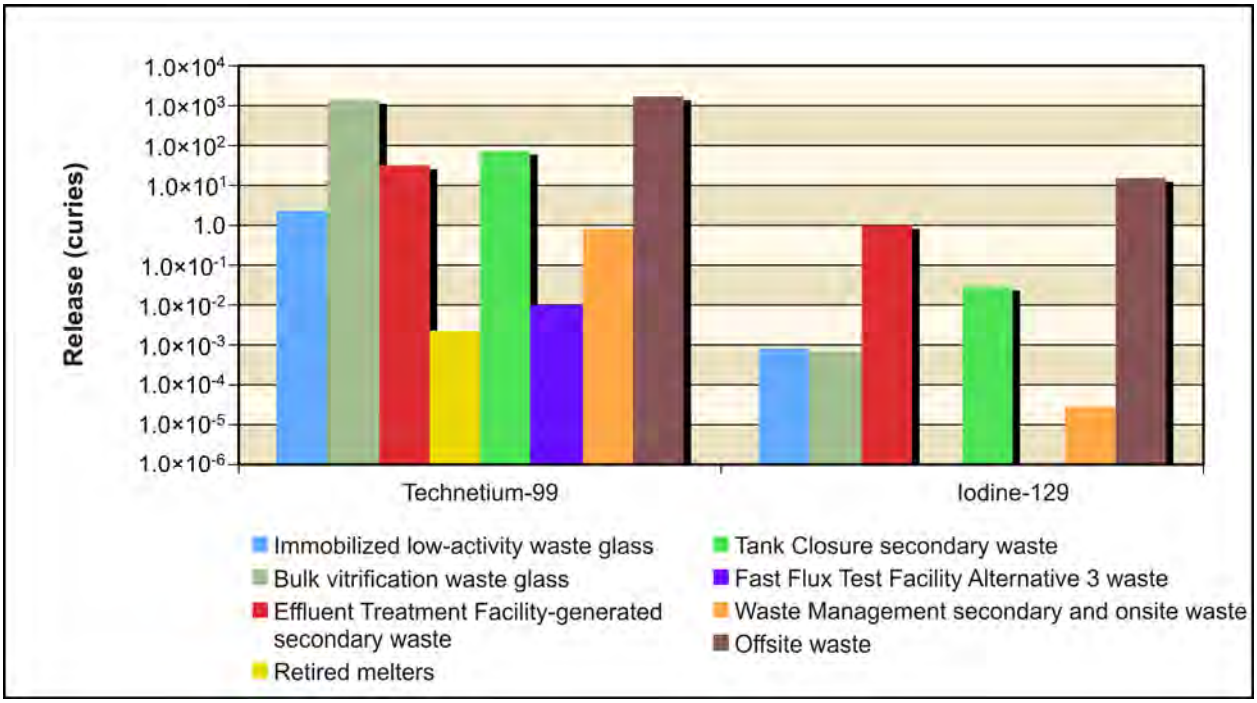


Figure 5–397. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

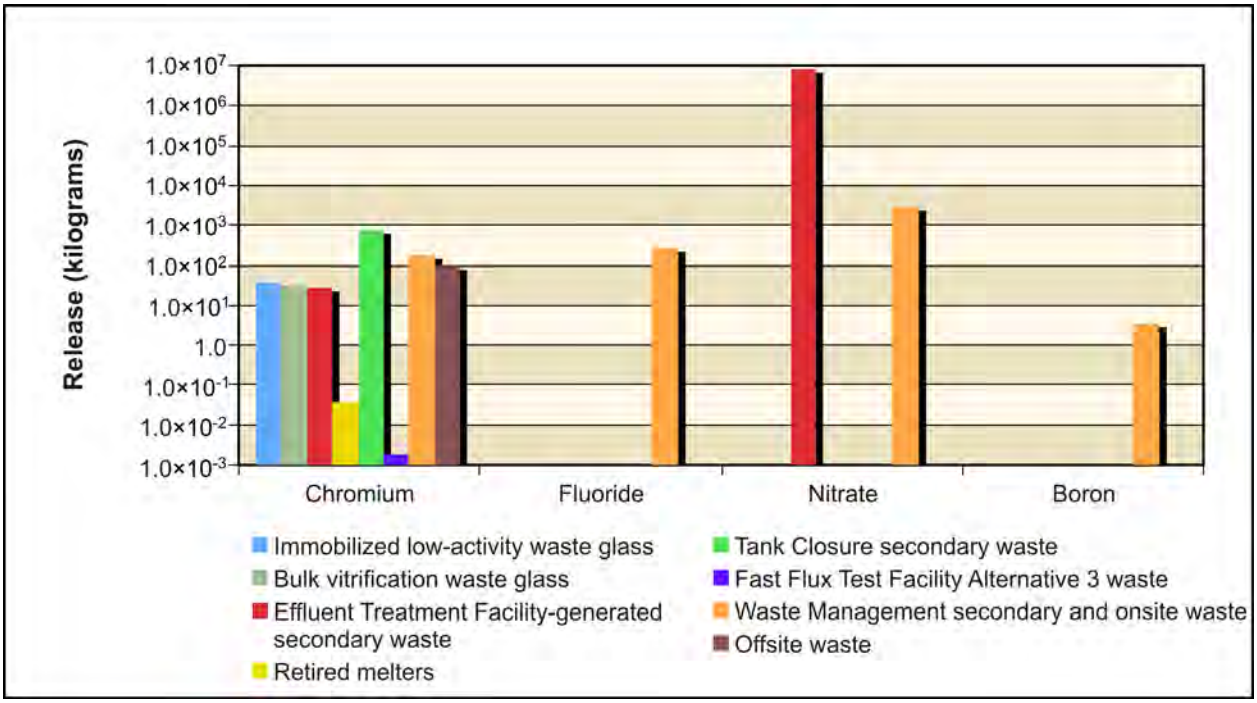


Figure 5–398. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

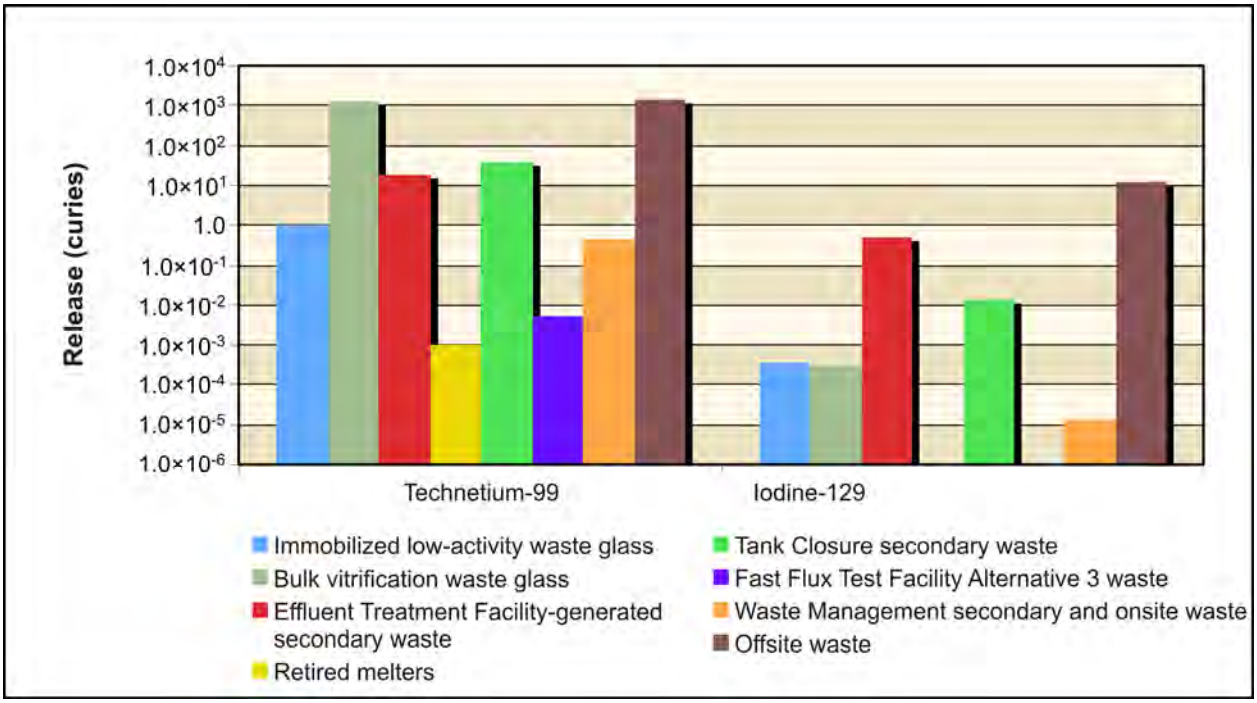


Figure 5–399. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

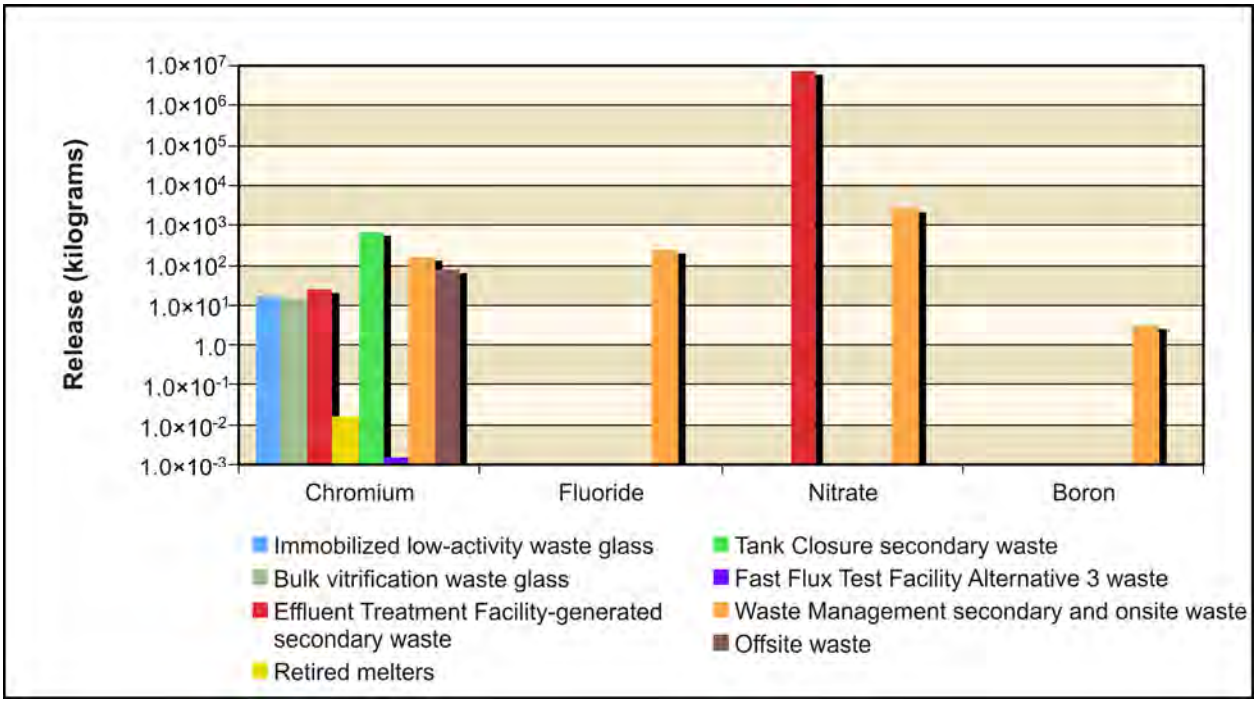


Figure 5–400. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

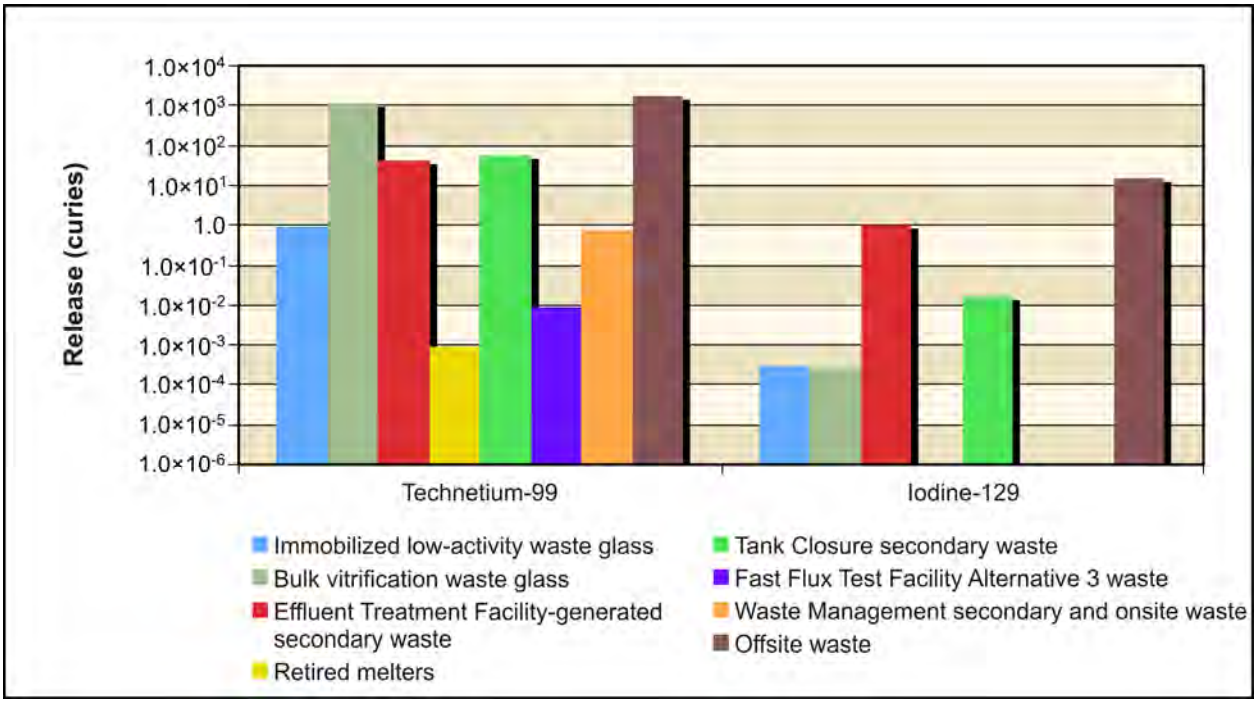


Figure 5–401. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

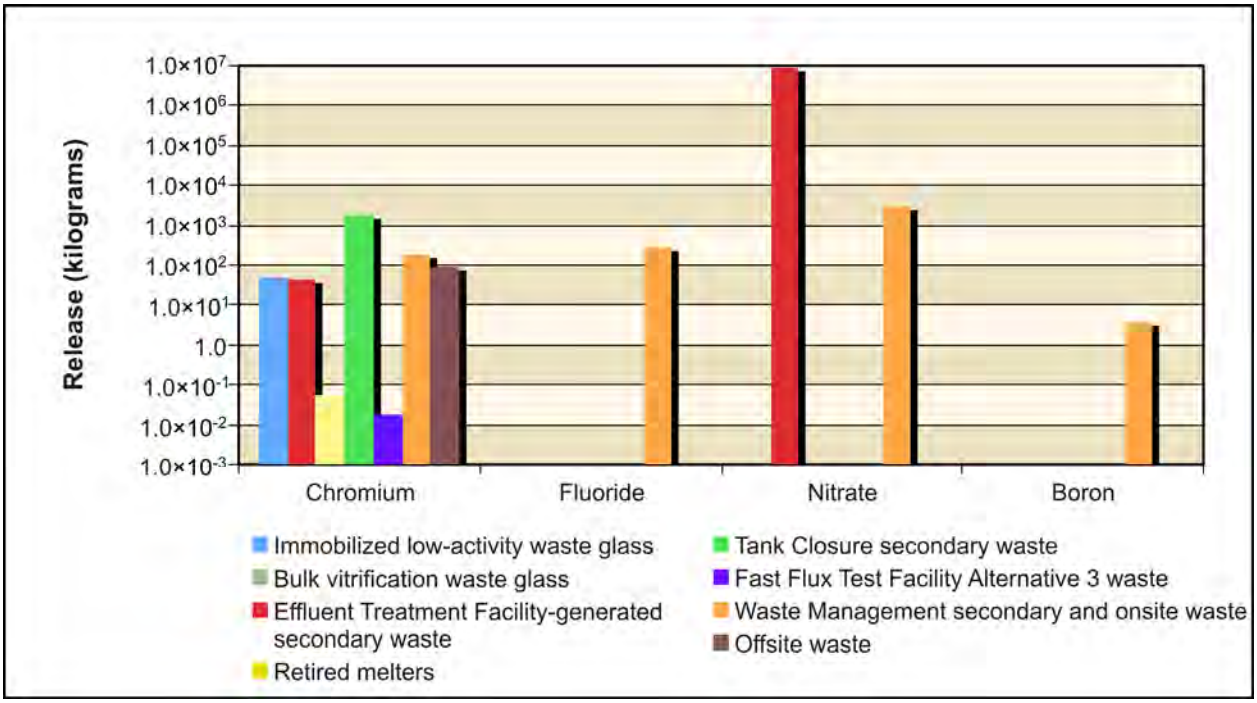


Figure 5–402. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

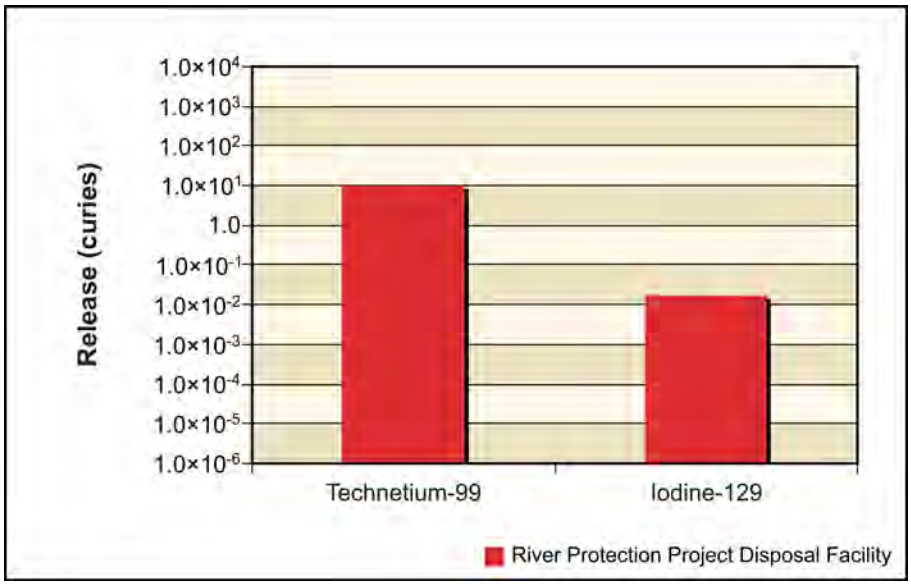


Figure 5–403. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

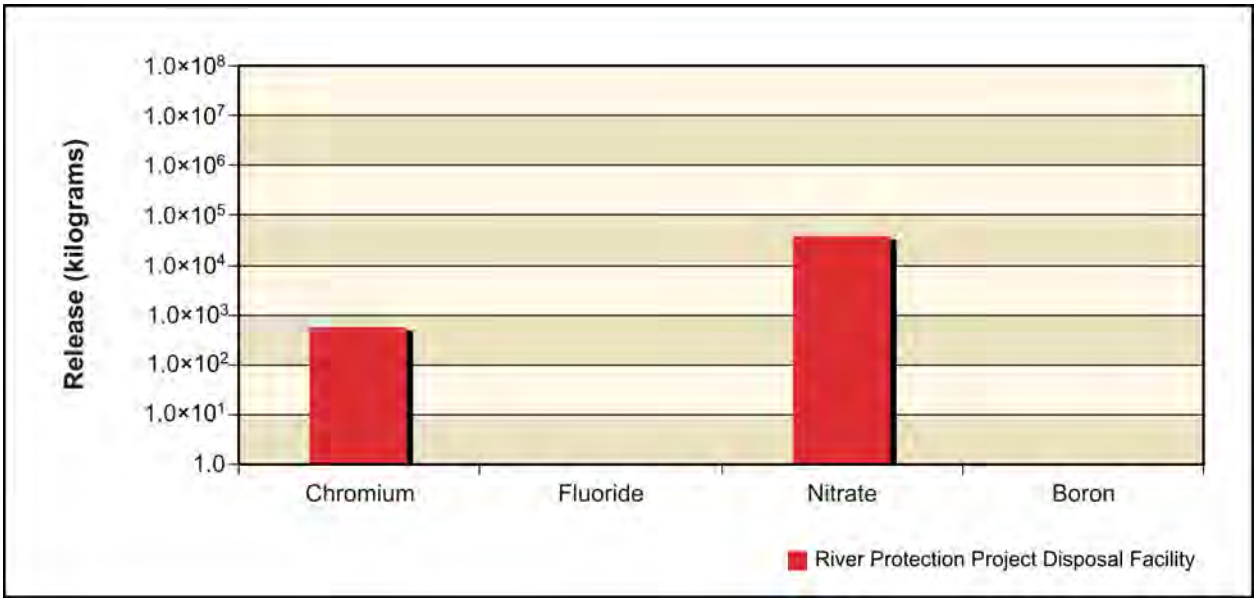


Figure 5–404. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

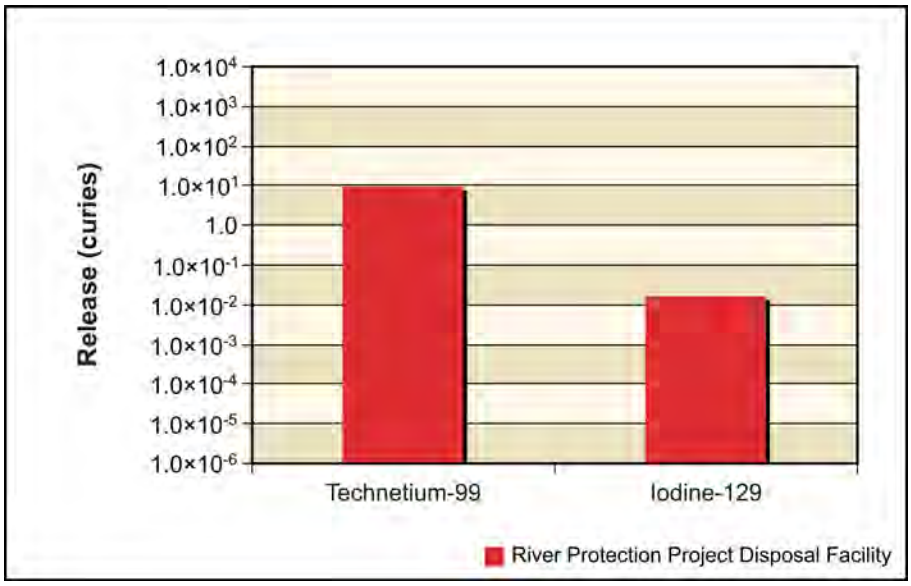


Figure 5–405. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Groundwater

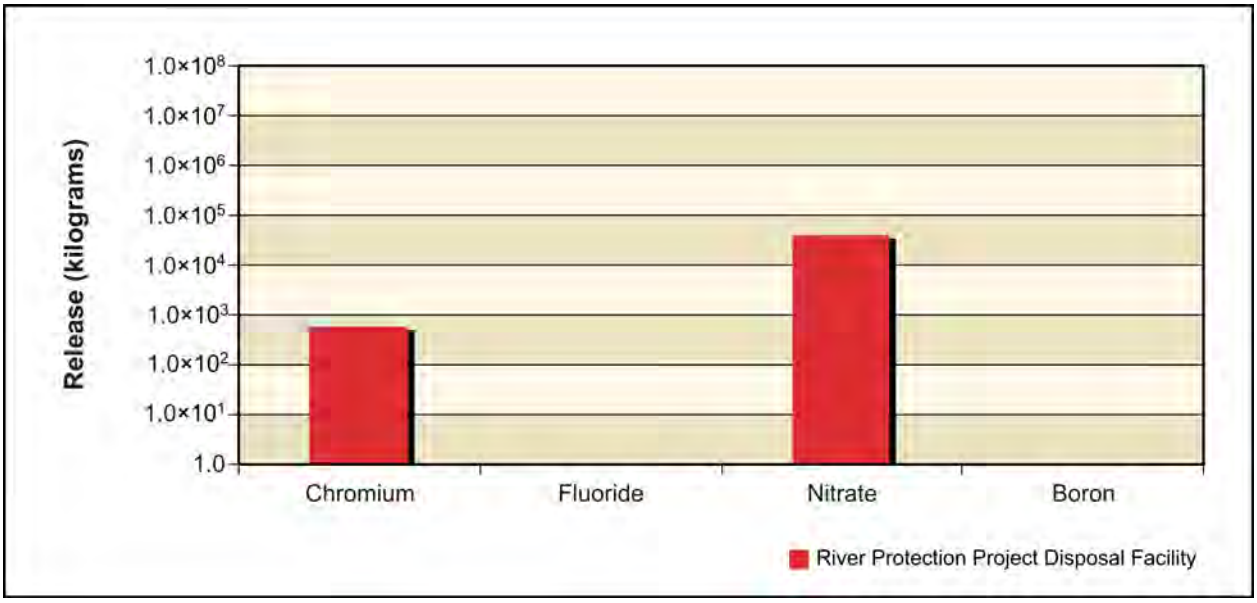


Figure 5–406. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Groundwater

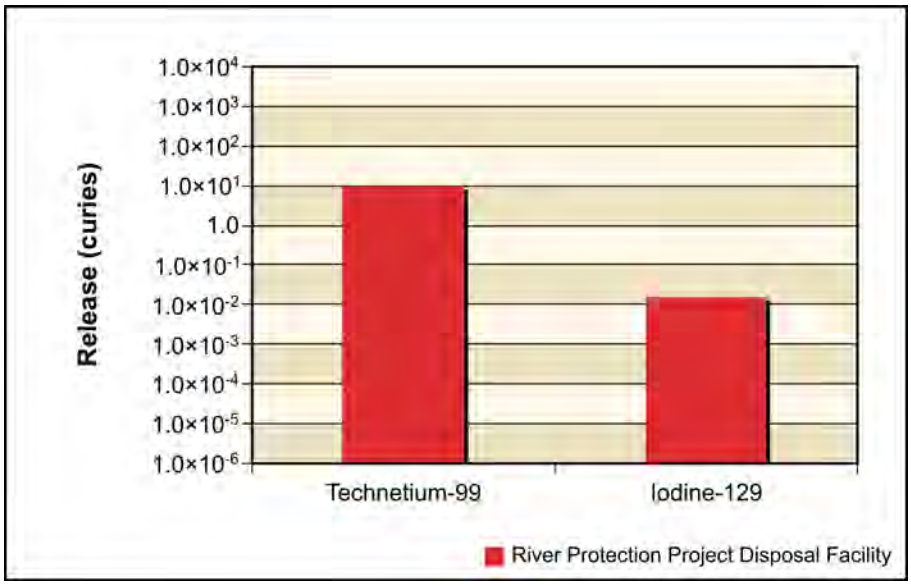


Figure 5–407. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Radiological Releases at River Protection Project Disposal Facility to Columbia River

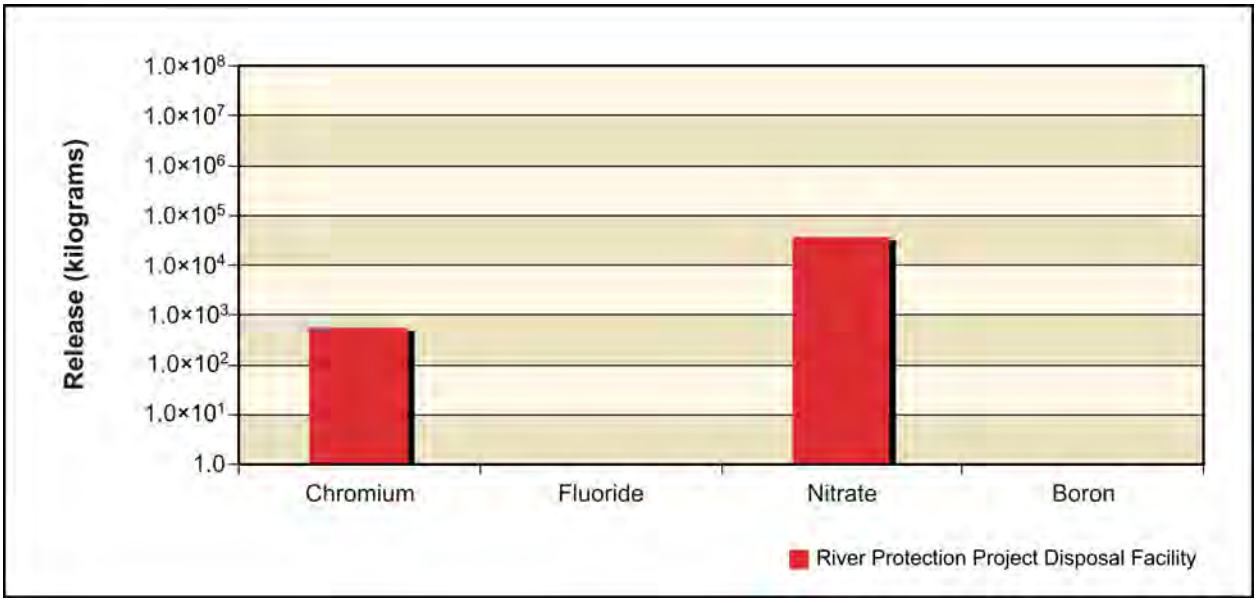


Figure 5–408. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter chemicals in micrograms per liter (see Figures 5–409 through 5–413). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude. Table 5–78 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–409 through 5–412 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). For technetium-99, a small rise in concentration is evident in the early years, peaking around CY 3940, but remaining over an order of magnitude below the benchmark concentration. Beginning in CY 5400, concentrations at the Core Zone Boundary begin climbing again, reaching a level just below the benchmark concentration at CY 7940. Iodine-129 follows a similar pattern, reaching a concentration slightly above the benchmark, while chromium and nitrate peak over an order of magnitude below the benchmark.

Figure 5–413 shows concentration versus time for total uranium. Because of the high retardation of uranium, no contamination appears until CY 9940, when total uranium concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter. Total uranium remains over seven orders of magnitude below the benchmark concentration at the Core Zone Boundary throughout the simulation. Uranium-238 does not surpass 1.0×10^{-8} picocuries per liter during the simulation.

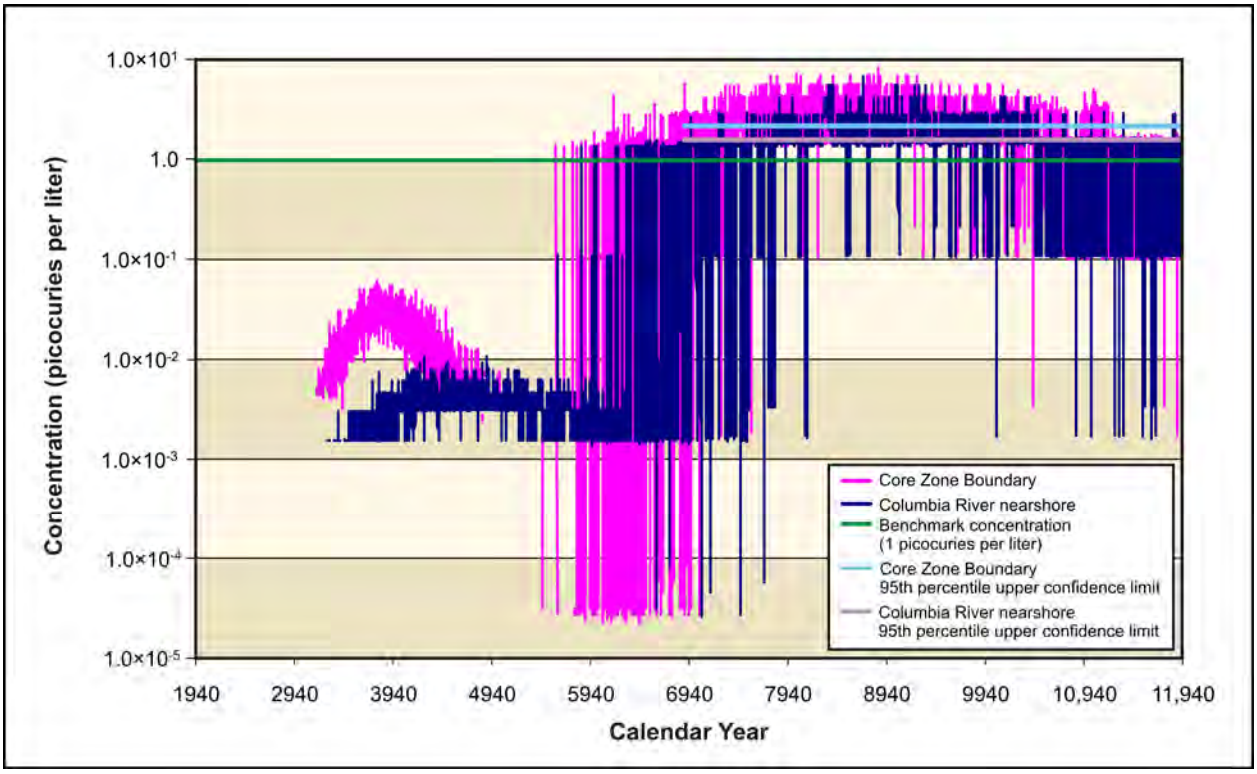


Figure 5–409. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Iodine-129 Concentration Versus Time

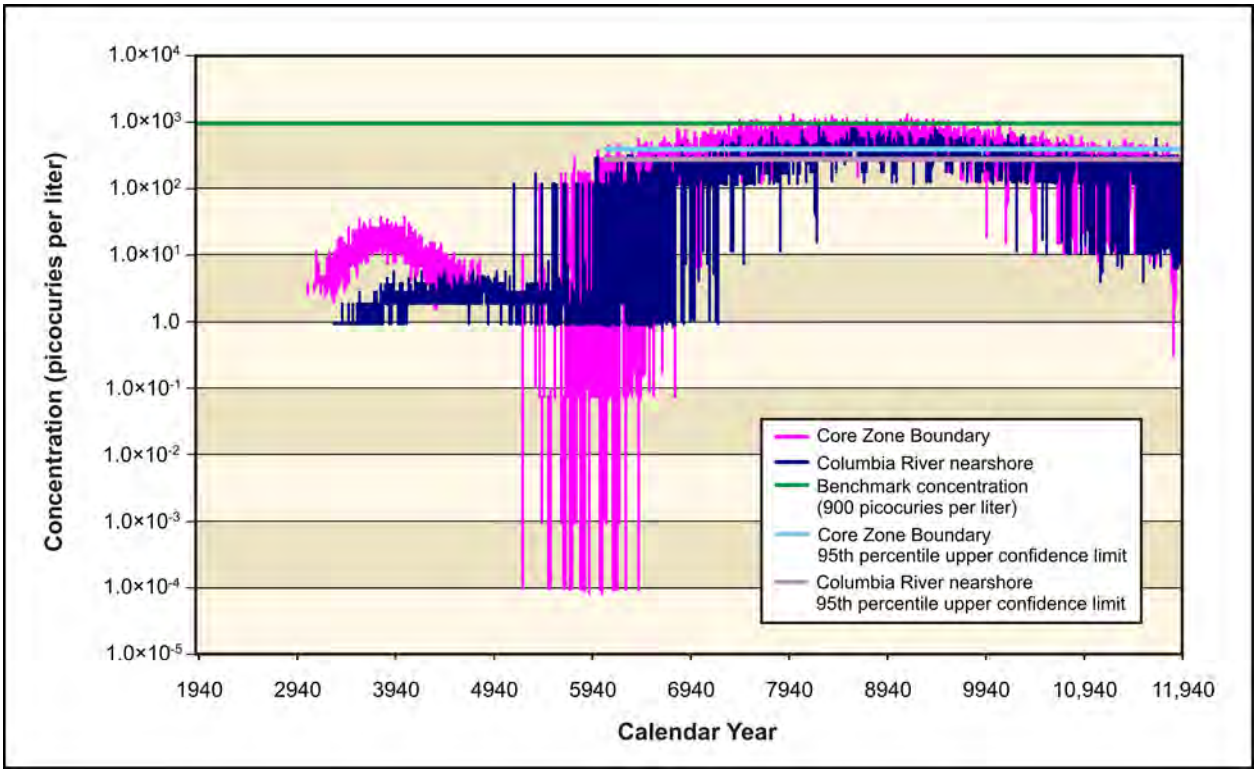


Figure 5–410. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Technetium-99 Concentration Versus Time

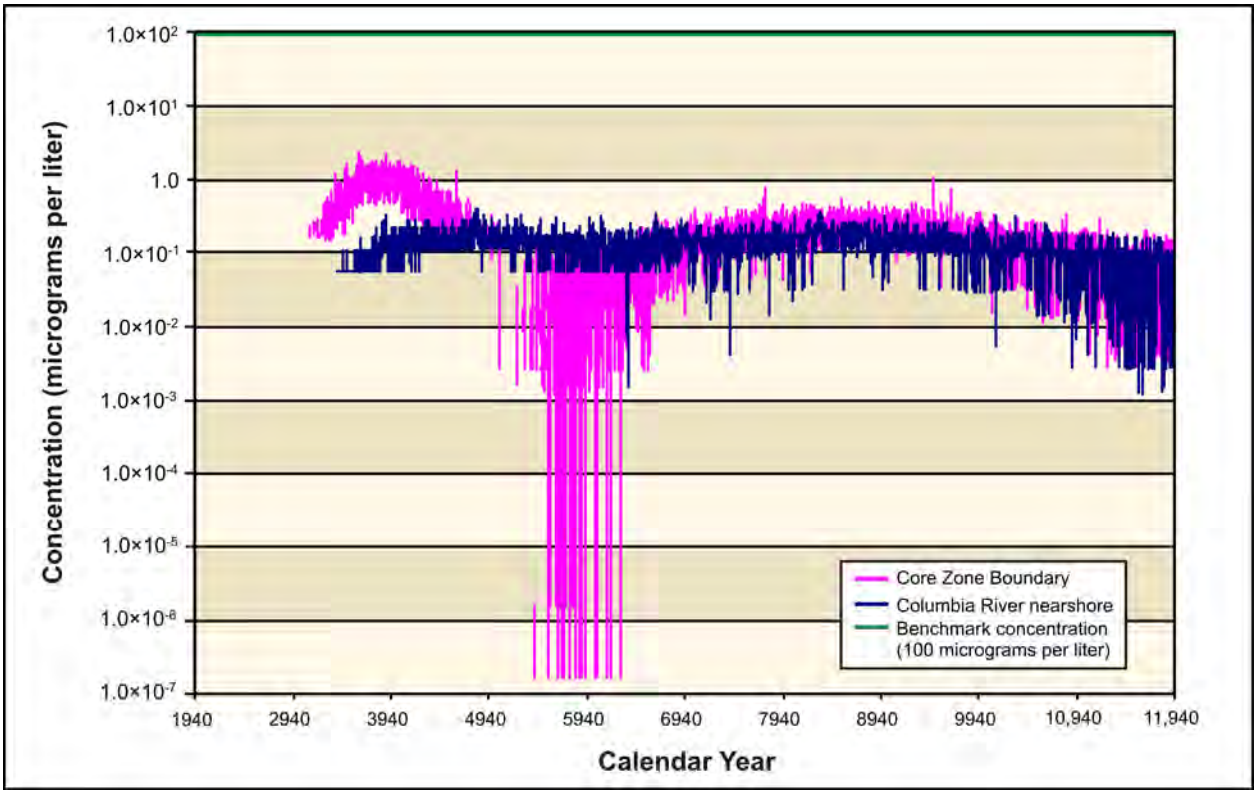


Figure 5–411. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Chromium Concentration Versus Time

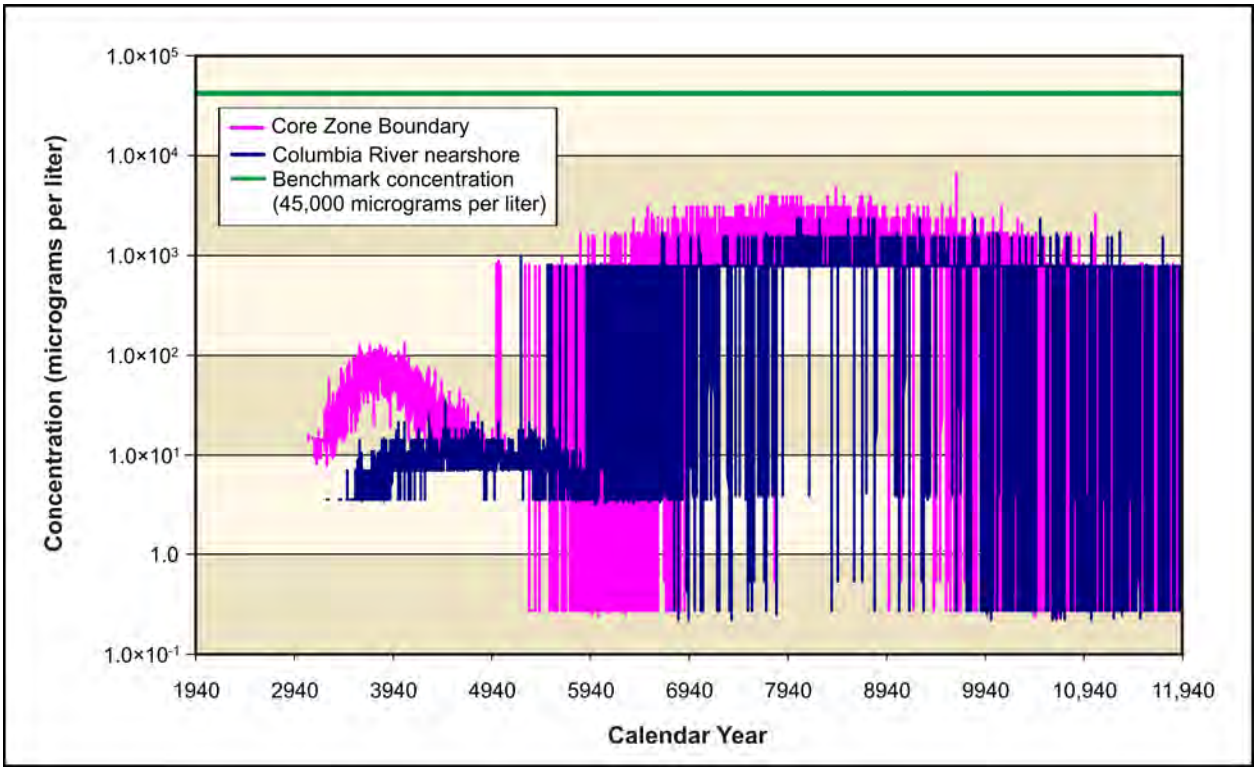


Figure 5–412. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Nitrate Concentration Versus Time

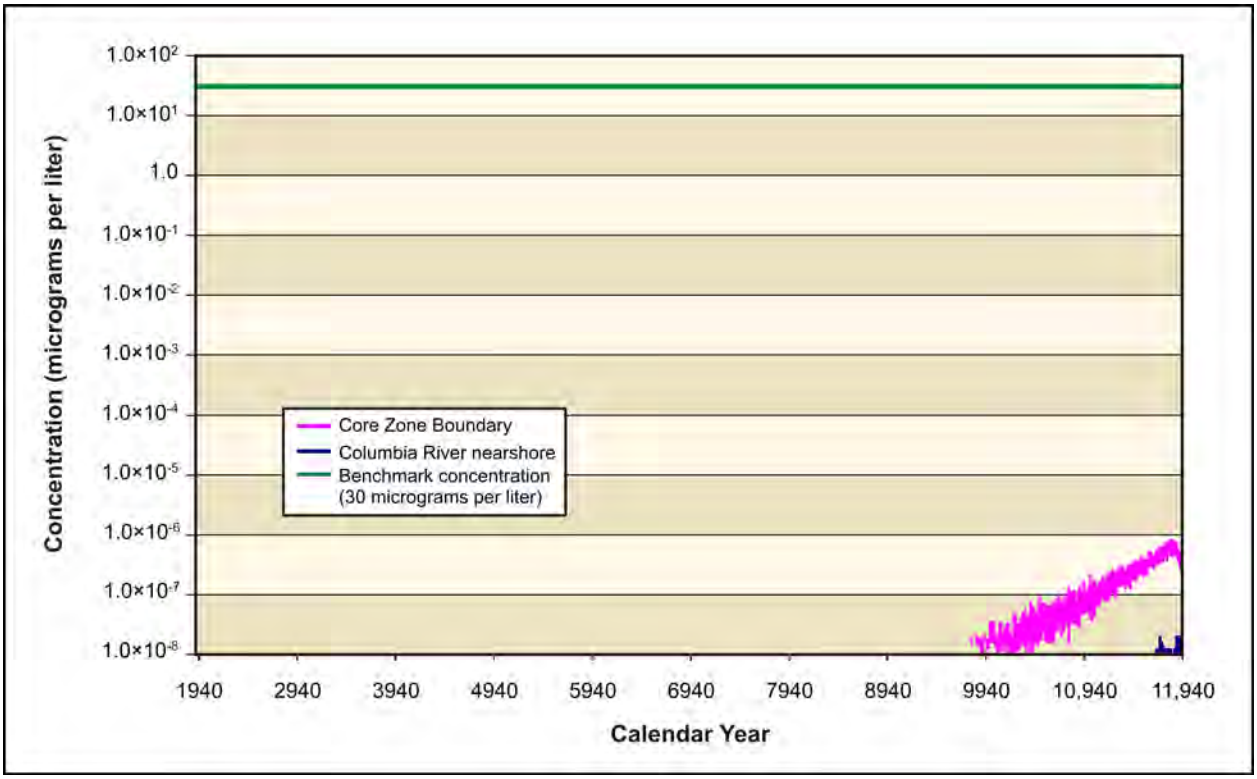


Figure 5–413. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Total Uranium Concentration Versus Time

Table 5–78. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,880**	33	**1,250**	815	900
	(8486)	(3825)	(7998)	(8273)	
Iodine-129	**18**	0.1	**8**	**7**	1
	(8195)	(3772)	(8858)	(8700)	
Chemical in micrograms per liter					
Chromium	2	2	2	0	100
	(8278)	(3856)	(3889)	(4826)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,400	149	5,860	3,680	45,000
	(7821)	(3811)	(8905)	(8144)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

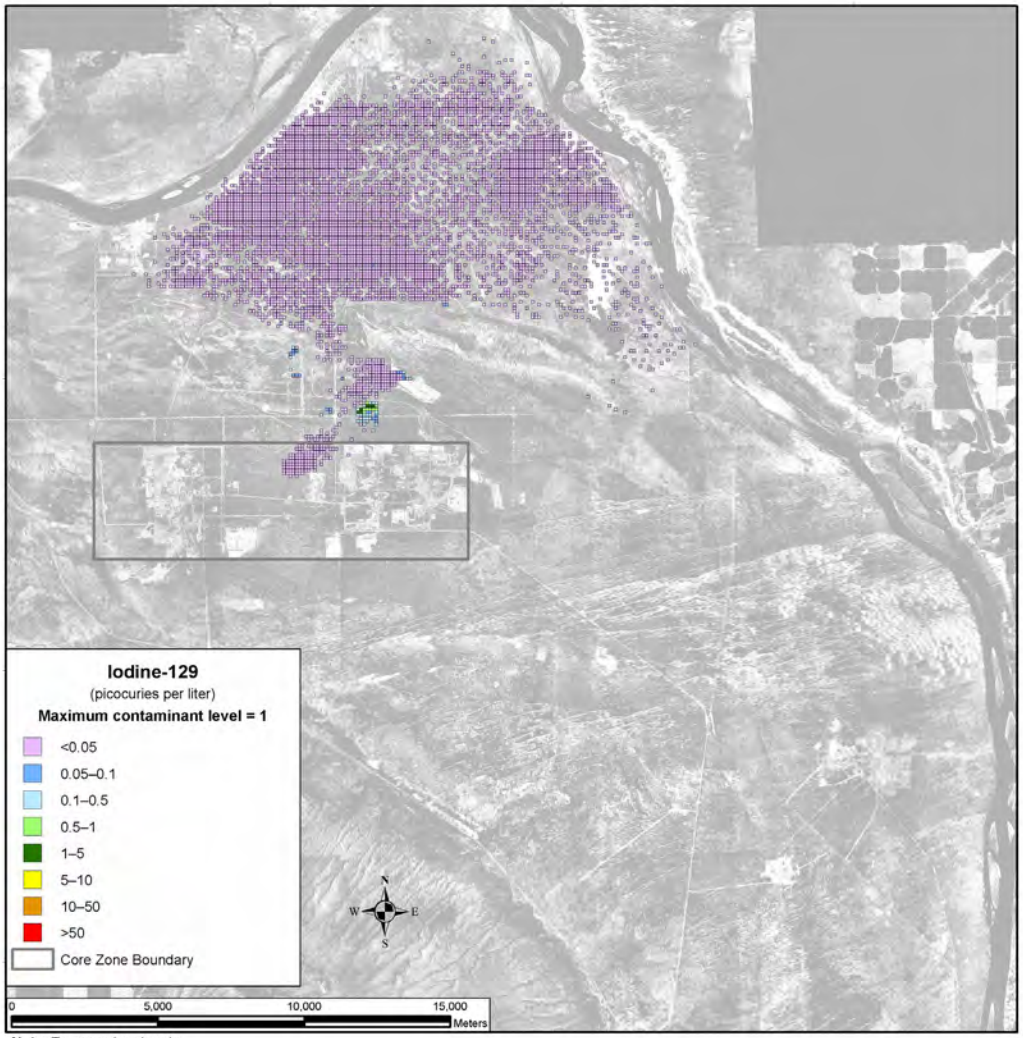
Key: COPC=constituent of potential concern; IDF-East=an Integrated Disposal Facility in the 200-East Area of Hanford; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–414 through 5–426). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

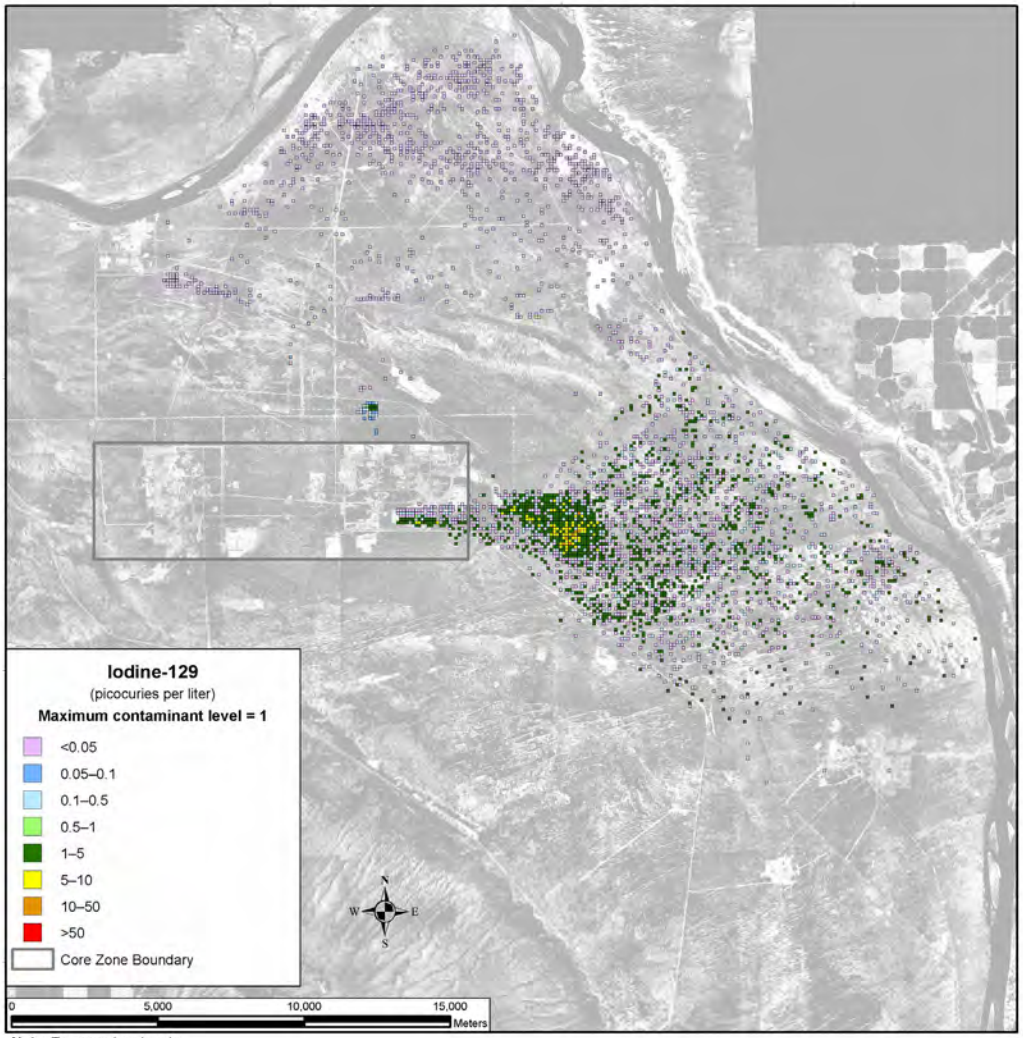
At CY 3890 (see Figure 5–414), there is a low-concentration plume of iodine-129 that stretches north from the RPPDF and through Gable Gap. By CY 7140 (see Figure 5–415), the plume from the RPPDF is gone, but a new plume has formed, traveling east from IDF-East. Concentrations in this plume reach a level over an order of magnitude above the benchmark. Figure 5–416 shows the iodine-129 concentration for CY 11,885. Technetium-99 (see Figures 5–417 through 5–419), chromium (see Figures 5–420 through 5–422), and nitrate (see Figures 5–423 through 5–425) show similar spatial distributions, with lower concentrations at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium shows a different spatial distribution over time. It is not as mobile as the COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. By CY 11,885, there is a plume extending through Gable Gap from the RPPDF (see Figure 5–426). Concentrations in all areas of the plume remain below one-twentieth of the benchmark.



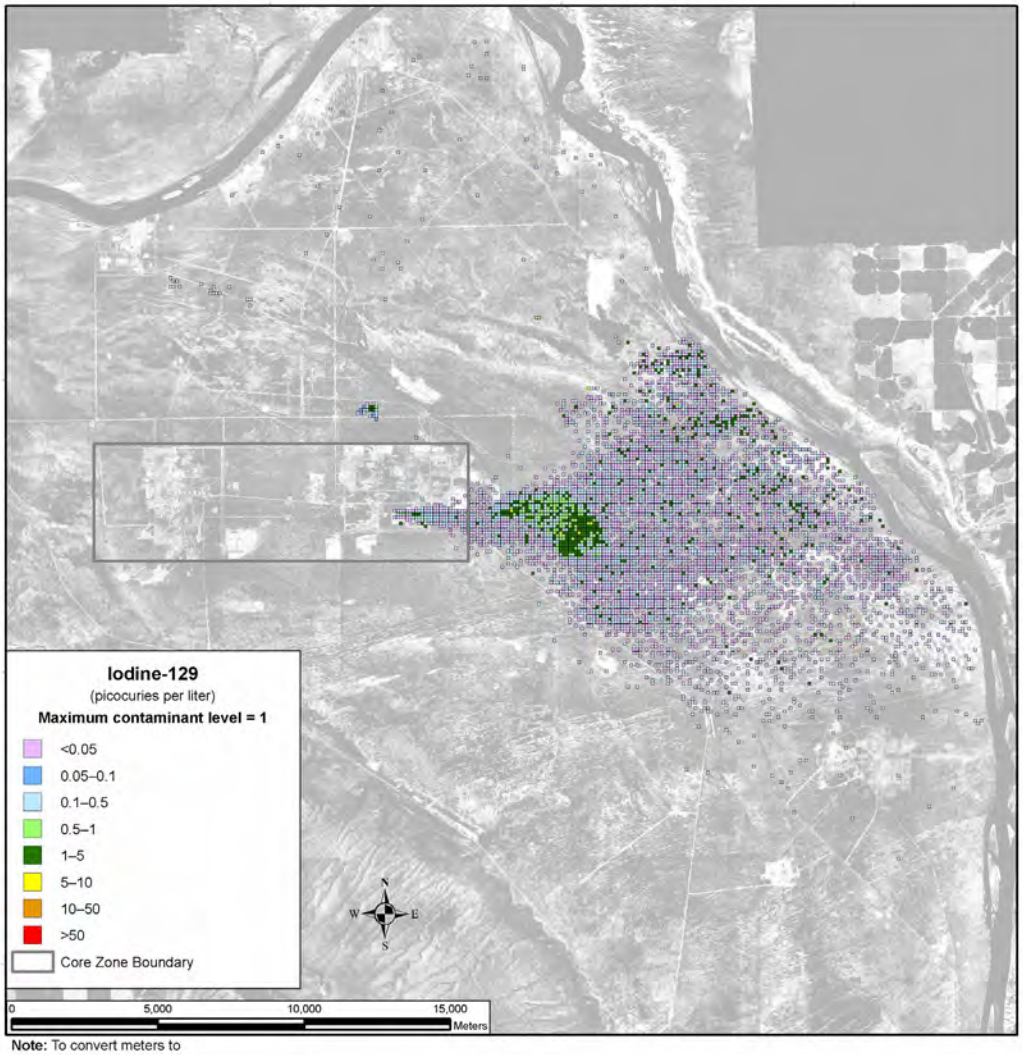
Note: To convert meters to feet, multiply by 3.281

Figure 5–414. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



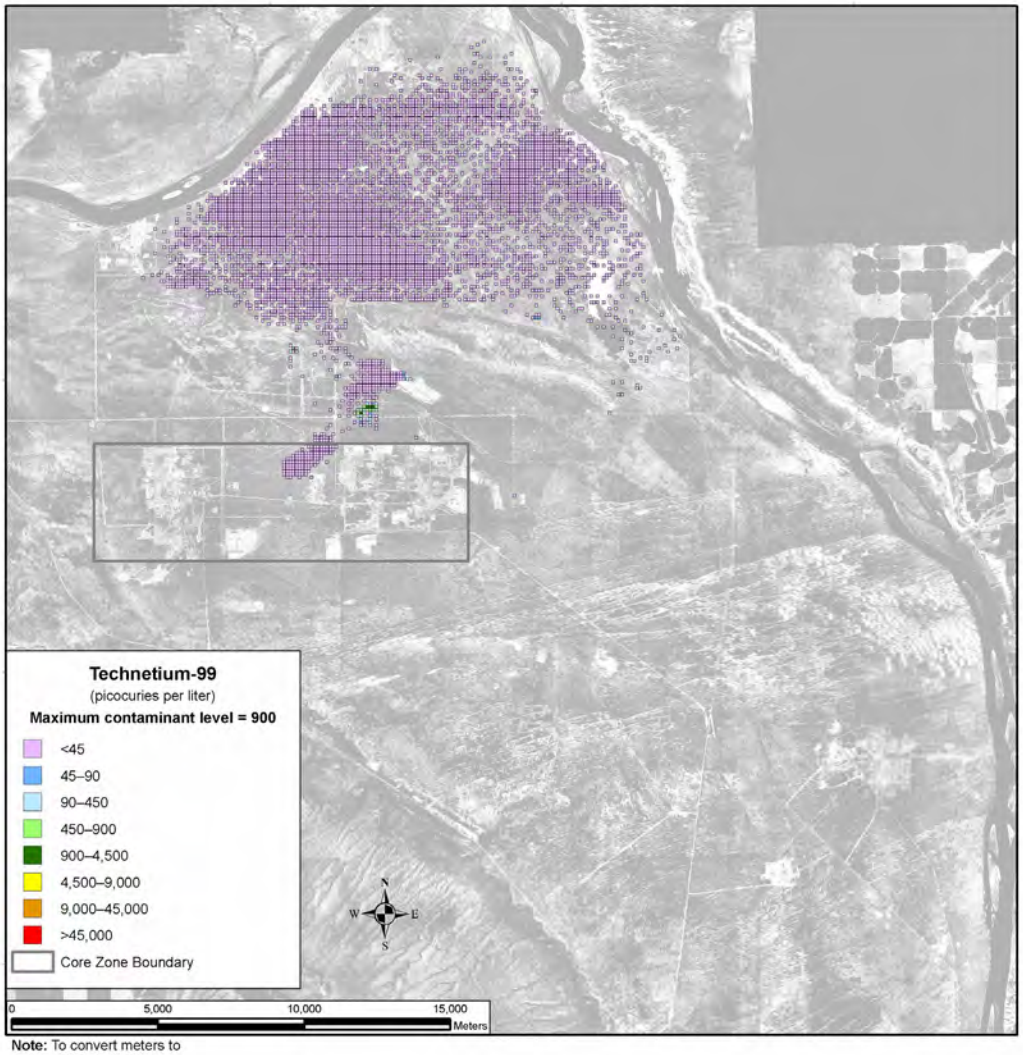
Note: To convert meters to feet, multiply by 3.281

Figure 5–415. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



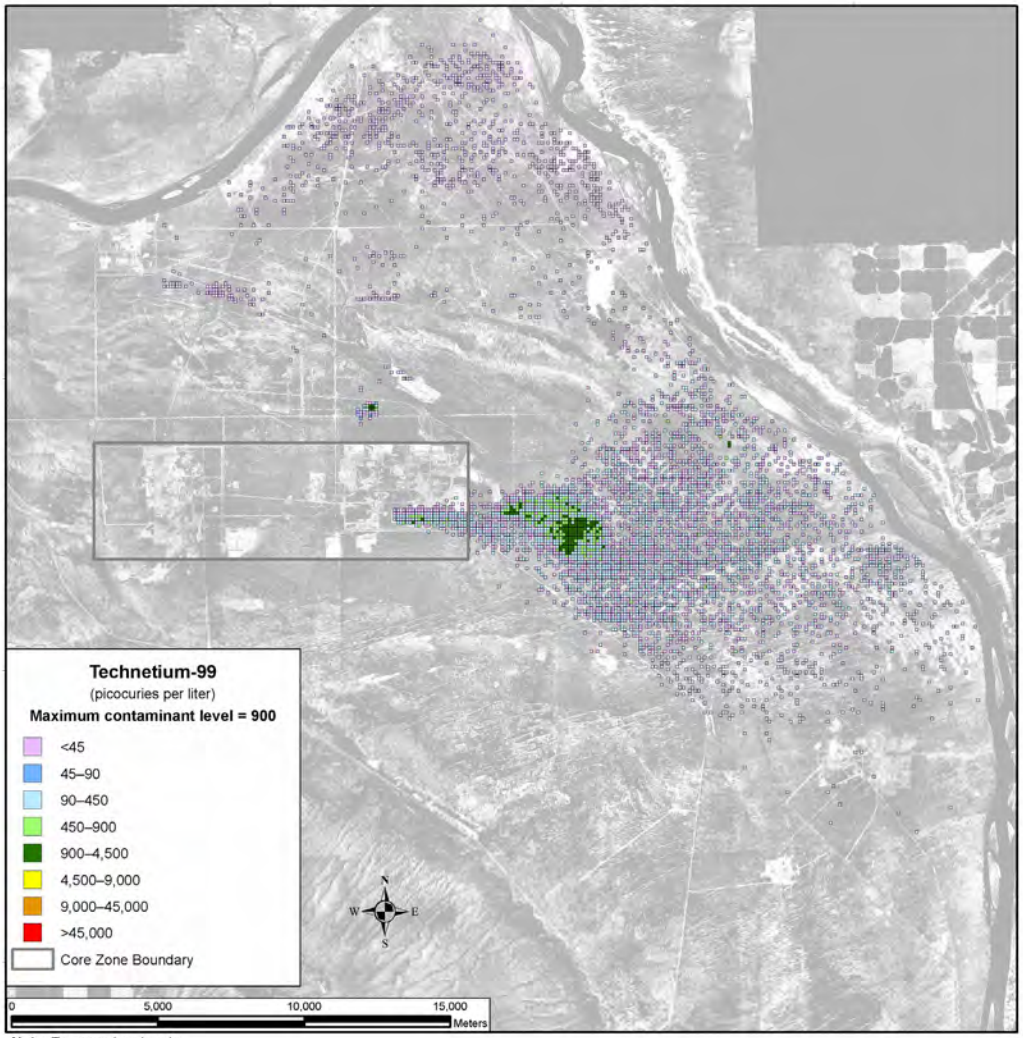
Note: To convert meters to feet, multiply by 3.281

Figure 5–416. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



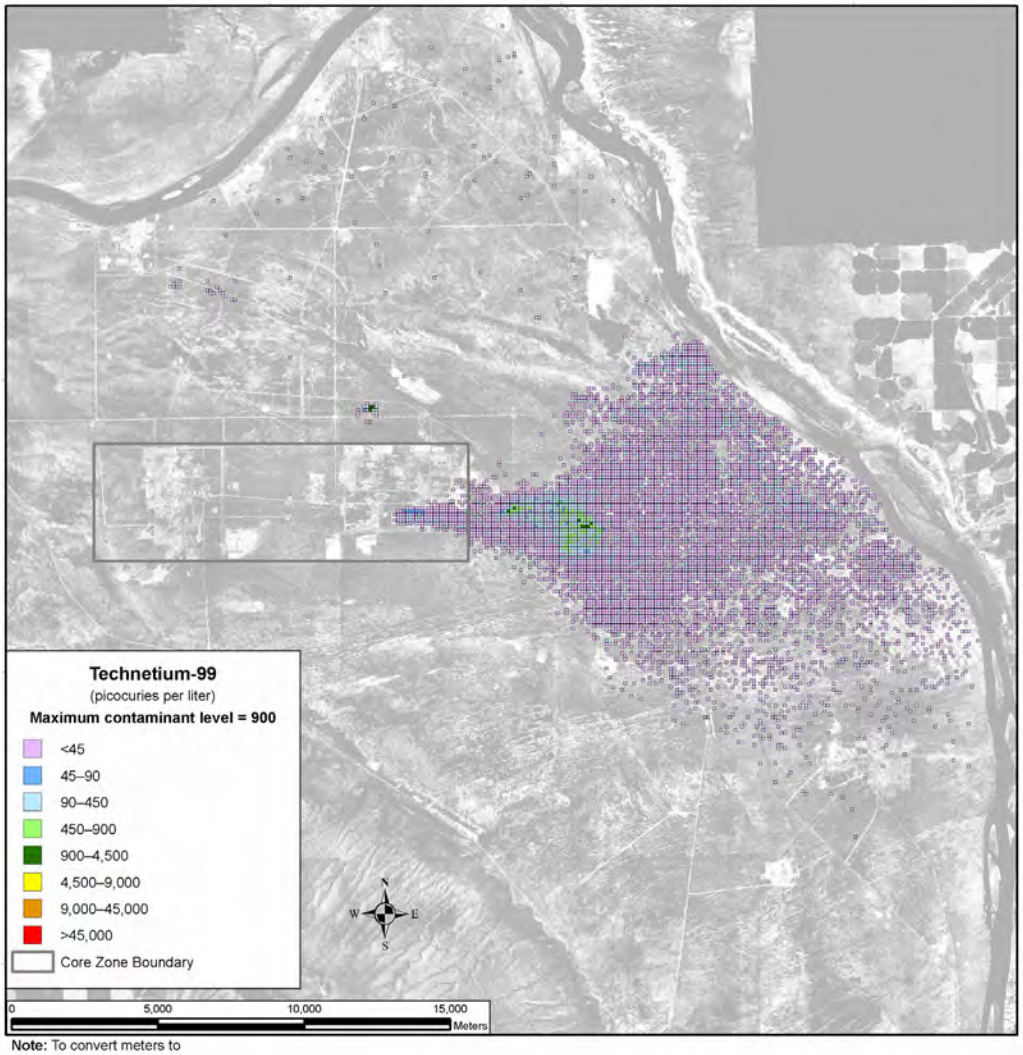
Note: To convert meters to feet, multiply by 3.281

Figure 5–417. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



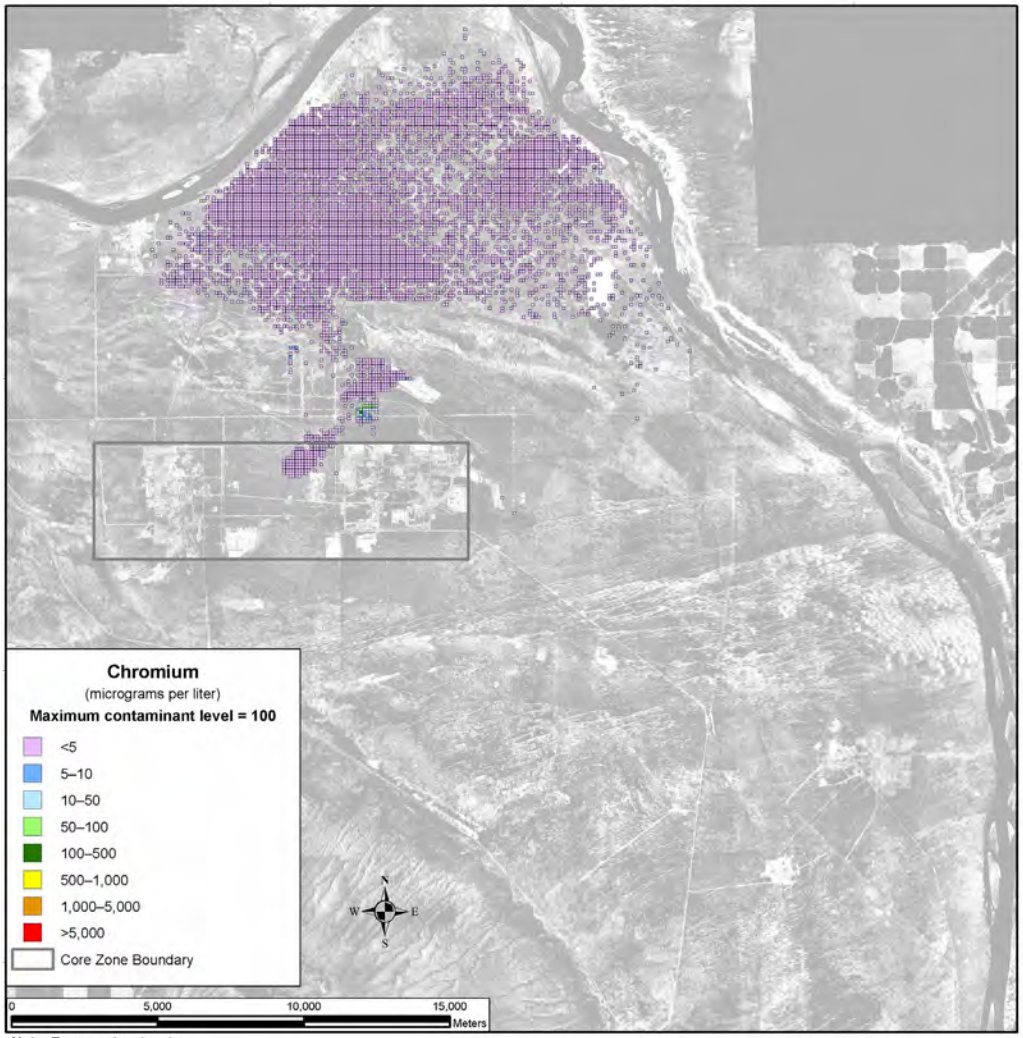
Note: To convert meters to feet, multiply by 3.281

Figure 5–418. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



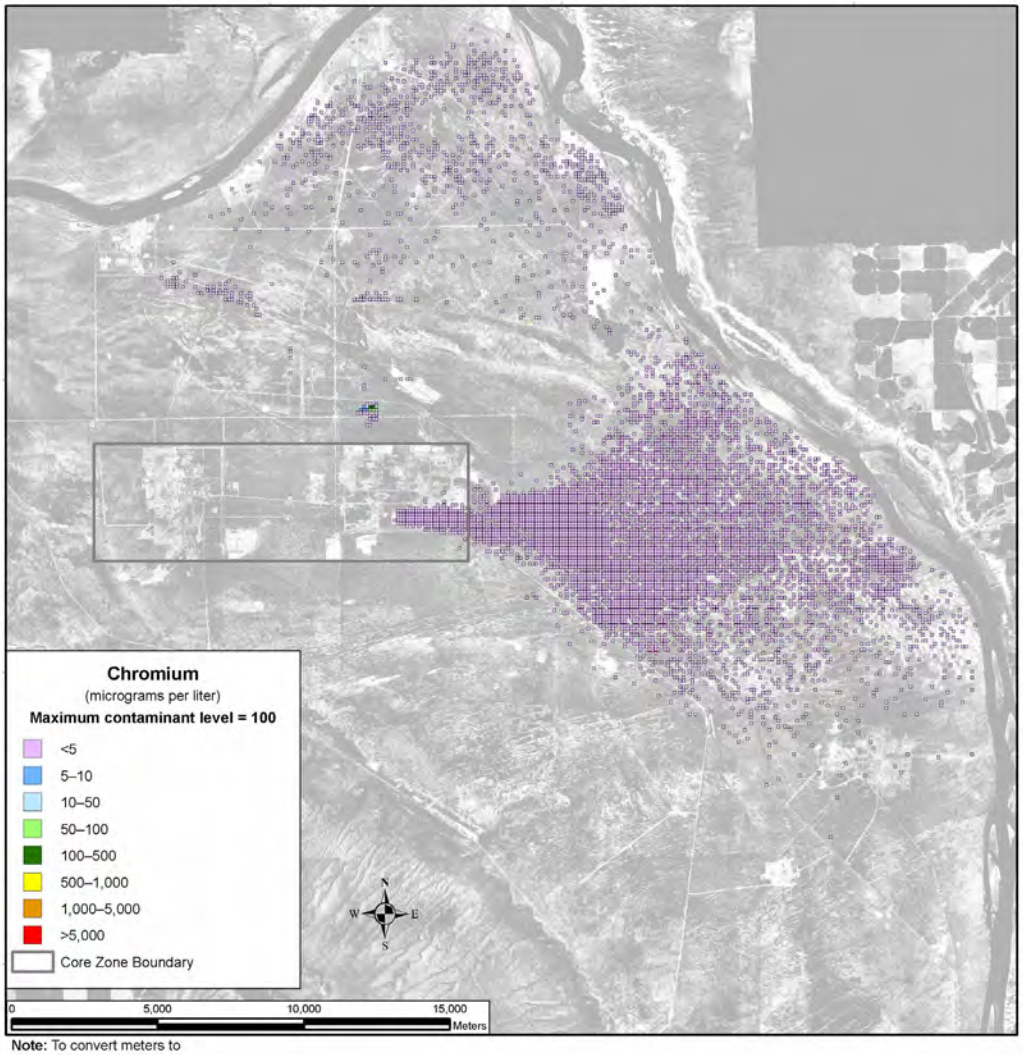
Note: To convert meters to feet, multiply by 3.281

Figure 5–419. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



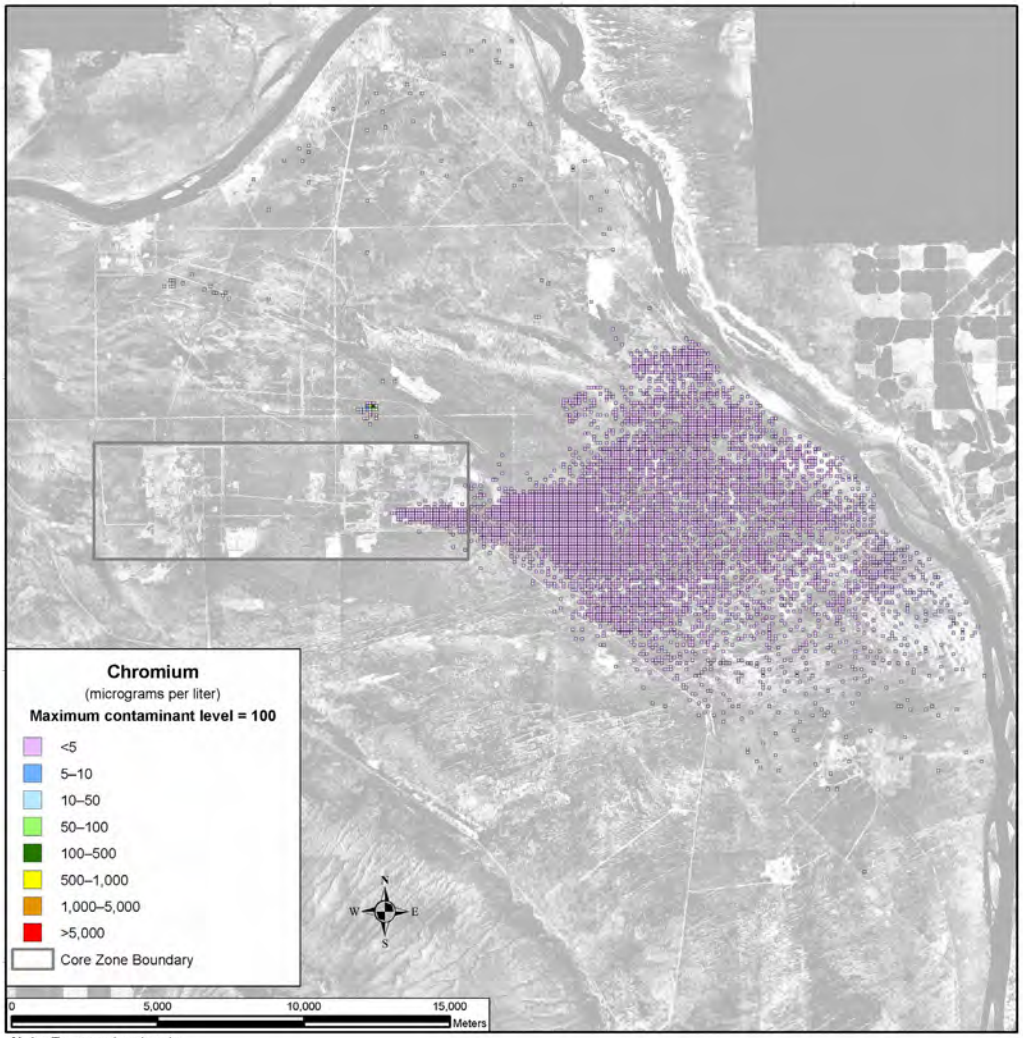
Note: To convert meters to feet, multiply by 3.281

Figure 5–420. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



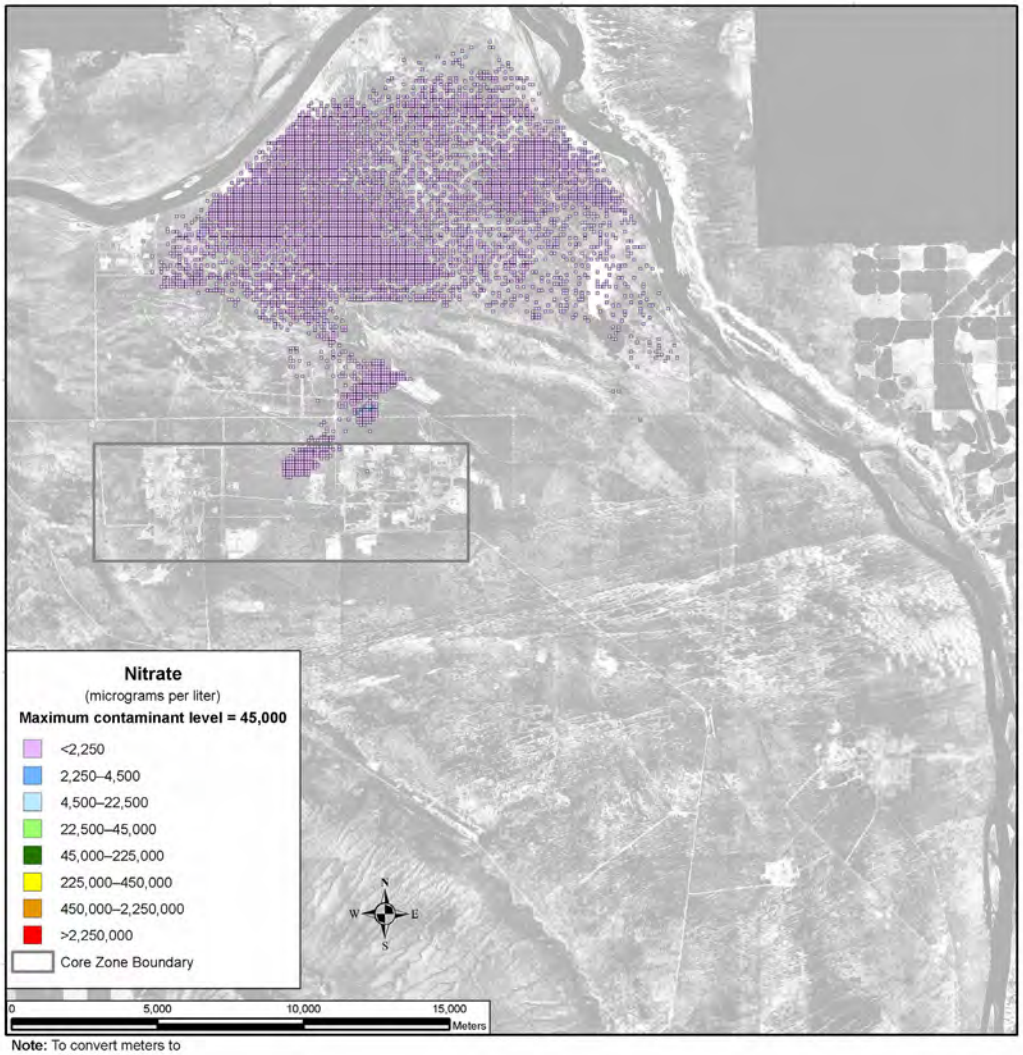
Note: To convert meters to feet, multiply by 3.281

Figure 5–421. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



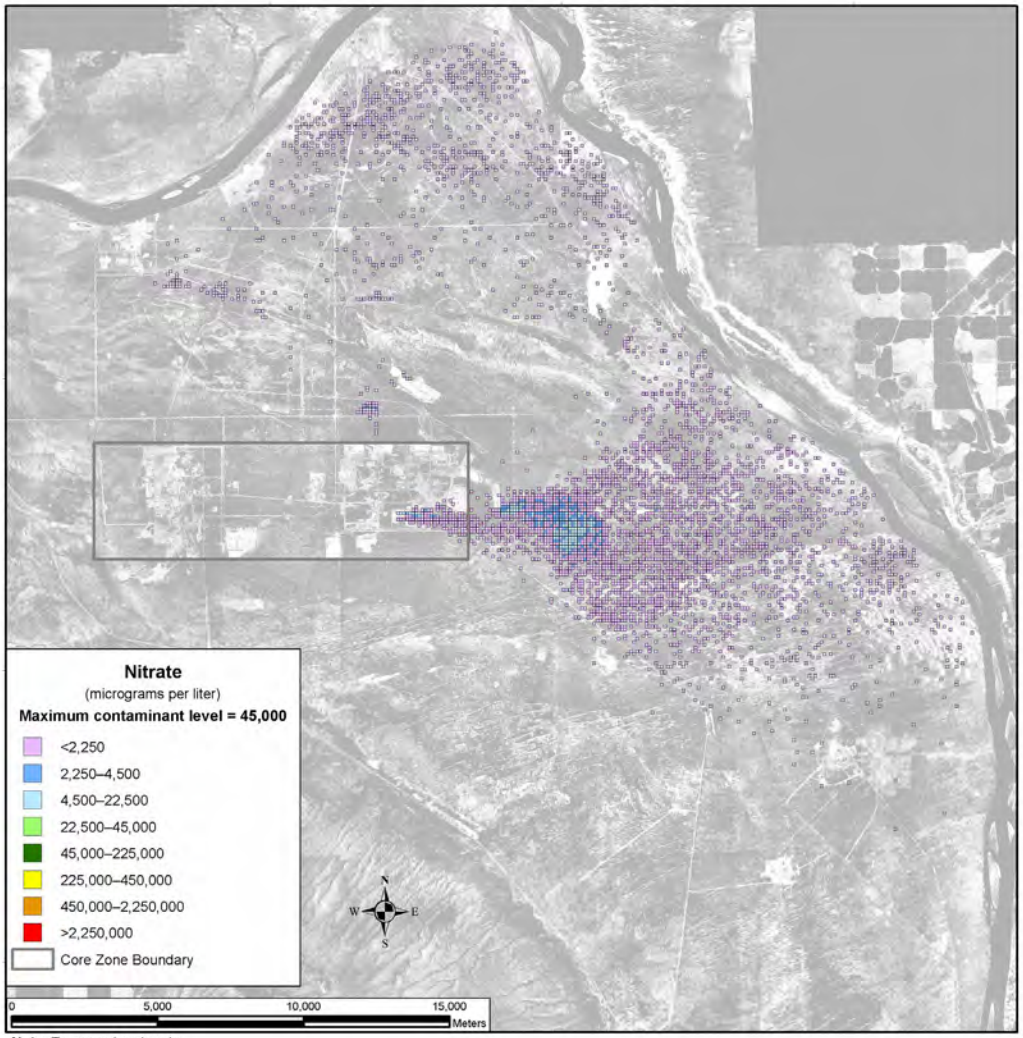
Note: To convert meters to feet, multiply by 3.281

Figure 5–422. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



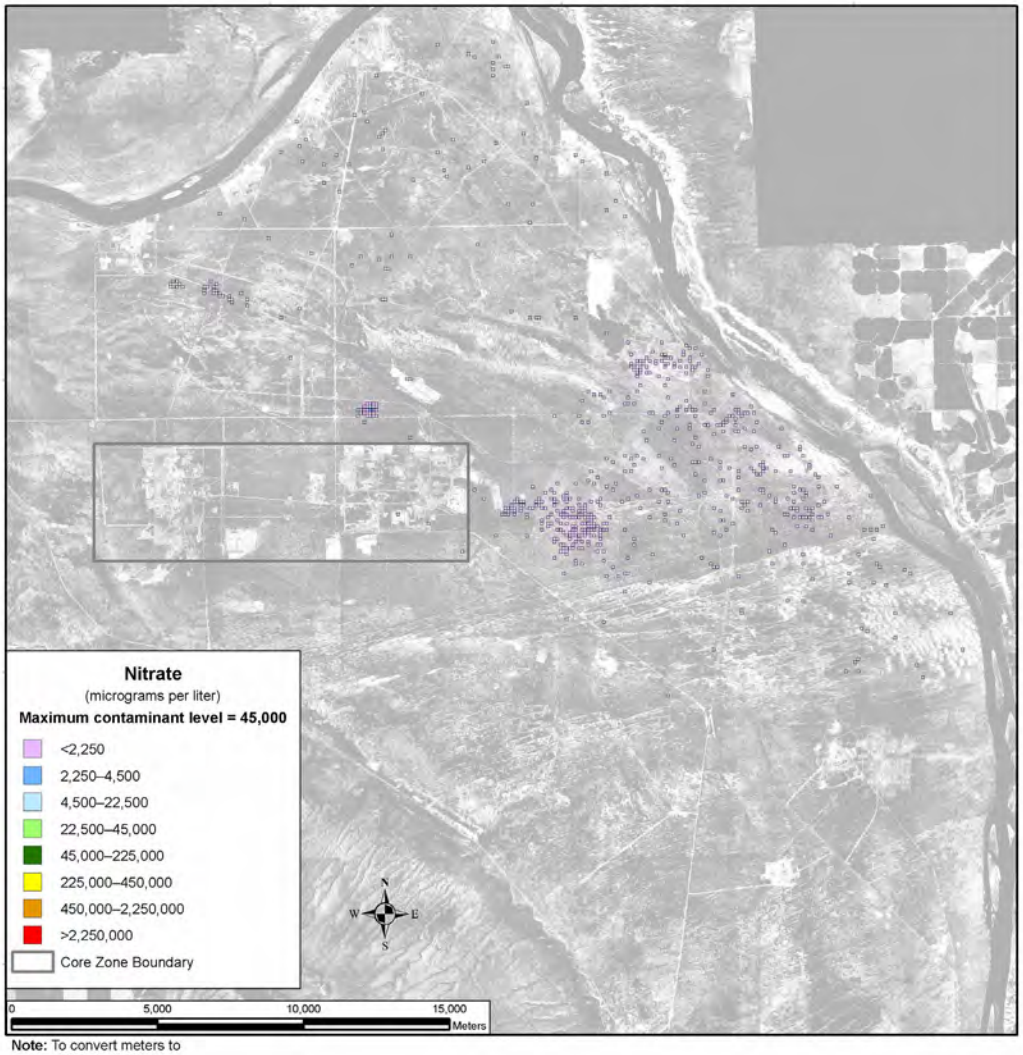
Note: To convert meters to feet, multiply by 3.281

Figure 5–423. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–424. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–425. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

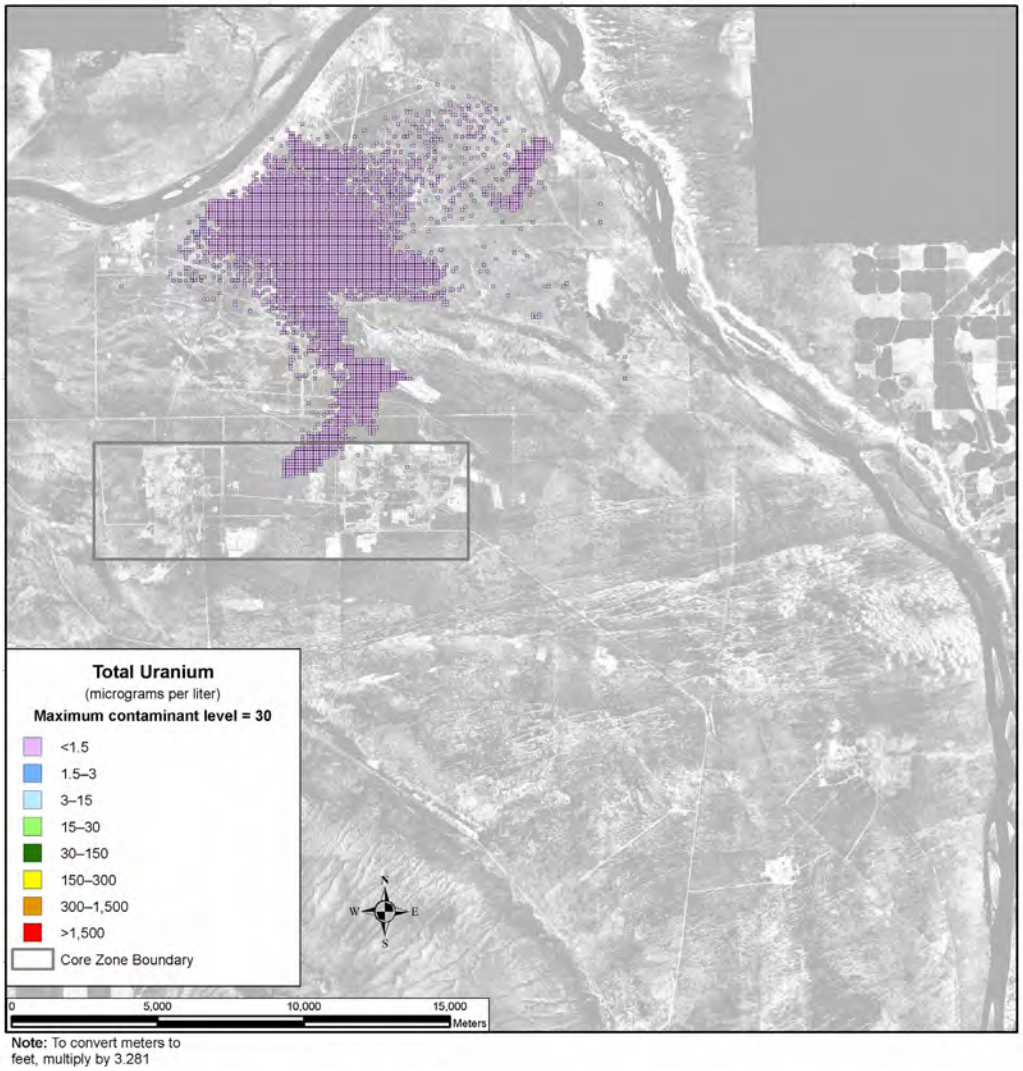


Figure 5–426. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-B, in general, discharges from IDF-East are the predominant contributors. The RPPDF is a secondary contributor.

For the conservative tracers, with the exception of chromium, concentrations at the Core Zone Boundary remain within an order of magnitude of the benchmark concentration during the last 5,000 years of the period of analysis. Concentrations at the Columbia River are slightly lower, but within an order of magnitude of the concentrations at the Core Zone Boundary. Chromium concentrations remain over two orders of magnitude below the benchmark at the Core Zone Boundary and the Columbia River.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species remain well below the benchmark at the Core Zone Boundary and the Columbia River throughout the simulation. The peak intensity and area of the contamination plume are near the end of the period of analysis.

5.3.1.2.1.3 Disposal Group 1, Subgroup 1-C

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-C covers disposal of waste generated under Tank Closure Alternative 3B and FFTF Decommissioning Alternative 2 or 3 as well as onsite- and offsite-generated waste. Waste would be converted to IHLW, ILAW glass, and cast stone waste. IHLW would be stored on site, while ILAW glass and cast stone waste would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129, technetium-99, and uranium-238
- Chemical risk drivers: none
- Chemical hazard drivers: acetonitrile, boron, chromium, fluoride, nitrate, and total uranium

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. Uranium-238 and total uranium were added to the COPC drivers; although their contribution to risk and hazard are not dominant during the year of peak risk or hazard, they become major contributors toward the end of the period of analysis. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for 100 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C.

The COPC drivers that are discussed in detail in this section fall into two categories. Iodine-129, technetium-99, acetonitrile, boron, chromium, and nitrate are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Uranium-238 and total uranium are long-lived, or stable, but are not as mobile as the other COPC drivers. These constituents move about seven times more slowly than groundwater. As the analyses of release, concentration versus time, and spatial distribution of the COPC drivers are presented, the distinct behavior of these groups will become apparent.

The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–427 through 5–438). Eight subtotals are plotted representing releases from ILAW glass, cast stone waste, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, onsite- and offsite-generated waste, and RPPDF waste. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over eight orders of magnitude.

Figure 5–427 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–428, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). The predominant source of acetonitrile, chromium, nitrate, and technetium-99 is the cast stone waste; of iodine-129 is offsite-generated waste. Other sources of contamination include ILAW glass, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite-generated waste.

Figure 5–429 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–430, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. With the exception of offsite-generated waste, of which nearly all that was released to the vadose zone reached groundwater in the analysis, only 40 to 50 percent of the technetium-99 and iodine-129 released to the vadose zone reached groundwater. Chromium from ILAW glass and retired melters behaves similarly to technetium-99 and iodine-129. When released from other sources, nearly all the chromium that enters the vadose zone reaches groundwater. For nitrate, fluoride, boron, and acetonitrile, nearly everything released to the vadose zone reaches groundwater.

Figure 5–431 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–432, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. In nearly all cases, between 90 and 100 percent of the amount released to groundwater reached the Columbia River in the analysis. The exceptions to this trend are the retired melters for both technetium-99 and iodine-129 and waste management secondary and onsite-generated waste for iodine-129. In these cases, nothing released to groundwater reached the Columbia River.

Figure 5–433 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–434, the chemical hazard drivers. For all types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the period of analysis). Technetium-99, iodine-129, chromium, and nitrate are all present at the RPPDF.

Figure 5–435 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–436, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All of the COPC drivers present at the RPPDF behave as conservative tracers, with essentially all of the mass released to the vadose zone reaching groundwater.

Figure 5–437 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–438, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. Essentially everything released to groundwater reached the Columbia River in the analysis for all COPC drivers present.

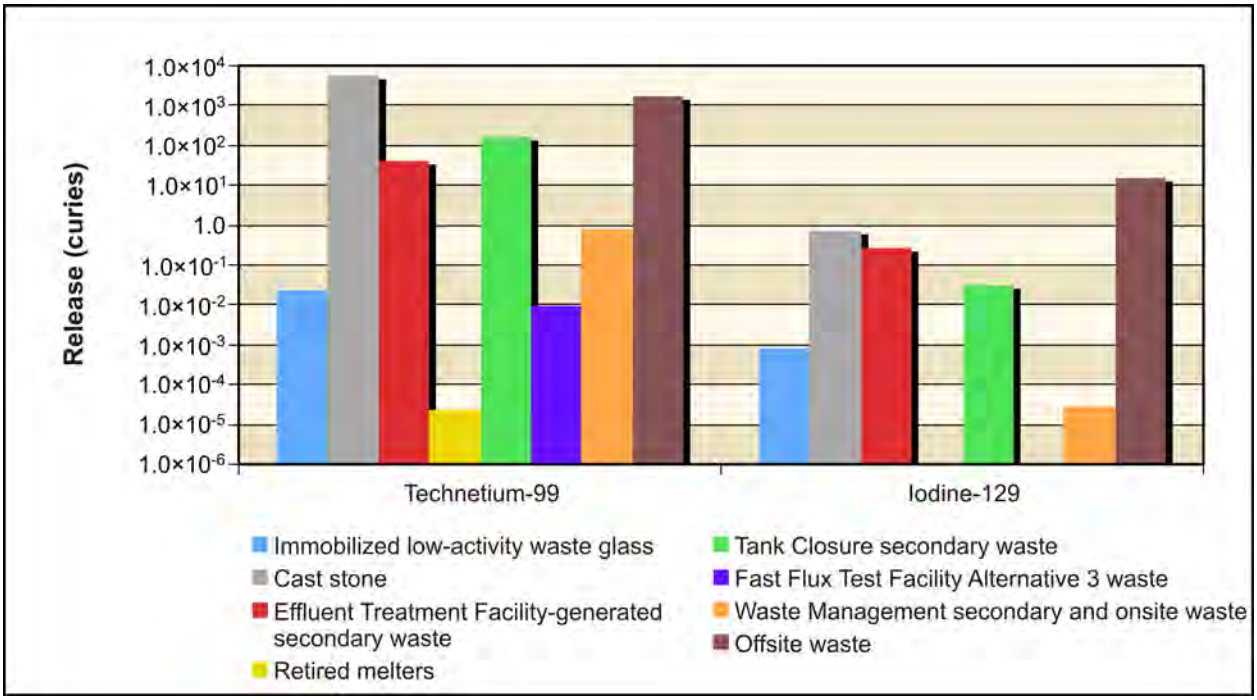


Figure 5–427. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

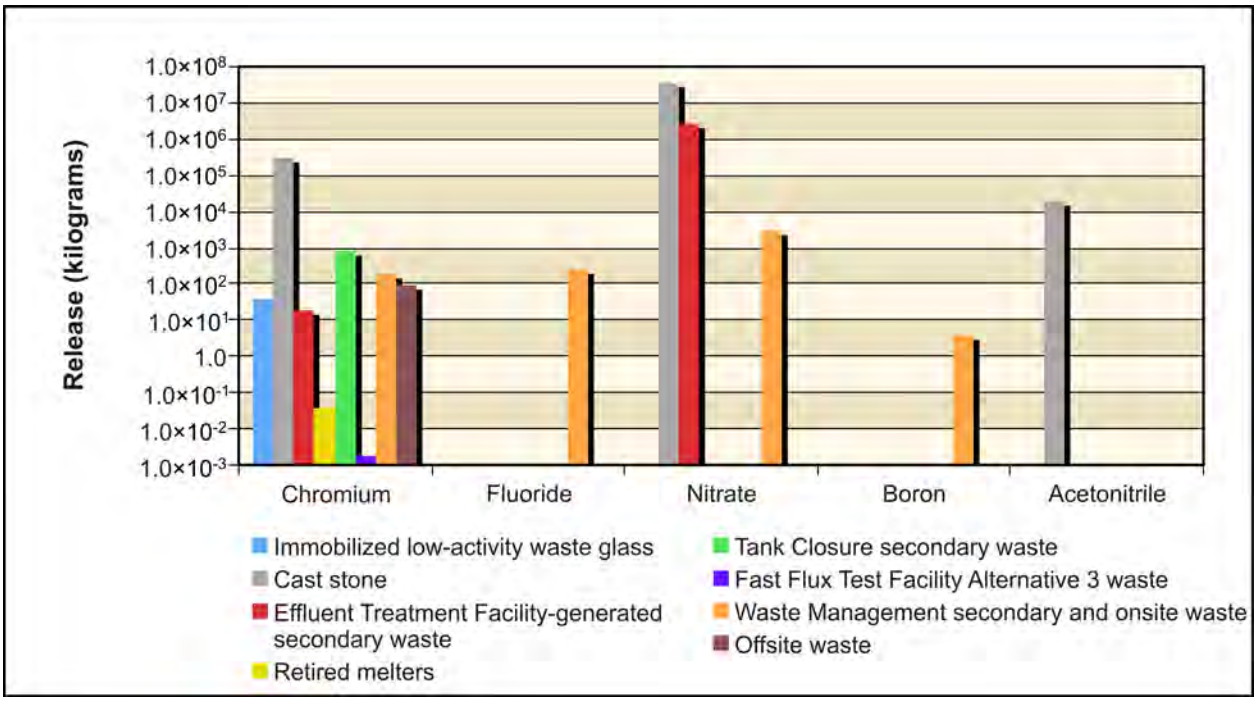


Figure 5–428. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

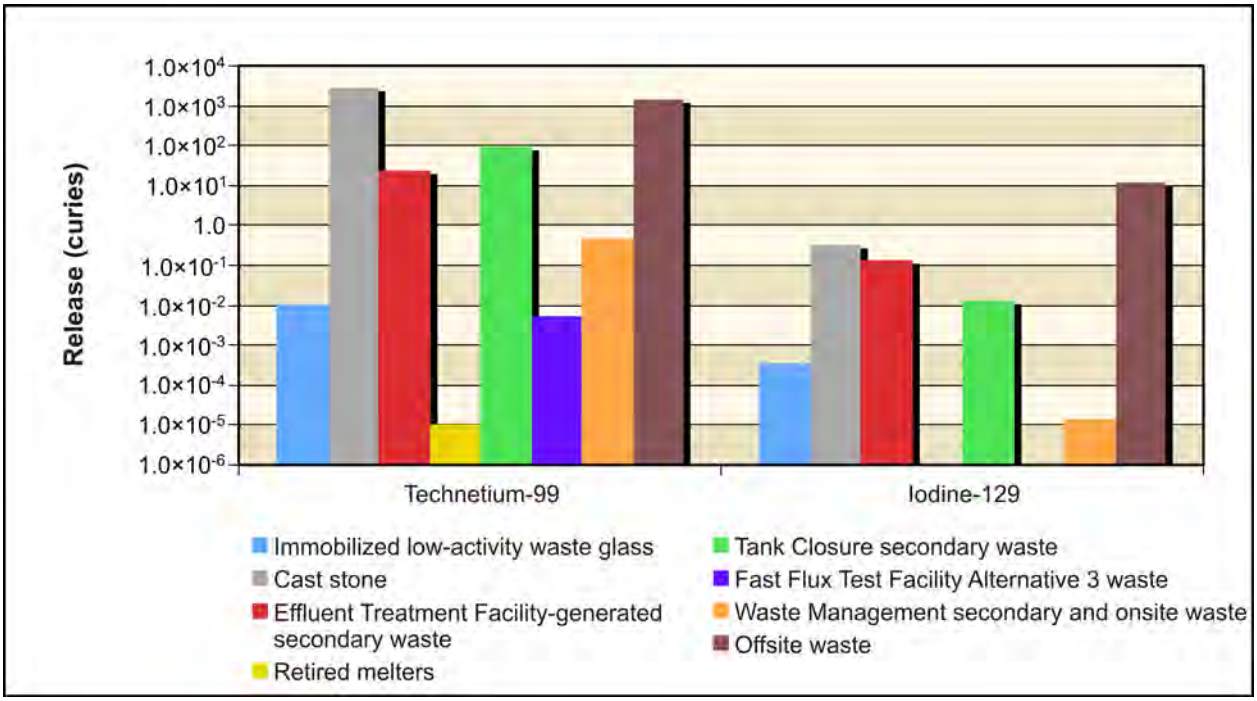


Figure 5–429. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

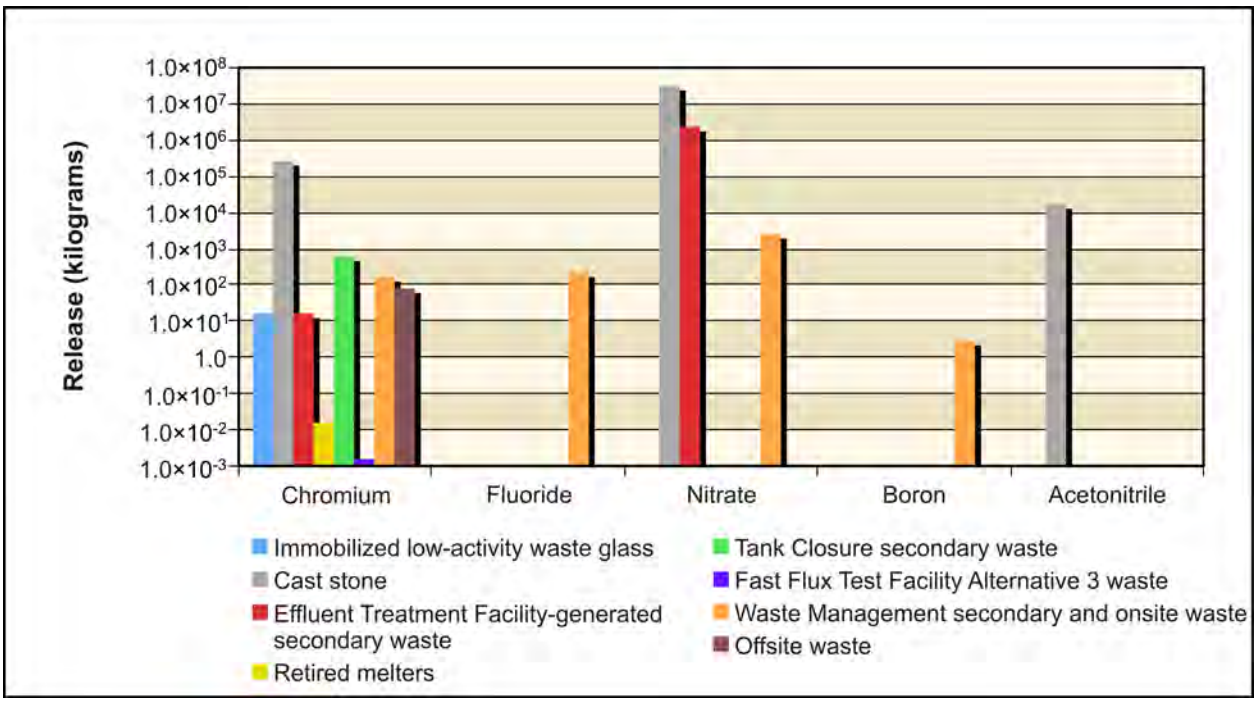


Figure 5–430. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

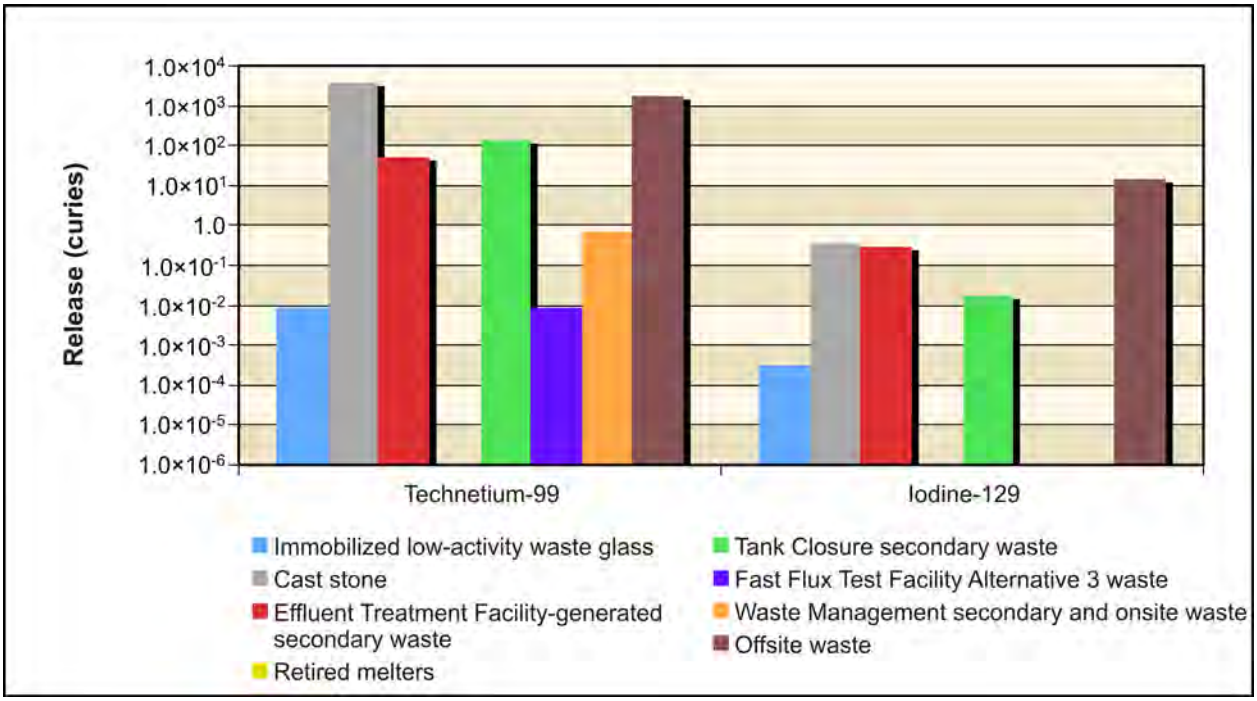


Figure 5–431. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

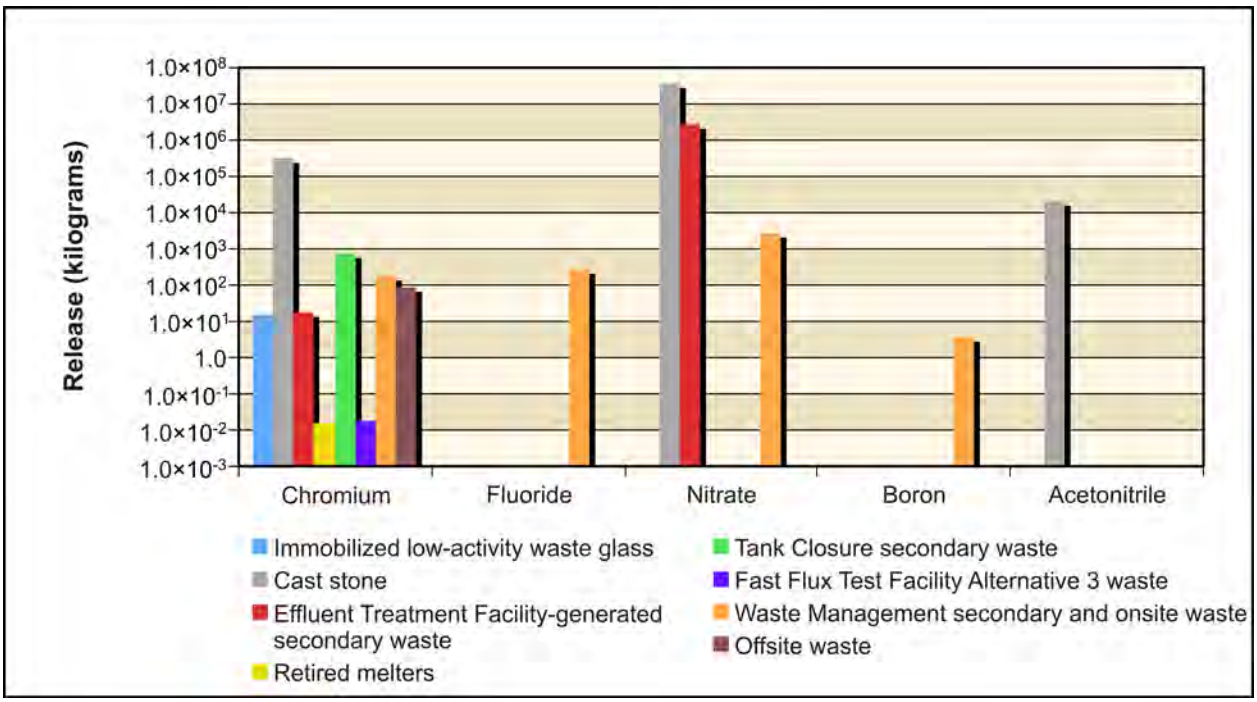


Figure 5–432. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

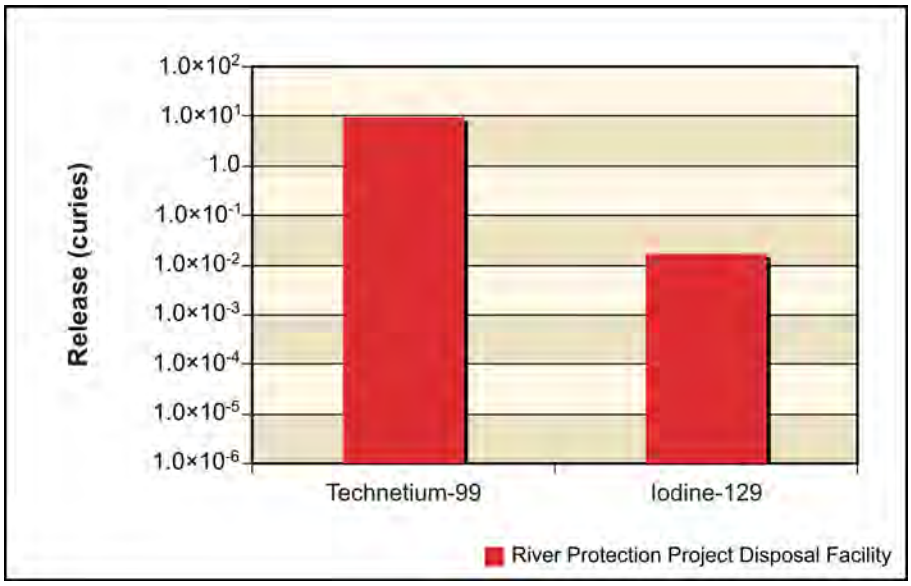


Figure 5–433. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

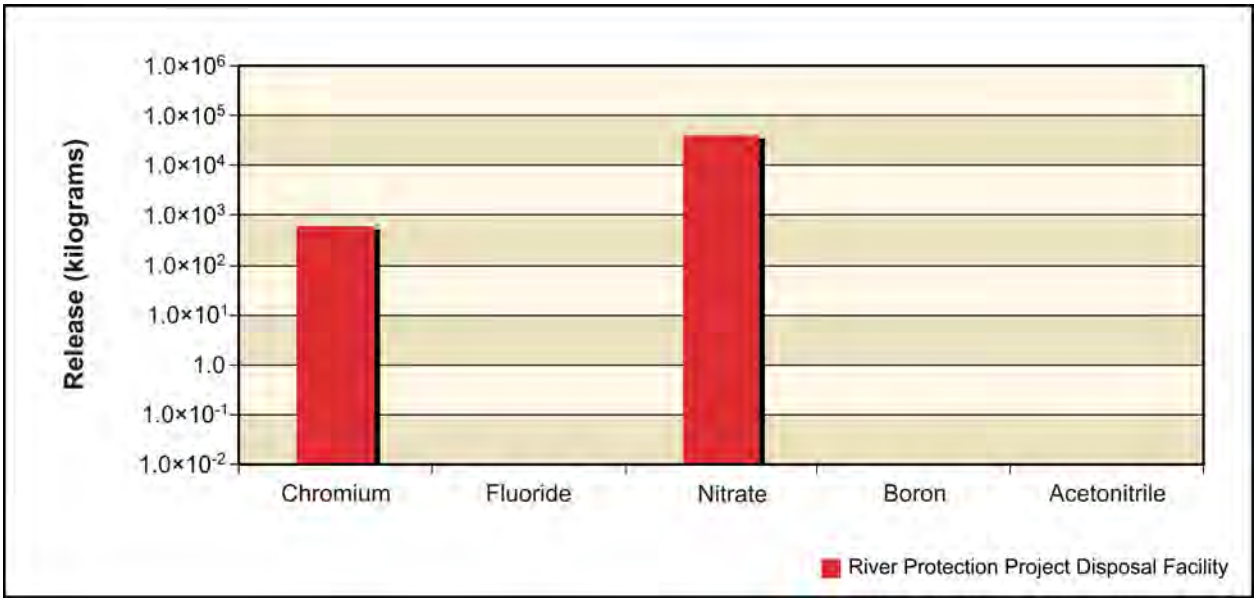


Figure 5–434. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

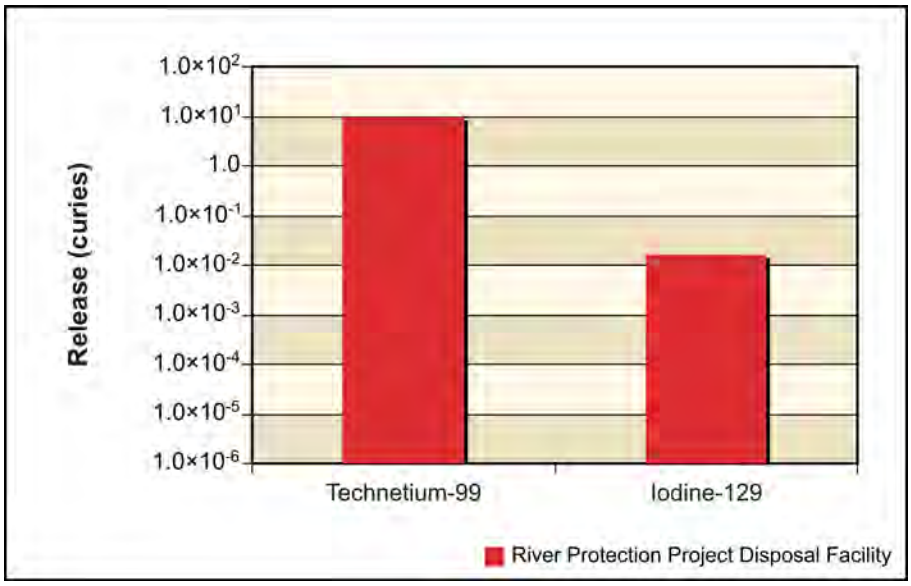


Figure 5–435. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at River Protection Project Disposal Facility to Groundwater

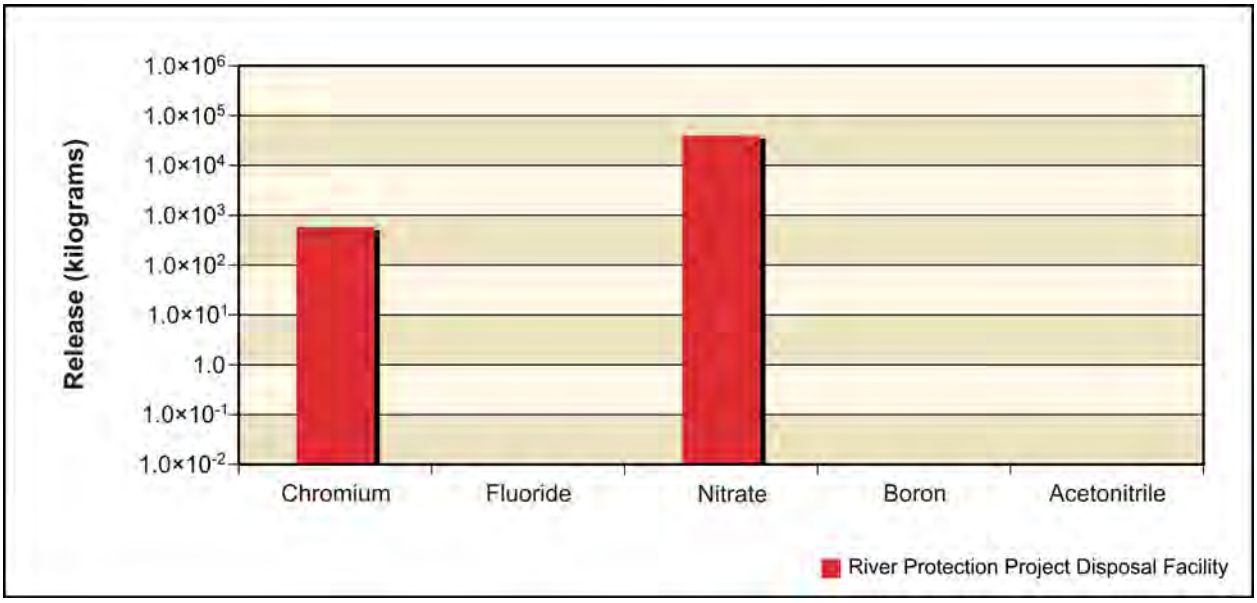


Figure 5–436. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at River Protection Project Disposal Facility to Groundwater

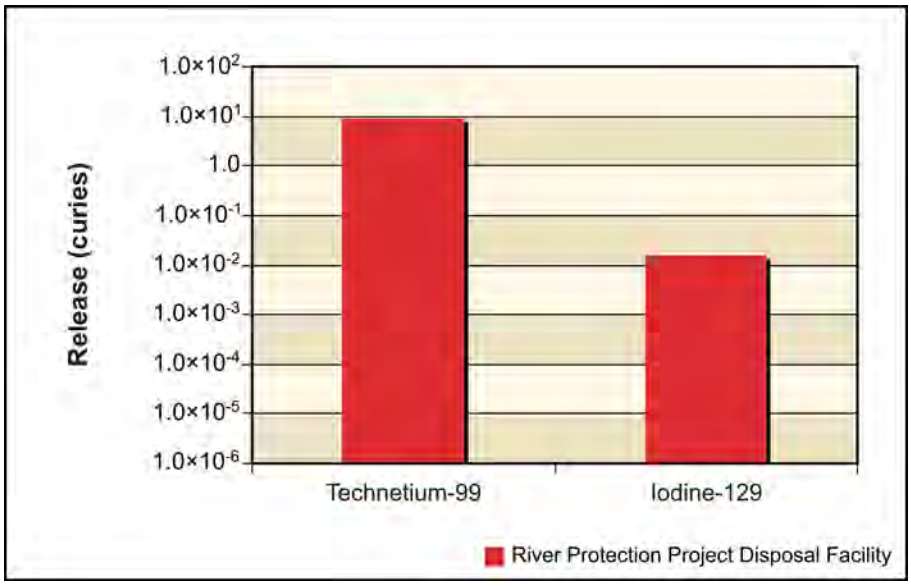


Figure 5–437. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Radiological Releases at River Protection Project Disposal Facility to Columbia River

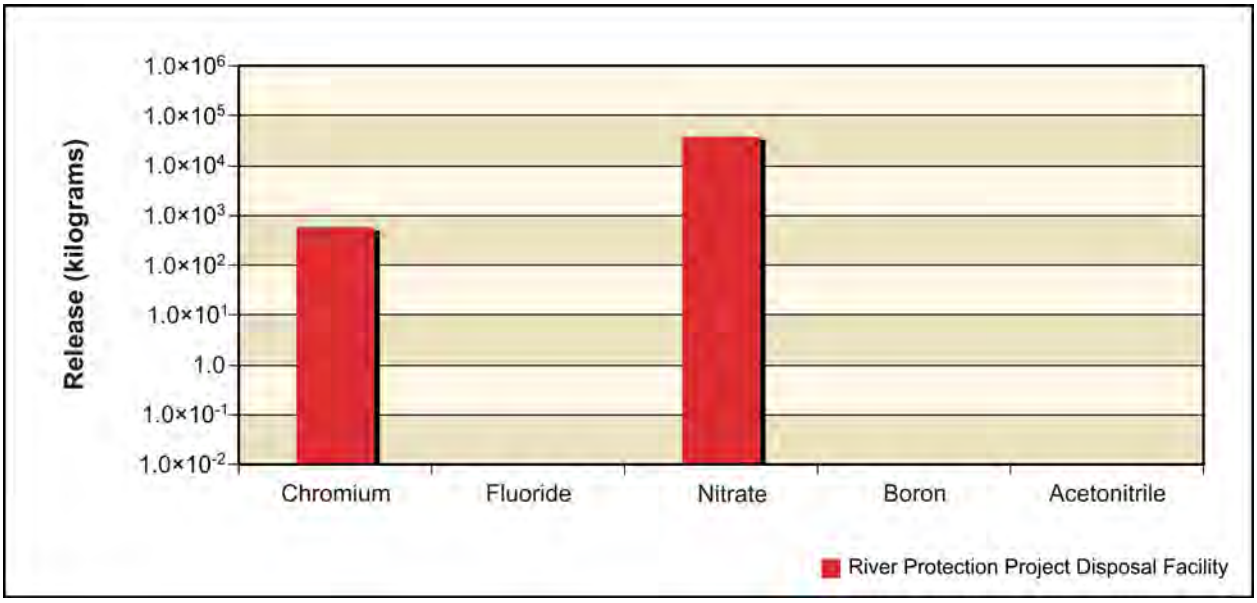


Figure 5–438. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–439 through 5–443). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is

basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–79 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–439 through 5–442 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate (the conservative tracers). For technetium-99, a small rise in concentration is evident in the early years, peaking around CY 3940 but remaining over an order of magnitude below the benchmark concentration. Beginning in CY 5400, concentrations at the Core Zone Boundary begin climbing again, stabilizing very near to the benchmark concentration at CY 7940. Iodine-129 follows a similar pattern, stabilizing slightly above the benchmark concentration, while chromium and nitrate peak below the benchmark.

Figure 5–443 shows concentration versus time for total uranium. Because of the high retardation of uranium, no contamination appears until CY 9940, when total uranium concentrations at the Core Zone Boundary first surpass 1.0×10^{-8} micrograms per liter.

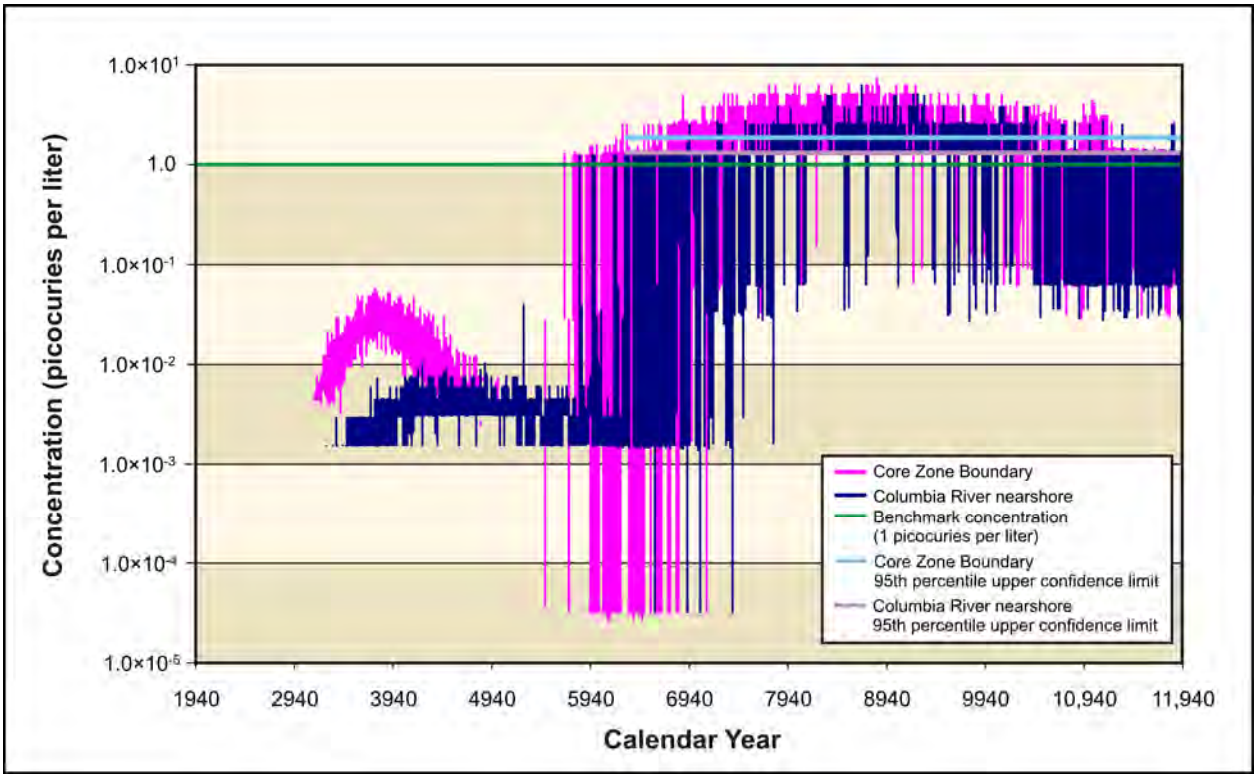


Figure 5–439. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Iodine-129 Concentration Versus Time

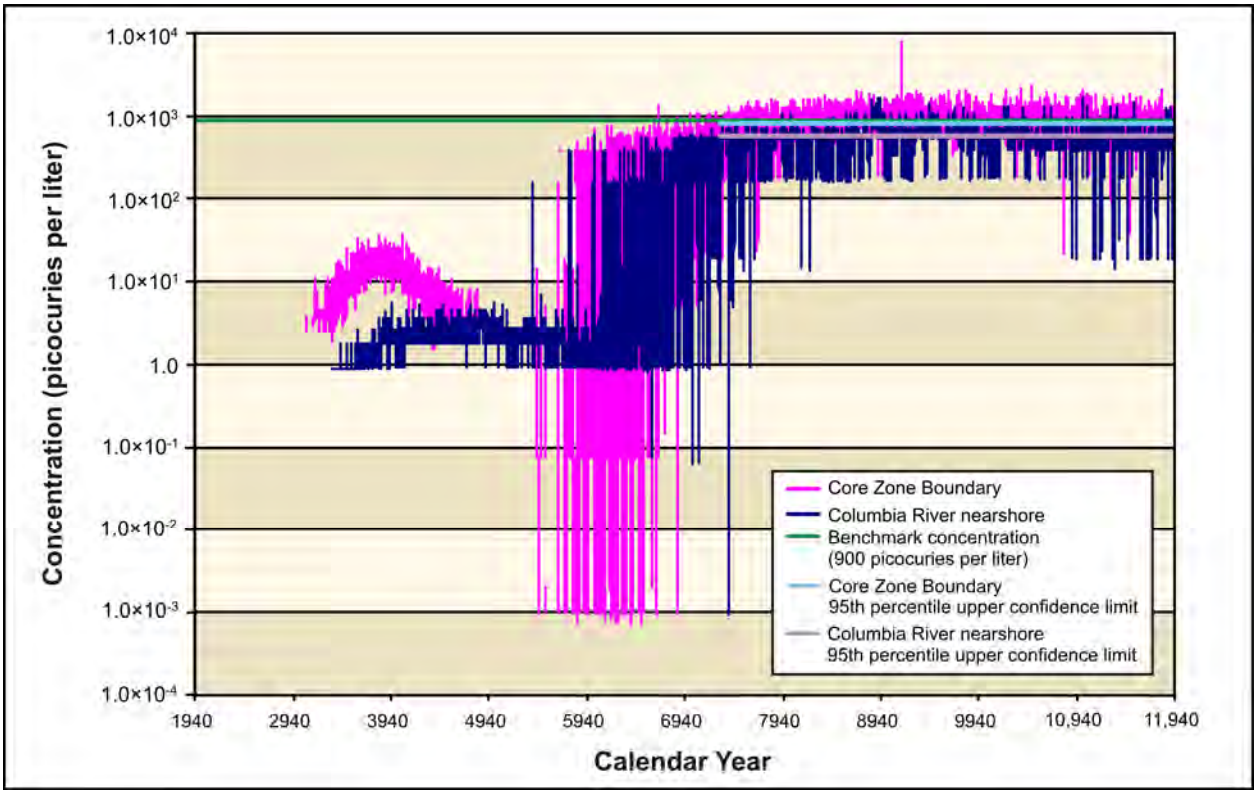


Figure 5–440. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Technetium-99 Concentration Versus Time

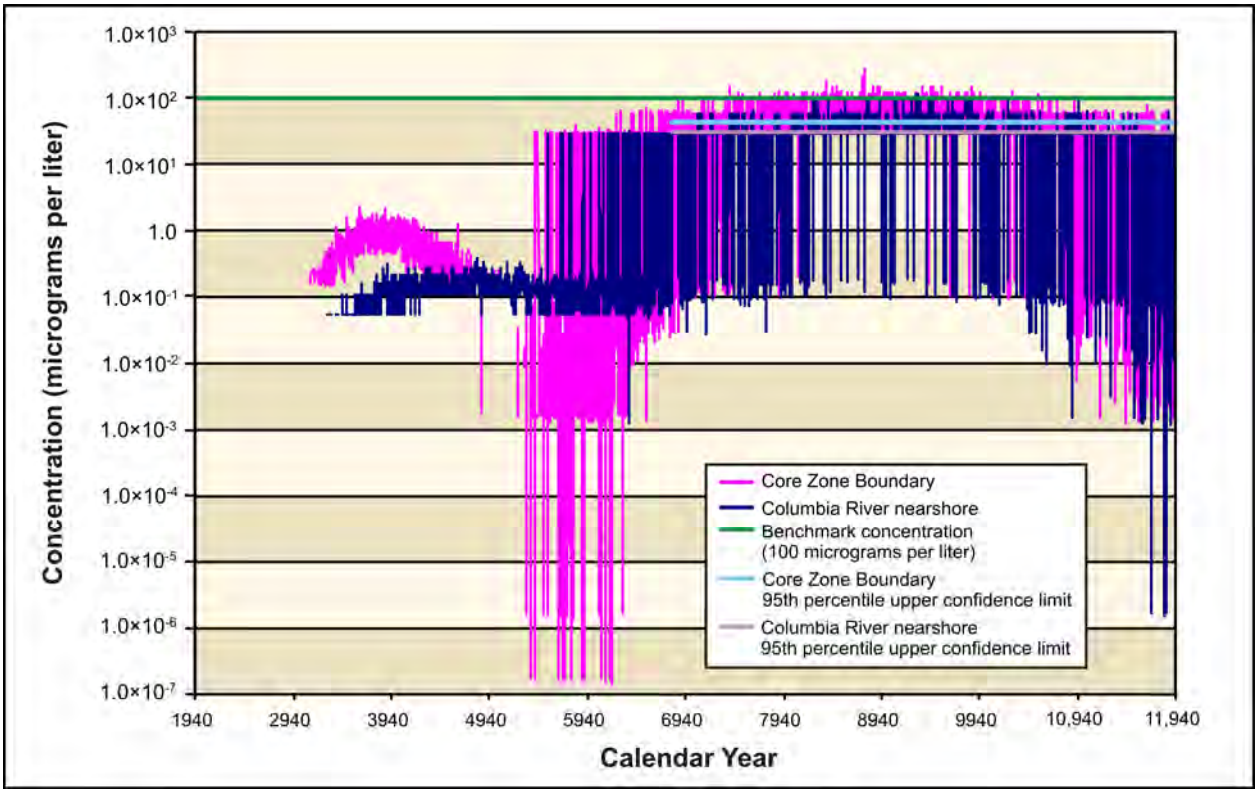


Figure 5–441. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Chromium Concentration Versus Time

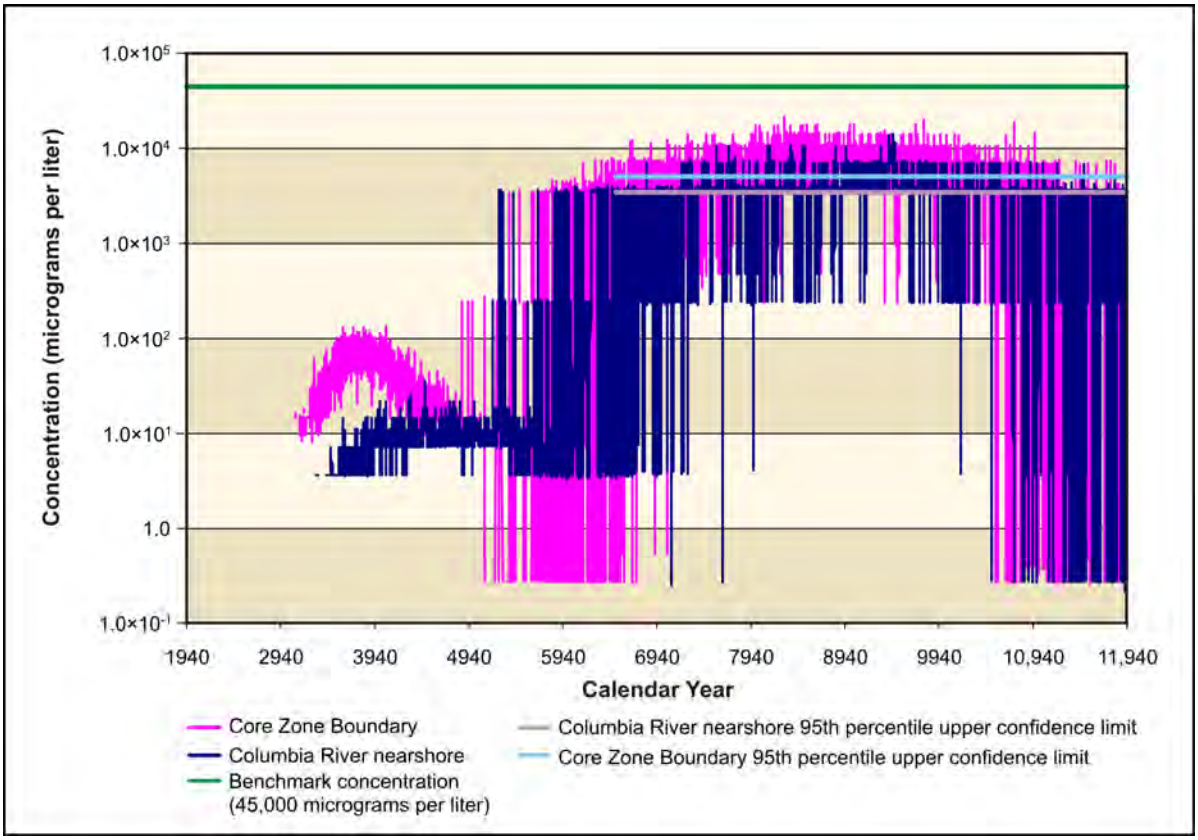


Figure 5–442. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Nitrate Concentration Versus Time

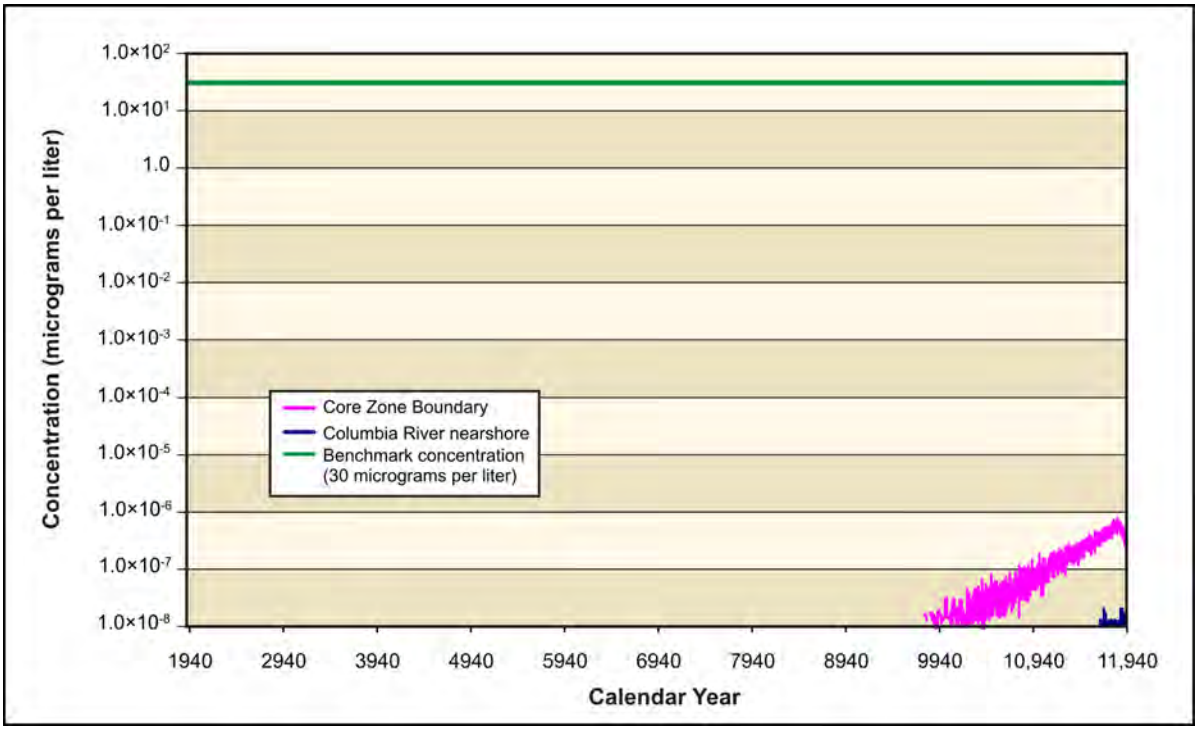


Figure 5–443. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Total Uranium Concentration Versus Time

Table 5–79. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore Groundwater

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**5,660** (9048)	33 (3825)	**8,160** (9163)	**1,690** (8927)	900
Iodine-129	**18** (8491)	0.1 (3772)	**8** (8858)	**7** (8700)	1
Chemical in micrograms per liter					
Acetonitrile	25 (8281)	0 (1940)	9 (8313)	7 (8973)	100
Chromium	**437** (8940)	2 (3856)	**265** (8760)	**116** (9311)	100
Fluoride	0 (8035)	0 (1940)	1 (7258)	0 (8913)	4,000
Nitrate	**50,200** (8665)	149 (3811)	21,200 (8290)	14,100 (9453)	45,000

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

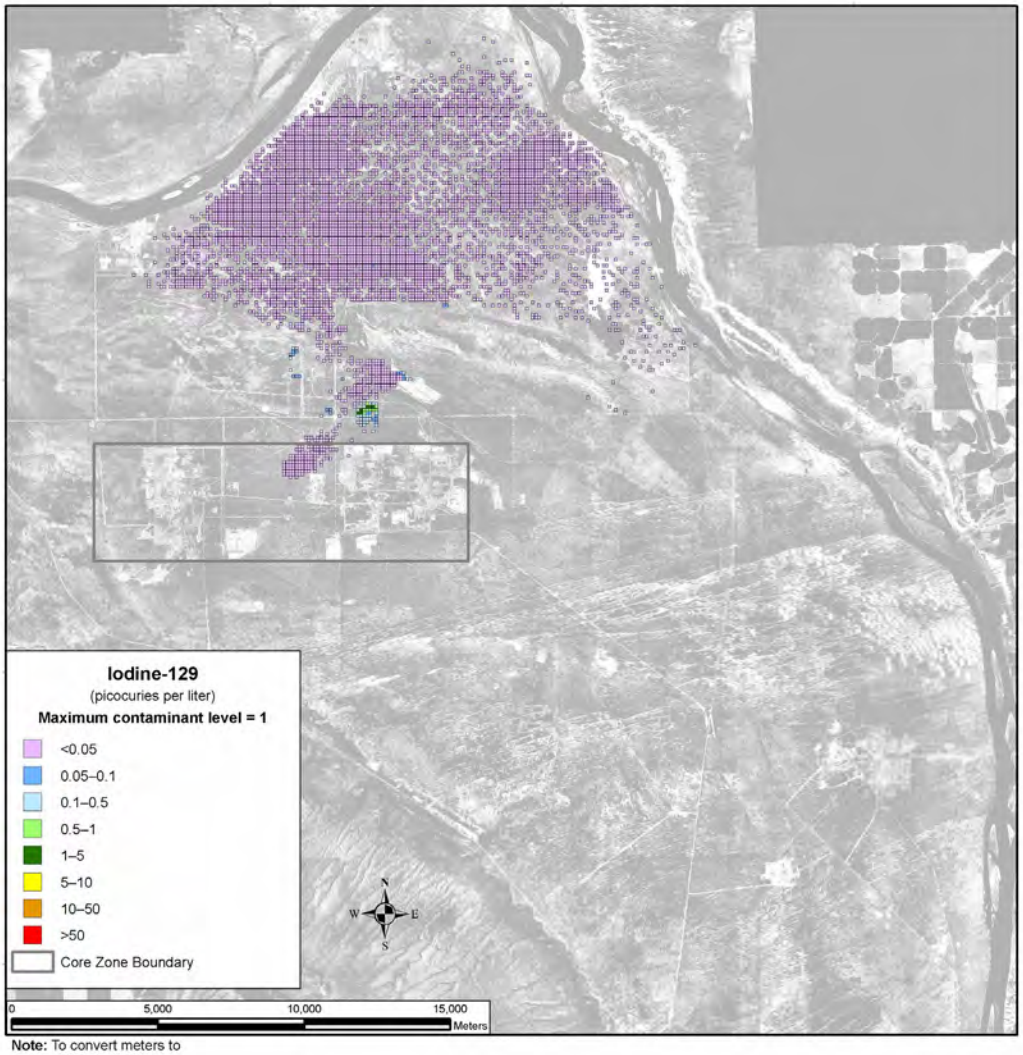
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–444 through 5–456). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

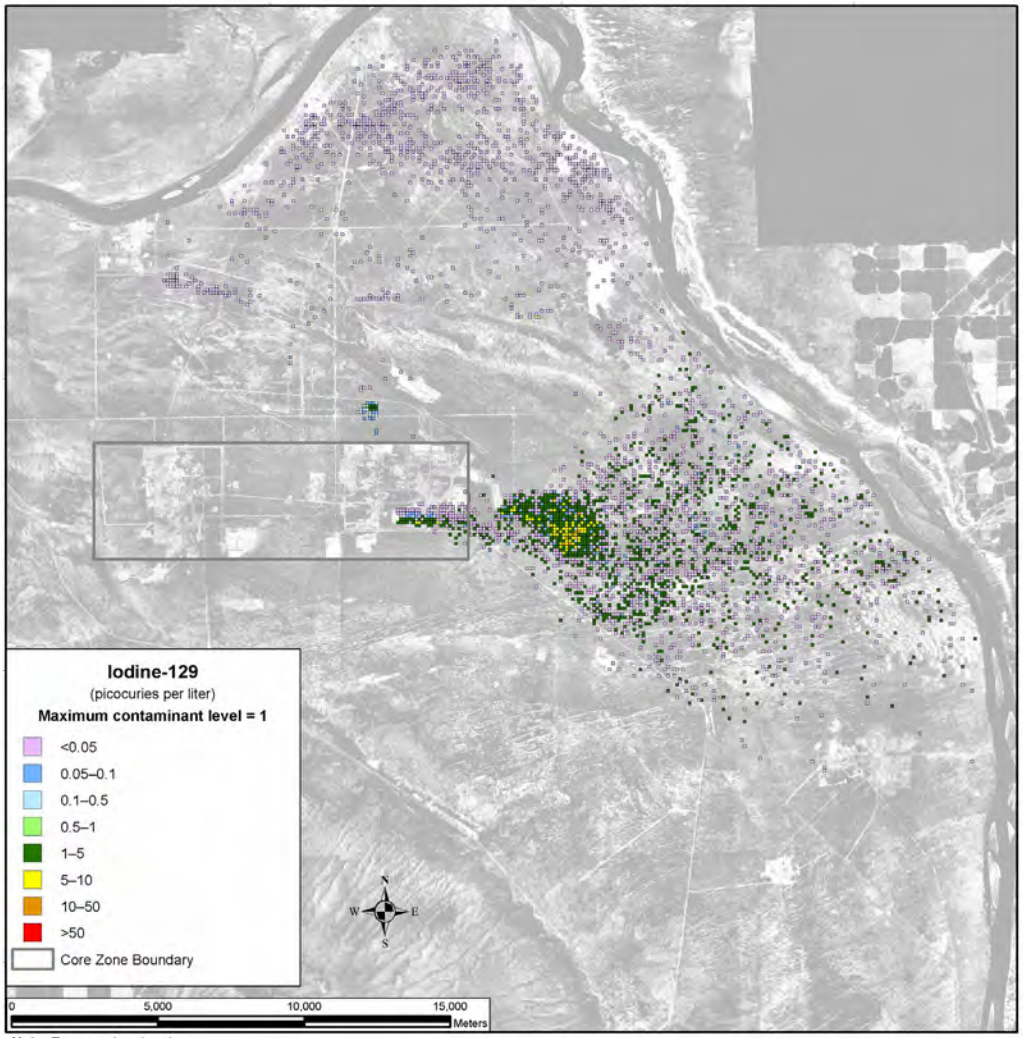
At CY 3890, there is a low-concentration plume of iodine-129 (see Figure 5–444) that stretches north from the RPPDF and through Gable Gap. By CY 7140 (see Figure 5–445), the plume from the RPPDF is gone, but a new plume has formed, traveling east from IDF-East. Concentrations in this plume are over an order of magnitude above the benchmark. Figure 5–446 shows the iodine-129 concentration for CY 11,885. Technetium-99 (see Figures 5–447 through 5–449), chromium (see Figures 5–450 through 5–452), and nitrate (see Figures 5–453 through 5–455) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium shows a different spatial distribution over time. It is not as mobile as the COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. By CY 11,885, there is a plume extending through Gable Gap from the RPPDF (see Figure 5–456). Concentrations in all areas of the plume remain below one-twentieth of the benchmark.



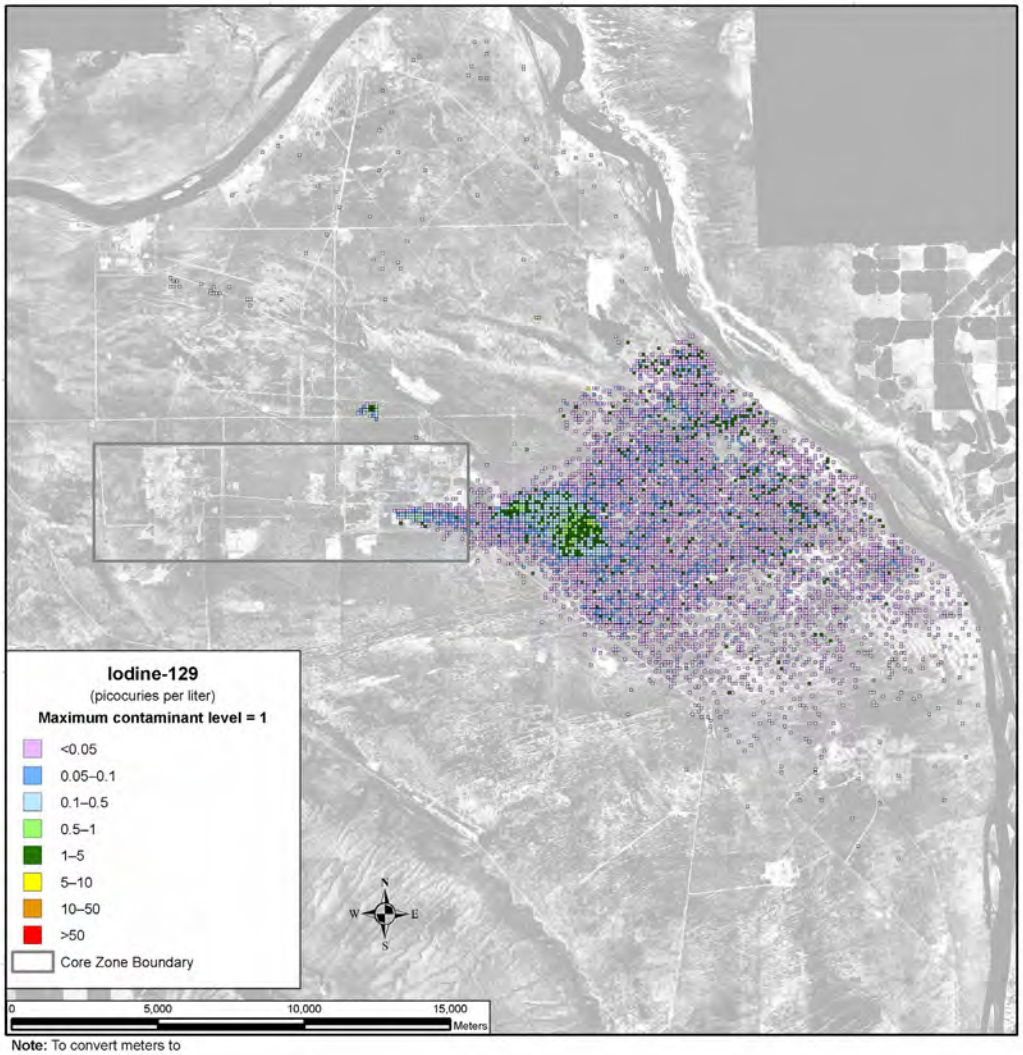
Note: To convert meters to feet, multiply by 3.281

Figure 5–444. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



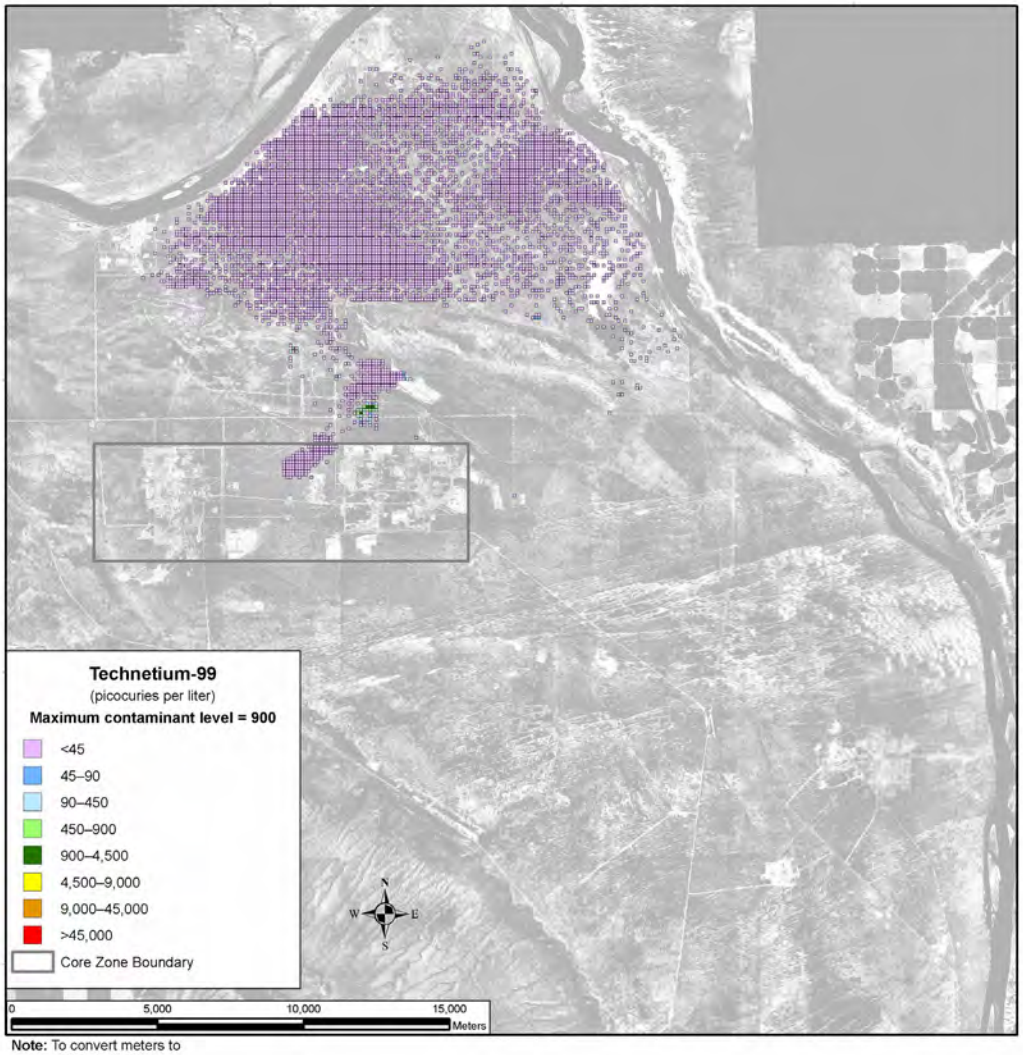
Note: To convert meters to feet, multiply by 3.281

Figure 5–445. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



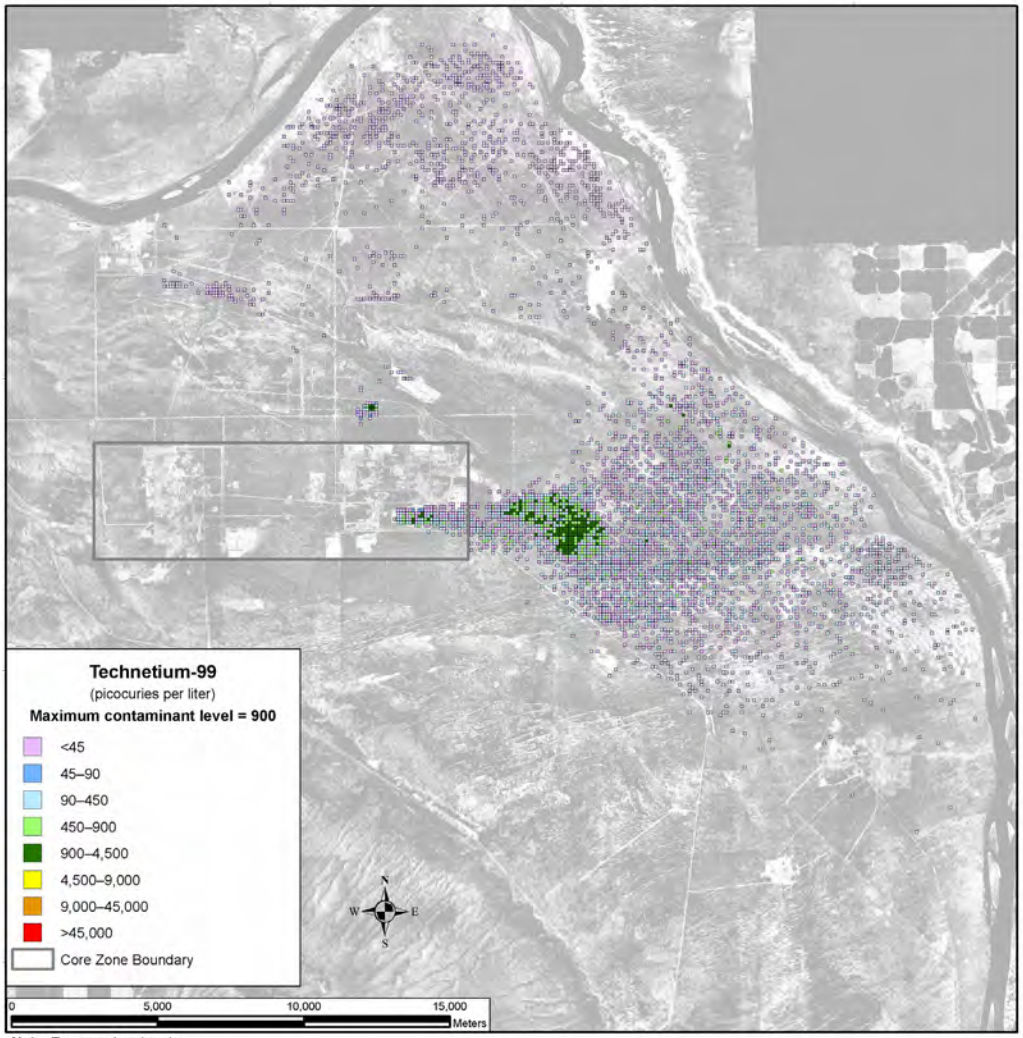
Note: To convert meters to feet, multiply by 3.281

Figure 5–446. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



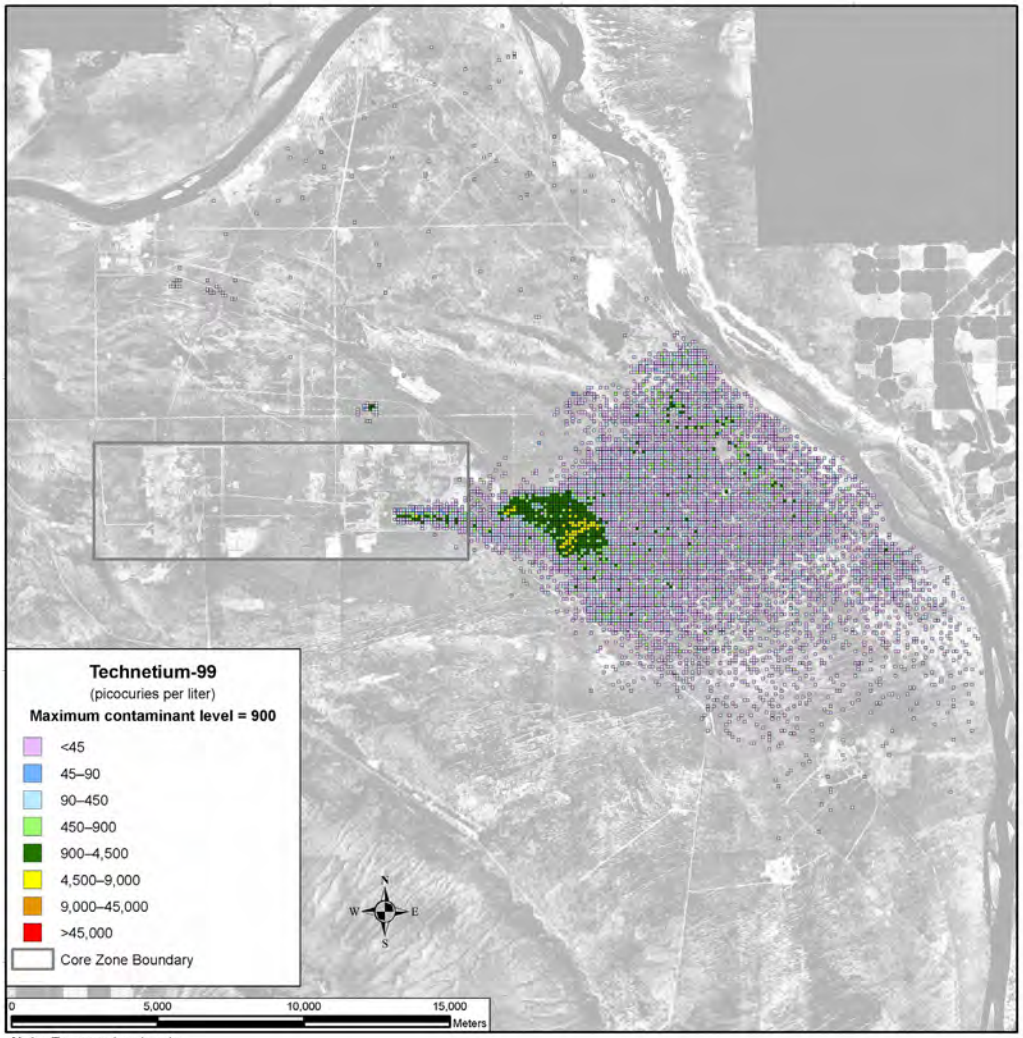
Note: To convert meters to feet, multiply by 3.281

Figure 5–447. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



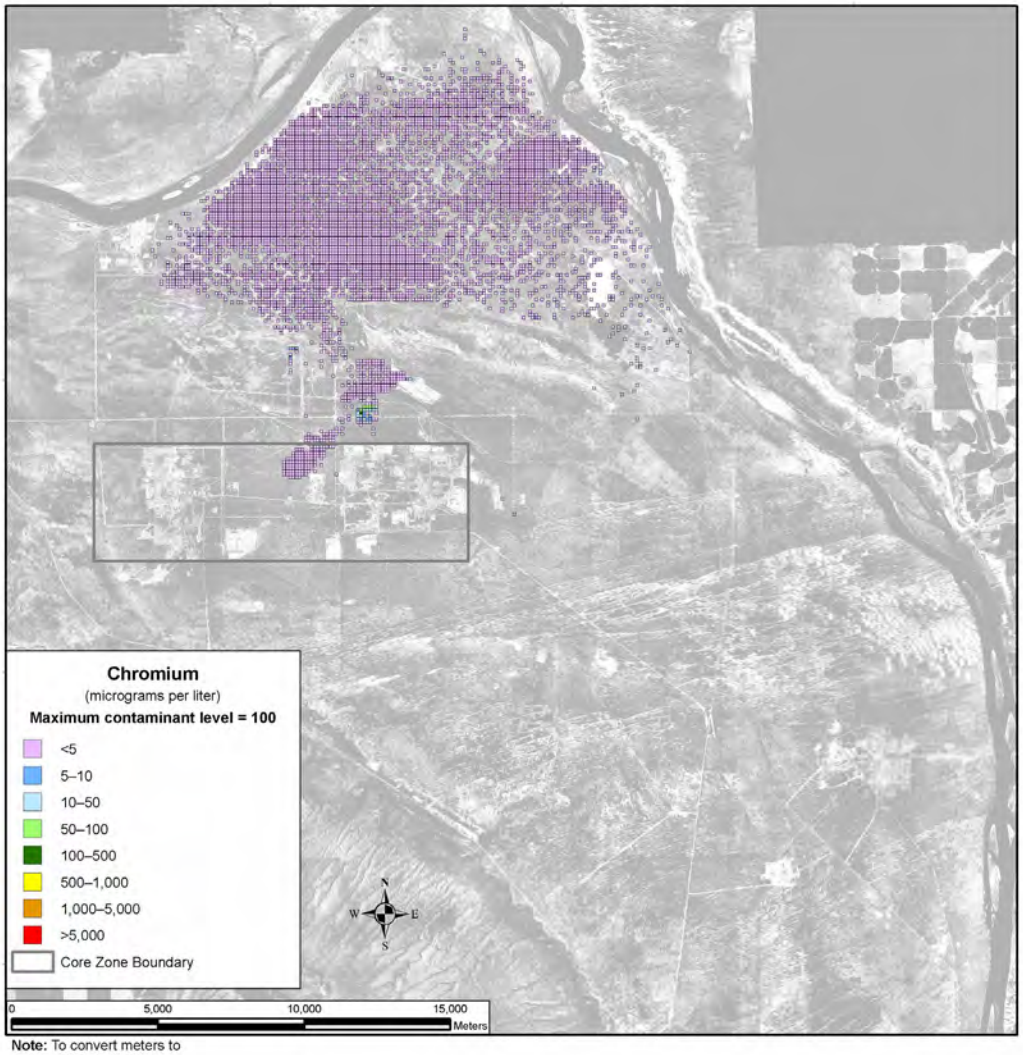
Note: To convert meters to feet, multiply by 3.281

Figure 5–448. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



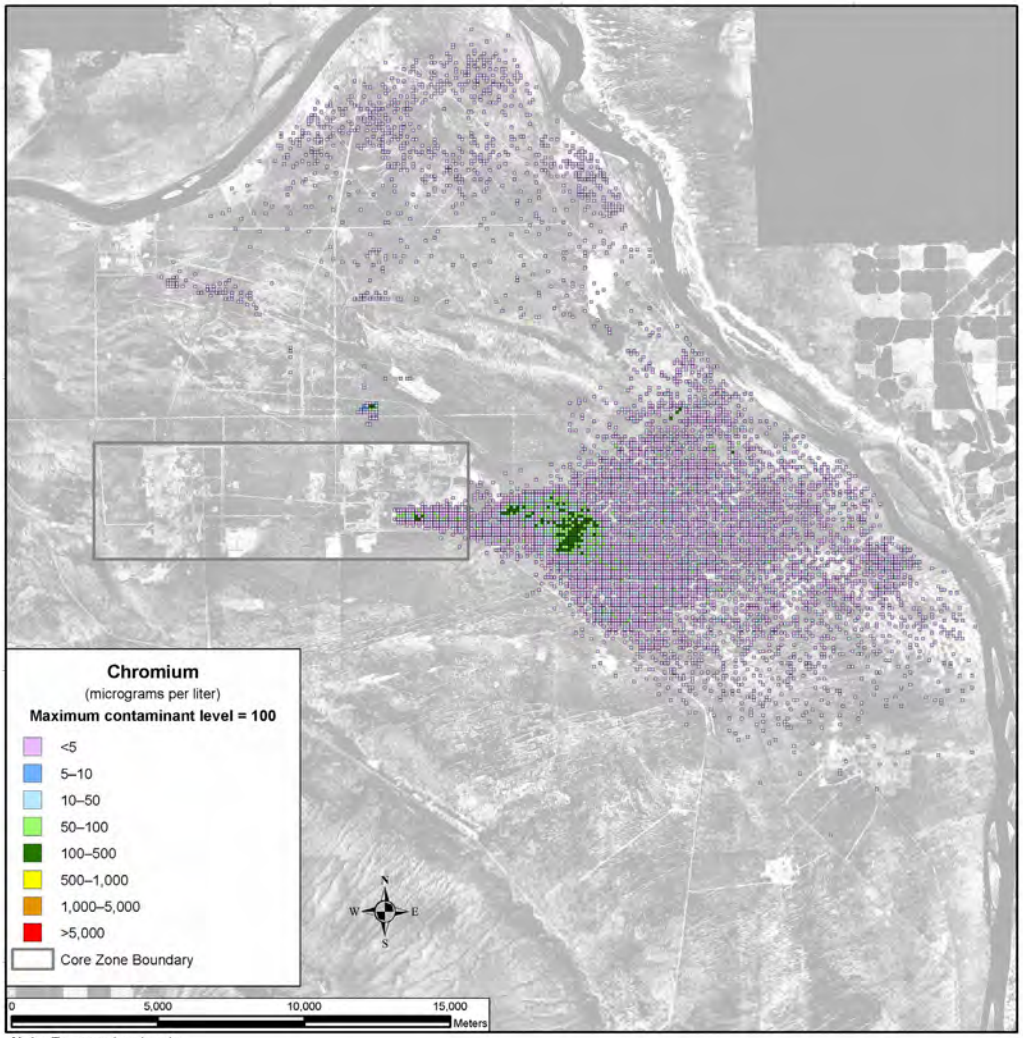
Note: To convert meters to feet, multiply by 3.281

Figure 5–449. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



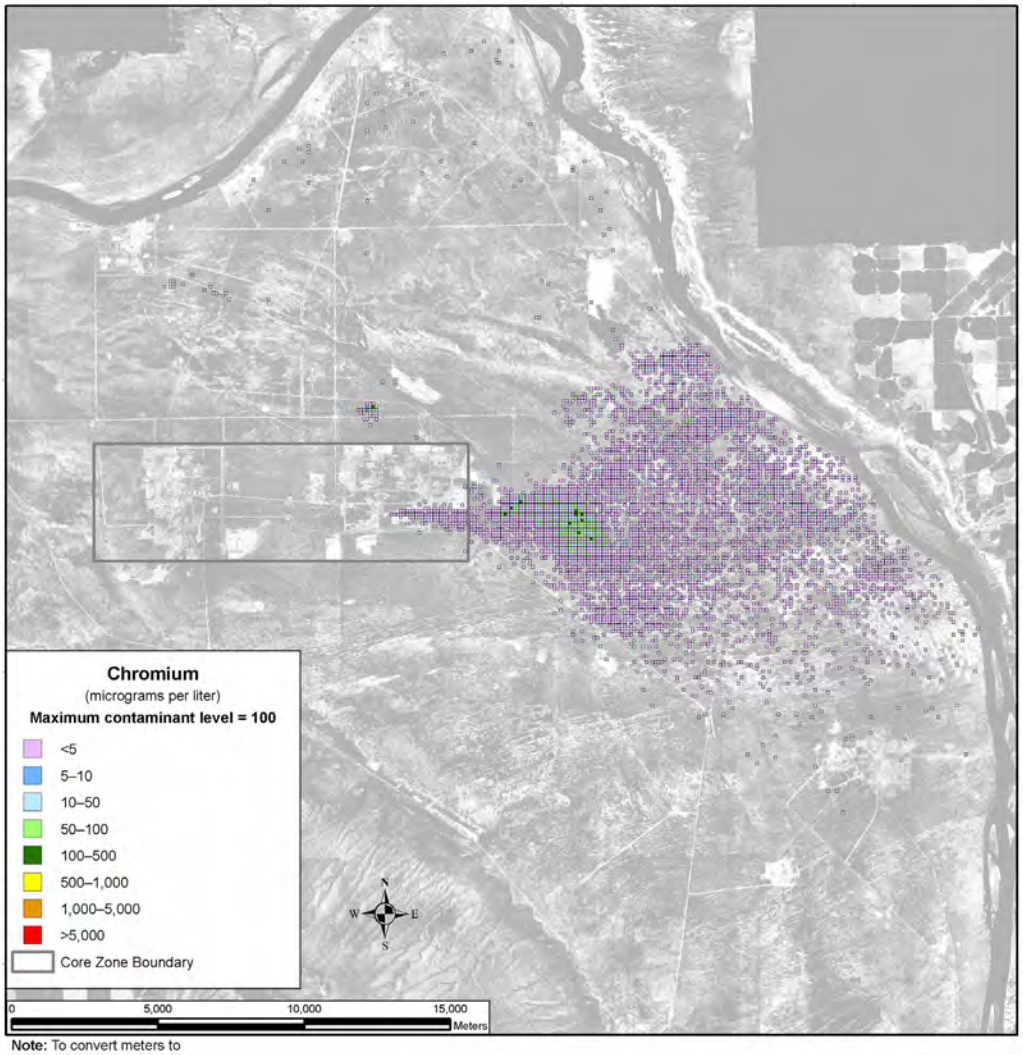
Note: To convert meters to feet, multiply by 3.281

Figure 5–450. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



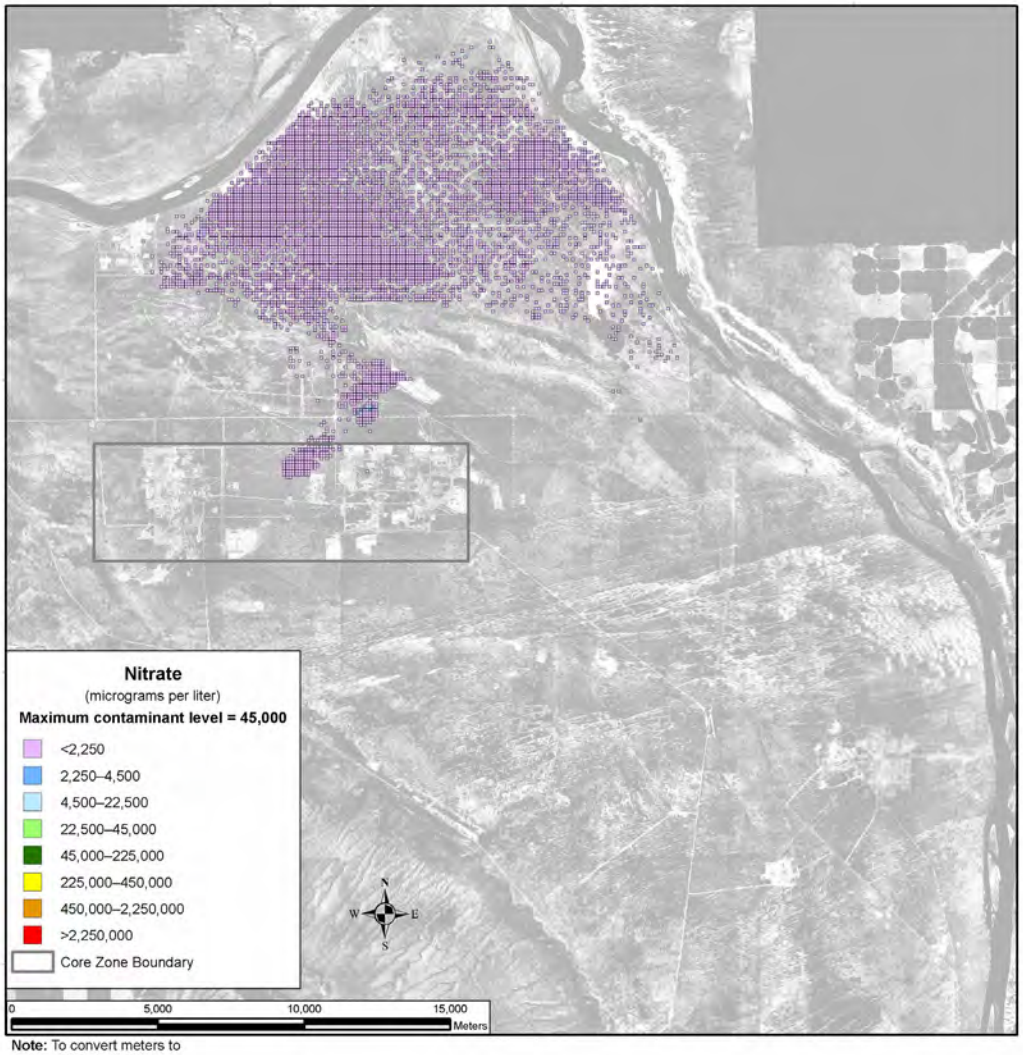
Note: To convert meters to feet, multiply by 3.281

Figure 5–451. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



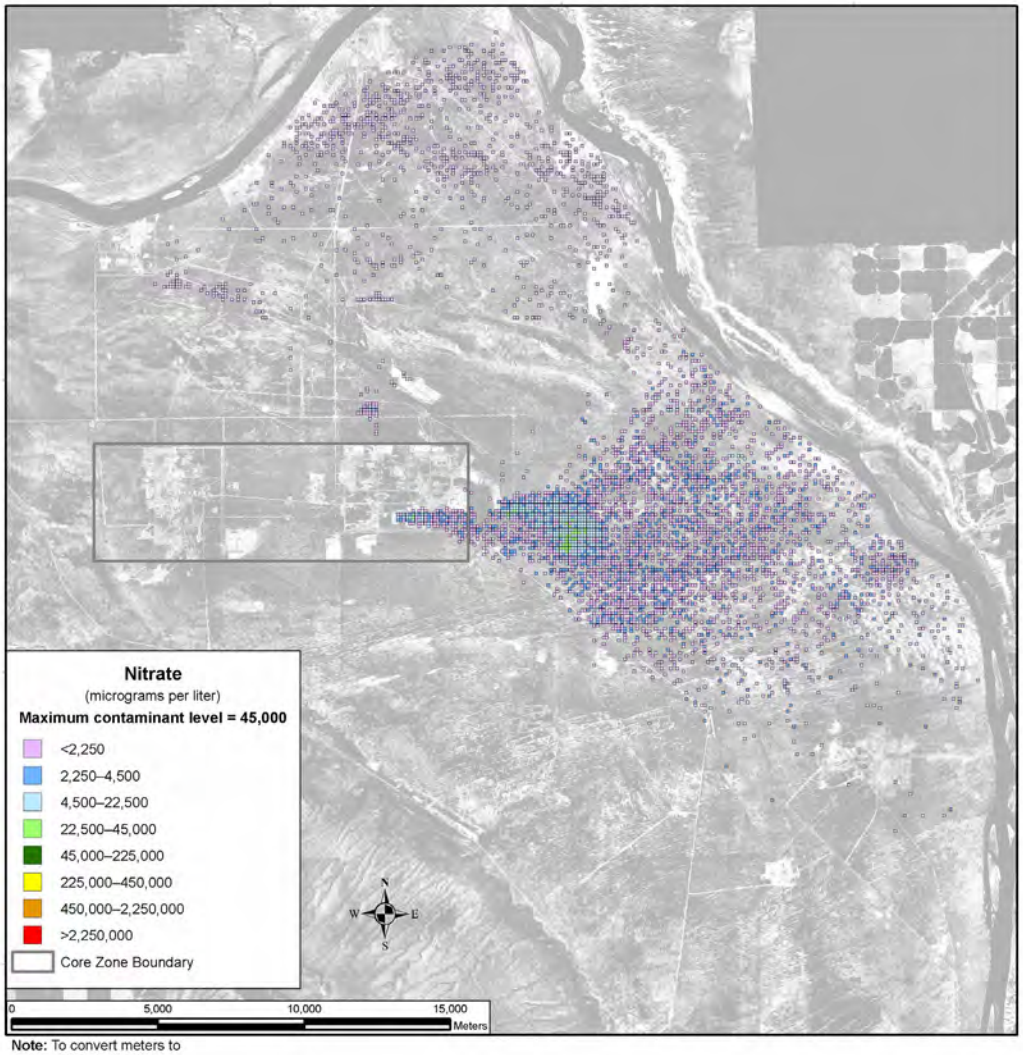
Note: To convert meters to feet, multiply by 3.281

Figure 5–452. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



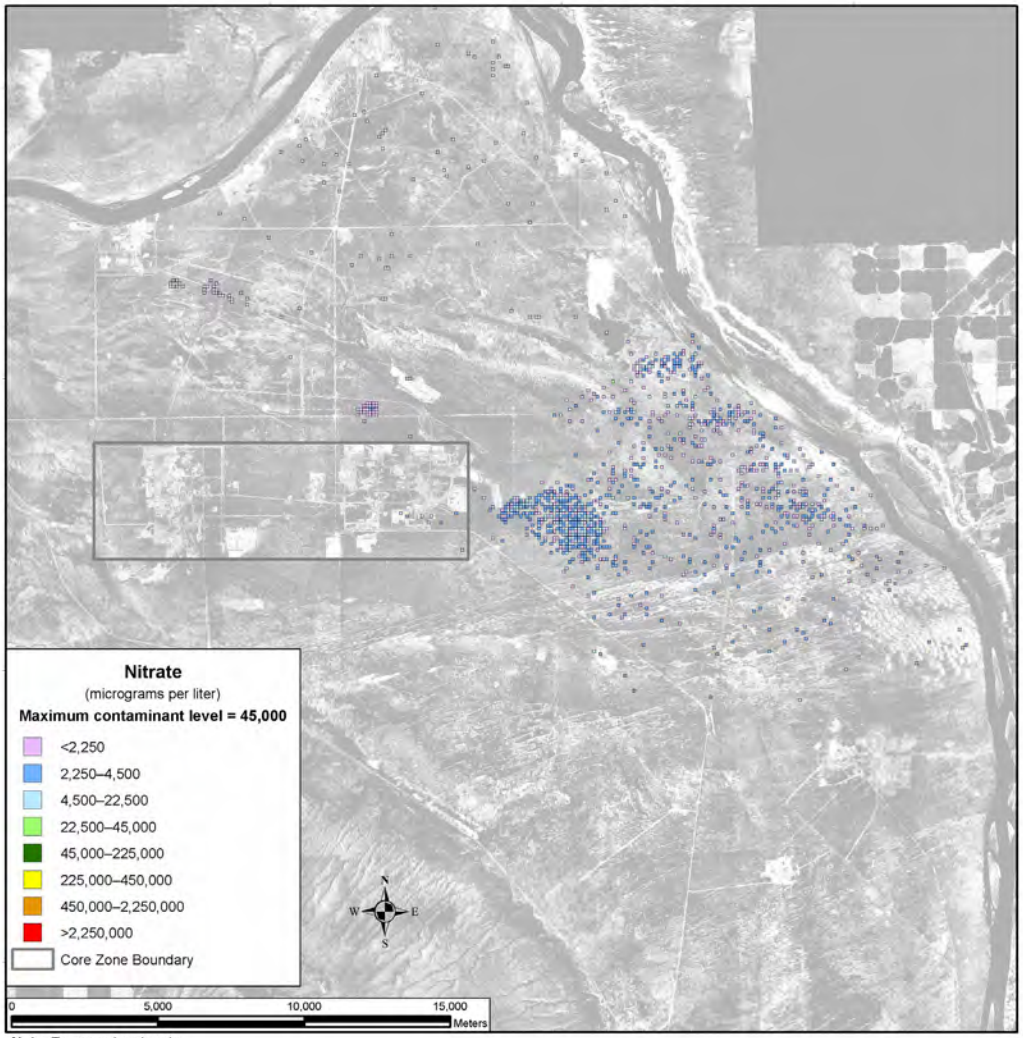
Note: To convert meters to feet, multiply by 3.281

Figure 5–453. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



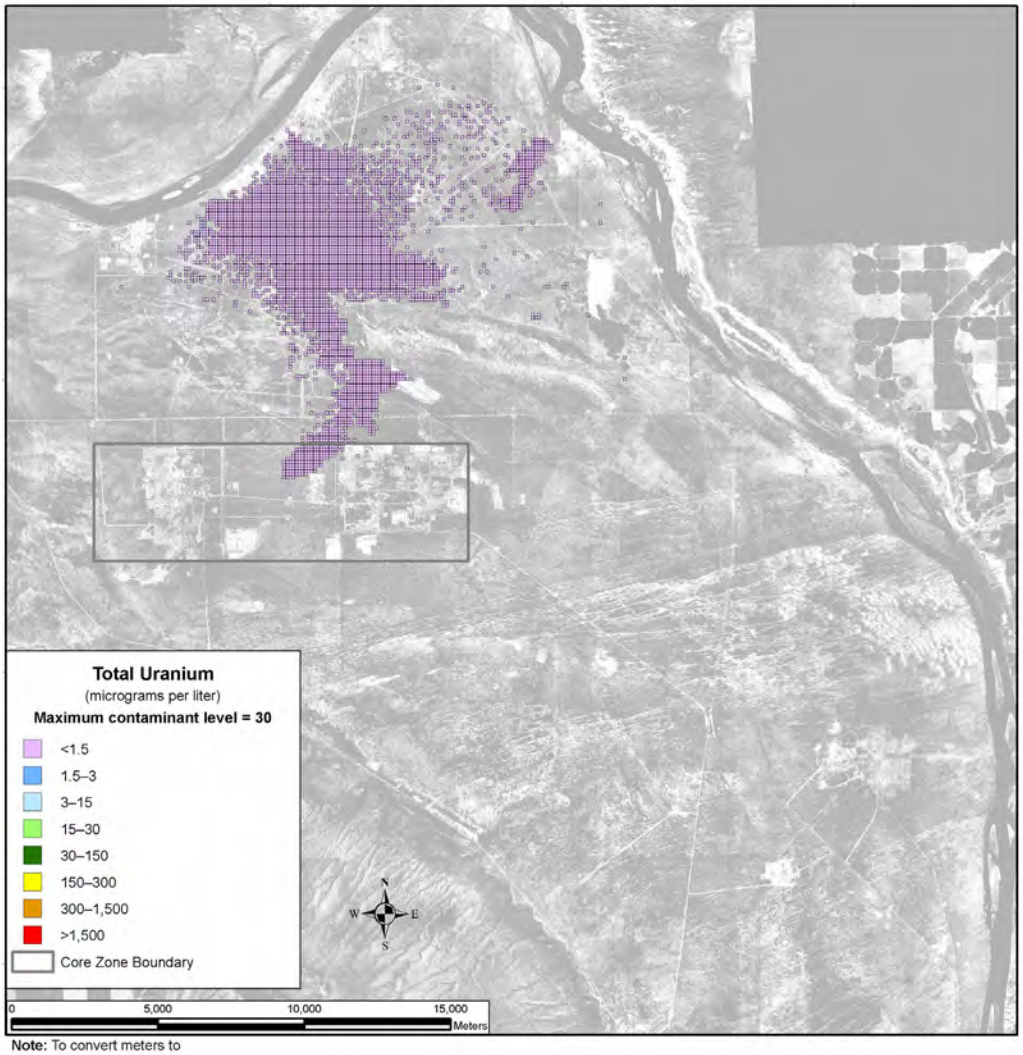
Note: To convert meters to feet, multiply by 3.281

Figure 5–454. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–455. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–456. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-C, in general, discharges from IDF-East are the predominant contributors. The RPPDF is a secondary contributor.

For the conservative tracers, concentrations at the Core Zone Boundary remain within an order of magnitude of the benchmark concentration during the last 5,000 years of the period of analysis. Concentrations at the Columbia River are slightly lower, but within an order of magnitude of the concentrations at the Core Zone Boundary. The intensities and areas of these groundwater plumes stabilize around CY 6940.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species remain well below the benchmark at the Core Zone Boundary and the Columbia River throughout the simulation. The peak intensity and area of the contamination plume are near the end of the period of analysis.

5.3.1.2.1.4 Disposal Group 1, Subgroup 1-D

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-D covers disposal of waste generated under Tank Closure Alternative 3C and FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW, ILAW glass, and steam reforming waste. IHLW would be stored on site, while ILAW glass and steam reforming waste would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when these facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2 is focused on the following COPC drivers:

- Radiological risk drivers: technetium-99 and iodine-129
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, fluoride, boron, and total uranium

The COPC drivers for Waste Management Alternative 2 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, chromium, fluoride, nitrate, and boron) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. Total uranium was added to the list because it begins to appear toward the end of the period of analysis. Total uranium is long-lived, or stable, but is not as mobile as the other COPC drivers; it moves about seven times more slowly than groundwater. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Disposal Group 1, Subgroup 1-D, in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–457 through 5–468). Eight subtotals are plotted for IDF-East representing releases from ILAW glass, ETF-generated secondary waste, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, onsite- and offsite-generated waste, steam reforming waste, retired melters, and waste management secondary waste. Release plots from the RPPDF are also included. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over eight orders of magnitude.

Figure 5–457 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–458, the chemical hazard drivers. Technetium-99 is released to the vadose zone from each of the subtotaled sources, with steam reforming waste and offsite-generated waste contributing the most. Iodine-129 had releases in the analysis from six of the sources, with steam reforming waste and offsite-generated waste also contributing the most. Chromium had six sources, with steam reforming waste and tank closure secondary waste providing the most releases. Nitrate was released only from ETF-generated secondary waste, waste management secondary waste, and onsite-generated waste. Fluoride and boron both were released only from waste management secondary waste and onsite-generated waste.

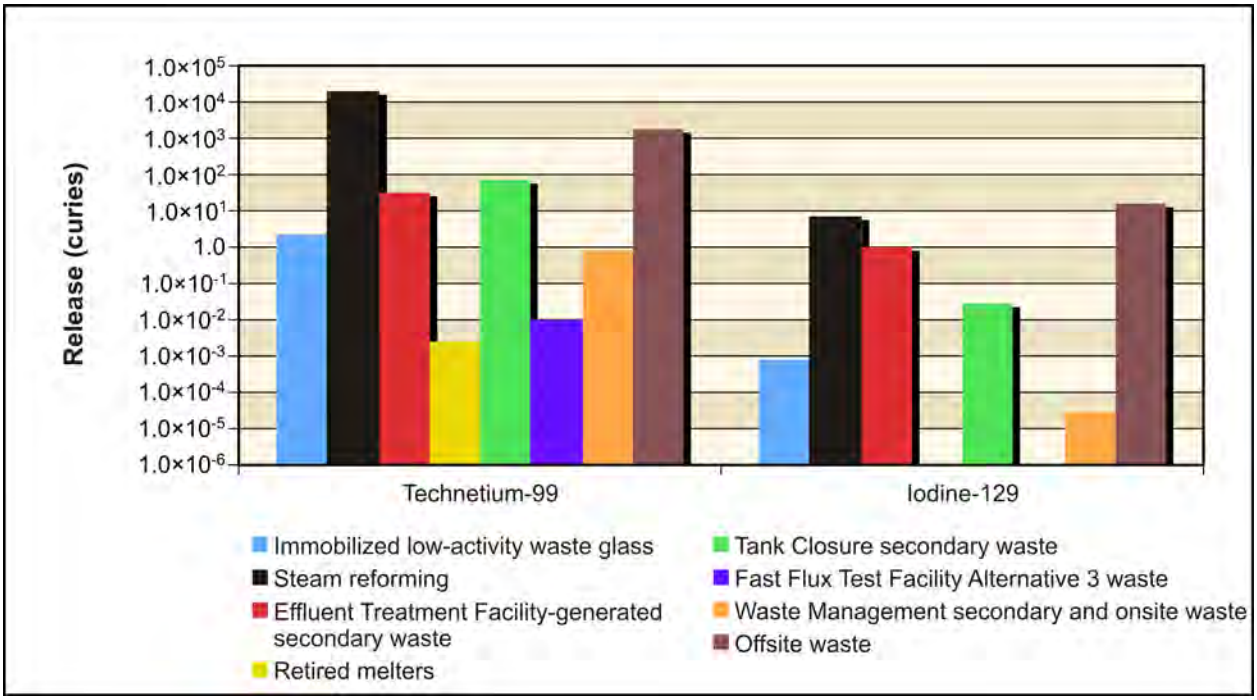


Figure 5–457. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

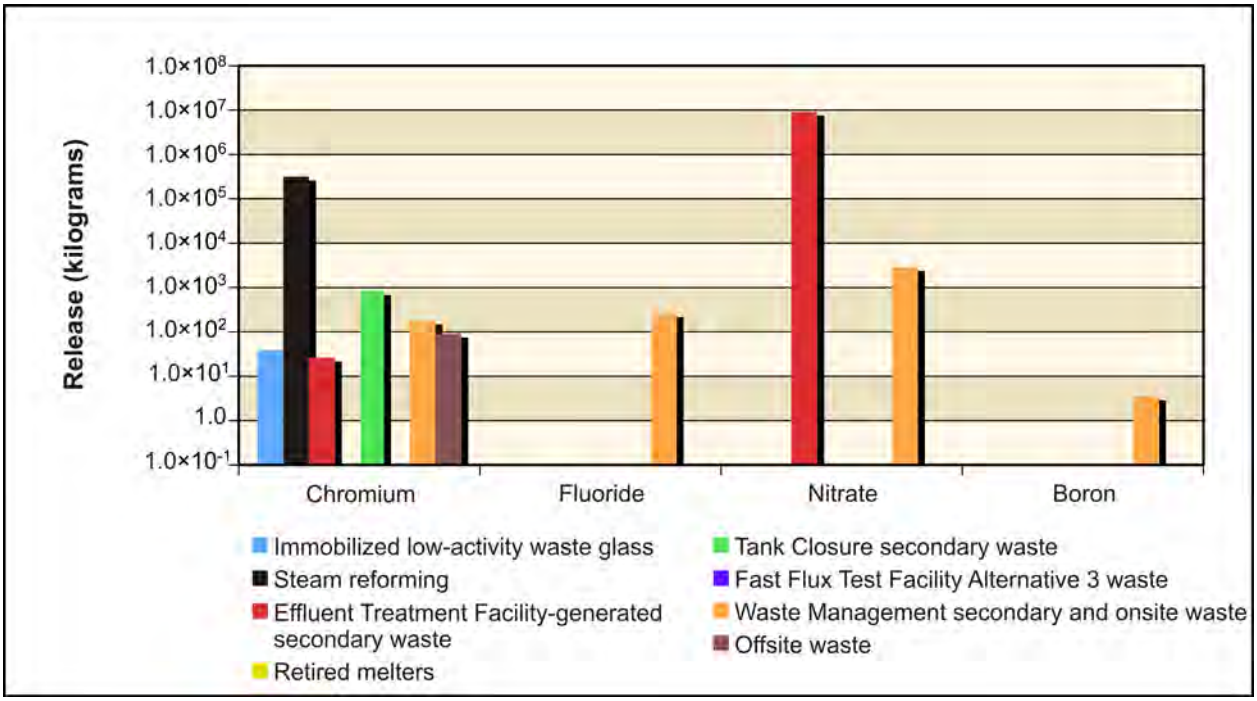


Figure 5–458. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

Figure 5–459 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–460, the chemical hazard drivers. Release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (technetium-99, iodine-129, chromium, nitrate, fluoride, and boron), the amount released to groundwater is typically equal to the amount released to the vadose zone. For technetium-99, the amount released to groundwater was essentially equal to that released to the vadose zone for steam reforming waste, ETF-generated secondary waste, and offsite-generated waste. For ILAW glass, retired melters, and tank closure secondary waste, about 45 to 50 percent of the technetium-99 released to the vadose zone was transferred to the groundwater. For FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite-generated waste, about 60 to 65 percent of the technetium-99 released to the vadose zone was transferred to the groundwater. For iodine-129, the amount released to groundwater was essentially equal to that released to the vadose zone for steam reforming waste and offsite-generated waste. For ILAW glass, ETF-generated secondary waste, tank closure secondary waste, waste management secondary waste, and onsite-generated waste, about 40 to 50 percent of the iodine-129 released to the vadose zone was transferred to the groundwater. For chromium, the amount released to groundwater was essentially equal to that released to the vadose zone for steam reforming waste, ETF-generated secondary waste, tank closure secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. For ILAW glass, about 40 percent of the chromium released to the vadose zone was transferred to the groundwater. For nitrate, the amount released to groundwater was essentially equal to that released to the vadose zone for ETF-generated secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. For fluoride, the amount released to groundwater was essentially equal to that released to the vadose zone for waste management secondary waste and onsite-generated waste. For boron, the amount released to groundwater was essentially equal to that released to the vadose zone for waste management secondary waste and onsite-generated waste.

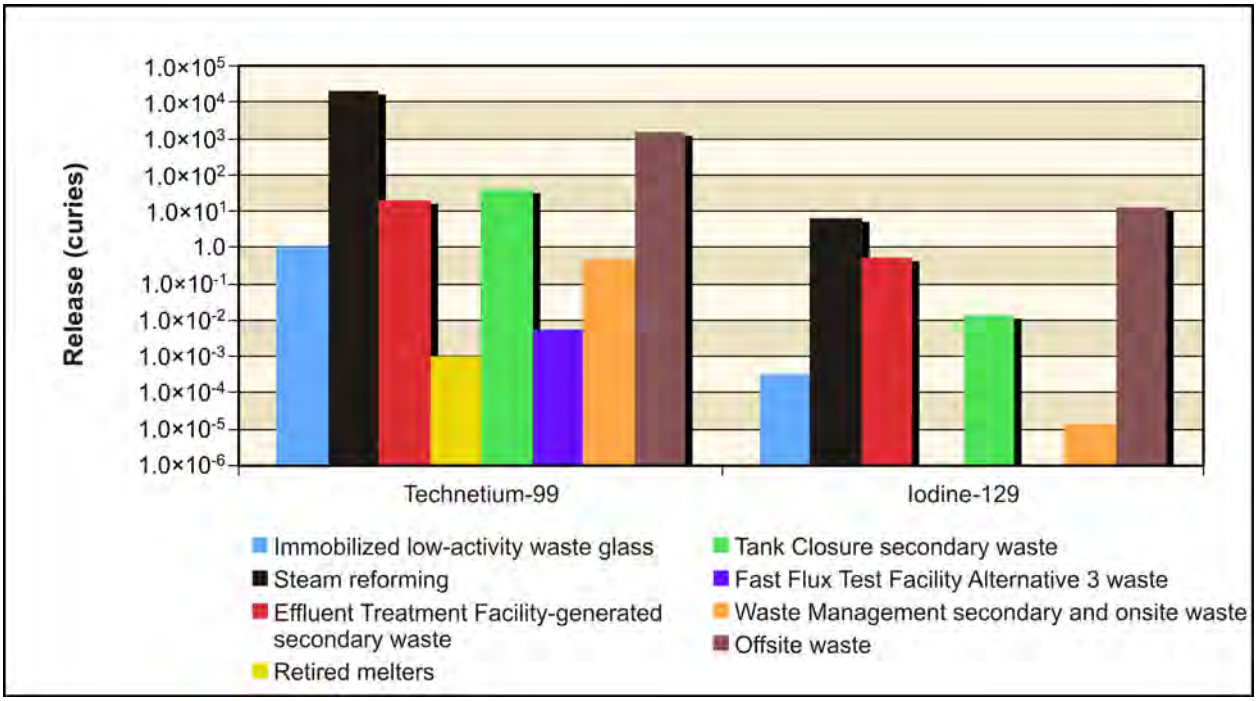


Figure 5–459. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

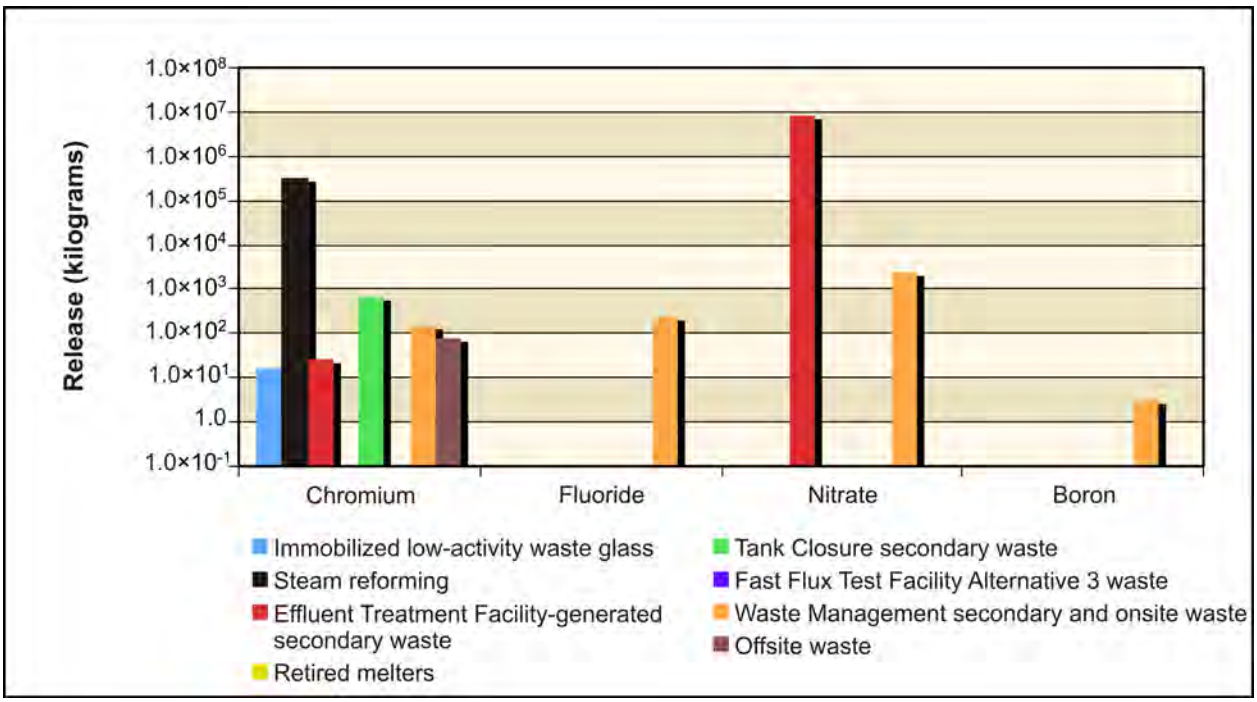


Figure 5–460. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

Figure 5–461 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–462, the chemical hazard drivers. For the conservative tracers (technetium-99, iodine-129, chromium, nitrate, fluoride, and boron), the amount released to the Columbia River is typically essentially equal to the amount released to the vadose zone. For technetium-99, the amount released to the Columbia River from the groundwater was about 90 to 98 percent for ILAW glass, steam reforming waste, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste. For iodine-129, the amount released to the Columbia River from the groundwater was about 90 to 100 percent for ILAW glass, stream reforming waste, ETF-generated secondary waste, tank closure secondary waste, and offsite-generated waste. Essentially none of the iodine-129 released from waste management secondary waste and onsite-generated waste from the groundwater was transferred to the Columbia River. For chromium, the amount released to the Columbia River from the groundwater was about 90 to 100 percent for ILAW glass, stream reforming waste, ETF-generated secondary waste, tank closure secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. For nitrate, the amount released to the Columbia River was essentially equal to that released to the groundwater for ETF-generated secondary waste, waste management secondary waste, and onsite- and offsite-generated waste. For fluoride, the amount released to the Columbia River was essentially equal to that released to the groundwater for waste management secondary waste and onsite-generated waste. For boron, the amount released to the Columbia River was essentially equal to that released to the groundwater for waste management secondary waste and onsite-generated waste.

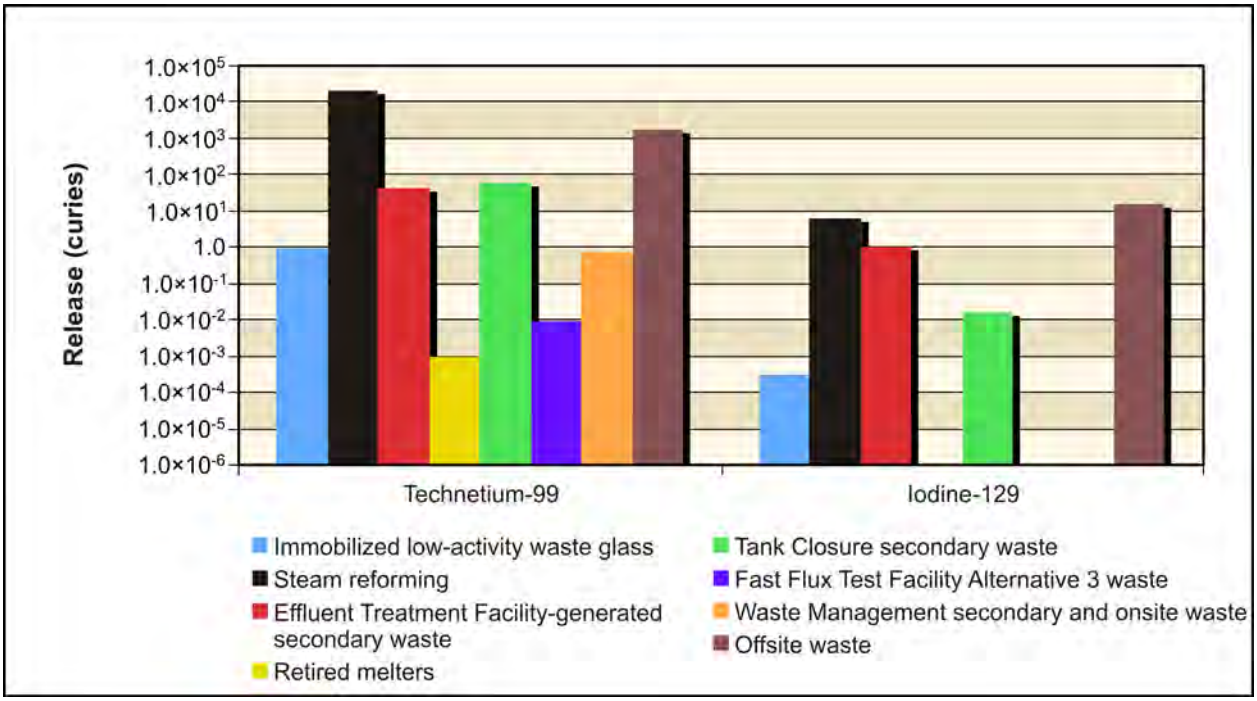


Figure 5–461. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

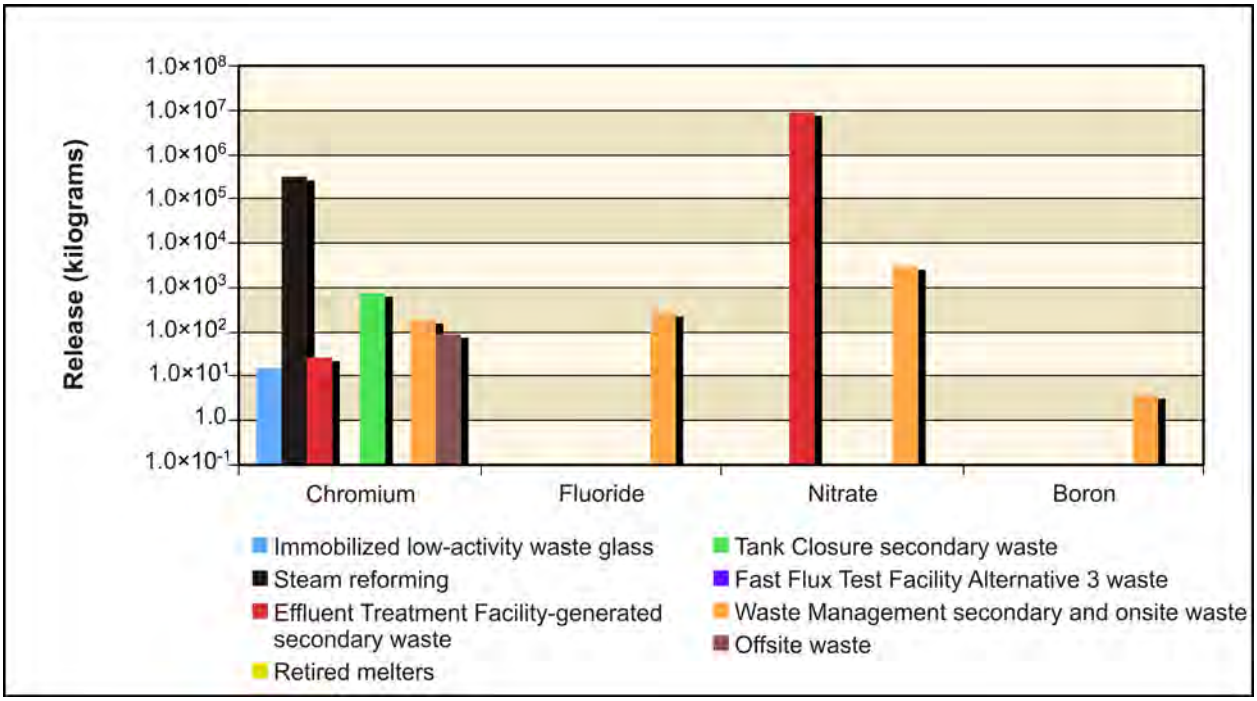


Figure 5–462. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

Figure 5–463 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–464, the chemical hazard drivers. The only constituents released to the vadose zone from the RPPDF were technetium-99, iodine-129, chromium, and nitrate.

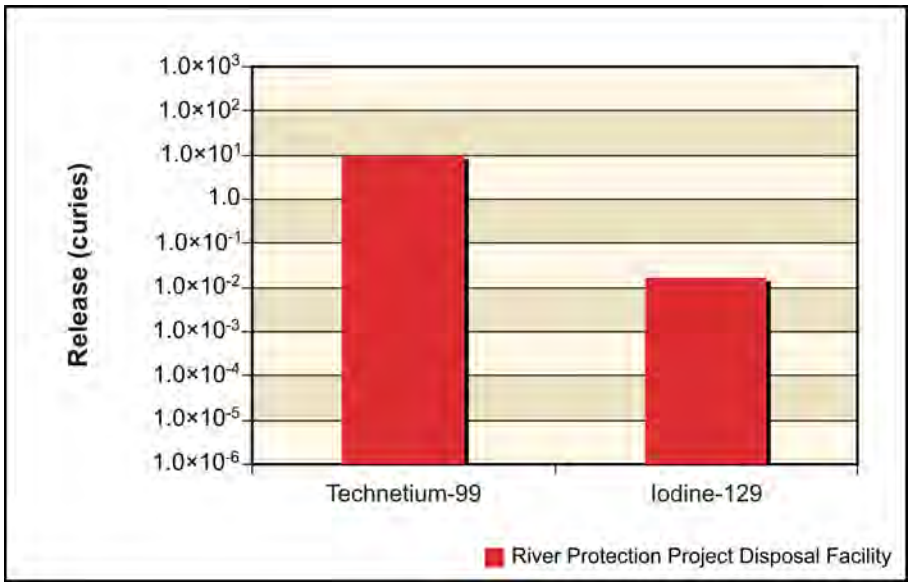


Figure 5–463. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

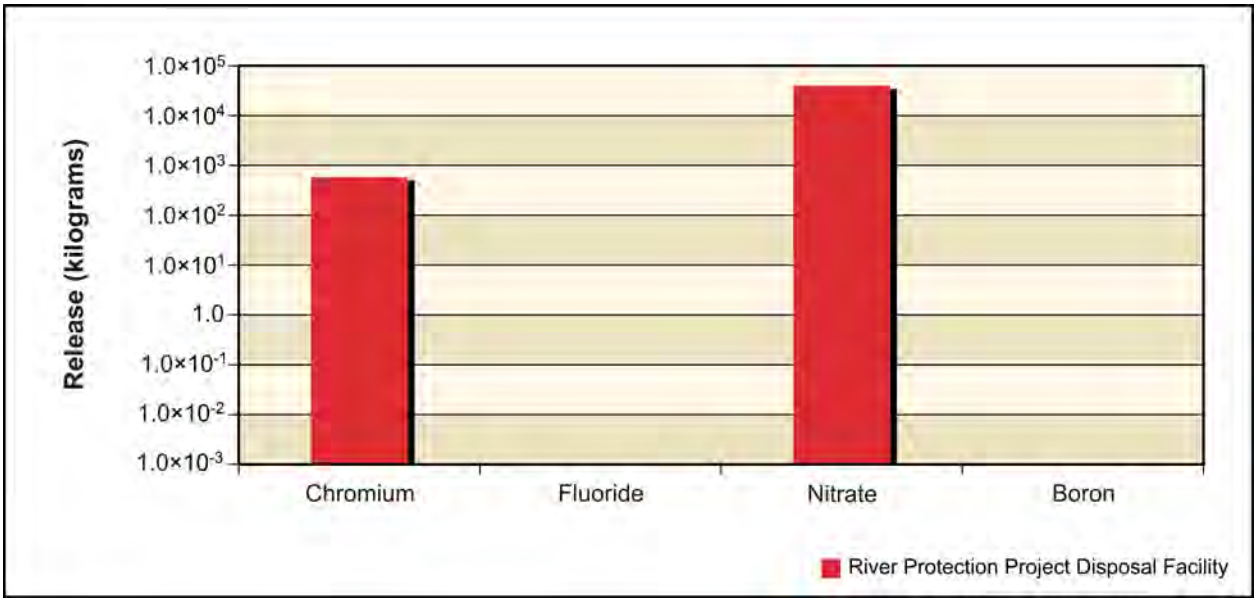


Figure 5–464. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

Figure 5–465 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–466, the chemical hazard drivers. For the RPPDF, the amount released to groundwater was essentially equal to that released to the vadose zone for technetium-99, iodine-129, chromium, and nitrate.

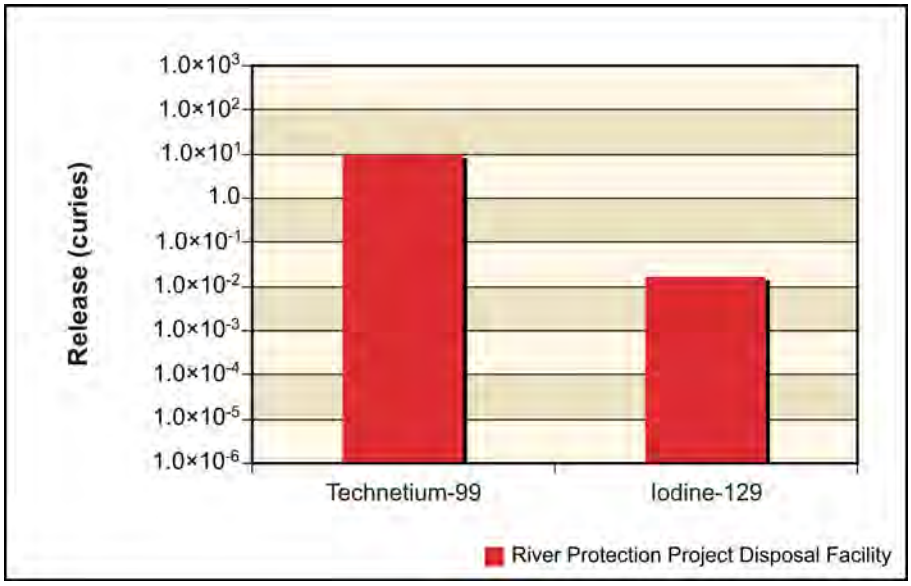


Figure 5–465. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at River Protection Project Disposal Facility to Groundwater

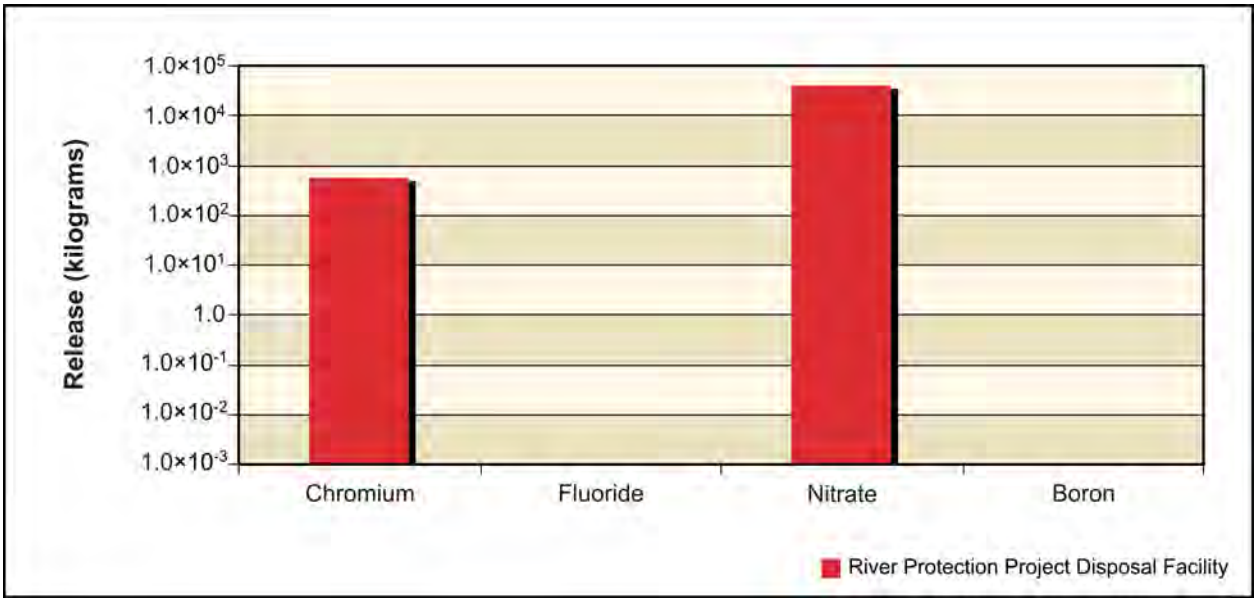


Figure 5–466. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at River Protection Project Disposal Facility to Groundwater

Figure 5–467 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–468, the chemical hazard drivers. For the RPPDF, about 95 percent of technetium-99, iodine-129, chromium, and nitrate released from the groundwater reached the Columbia River.

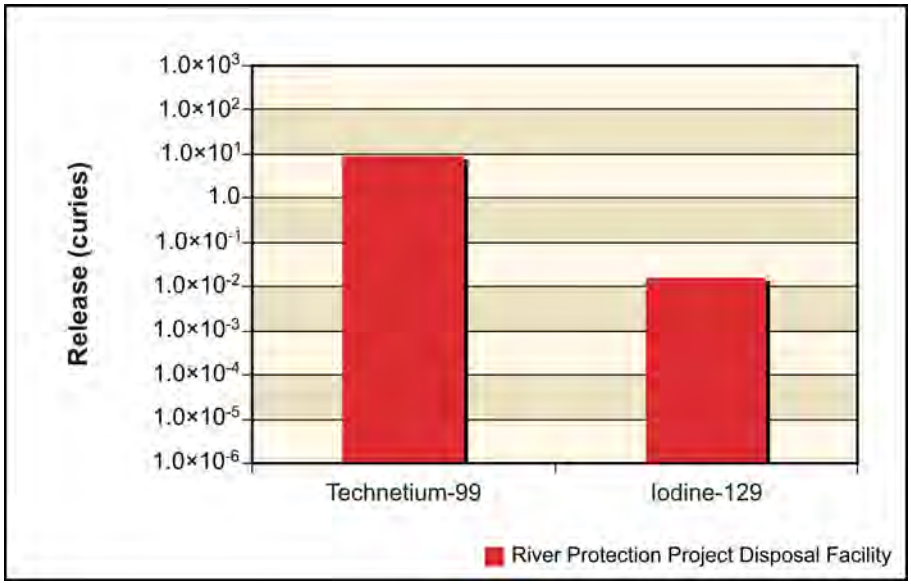


Figure 5–467. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Radiological Releases at River Protection Project Disposal Facility to Columbia River

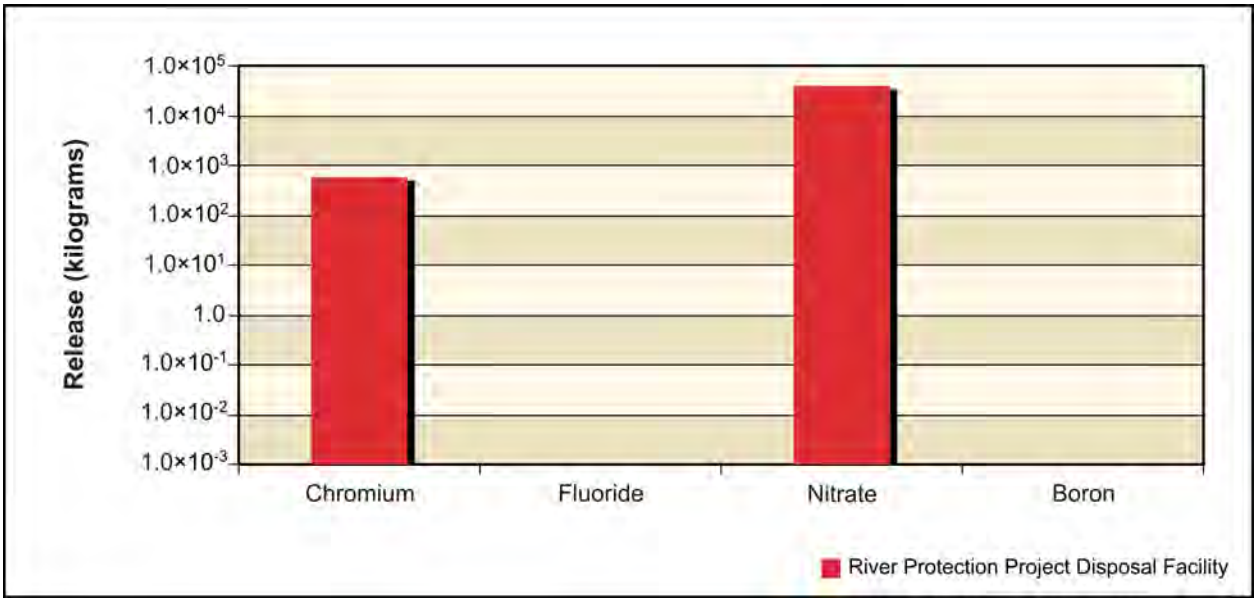


Figure 5–468. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–469 through 5–473). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Table 5–80 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figure 5–469 shows the concentration versus time plot for technetium-99. Releases cause the groundwater concentrations at the Core Zone Boundary and at the Columbia River nearshore to exceed the benchmark concentration by about one-half of an order of magnitude at around CY 6000. The concentrations at the Core Zone Boundary and the Columbia River nearshore remain above the benchmark concentration through the end of the period of analysis.

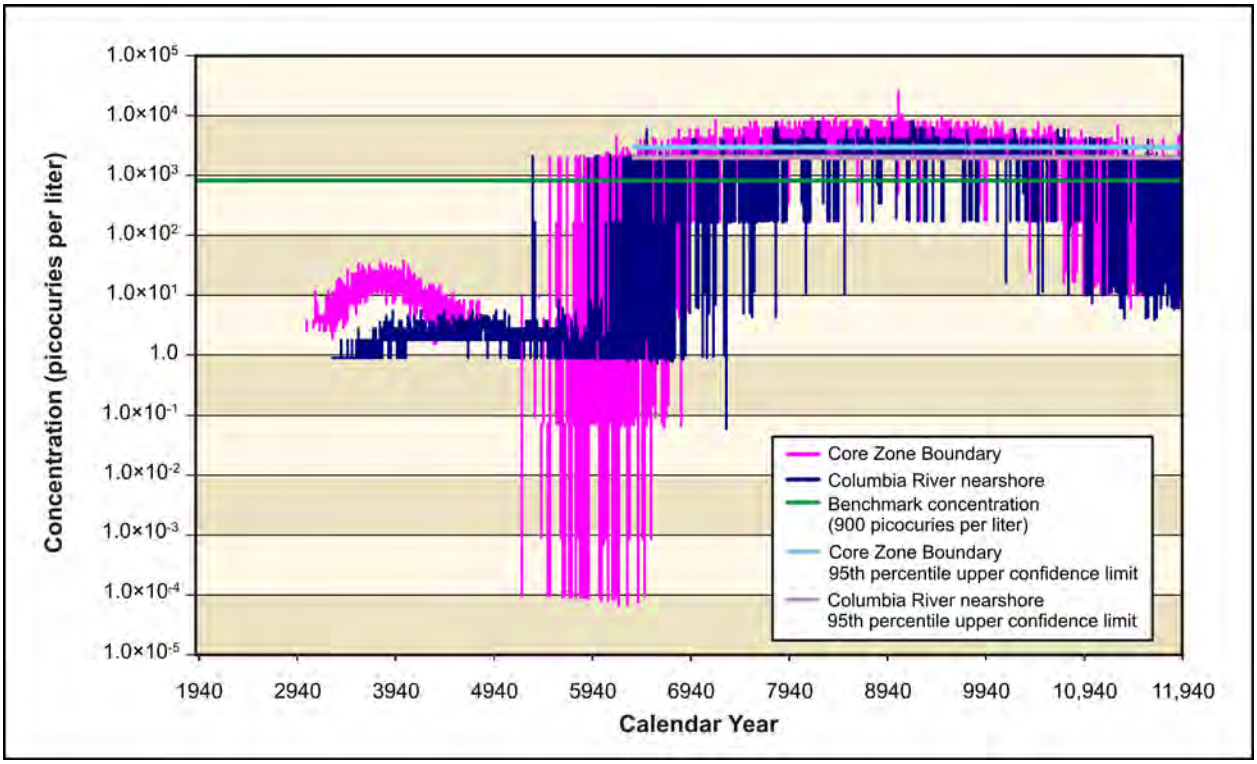


Figure 5–469. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Technetium-99 Concentration Versus Time

The plot of concentration of iodine-129 versus time shows a pattern similar to that of technetium-99 (see Figure 5–470).

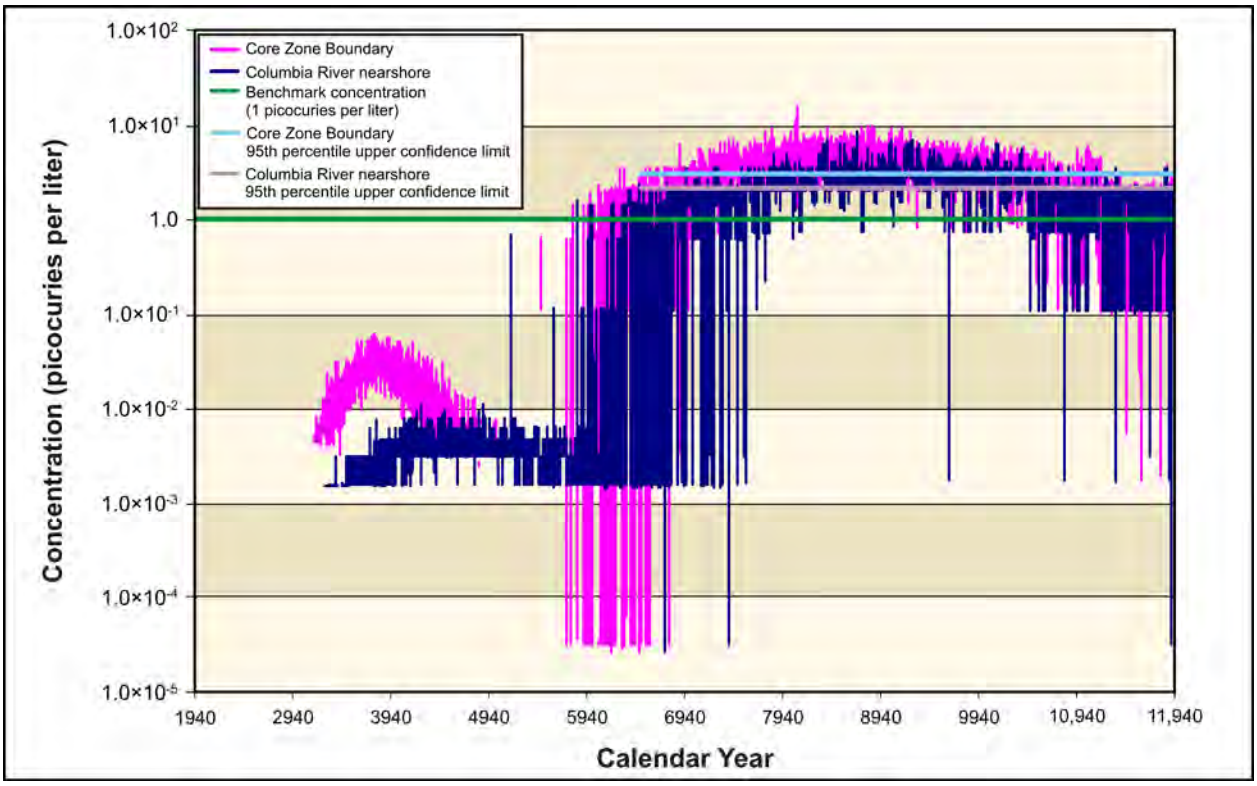


Figure 5–470. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Iodine-129 Concentration Versus Time

Figure 5–471 shows the concentration versus time plot for chromium. The concentrations at the Core Zone Boundary exceed the benchmark from about CY 7000 to 10,000. During the same time period, concentrations from the Columbia River nearshore approach the benchmark, but never reach it. The concentrations at the Core Zone Boundary and the Columbia River nearshore both remain about one-half of an order of magnitude below the benchmark at the end of the period of analysis.

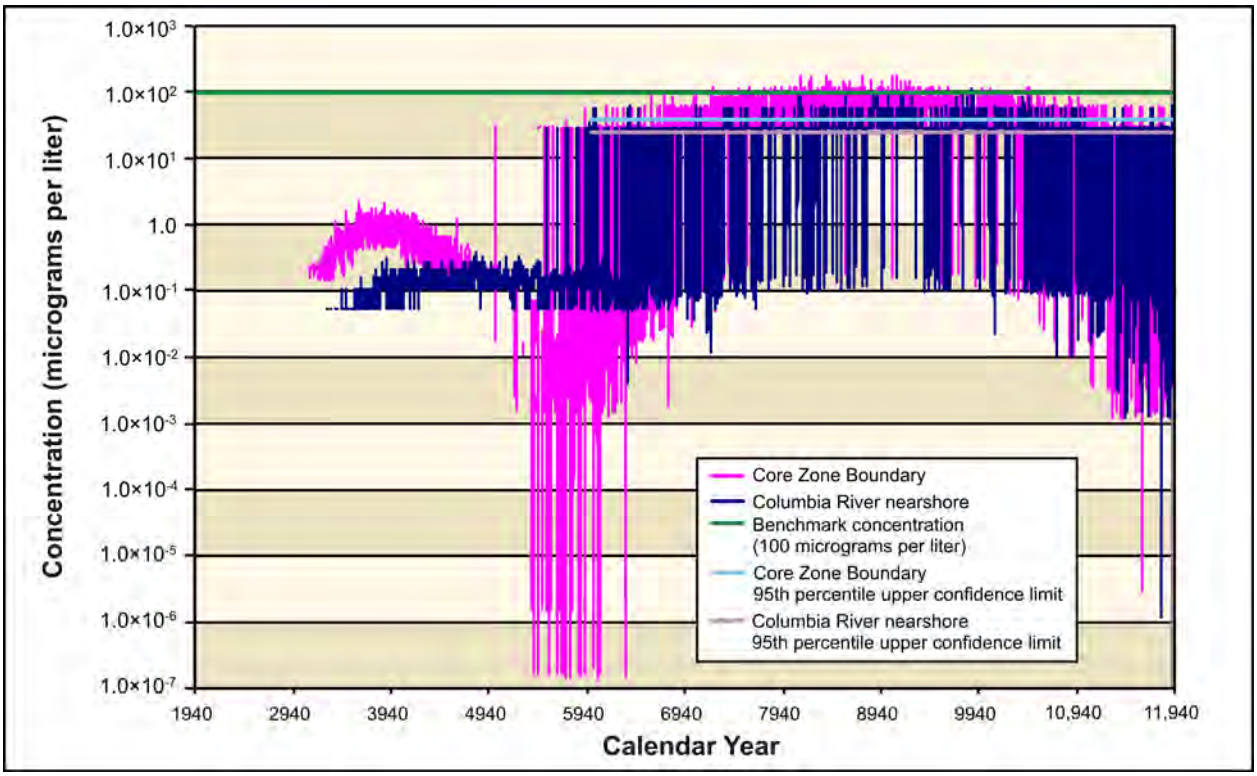


Figure 5–471. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Chromium Concentration Versus Time

Figure 5–472 shows the concentration versus time plot for nitrate. The concentrations at the Core Zone Boundary and the Columbia River nearshore both peak at around CY 8000. Even at the concentration's peak, nitrate levels still remain about one to one and one-half orders of magnitude below the benchmark level.

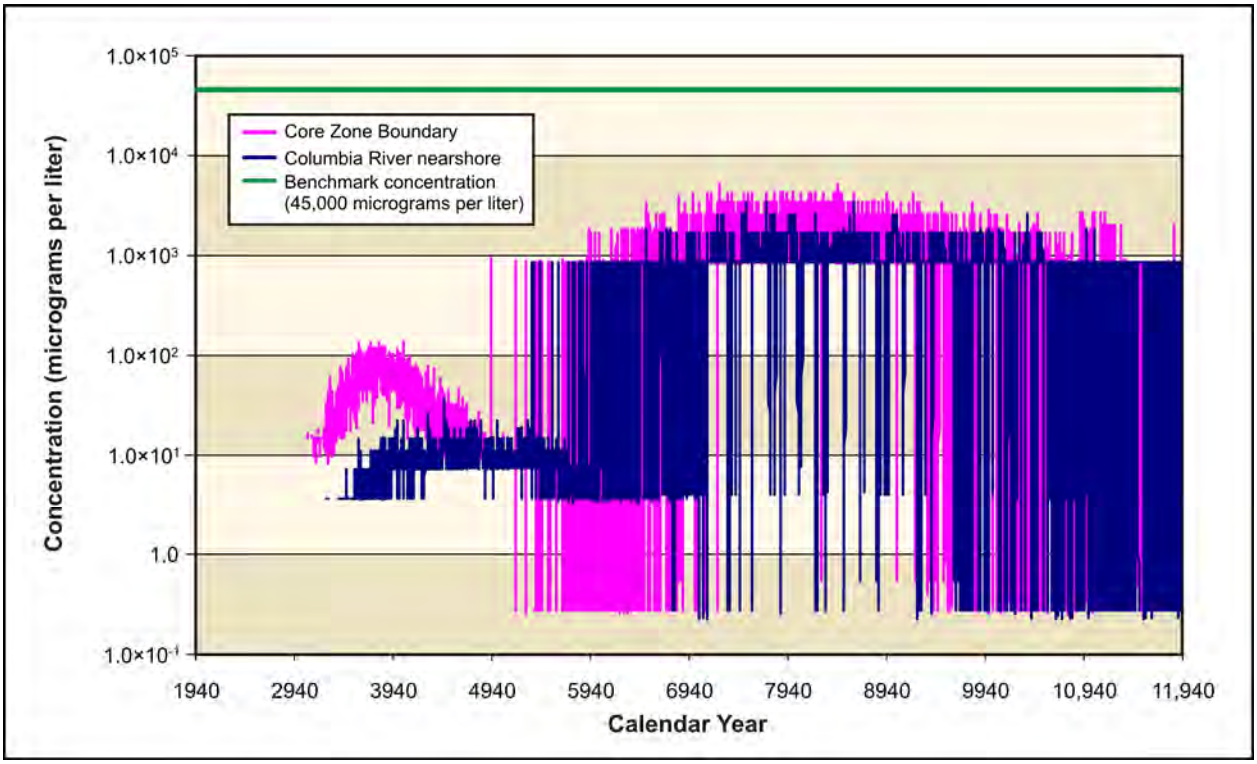


Figure 5–472. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Nitrate Concentration Versus Time

Figure 5–473 shows the concentration versus time plot for total uranium. It is not until around CY 9900 that concentrations begin to appear on the graph. The concentrations at the Core Zone Boundary and the Columbia River nearshore both remain about eight to nine orders of magnitude below the benchmark level.

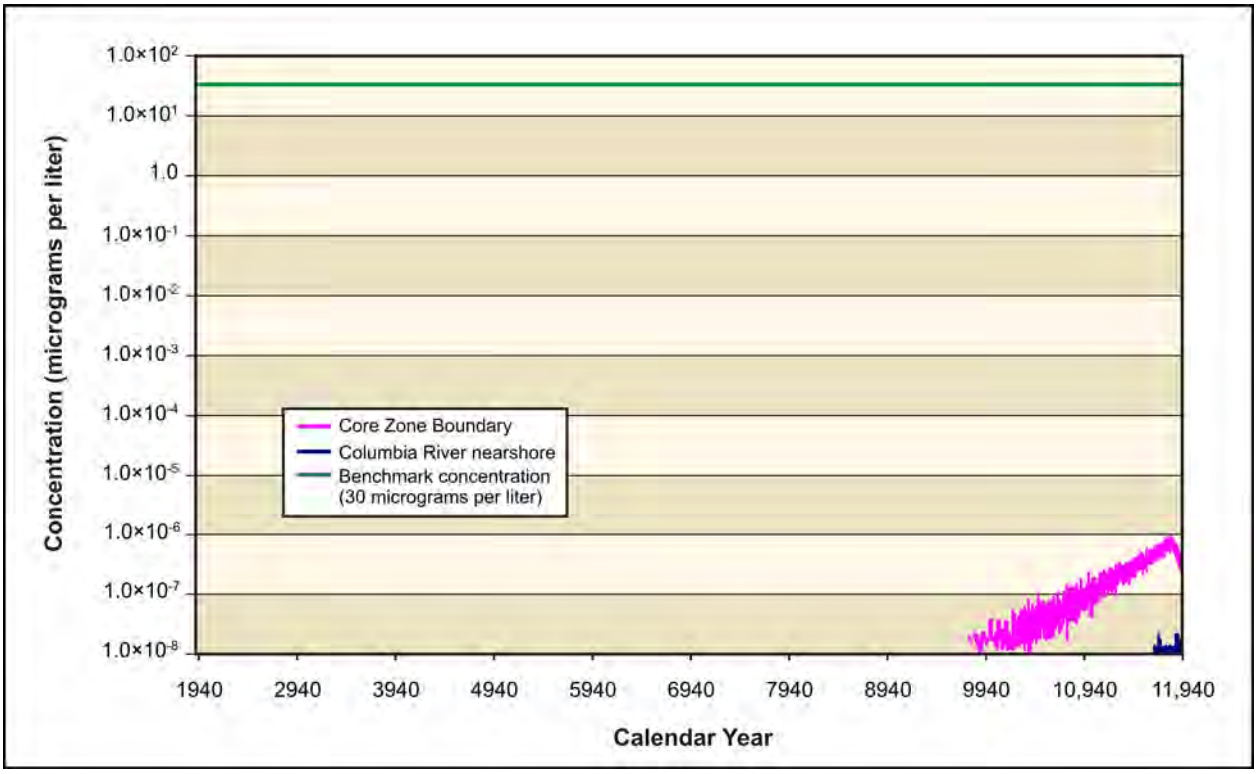


Figure 5–473. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Total Uranium Concentration Versus Time

Table 5–80. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**30,100**	33	**24,800**	**7,610**	900
	(9032)	(3825)	(9067)	(8274)	
Iodine-129	**24**	0.1	**16**	**8**	1
	(8195)	(3772)	(8082)	(8699)	
Chemical in micrograms per liter					
Chromium	**436**	2	**174**	**116**	100
	(9071)	(3856)	(8397)	(9878)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,500	149	4,970	3,320	45,000
	(7859)	(3811)	(7269)	(7744)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

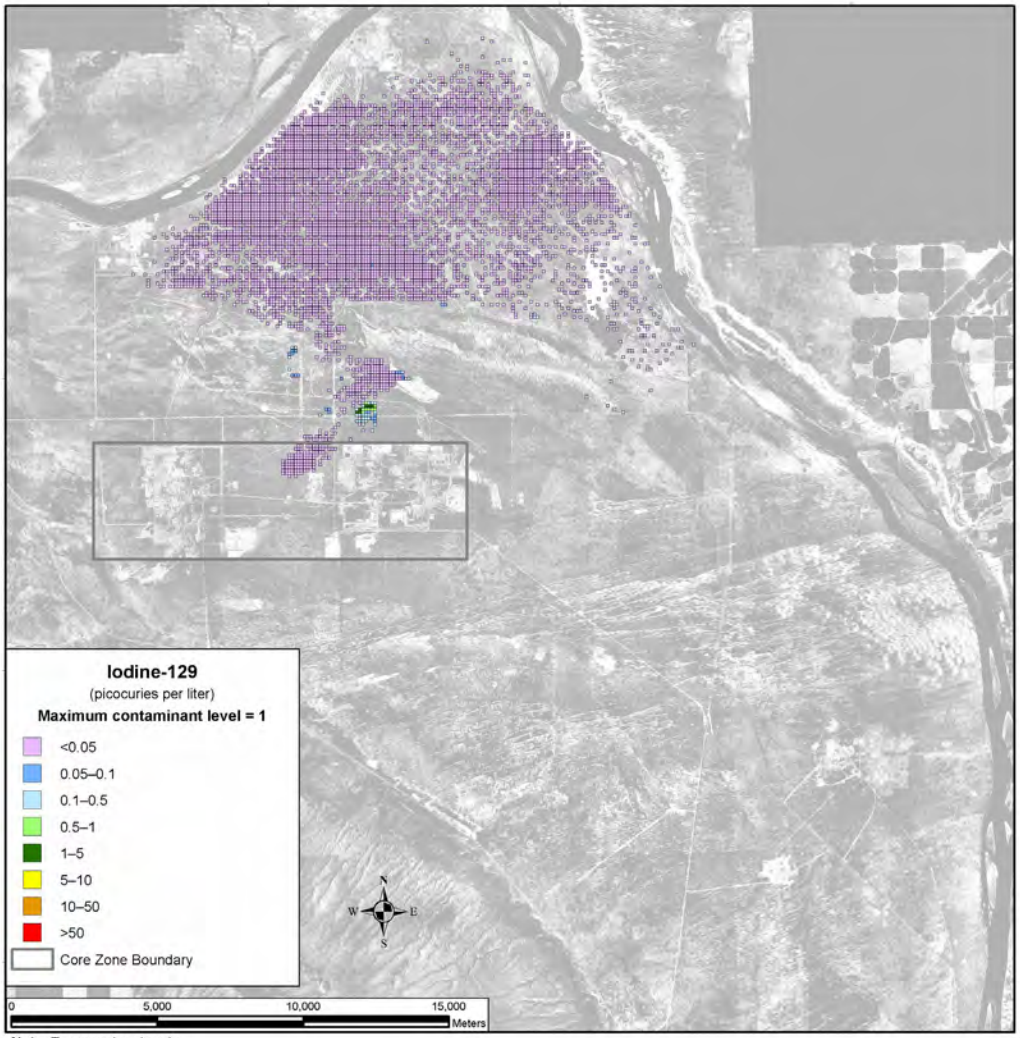
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Disposal Group 1, Subgroup 1-D, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

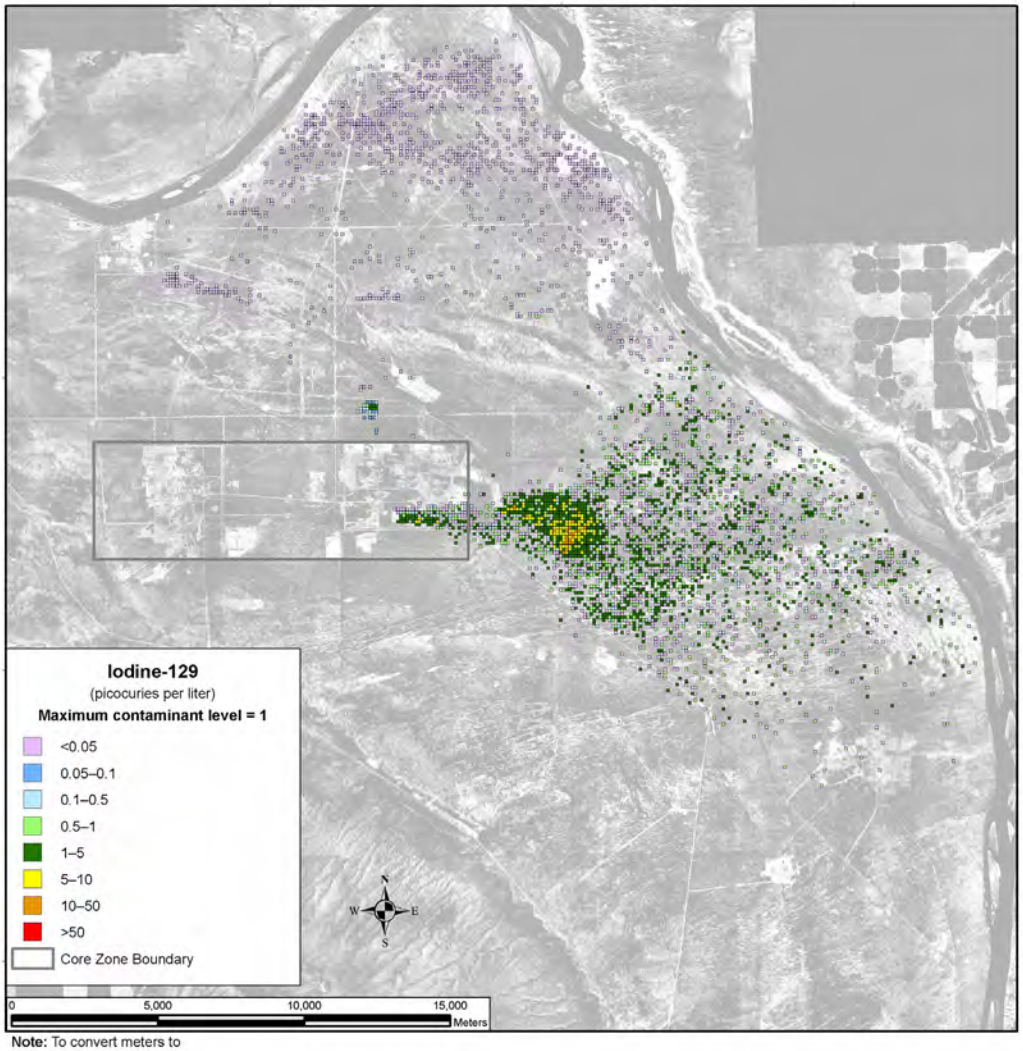
Figure 5–474 shows the spatial distribution of groundwater concentration of iodine-129 during CY 3890. Releases from the RPPDF create a plume extending northerly through Gable Gap toward the Columbia River. Peak concentrations in this plume exceed the benchmark by about one to five times, although the majority of the plume has concentrations less than one-twentieth of the benchmark. By CY 7140, releases from IDF-East create a new plume extending easterly toward the Columbia River (see Figure 5–475). Peak concentrations in this plume exceed the benchmark by 10 to 50 times. By the end of the period of analysis (CY 11,885), the plume created by the RPPDF has mostly dissipated, while the IDF-East plume continues to persist, with small patches exceeding the benchmark by about 5 to 10 times (see Figure 5–476). Technetium-99 shows a similar spatial distribution over time (see Figure 5–477 through 5–479). Chromium and nitrate also show a similar spatial distribution over time, but with less-intense areas of peak concentration (see Figures 5–480 through 5–485).

Total uranium is not as mobile as those COPCs discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–486 shows the distribution of total uranium during CY 11,885. A plume that is less than one-twentieth of the benchmark was released from the RPPDF and is extending northerly through Gable Gap toward the Columbia River. Because of the slow nature of the pore water velocity, most of the uranium releases are expected to occur after the period of analysis is over.



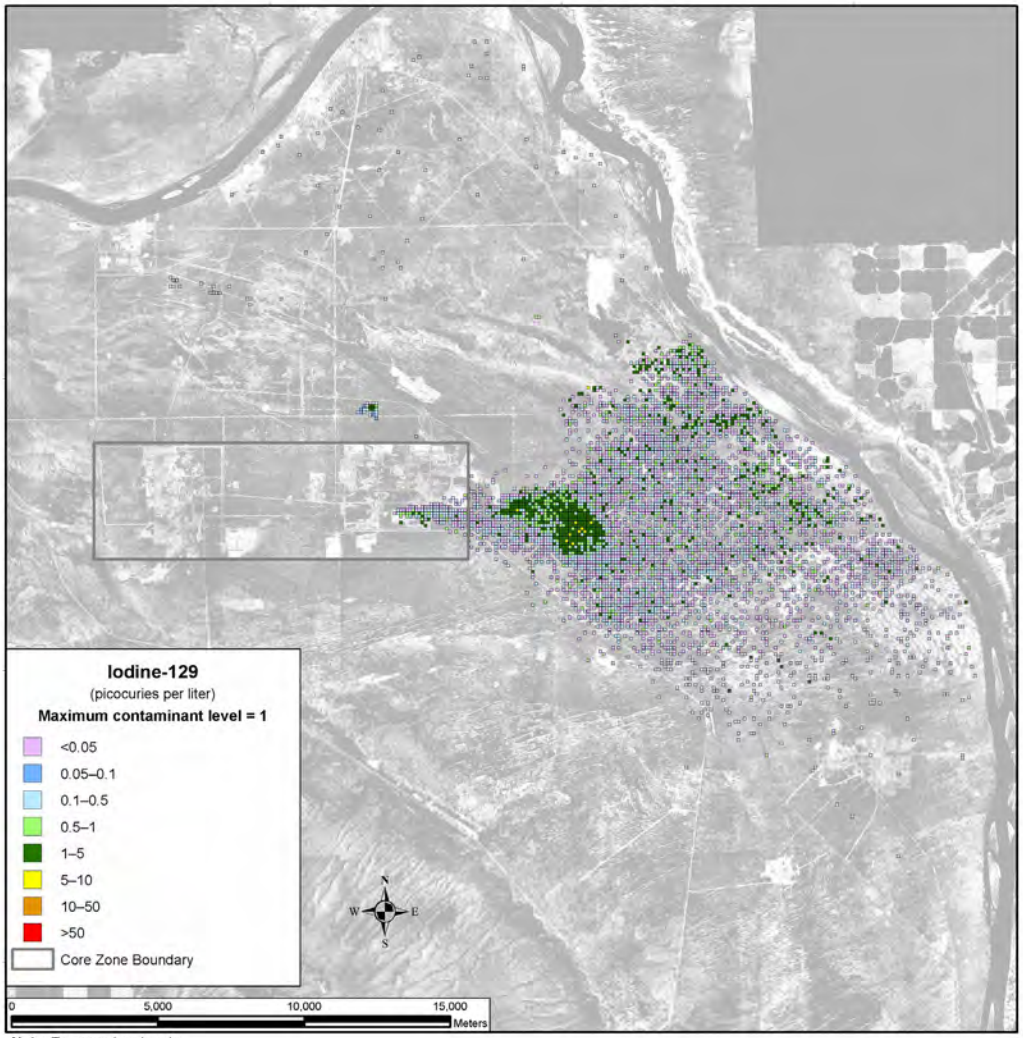
Note: To convert meters to feet, multiply by 3.281

Figure 5–474. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



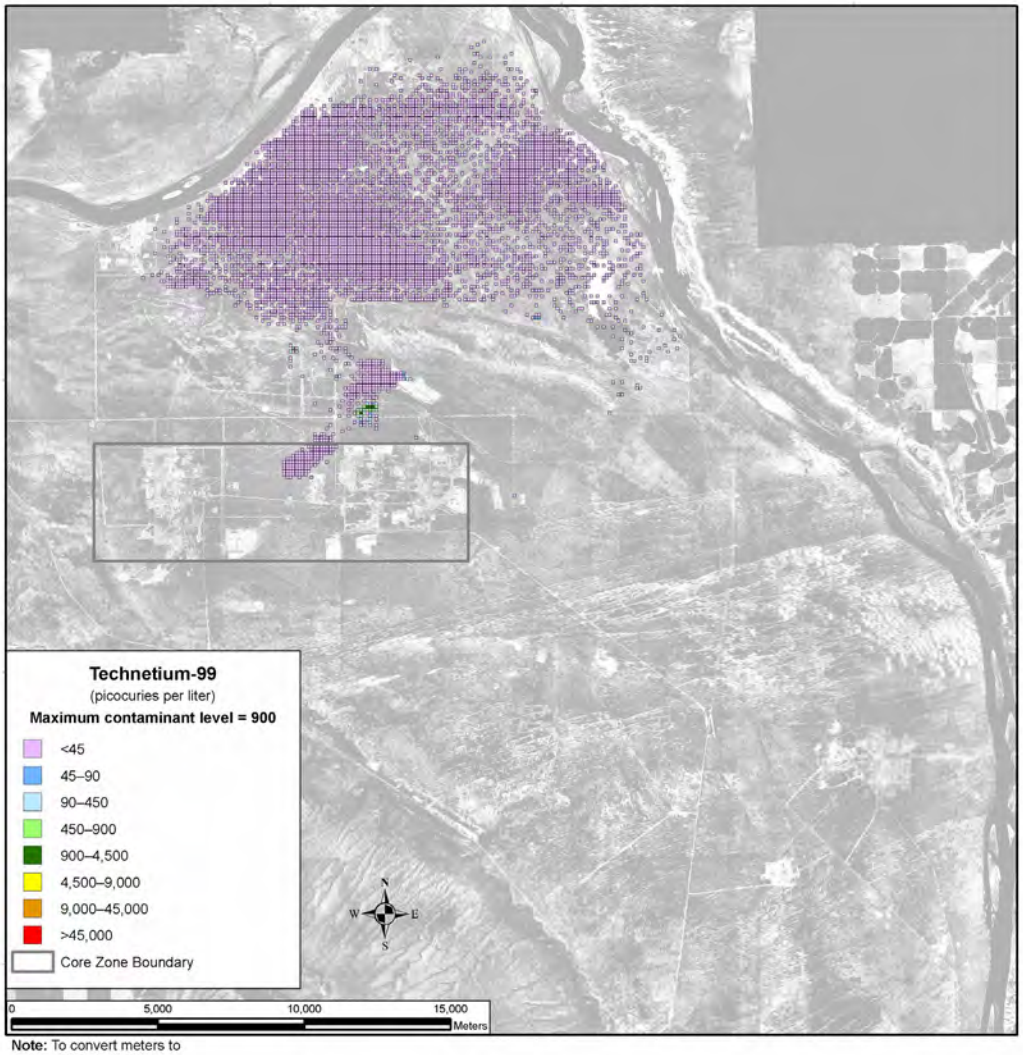
Note: To convert meters to feet, multiply by 3.281

Figure 5–475. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



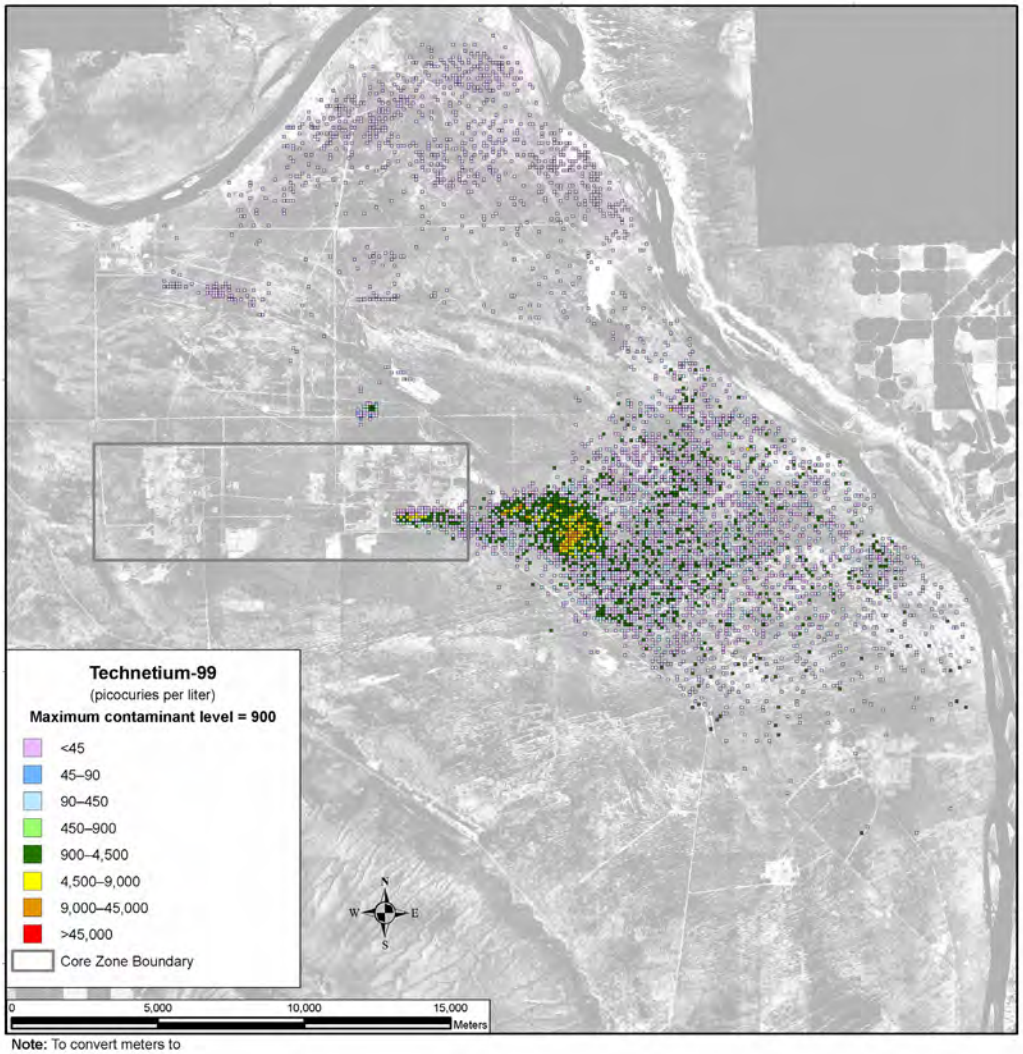
Note: To convert meters to feet, multiply by 3.281

Figure 5–476. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



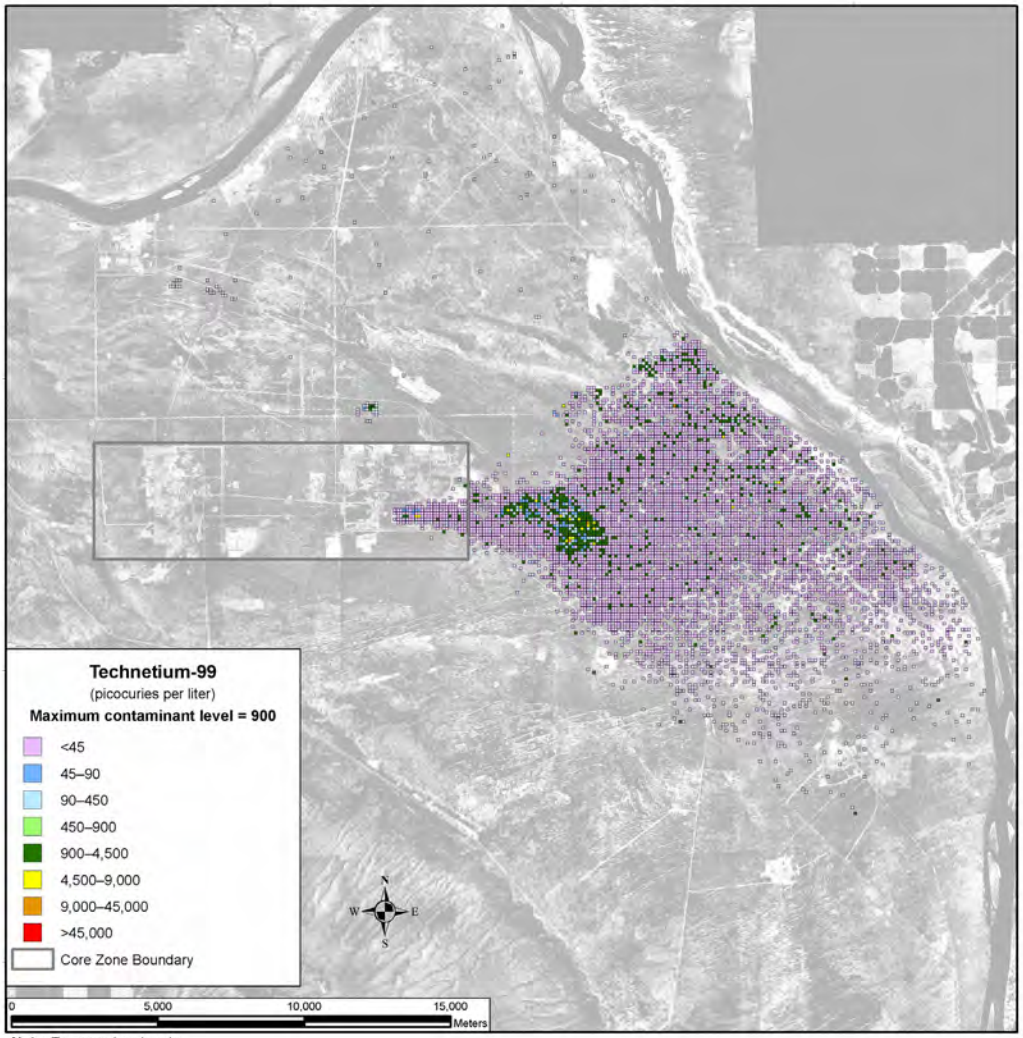
Note: To convert meters to feet, multiply by 3.281

Figure 5–477. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



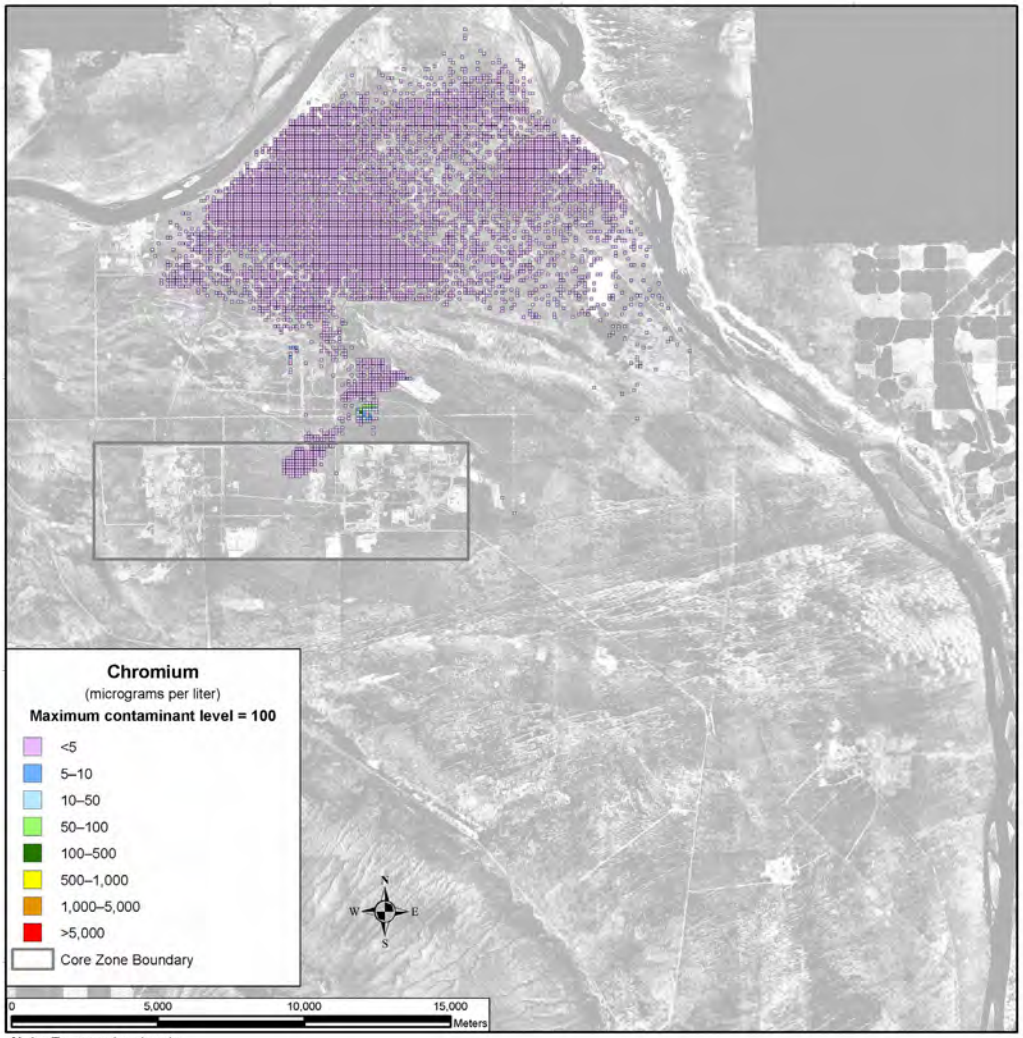
Note: To convert meters to feet, multiply by 3.281

Figure 5–478. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



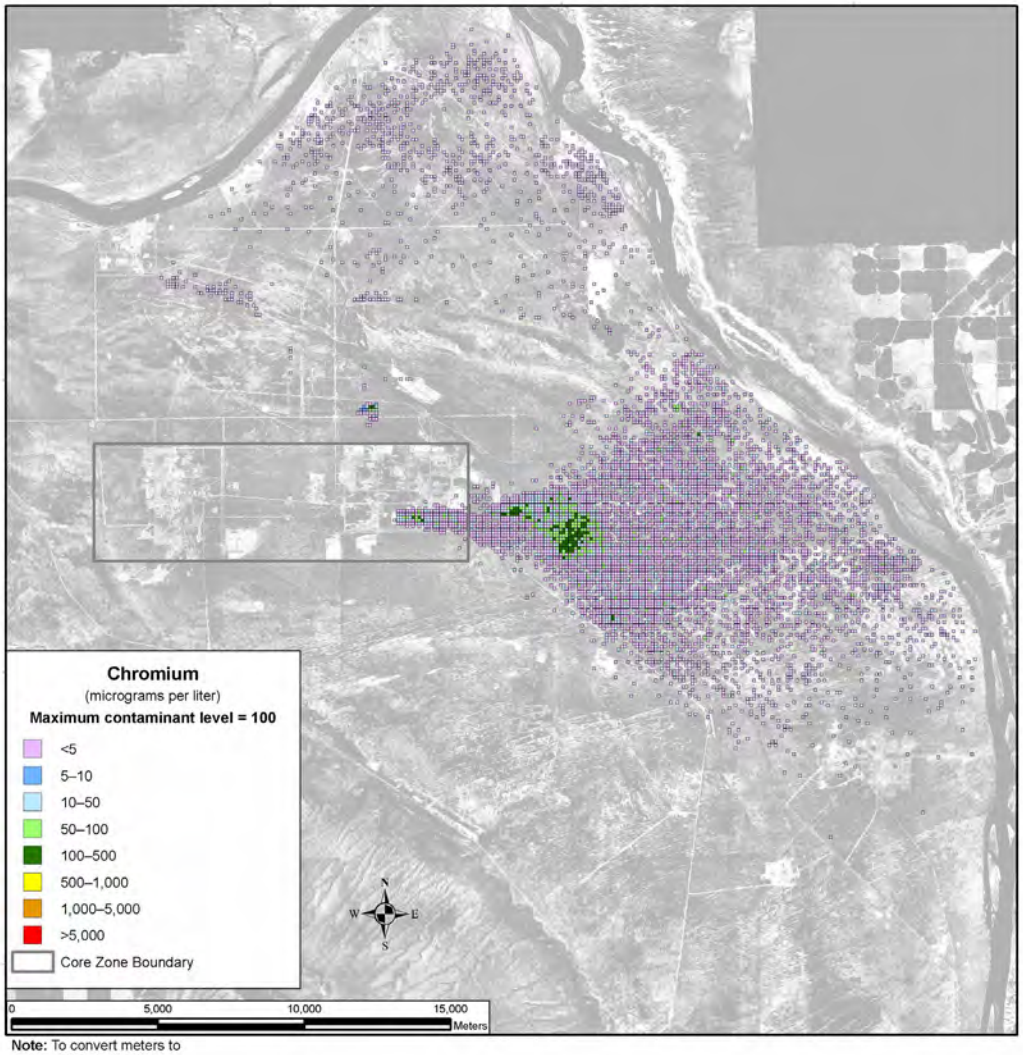
Note: To convert meters to feet, multiply by 3.281

Figure 5–479. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



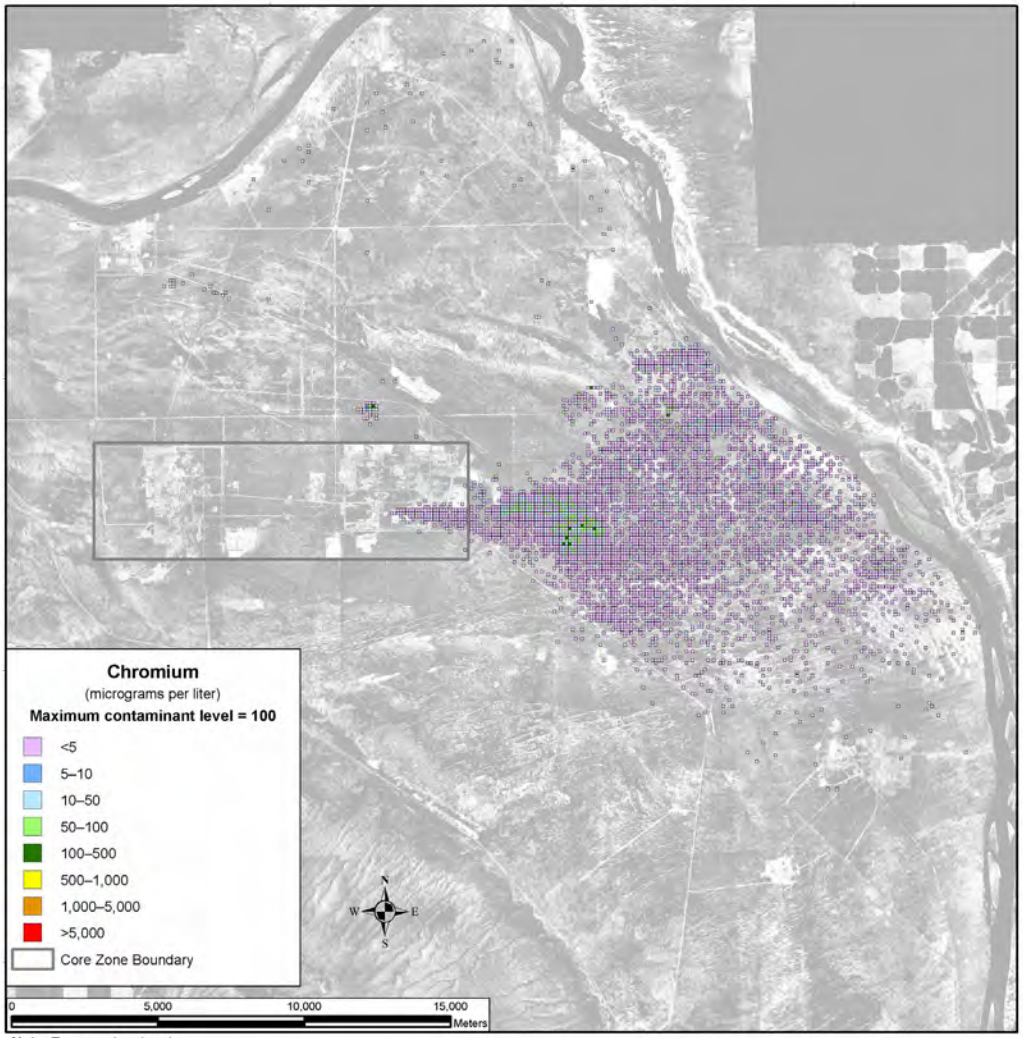
Note: To convert meters to feet, multiply by 3.281

Figure 5–480. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



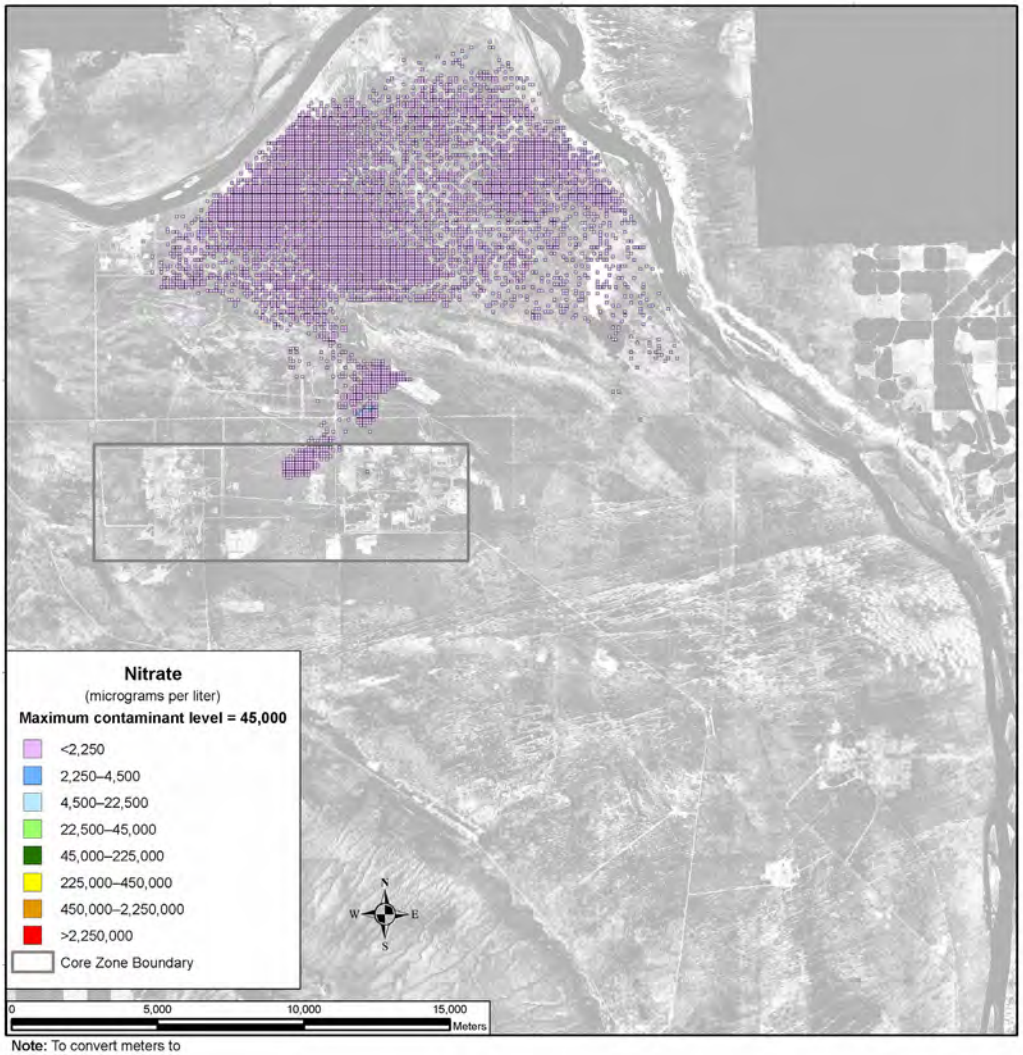
Note: To convert meters to feet, multiply by 3.281

Figure 5–481. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



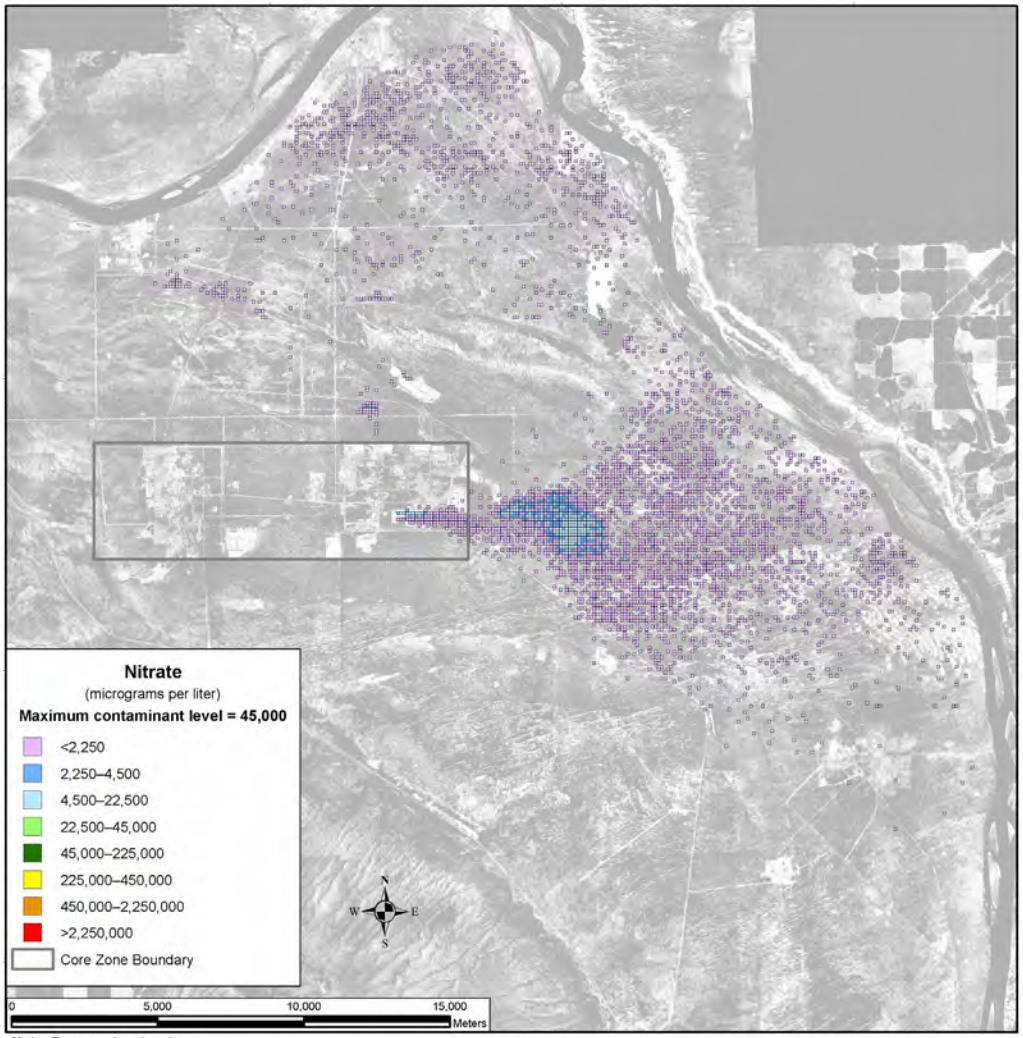
Note: To convert meters to feet, multiply by 3.281

Figure 5–482. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



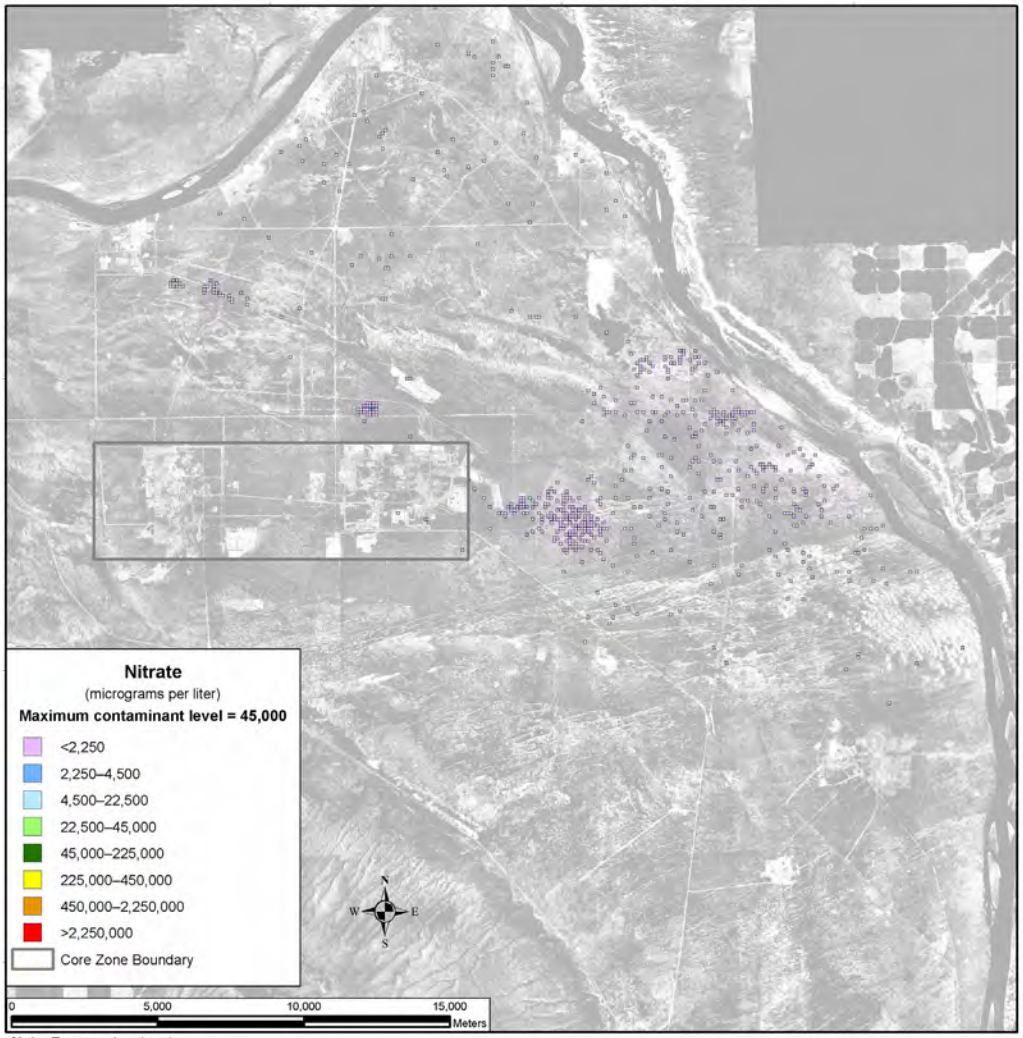
Note: To convert meters to feet, multiply by 3.281

Figure 5–483. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



Note: To convert meters to feet, multiply by 3.281

Figure 5–484. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–485. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

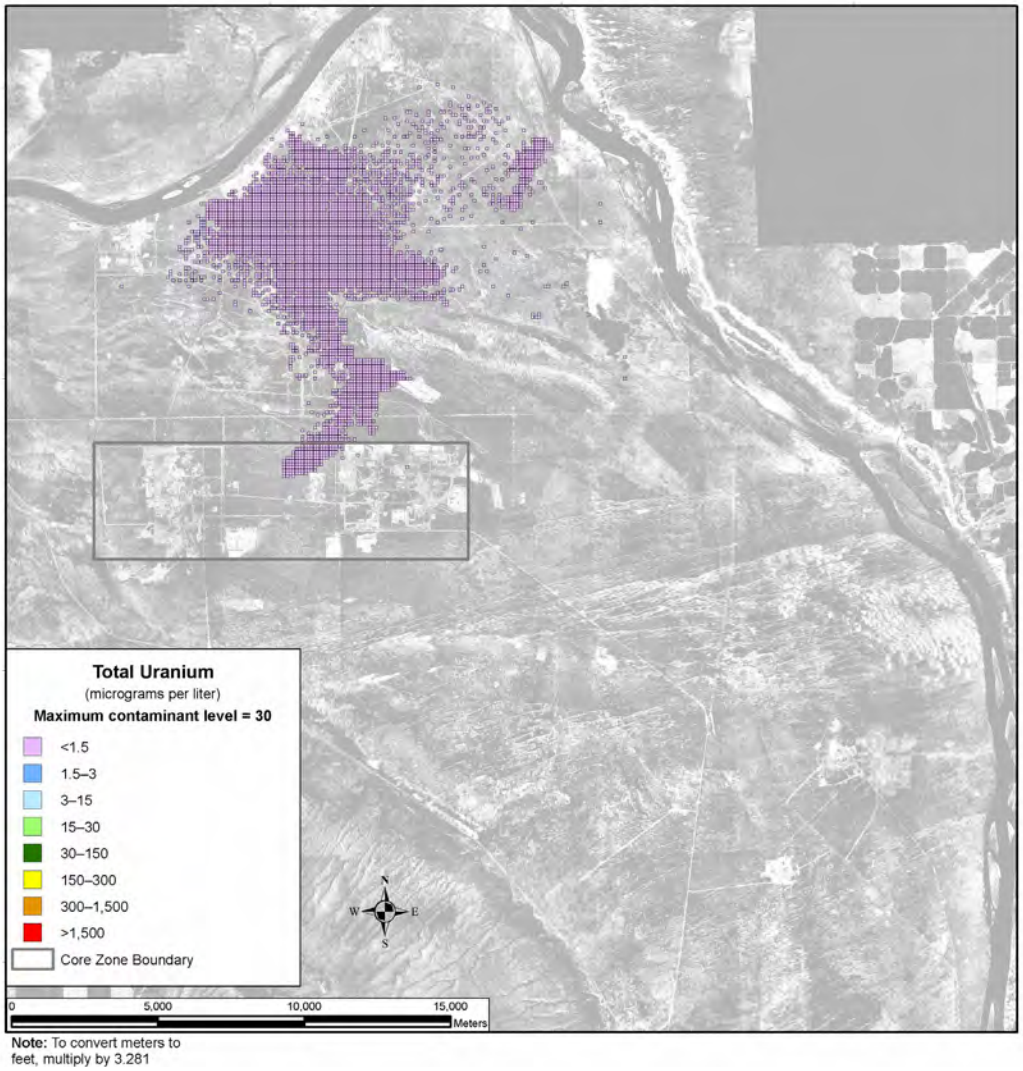


Figure 5–486. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-D, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

For technetium-99, releases cause the groundwater concentrations at the Core Zone Boundary and at the Columbia River nearshore to exceed the benchmark concentration by about one-half of an order of magnitude at around CY 6000. The concentrations at the Core Zone Boundary and at the Columbia River nearshore remain above the benchmark concentration through the end of the period of analysis. Iodine-129 showed a pattern similar to that of technetium-99.

For chromium, the concentrations at the Core Zone Boundary exceed the benchmark from about CY 7000 to 10,000. During the same time period, concentrations from the Columbia River nearshore approach the benchmark, but never reach it. The concentrations at the Core Zone Boundary and the Columbia River nearshore both remain about one-half of an order of magnitude below the benchmark at the end of the period of analysis.

Nitrate concentrations at the Core Zone Boundary and the Columbia River nearshore both peak at around CY 8000. Even at the concentration's peak, nitrate levels still remain about one to one and one-half orders of magnitude below the benchmark level.

It is not until around CY 9900 that total uranium concentrations begin to register on the graph. The concentrations at the Core Zone Boundary and the Columbia River nearshore both remain at about eight to nine orders of magnitude below the benchmark level.

5.3.1.2.1.5 Disposal Group 1, Subgroup 1-E

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-E covers disposal of waste generated under Tank Closure Alternative 4 and either FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW, ILAW glass, bulk vitrification glass, and cast stone waste. IHLW would be stored on site, while ILAW glass, bulk vitrification glass, and cast stone waste would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when the facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment, and modified RCRA Subtitle C barriers would be emplaced over IDF-East and the RPPDF to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, nitrate, and acetonitrile

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, nitrate, acetonitrile) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The

other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E (IDF-East and the RPPDF releases), in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–487 through 5–498). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility

IDF-East has nine subtotals plotted representing releases from ILAW glass, bulk vitrification glass, cast stone waste, ETF-generated secondary waste, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary waste, and onsite- and offsite-generated waste.

Figure 5–487 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–488, the chemical hazard drivers. For all nine types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The predominant source of technetium-99 is cast stone waste and of iodine-129 is offsite-generated waste. For chemicals, the predominant source of chromium, nitrate, and acetonitrile is cast stone waste. The predominant sources of fluoride and boron are waste management secondary waste and onsite-generated waste.

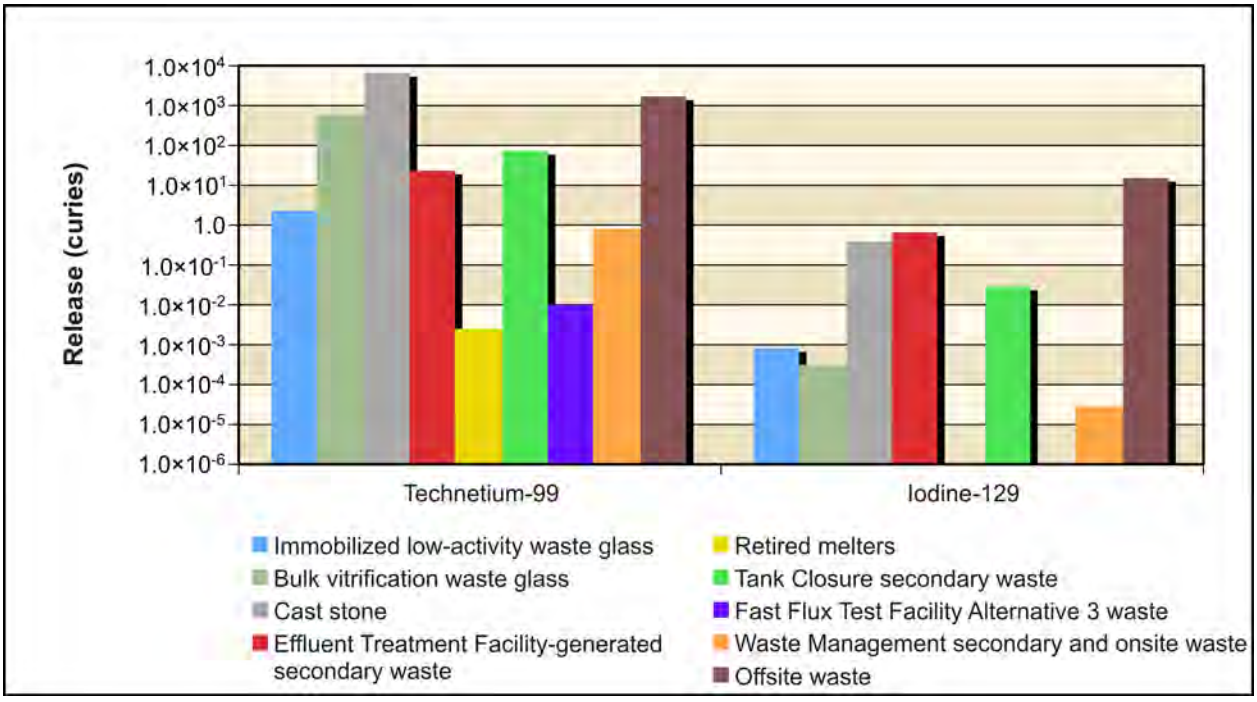


Figure 5–487. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at 200-East Area Integrated Disposal Facility to Vadose Zone

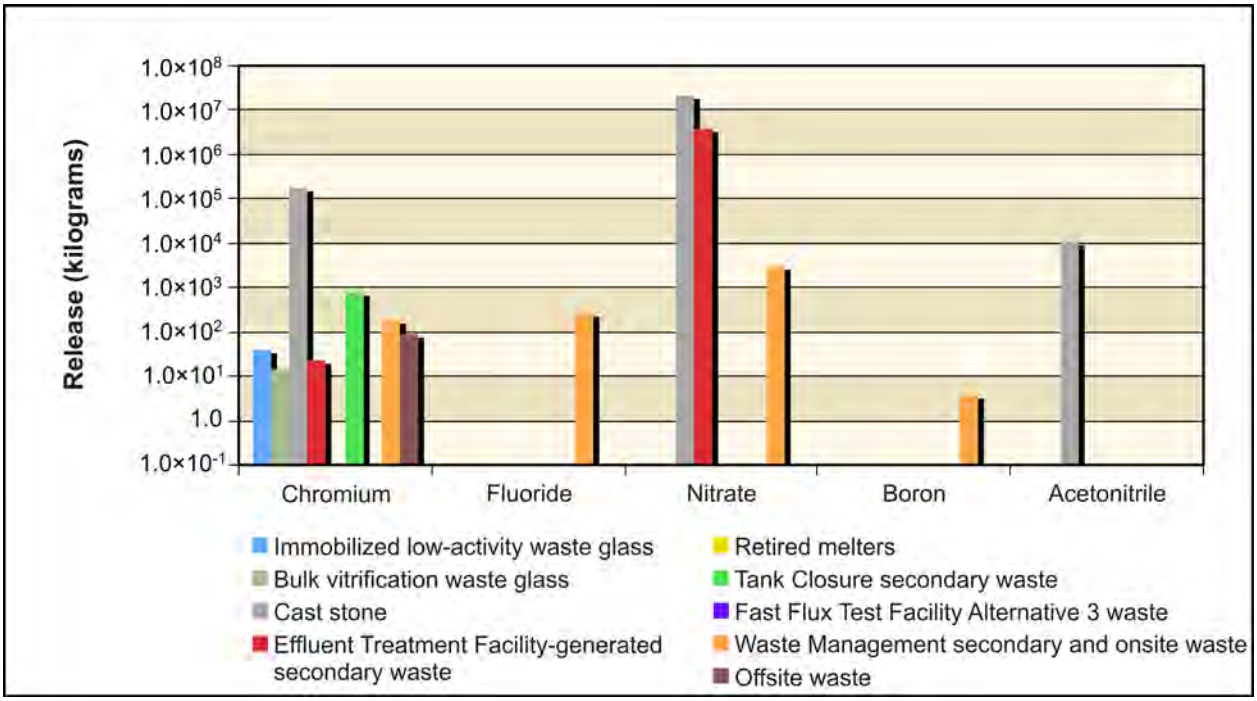


Figure 5–488. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at 200-East Area Integrated Disposal Facility to Vadose Zone

Figure 5–489 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–490, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, nitrate, fluoride, boron, and acetonitrile, the amount released to groundwater is essentially equal to the amount released to the vadose zone. This means that there is less than one order of magnitude difference. Overall, about 53 percent of the radionuclide amount (curies) released to the vadose zone during the period of analysis reached the groundwater; approximately 99 percent of the chemical quantity (kilograms) reached the groundwater.

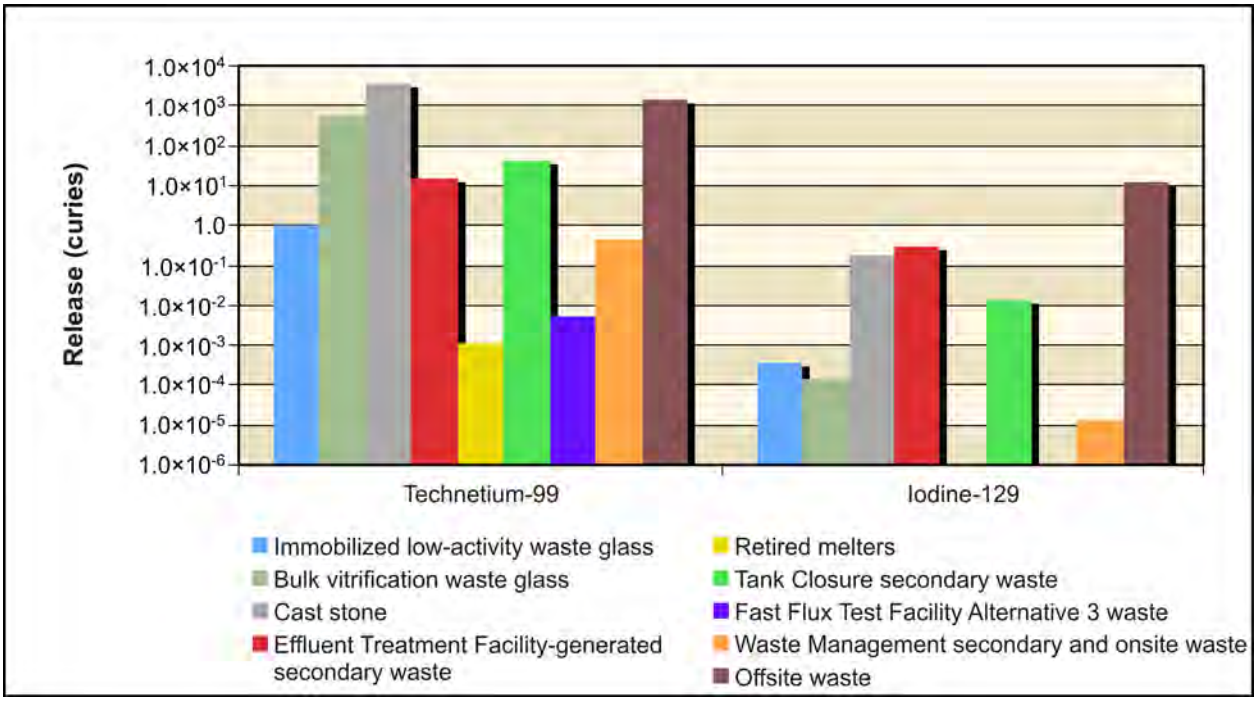


Figure 5–489. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at 200-East Area Integrated Disposal Facility to Groundwater

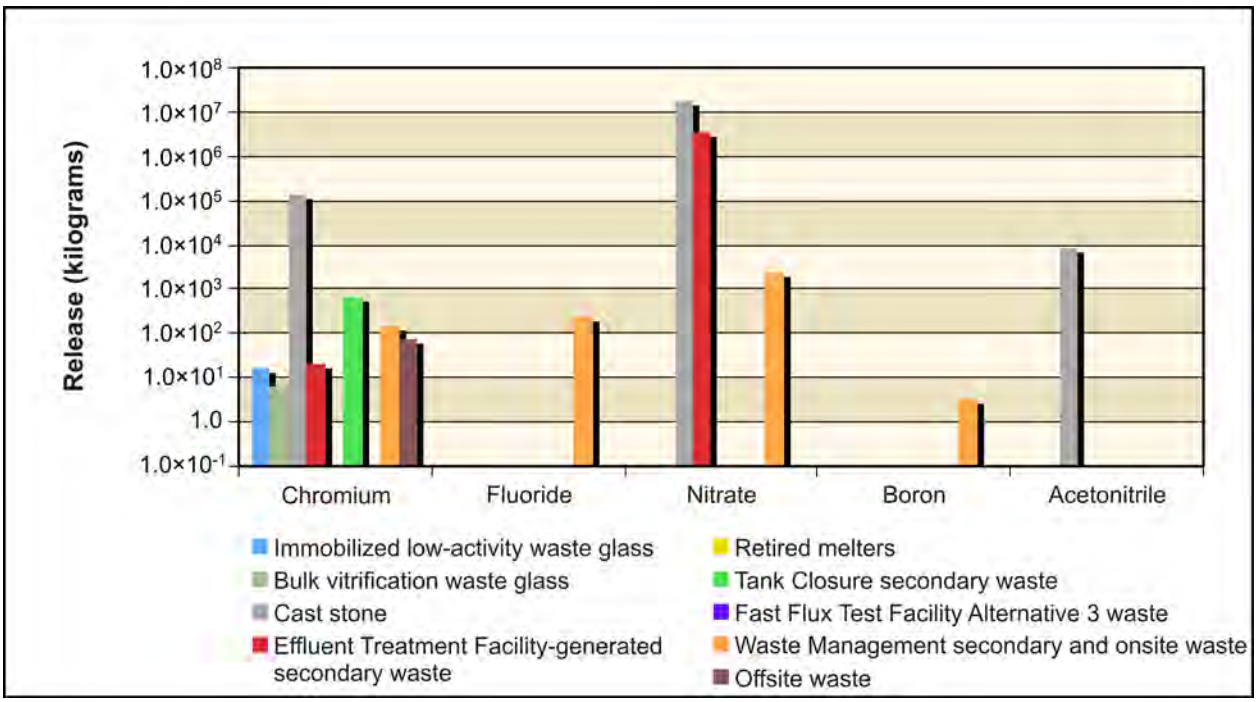


Figure 5–490. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at 200-East Area Integrated Disposal Facility to Groundwater

Figure 5–491 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–492, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For iodine-129, technetium-99, chromium, nitrate, fluoride, boron, and acetonitrile, the amount released to the Columbia River is essentially equal to the amount released to groundwater. Overall, about 75 percent of the radionuclide amount (curies) released to the groundwater during the period of analysis reached the river; approximately 98 percent of the chemical quantity (kilograms) reached the river.

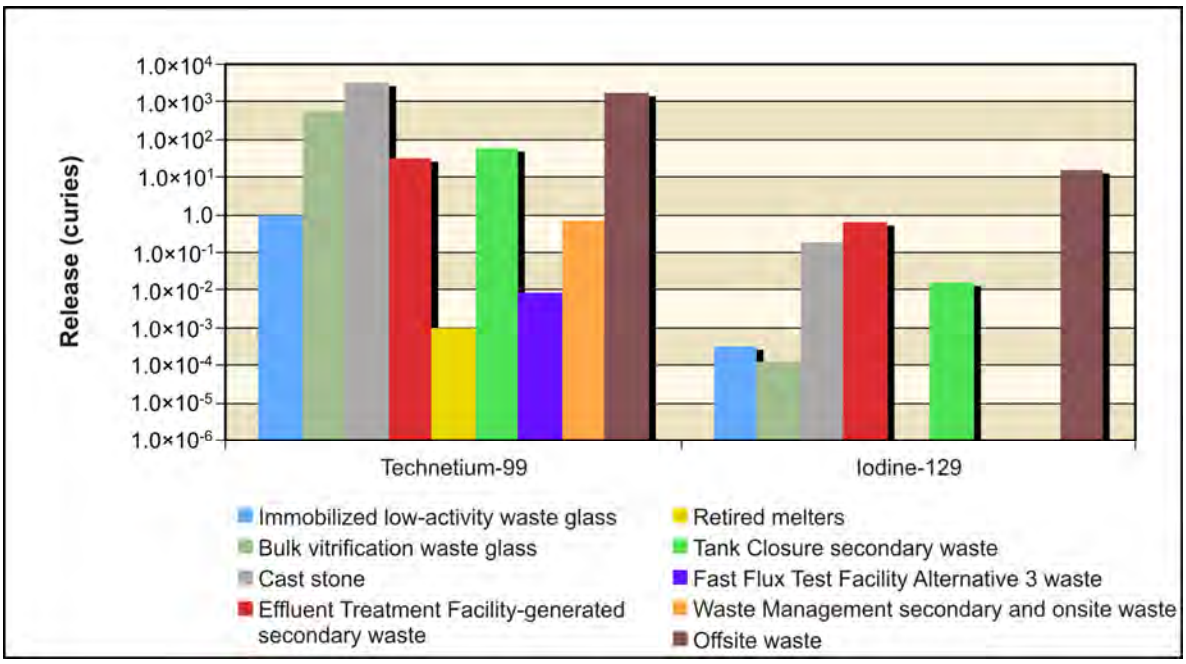


Figure 5–491. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at 200-East Area Integrated Disposal Facility to Columbia River

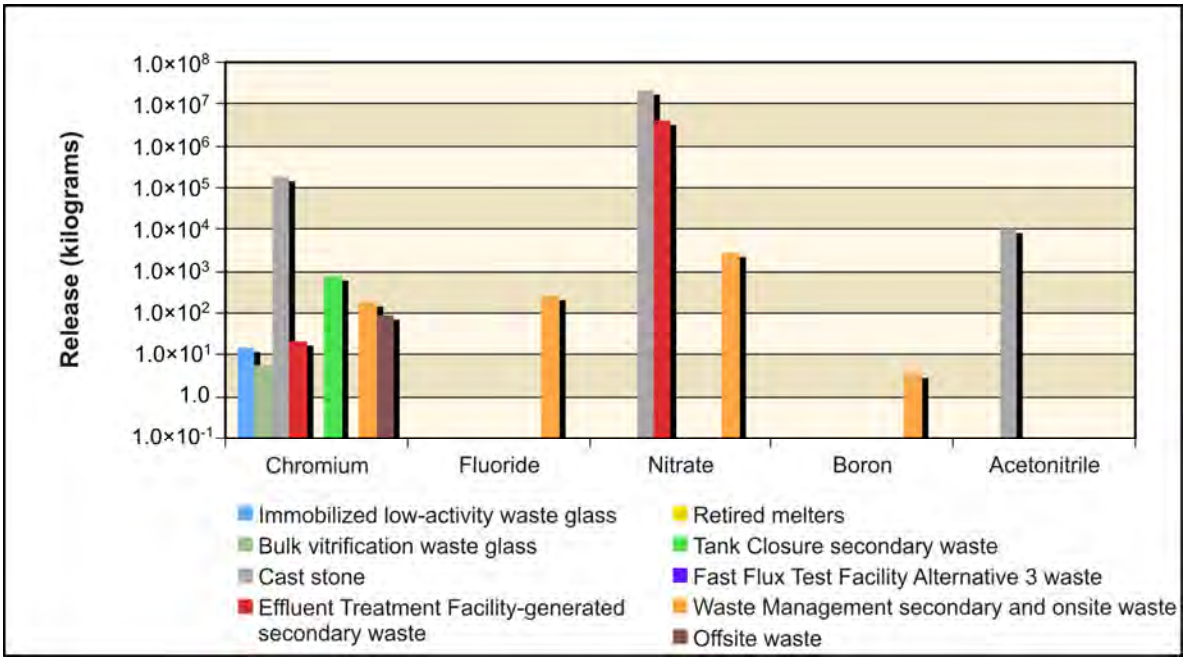


Figure 5–492. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at 200-East Area Integrated Disposal Facility to Columbia River

River Protection Project Disposal Facility

Figure 5–493 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–494, the chemical hazard drivers. Release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The vadose zone radiological sources from the RPPDF are technetium-99 (largest) and iodine-129 (smallest). The chemical hazard sources from the RPPDF are nitrate (largest) and chromium (smallest). Fluoride, boron, and acetonitrile are not released from the RPPDF.

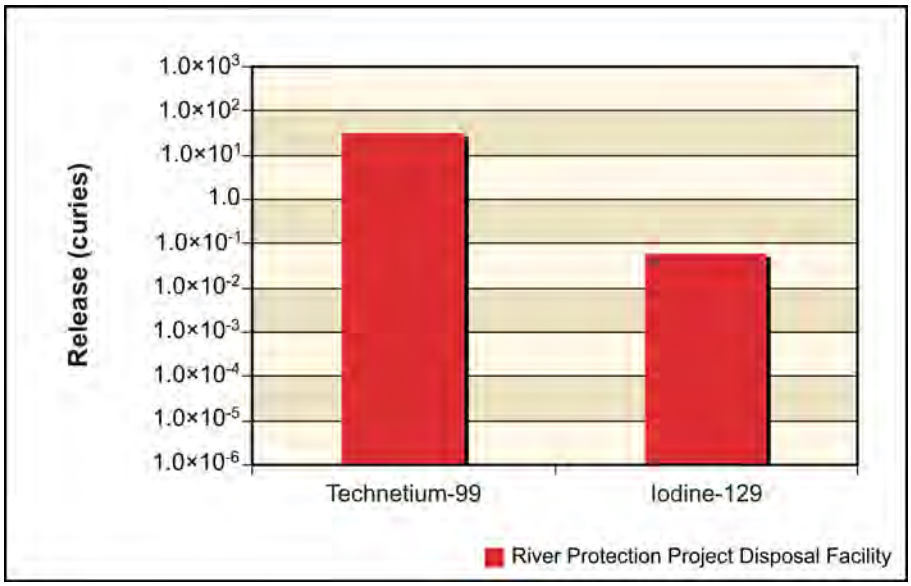


Figure 5–493. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at River Protection Project Disposal Facility to Vadose Zone

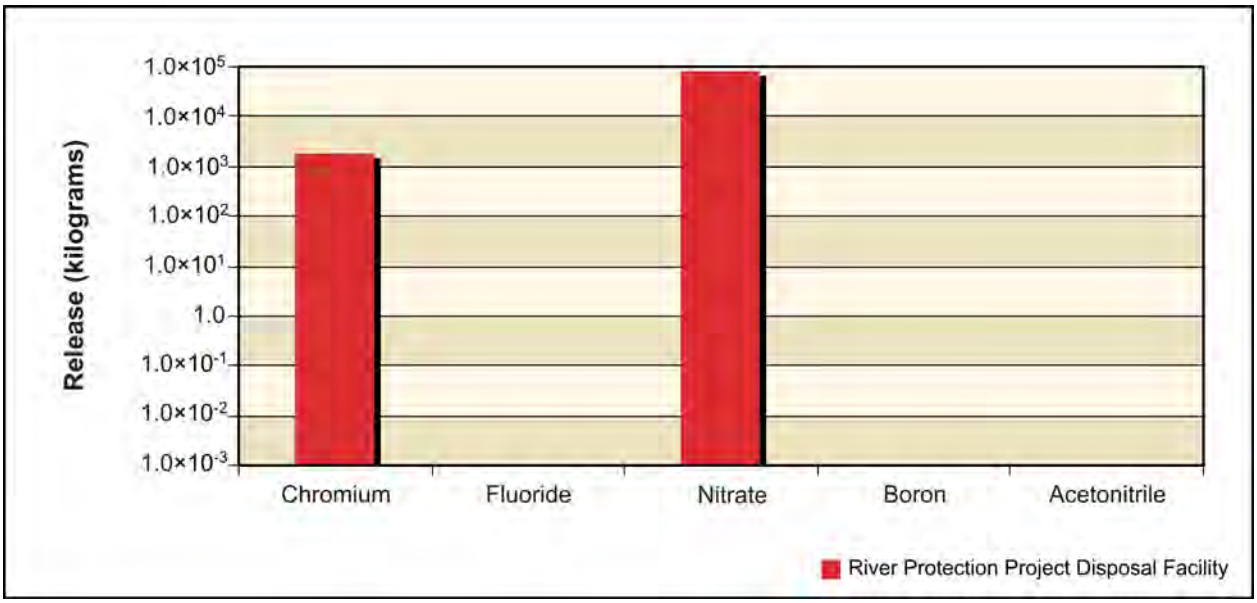


Figure 5–494. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at River Protection Project Disposal Facility to Vadose Zone

Figure 5–495 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–496, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. Overall, about 100 percent of the radionuclide amount (curies) released to the vadose zone during the period of analysis reached the groundwater; approximately 100 percent of the chemical quantity (kilograms) reached the groundwater.

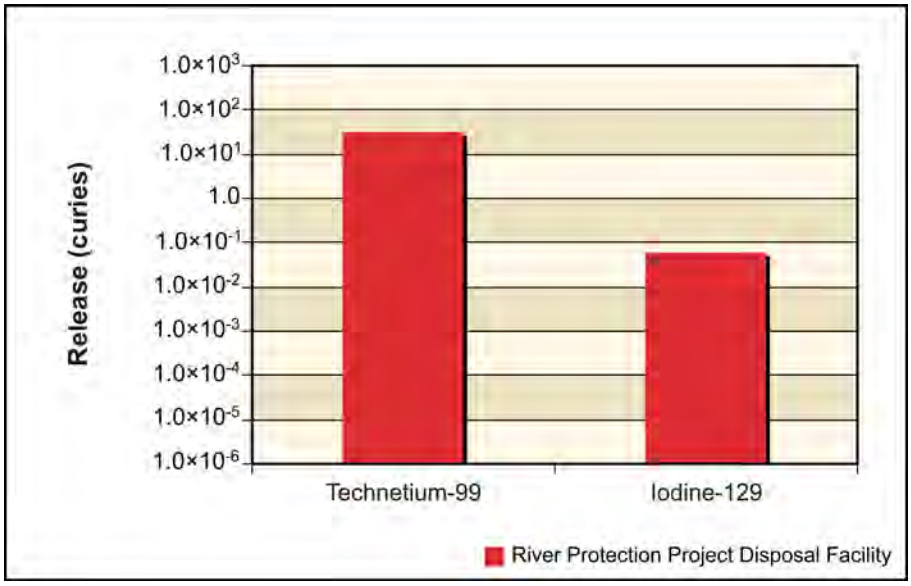


Figure 5–495. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at River Protection Project Disposal Facility to Groundwater

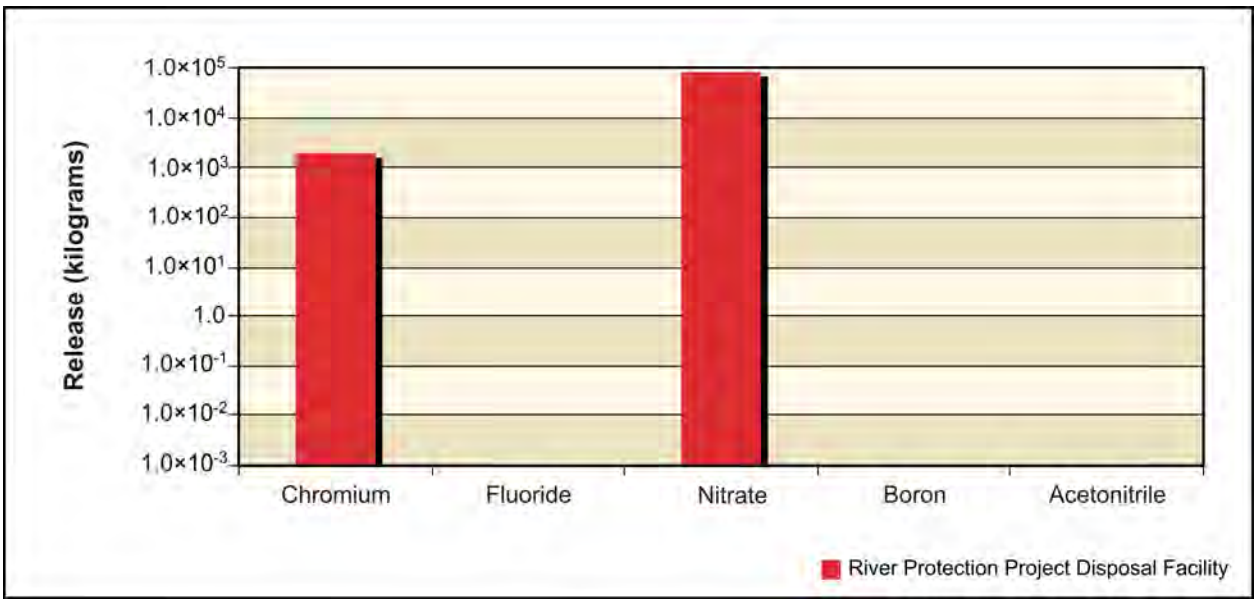


Figure 5–496. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at River Protection Project Disposal Facility to Groundwater

Figure 5–497 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–498, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For iodine-129, technetium-99, chromium, and nitrate, the amount released to the Columbia River is essentially equal to the amount released to groundwater. Overall, 96 percent of the radionuclide amount (curies) released to the groundwater during the period of analysis reached the river; 96 percent of the chemical quantity (kilograms) reached the river.

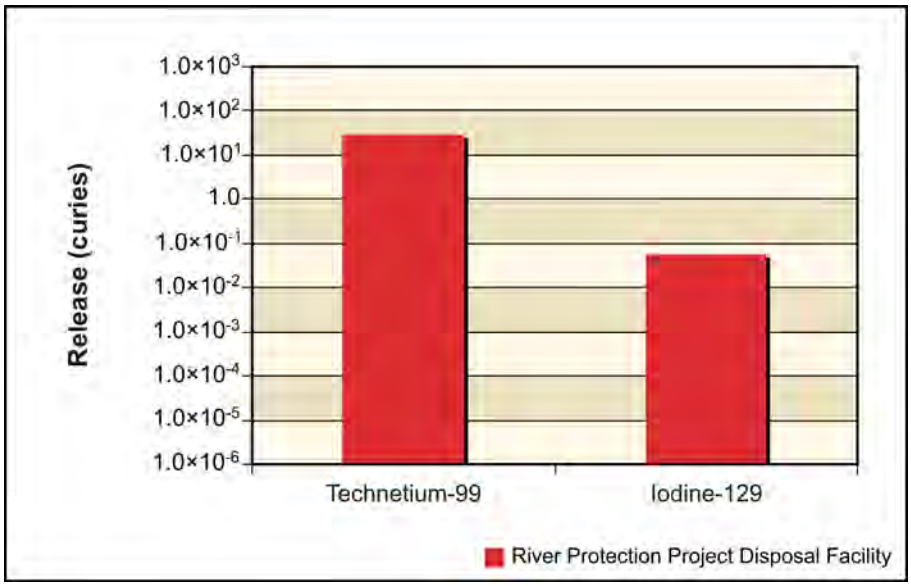


Figure 5–497. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Radiological Release at River Protection Project Disposal Facility to Columbia River

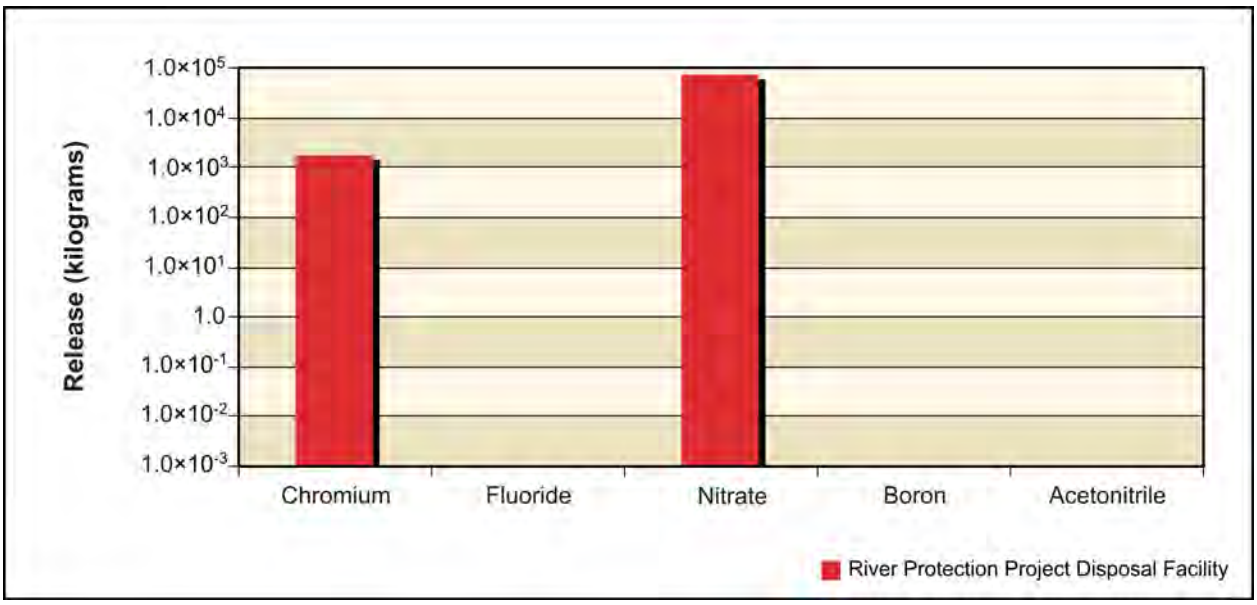


Figure 5–498. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chemical Release at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter (see Figures 5–499 though 5–503). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Table 5–81 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–499 through 5–502 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate. Releases from IDF-East and the RPPDF cause technetium-99 and iodine-129 groundwater concentrations to exceed benchmark concentrations by less than one order of magnitude during the later part of the period of analysis. Nitrate and chromium do not exceed benchmark concentrations. During this time, technetium-99 and iodine-129 groundwater concentrations at the Columbia River nearshore exceed the benchmark concentrations. Releases from IDF-East and the RPPDF cause groundwater concentrations to exceed benchmark concentrations by less than one order of magnitude during the middle and later parts of the period of analysis.

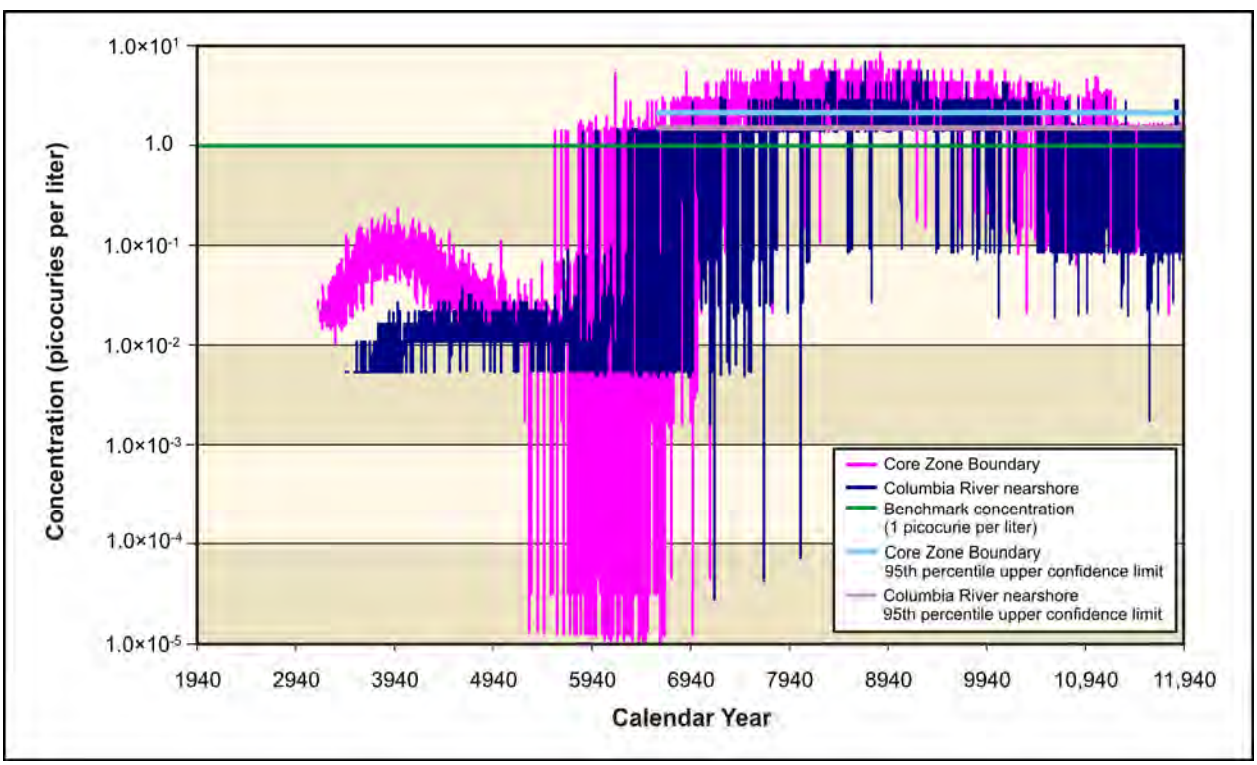


Figure 5–499. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Iodine-129 Concentration Versus Time

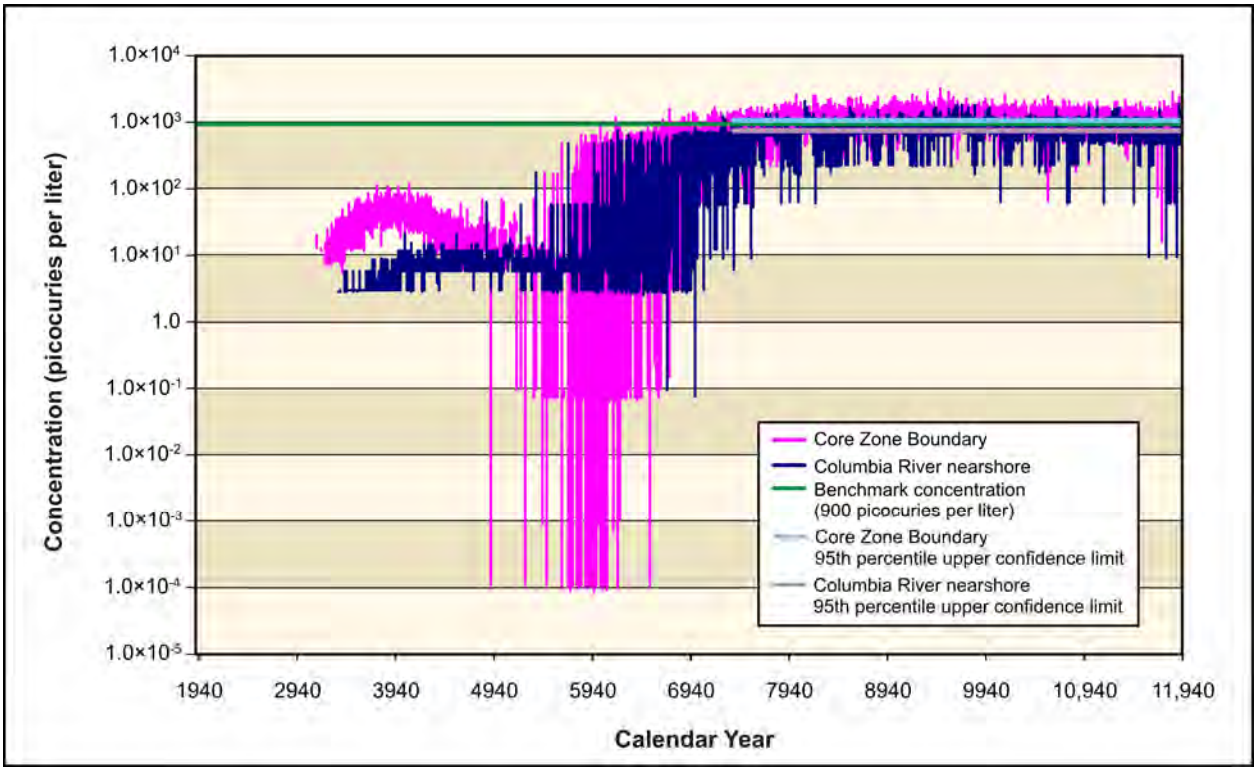


Figure 5–500. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Technetium-99 Concentration Versus Time

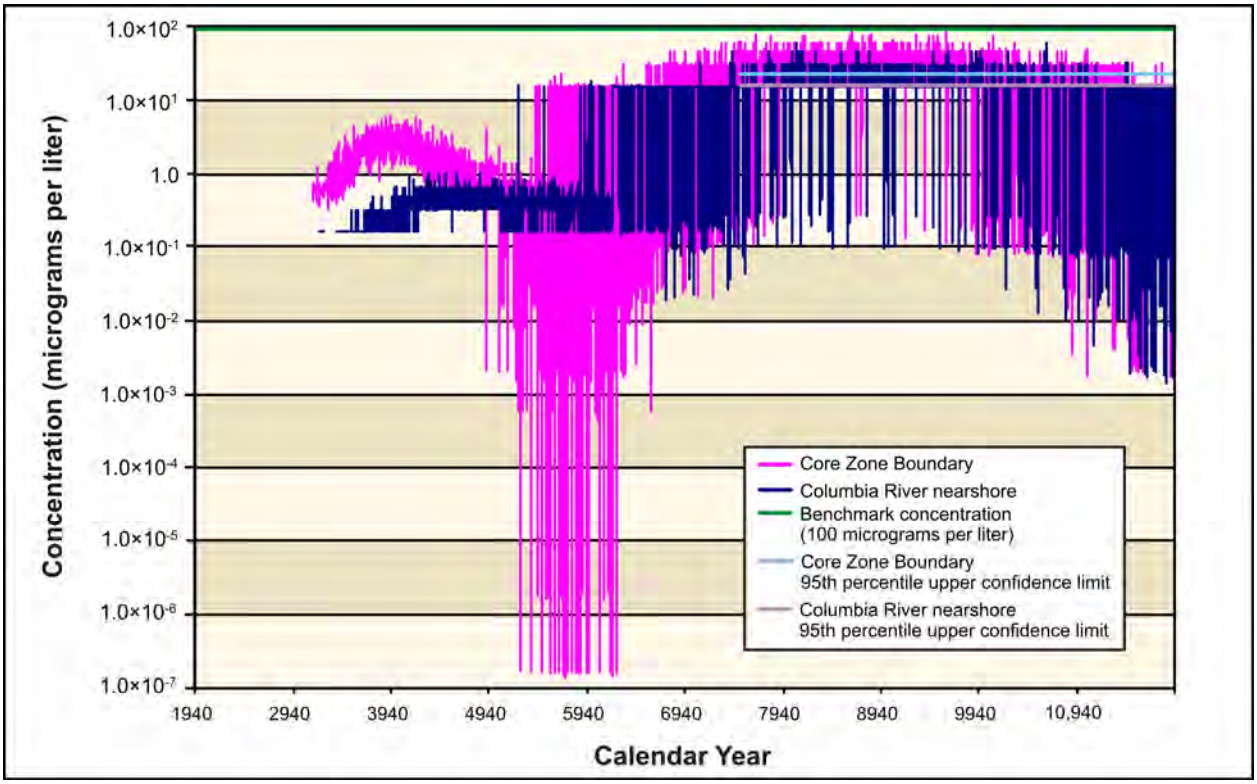


Figure 5–501. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Chromium Concentration Versus Time

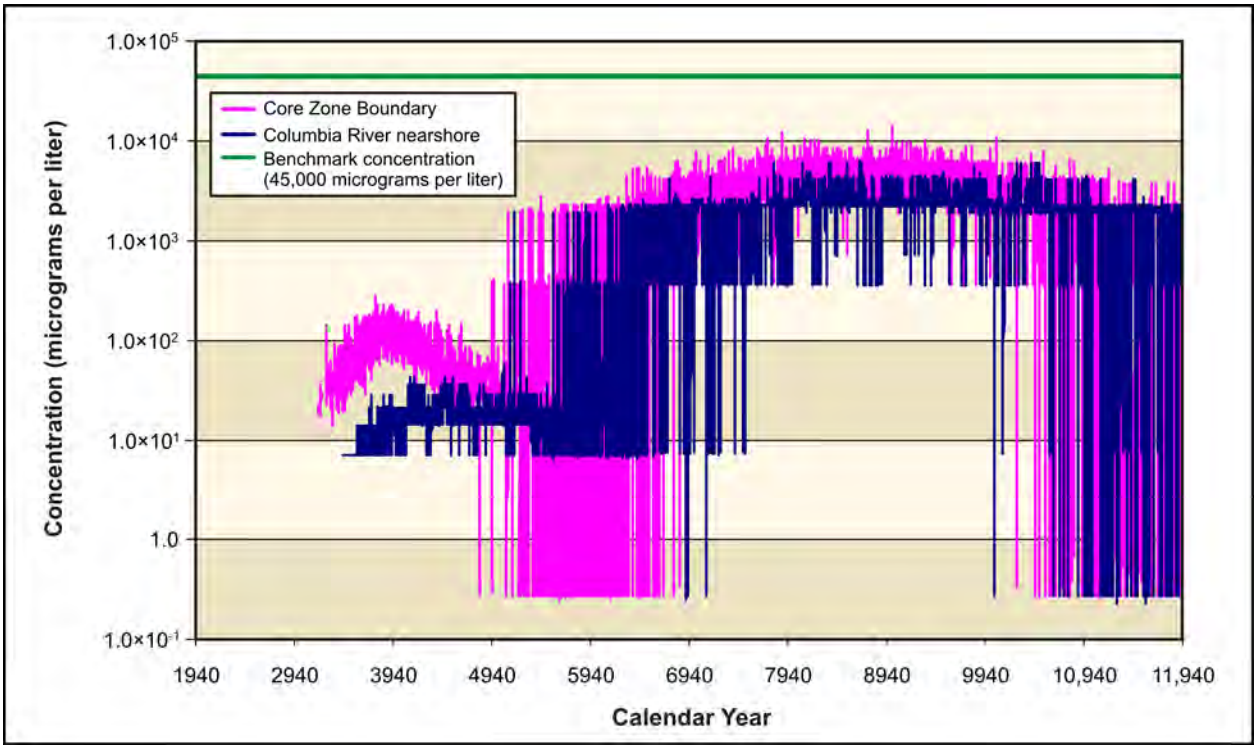


Figure 5–502. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Nitrate Concentration Versus Time

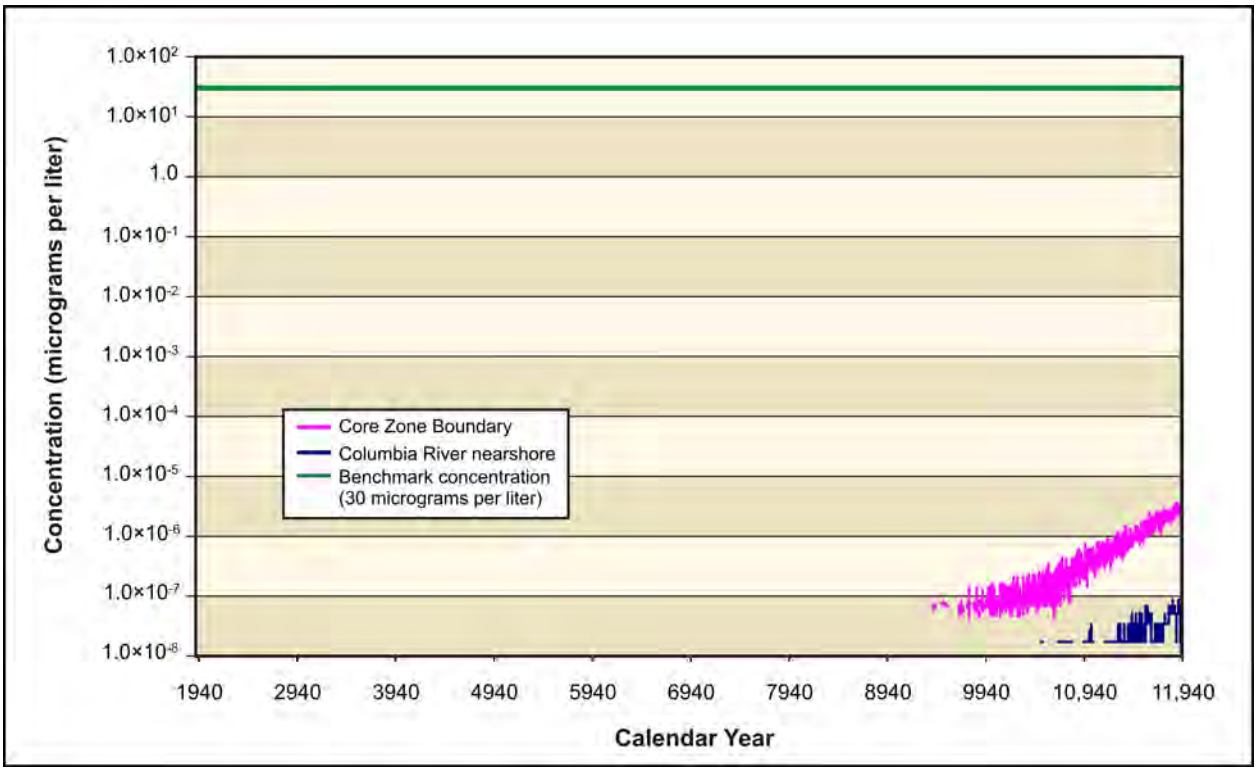


Figure 5–503. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Total Uranium Concentration Versus Time

Figure 5–503 shows concentration versus time for total uranium. Late releases from IDF-East and the RPPDF result in groundwater concentrations that are seven orders of magnitude lower than benchmark concentrations for total uranium. Total uranium concentrations, while very minimal, continue to rise throughout the duration of the period of analysis, but never exceed the benchmark concentrations by the end of the period of analysis.

Table 5–81. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**6,490**	103	**3,090**	**2,030**	900
	(9035)	(3822)	(9499)	(8117)	
Iodine-129	**18**	0.2	**8**	**7**	1
	(8491)	(3940)	(8858)	(8699)	
Chemical in micrograms per liter					
Acetonitrile	16	0	5	4	100
	(7959)	(1940)	(7381)	(6849)	
Chromium	**224**	6	96	64	100
	(9069)	(3804)	(8643)	(8079)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	29,000	229	13,900	6,380	45,000
	(9330)	(4042)	(8994)	(8673)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

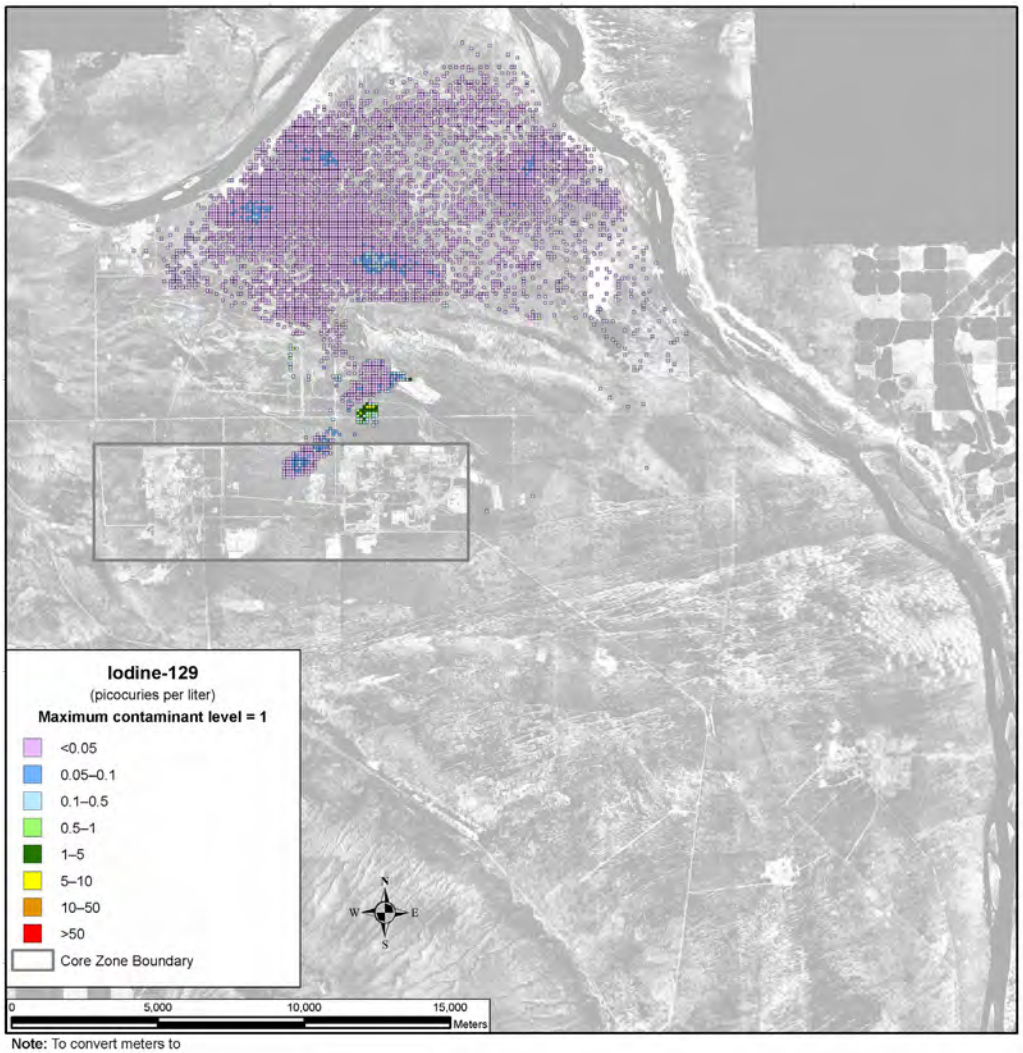
ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–504 through 5–516). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

Figure 5–504 shows the spatial distribution of groundwater concentration for iodine-129 during CY 3890. Releases from the RPPDF result in groundwater concentration plumes that exceed the benchmark concentration north of the Core Zone Boundary. Peak concentrations in this plume are only slightly greater than the benchmark concentration and only in a very small area north of the Core Zone Boundary. During year 7140, releases from IDF-East create a plume exceeding the benchmark, extending from the 200-East Area moving eastward toward the Columbia River (see Figure 5–505). Also by CY 7140, most of the RPPDF plume continues to move north and reaches the Columbia River. By CY 11,885, most of the mass in the IDF-East plume is still moving eastward toward the Columbia River, with only small, isolated pockets of high concentration exceeding the benchmark (see Figure 5–506). Technetium-99 (see Figures 5–507 through 5–509), chromium (see Figures 5–510 through 5–512), and nitrate

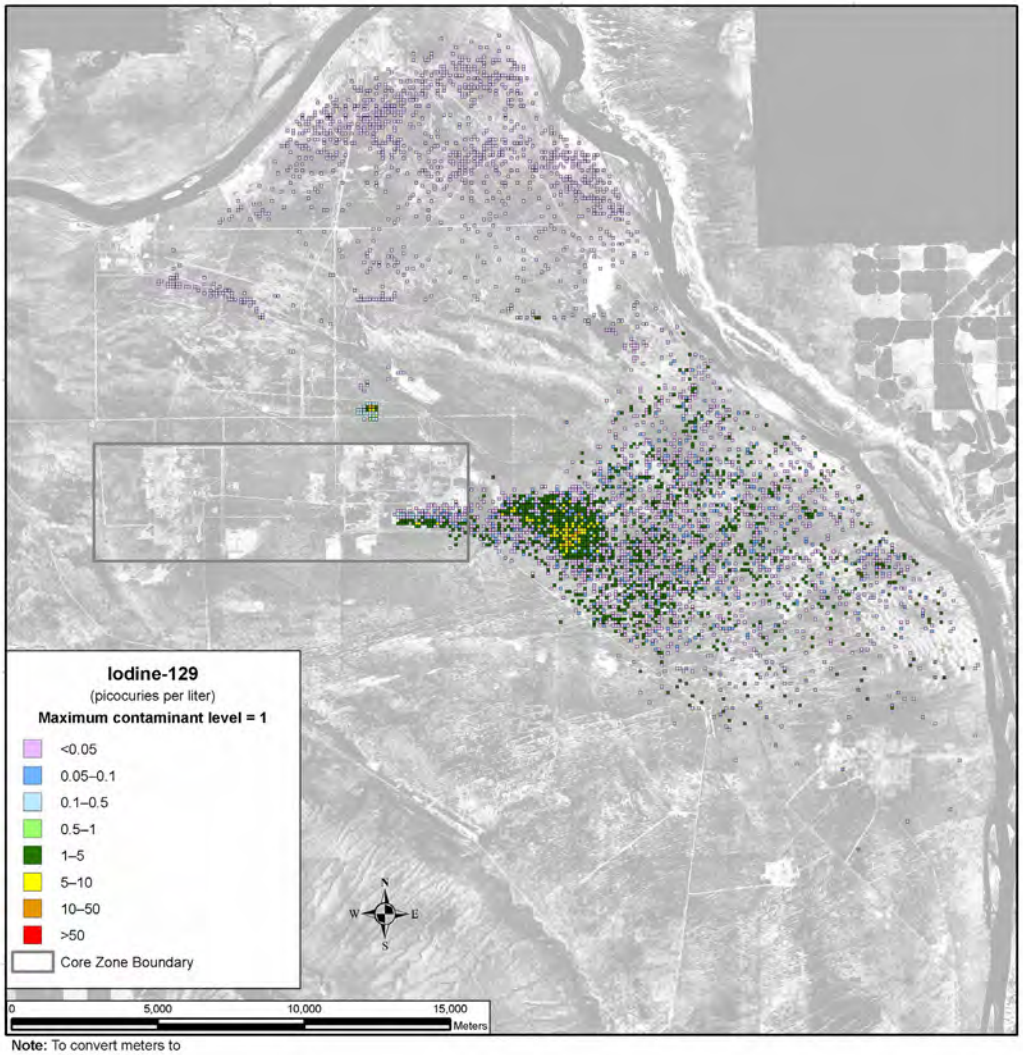
(see Figures 5–513 through 5–515) show similar spatial distributions at selected times. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

Total uranium shows a different spatial distribution over time. This COPC is not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–516 shows the distribution of total uranium during CY 11,885. Releases from the RPPDF result in a groundwater plume that starts in the Core Zone and moves north through Gable Mountain. However, this plume does not exceed the benchmark concentration during the period of analysis.



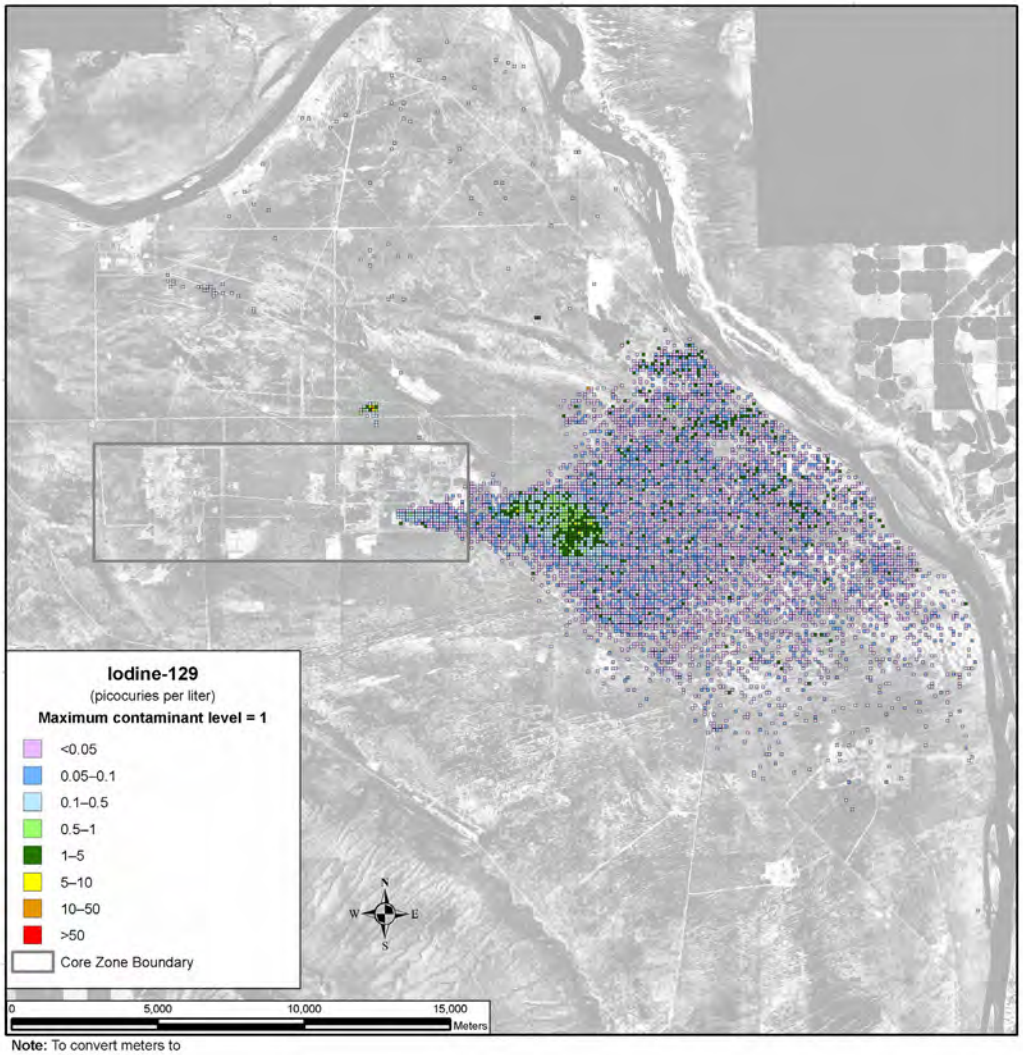
Note: To convert meters to feet, multiply by 3.281

Figure 5–504. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



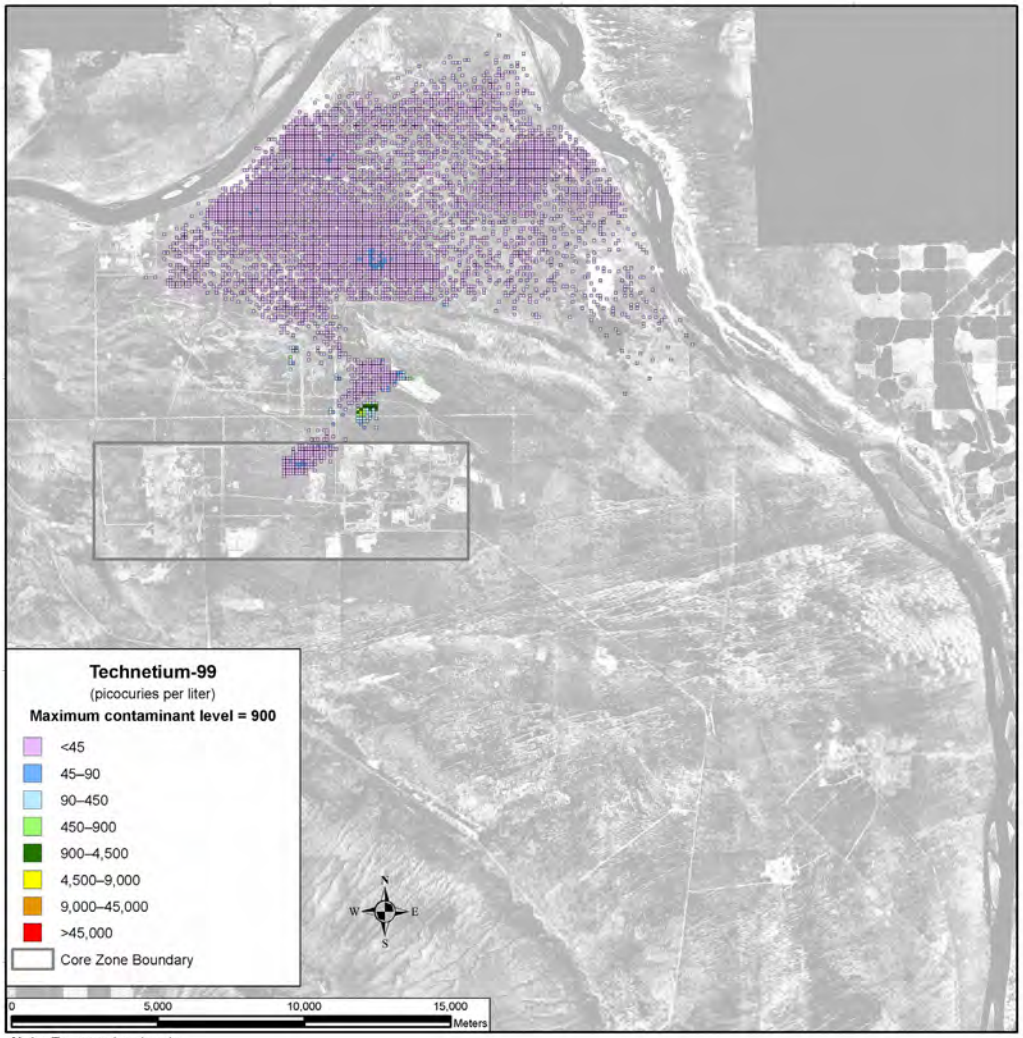
Note: To convert meters to feet, multiply by 3.281

Figure 5–505. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



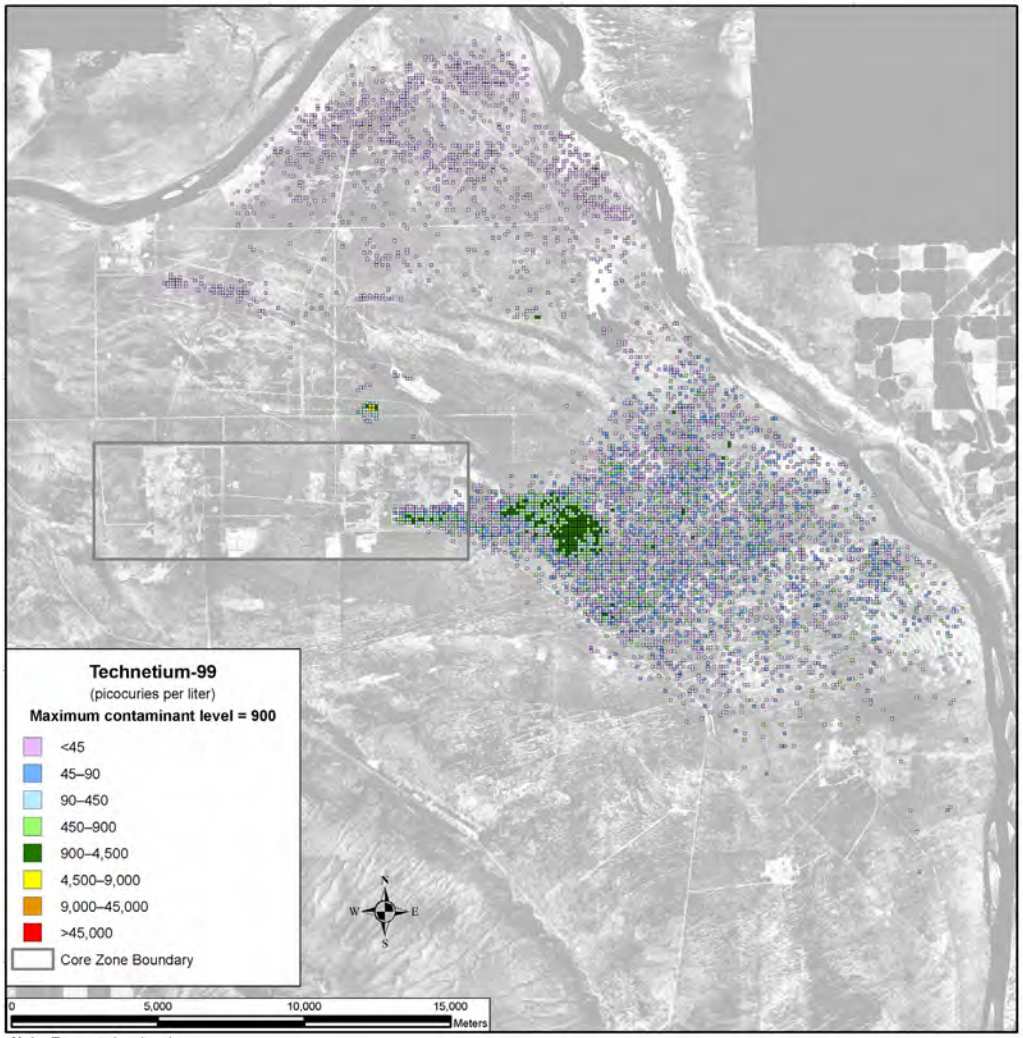
Note: To convert meters to feet, multiply by 3.281

Figure 5–506. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



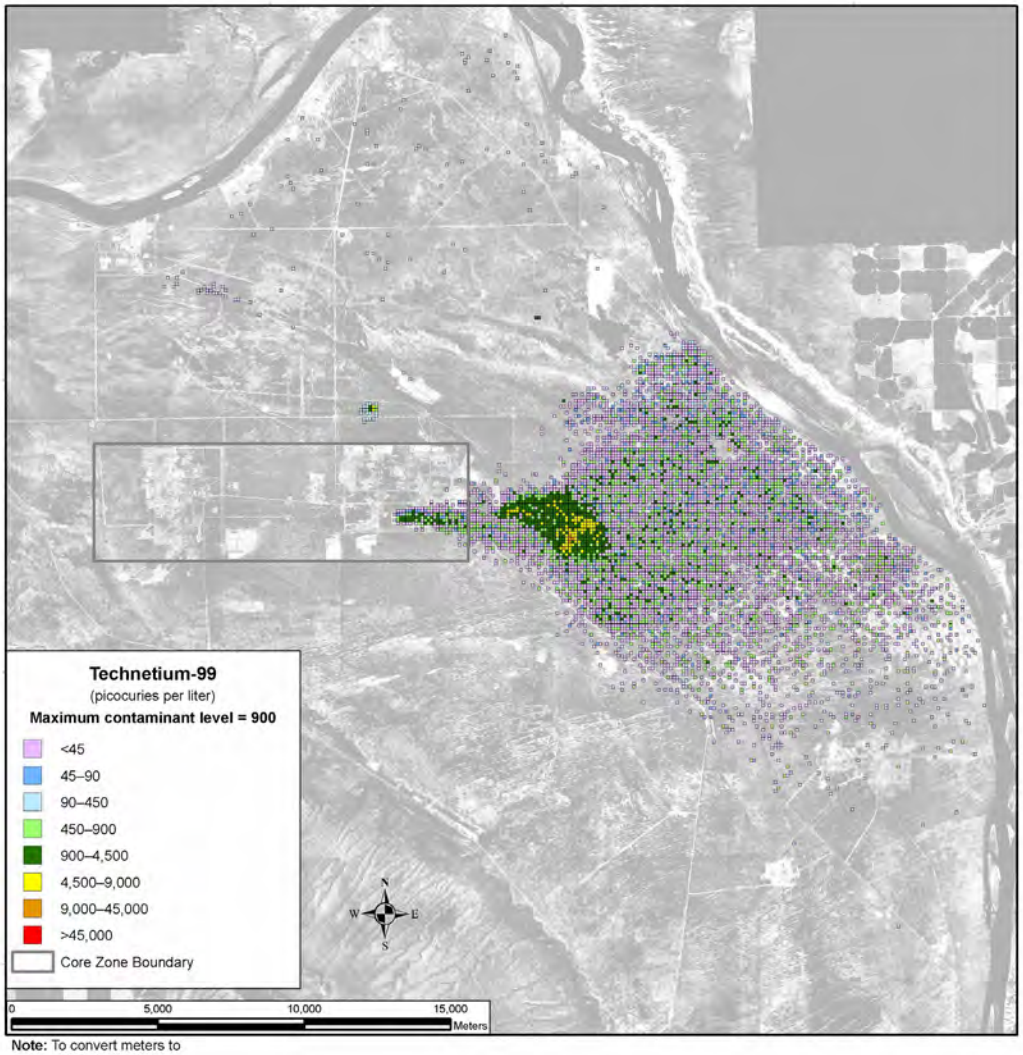
Note: To convert meters to feet, multiply by 3.281

Figure 5–507. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



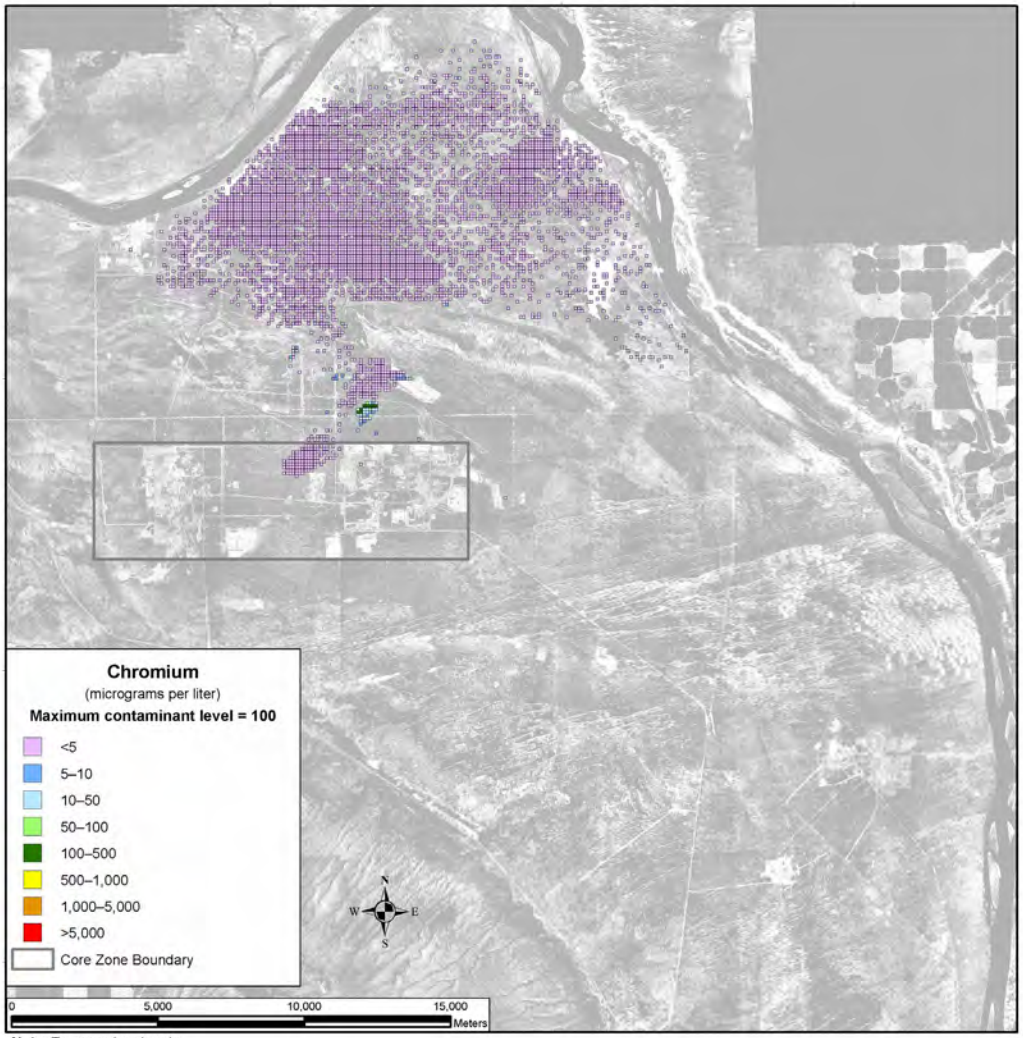
Note: To convert meters to feet, multiply by 3.281

Figure 5–508. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



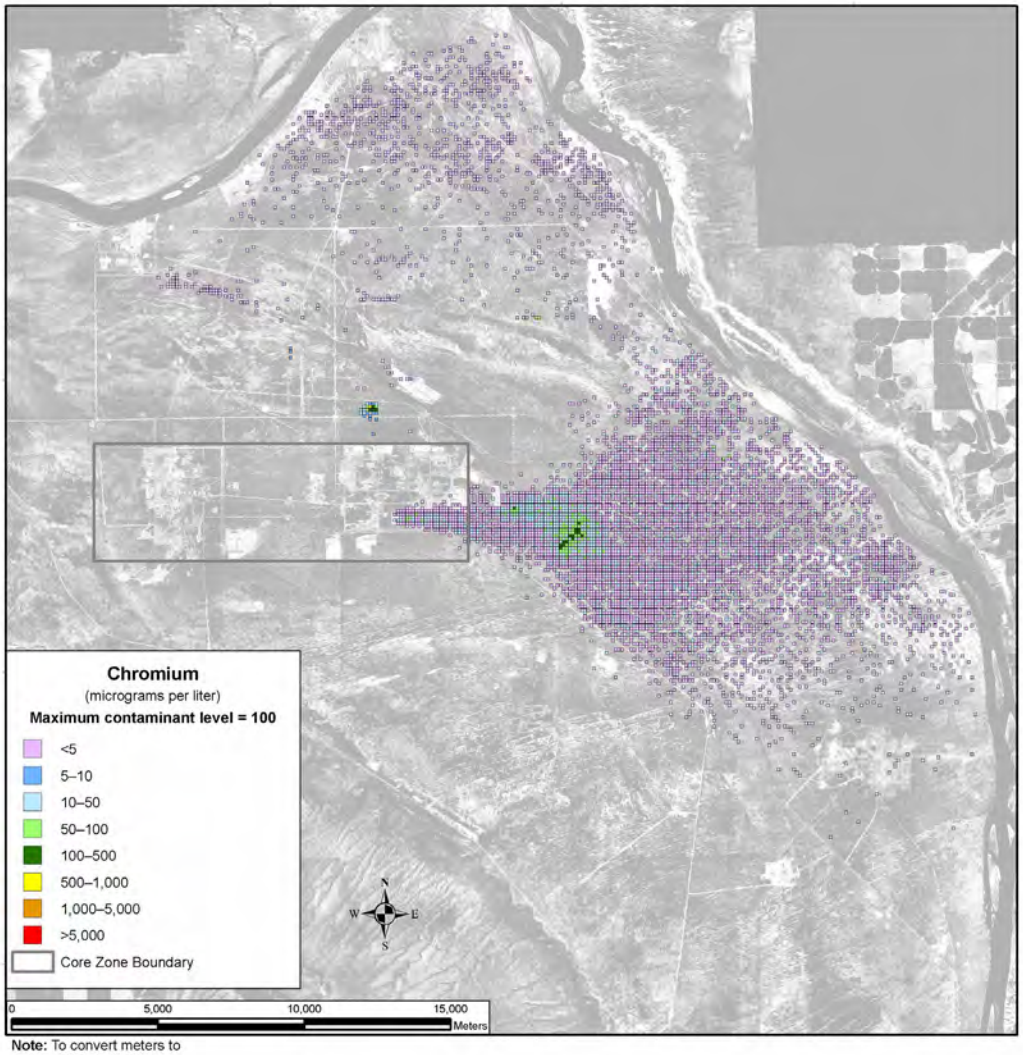
Note: To convert meters to feet, multiply by 3.281

Figure 5–509. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



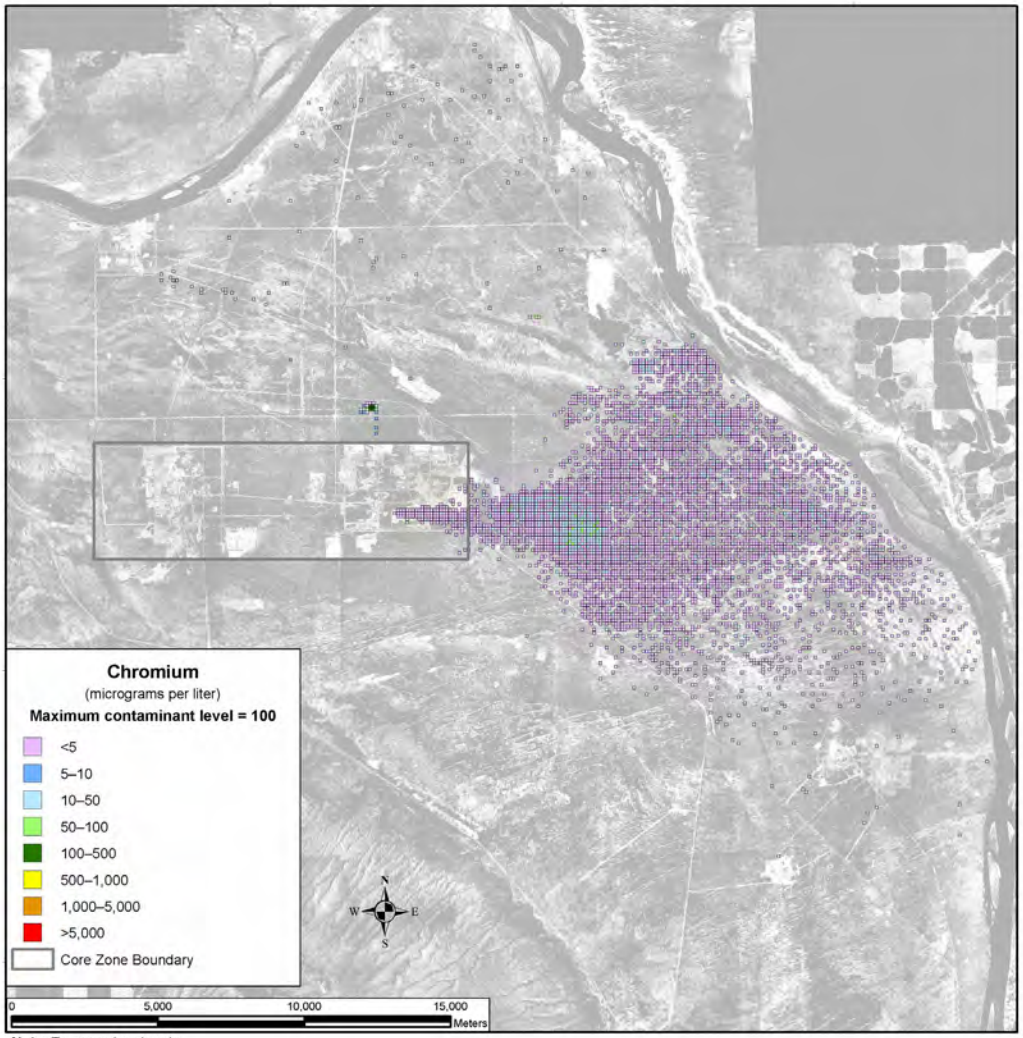
Note: To convert meters to feet, multiply by 3.281

Figure 5–510. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



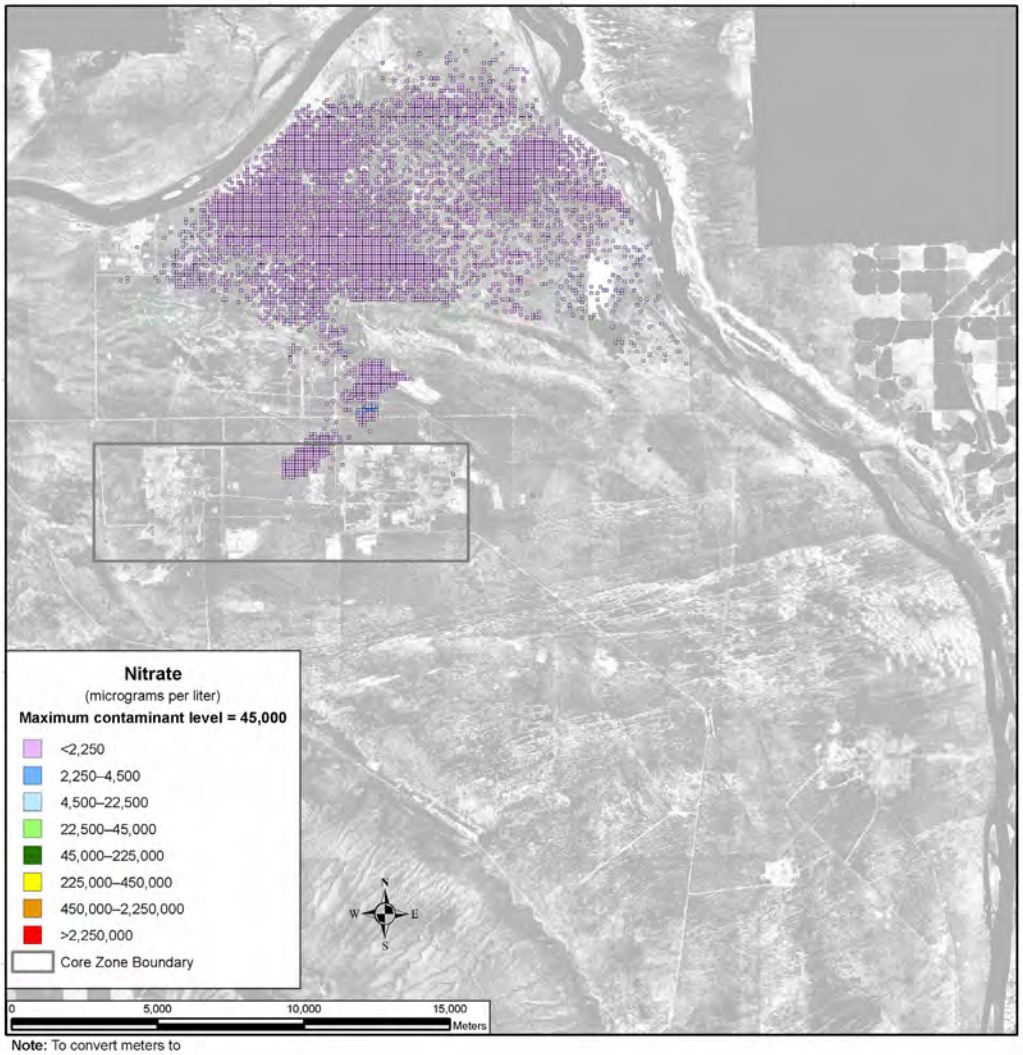
Note: To convert meters to feet, multiply by 3.281

Figure 5–511. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



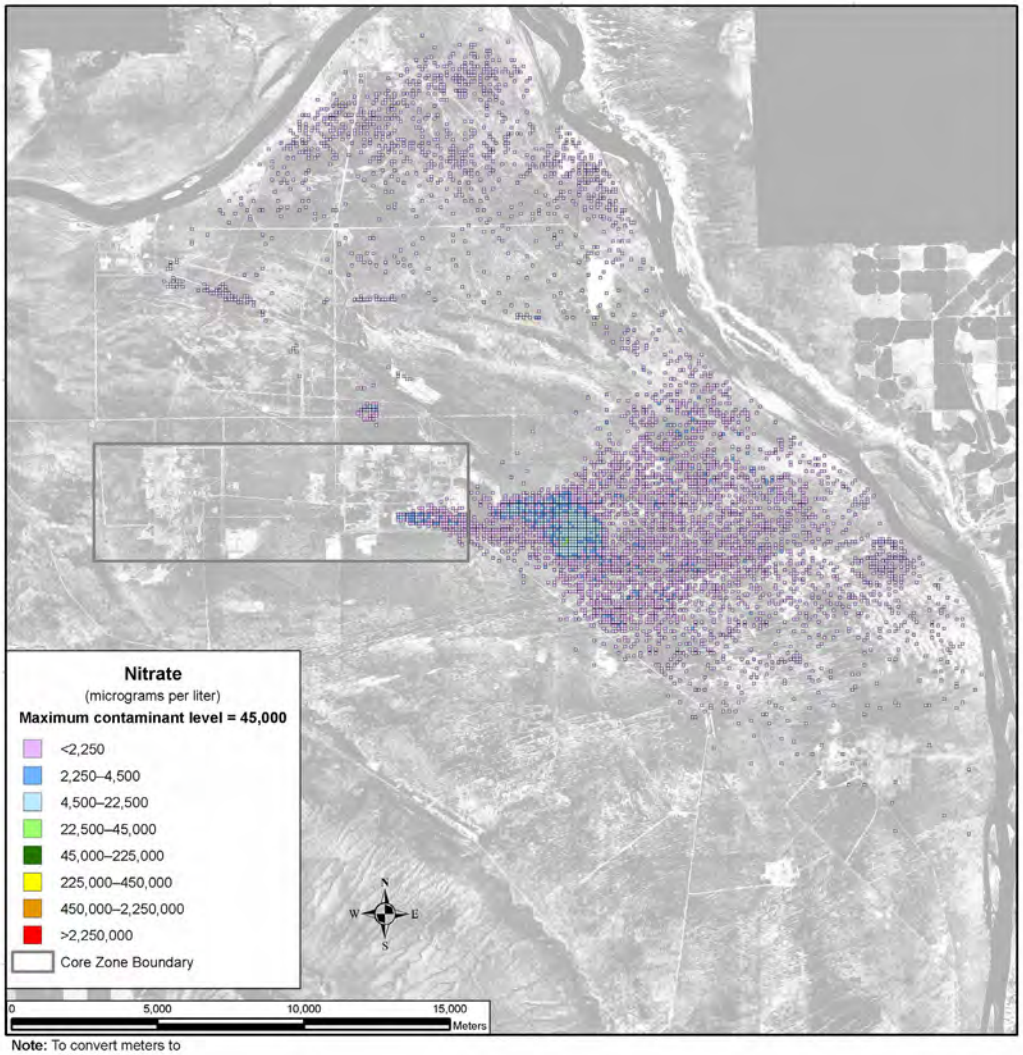
Note: To convert meters to feet, multiply by 3.281

Figure 5–512. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



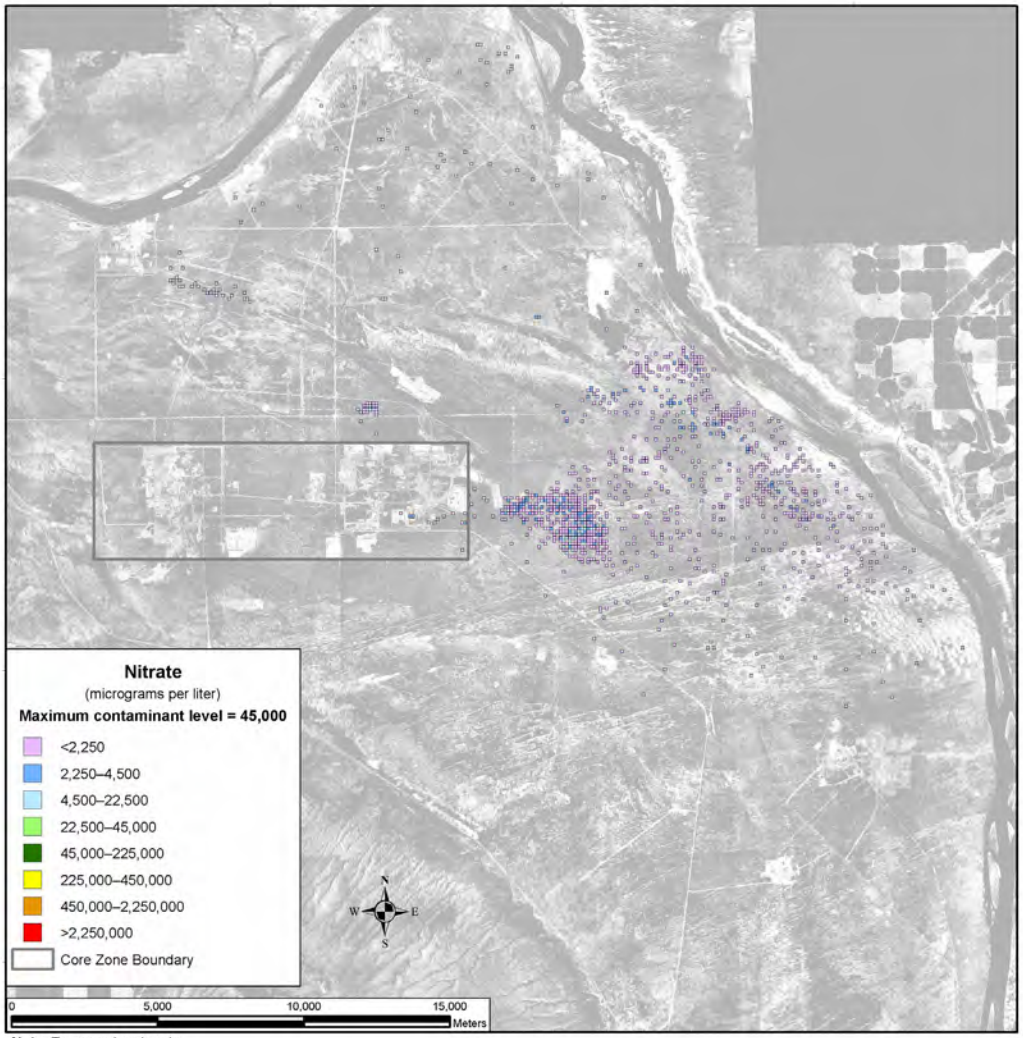
Note: To convert meters to feet, multiply by 3.281

Figure 5–513. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



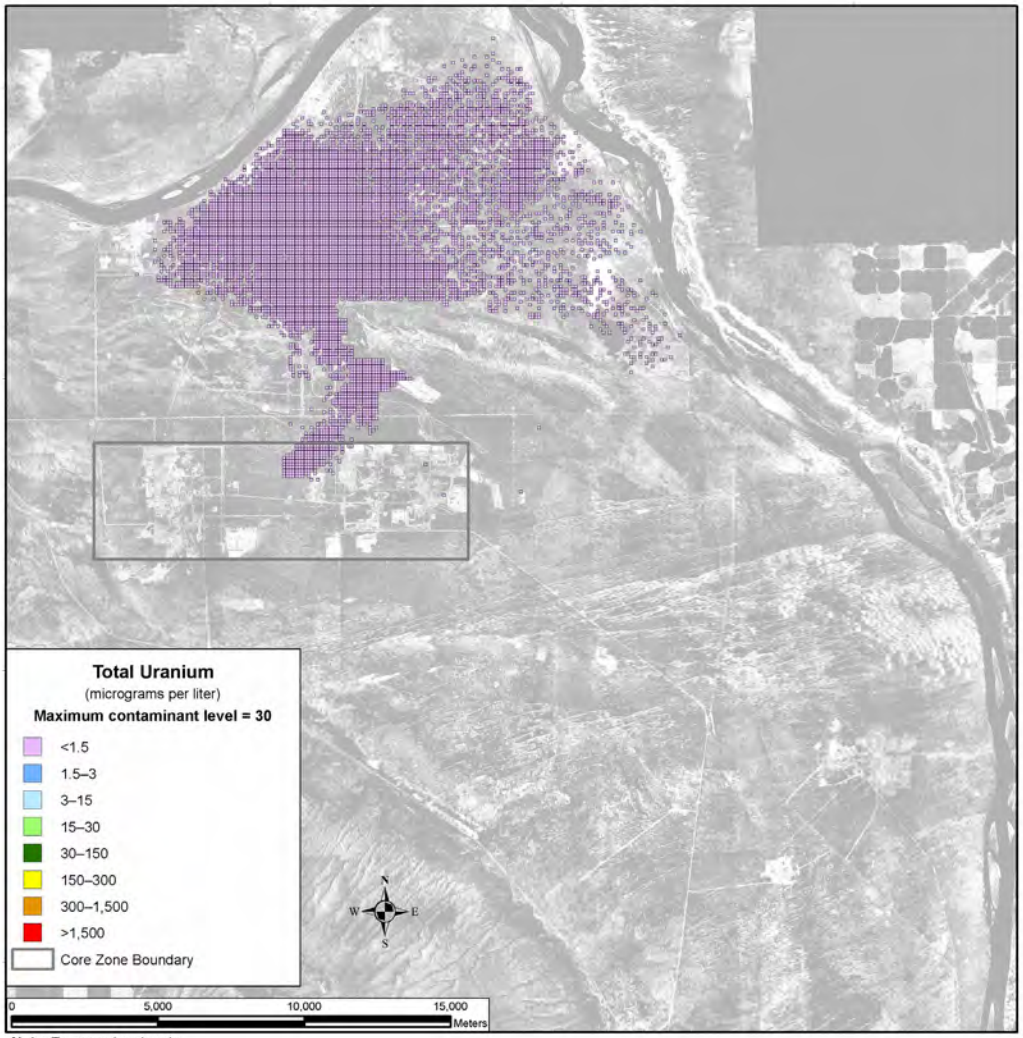
Note: To convert meters to feet, multiply by 3.281

Figure 5–514. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–515. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–516. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group1, Subgroup 1-E, in general, the inventories remaining at both IDF-East and the RPPDF, which would be available for release to the environment at the start of the post-disposal period, are predominant contributors.

For the conservative tracers, concentrations slightly outside the Core Zone Boundary exceed benchmark standards by one order of magnitude during most of the period of analysis. Concentrations at the Columbia River are about one order of magnitude smaller. The intensities and areas of these groundwater plumes peak between CYs 7140 and 11,885.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species do not exceed the benchmark at the Core Zone Boundary or Columbia River.

5.3.1.2.1.6 Disposal Group 1, Subgroup 1-F

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-F covers disposal of Tank Closure Alternative 5, FFTF Decommissioning Alternative 3, and onsite and offsite waste. Waste would be converted to IHLW, ILAW glass, bulk vitrification glass, and cast stone waste. IHLW would be stored on site, while ILAW glass, bulk vitrification glass, and cast stone waste would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E, as follows:

- The disposal period was assumed to start with the onset of disposal operations for IDF-East in CY 2009 and continue through CY 2050, when the disposal facility would be operationally closed and postclosure care would cease. During the disposal period the materials in this permitted, operational facility is not available for release to the environment. The RPPDF is not constructed and operated for this subgroup.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in IDF-East become available for release to the environment, and modified RCRA Subtitle C barrier would be emplaced over IDF-East to limit infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F. Complete results for all 40 COPCs are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, nitrate, and acetonitrile.

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, acetonitrile, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, in terms of the total amounts of radionuclide and chemical COPCs released to the vadose zone,

groundwater, and Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–517 through 5–522). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility

Figure 5–517 shows the estimated release to the vadose zone for the radiological risk drivers and Figure 5–518, the chemical hazard drivers. The COPC inventories in the waste forms are a major factor in the release quantities of a COPC to the vadose zone. The predominant source of technetium-99 is cast stone waste (60 percent), followed by offsite-generated waste (28 percent) and bulk vitrification glass (9 percent). Most of the iodine-129 (87 percent) is released from offsite-generated waste, followed by ETF-generated secondary waste (12 percent). All of the fluoride and boron are released by waste management secondary waste and onsite-generated waste. All of the acetonitrile is released by cast stone waste. The predominant source for chromium (78 percent) is sulfate grout, with some from cast stone waste (22 percent). The sources of nitrate are ETF-generated secondary waste (57 percent) and cast stone waste (43 percent).

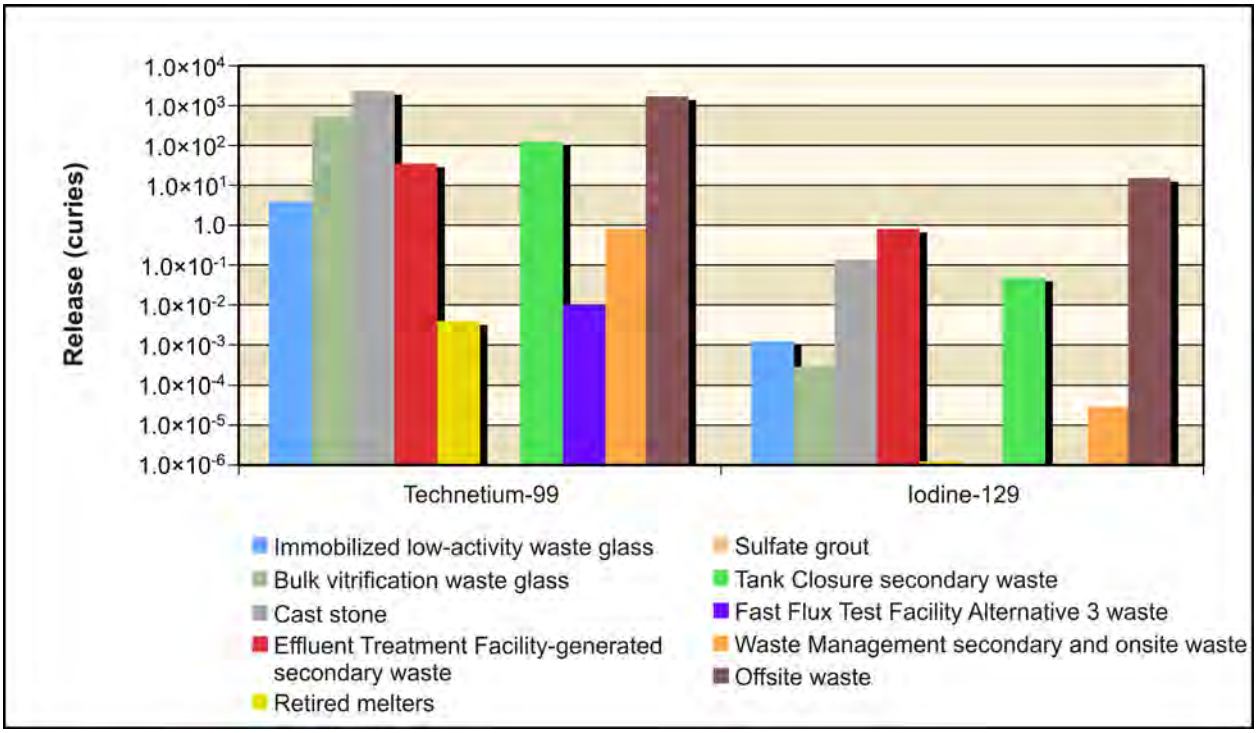


Figure 5–517. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

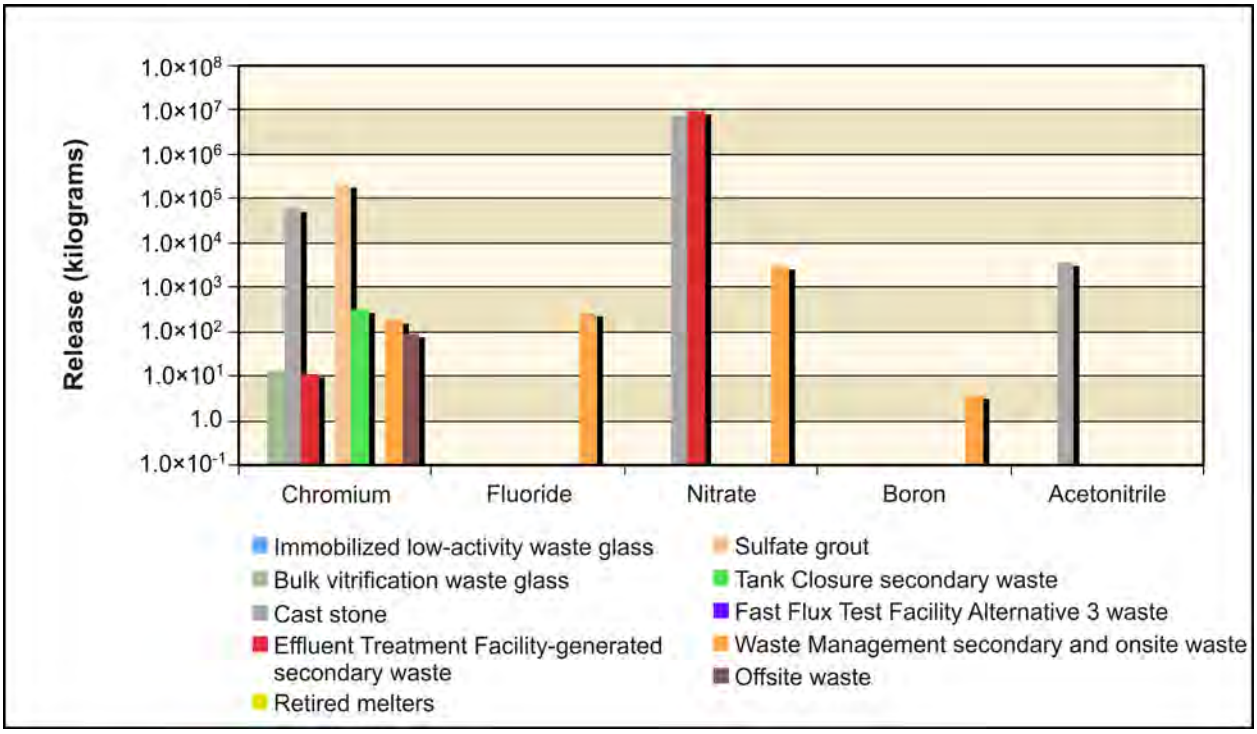


Figure 5–518. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

Figure 5–519 shows the estimated release to groundwater for the radiological risk drivers and Figure 5–520, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All of the chromium, nitrate, fluoride, boron, and acetonitrile from the vadose zone are released to groundwater during the period of analysis. About 63 percent of the technetium-99 released to the vadose zone reached the groundwater in the analysis; about 92 percent of the iodine-129 reached the groundwater.

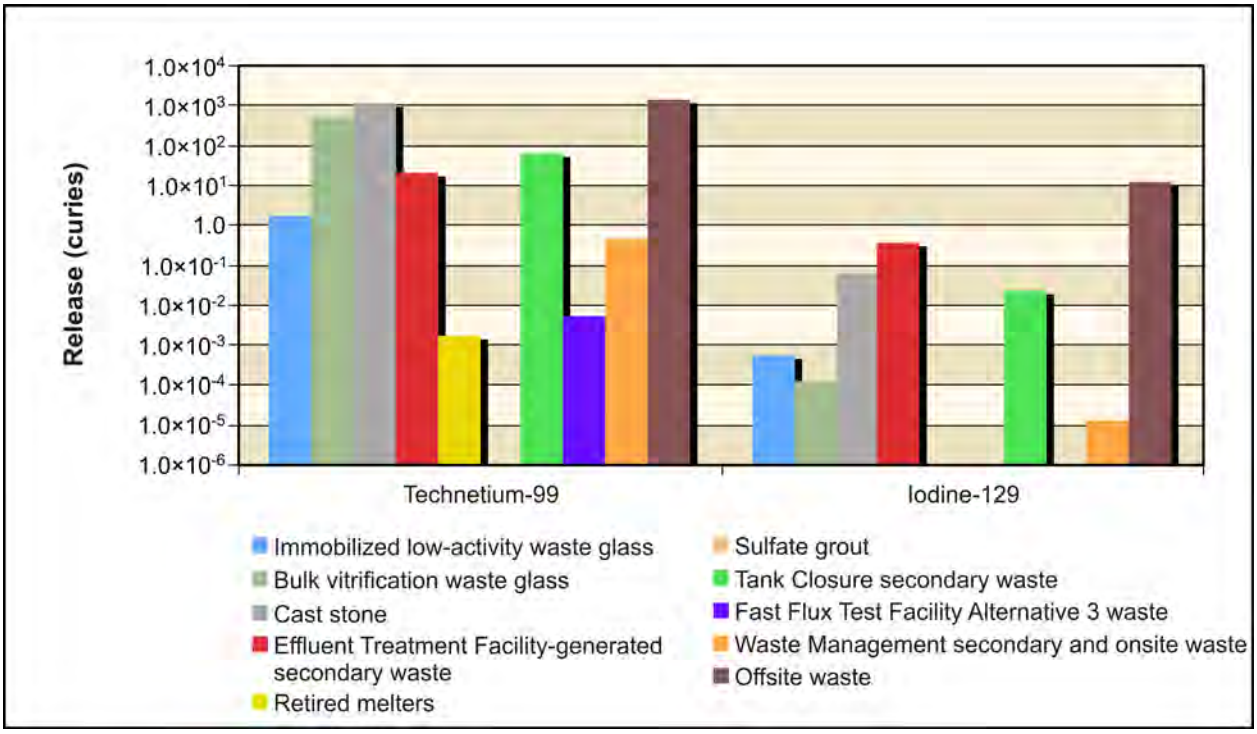


Figure 5–519. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

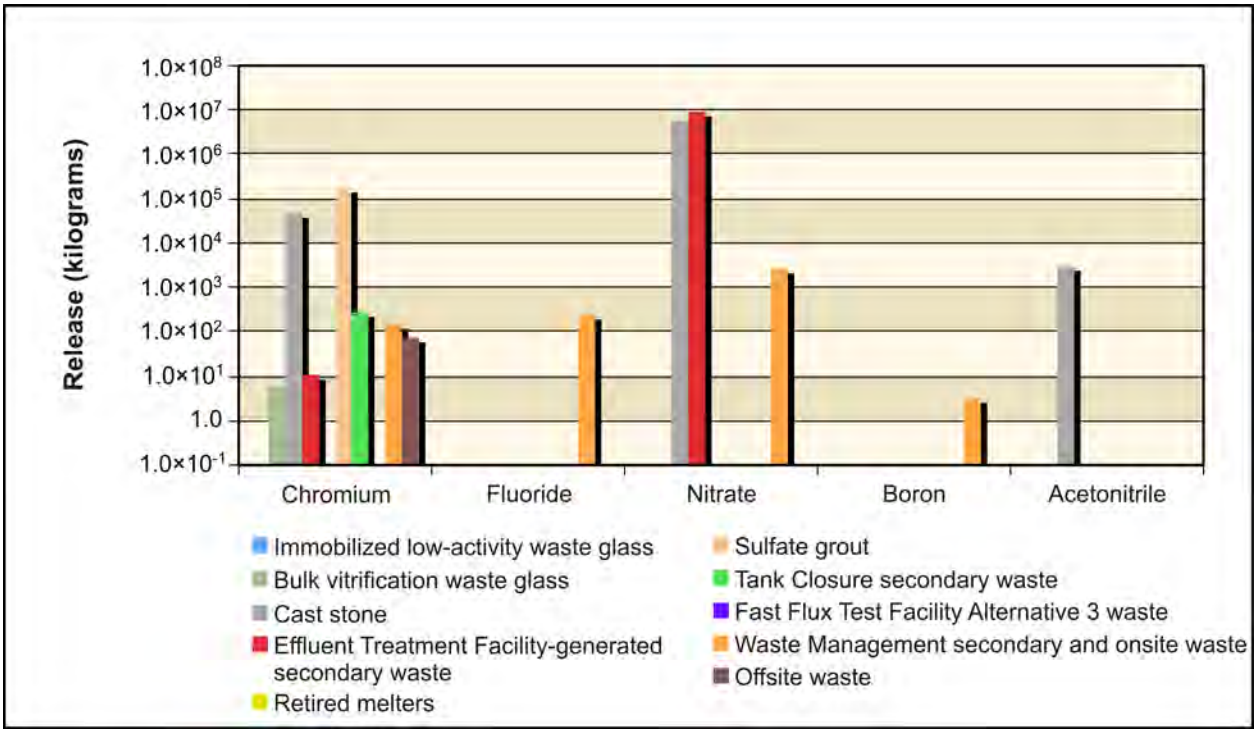


Figure 5–520. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

Figure 5–521 shows the estimated release to the Columbia River for the radiological risk drivers and Figure 5–522, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPCs. All of the groundwater technetium-99, iodine-129, chromium, nitrate, fluoride, boron, and acetonitrile, are released to the Columbia River.

Overall, about 60 percent of the vadose zone technetium-99 and 90 percent of the iodine-129 reached the Columbia River within the time period of this analysis. About 96 to 98 percent of the vadose zone chromium, nitrate, fluoride, boron, and acetonitrile reached the Columbia River during the period of analysis. No uranium-238 or total uranium is released to the groundwater or Columbia River.

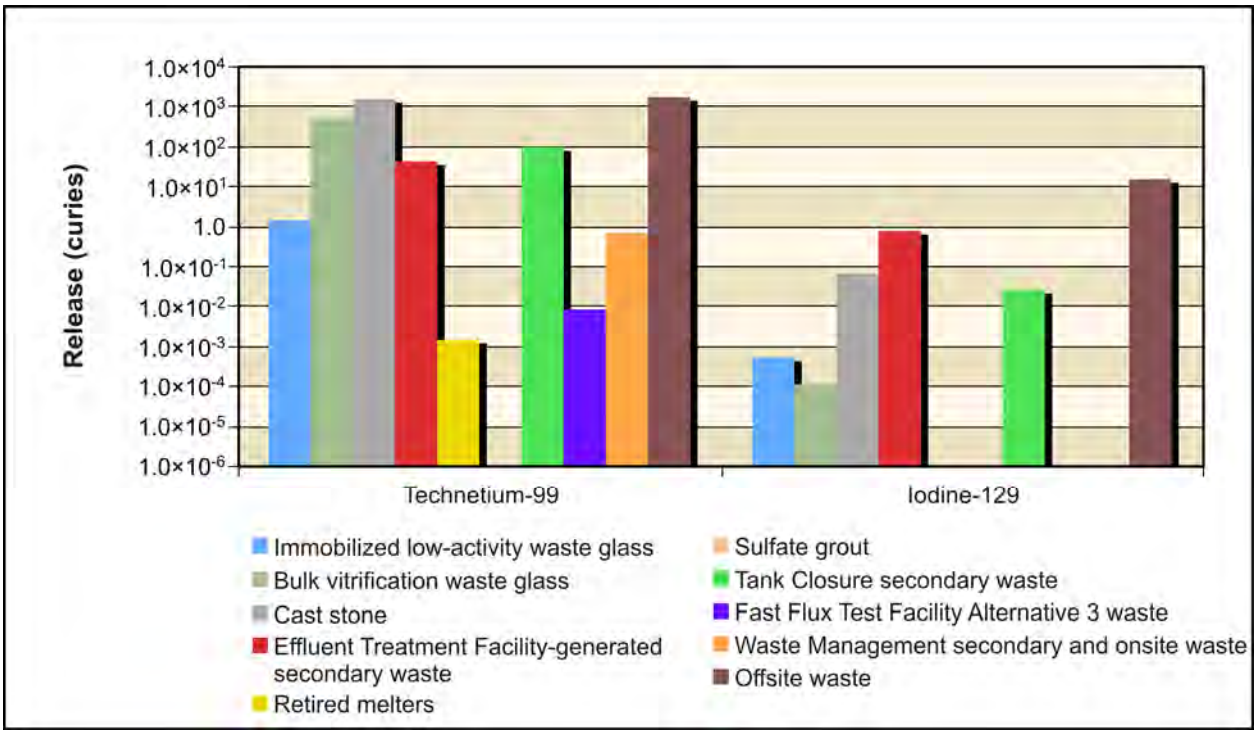


Figure 5–521. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

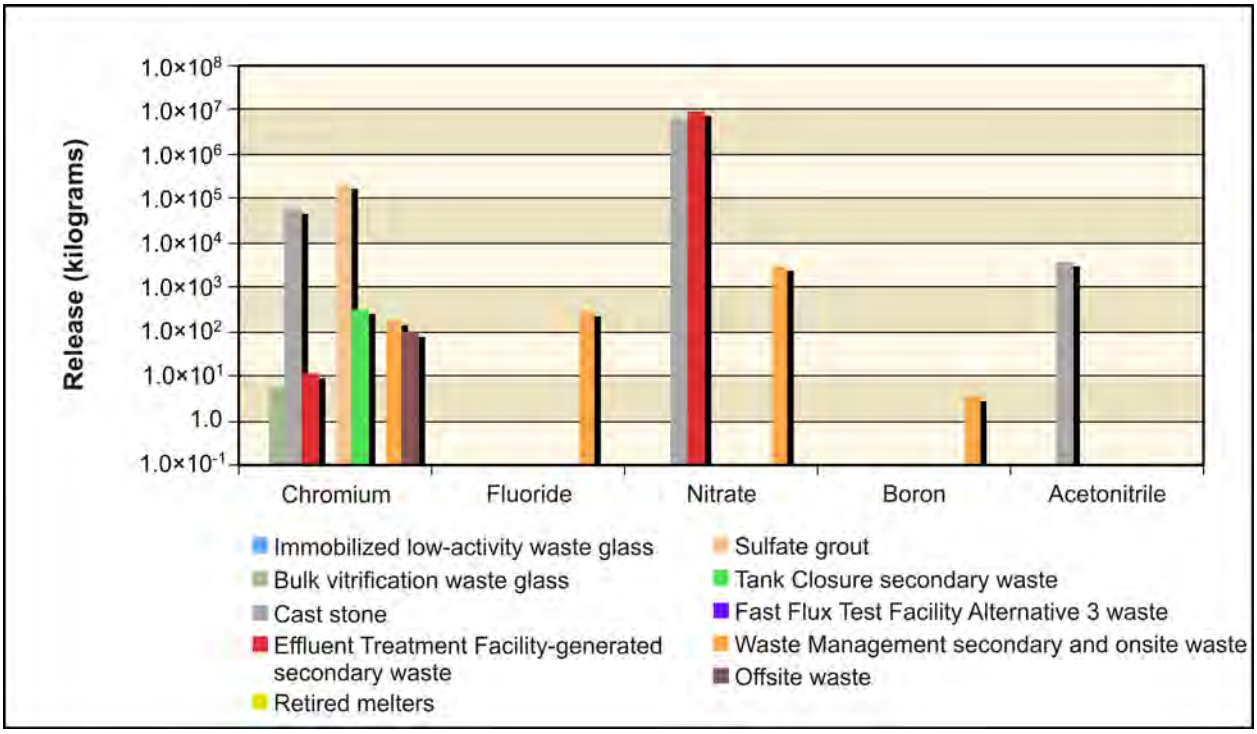


Figure 5–522. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. In the concentration versus time graphs, the concentrations of radionuclides are in picocuries per liter, chemicals in micrograms per liter. The benchmark concentration is also shown for each radionuclide and chemical. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Table 5–82 gives the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Table 5–82. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**3,510**	N/A	**1,500**	891	900
	(8276)		(9155)	(8090)	
Iodine-129	**18**	N/A	**8**	**7**	1
	(8195)		(8858)	(8699)	
Chemical in micrograms per liter					
Acetonitrile	5	N/A	2	1	100
	(8475)		(9519)	(8575)	
Chromium	**335**	N/A	**148**	**110**	100
	(8735)		(8764)	(8819)	
Fluoride	0	N/A	1	0	4,000
	(8035)		(7258)	(8913)	
Nitrate	21,400	N/A	7,420	4,560	45,000
	(8448)		(8887)	(8787)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; N/A=not applicable; RPPDF=River Protection Project Disposal Facility.

Figures 5–523 through 5–526 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate. During the latter part of the analysis time period, the groundwater concentrations of iodine-129 from IDF-East exceed the benchmark concentrations at both the Core Zone Boundary and the Columbia River nearshore (see Figure 5–523). However, the concentrations of iodine-129 are never more than one order of magnitude above the benchmark concentration level. The concentrations of technetium-99 and chromium (see Figures 5–524 and 5–525) approach but never exceed their benchmark concentrations. The concentration of nitrate always remains at least one order of magnitude less than its benchmark concentration (see Figure 5–526).

There are no detectable releases of either uranium-238 or total uranium to the environment over this analysis period.

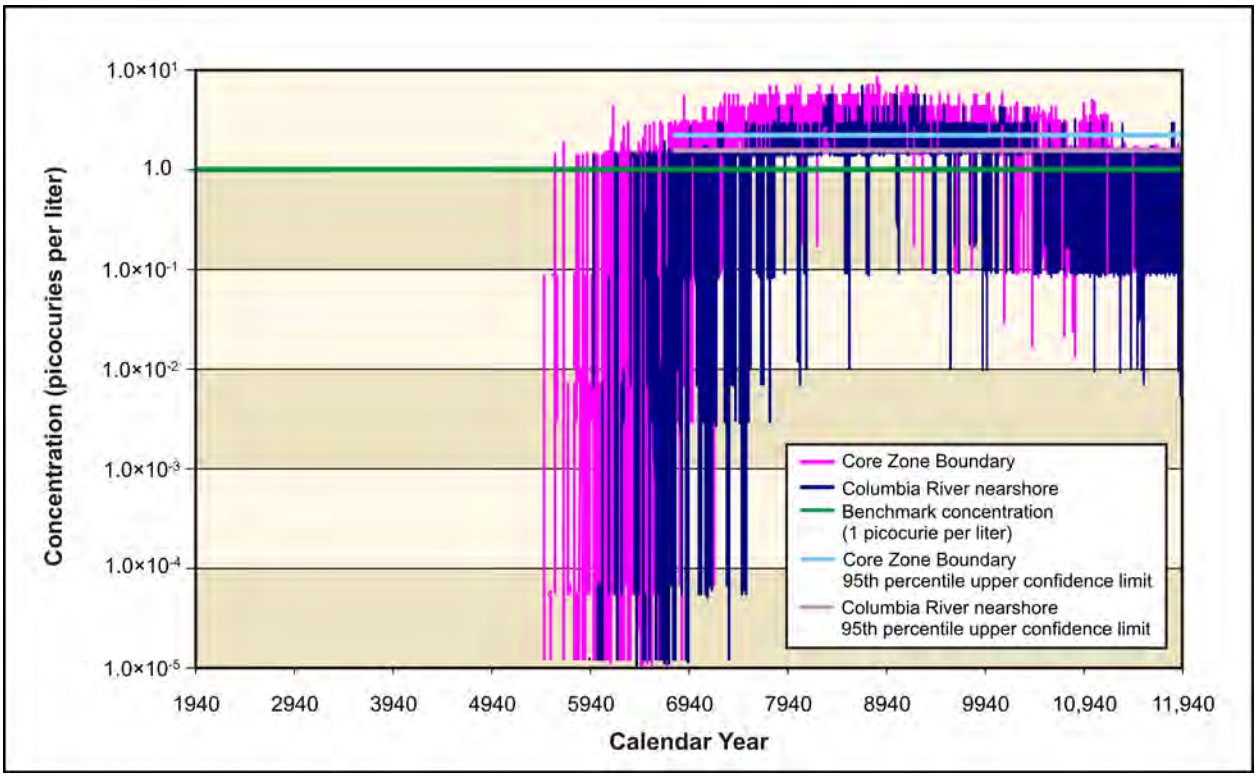


Figure 5–523. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Iodine-129 Concentration Versus Time

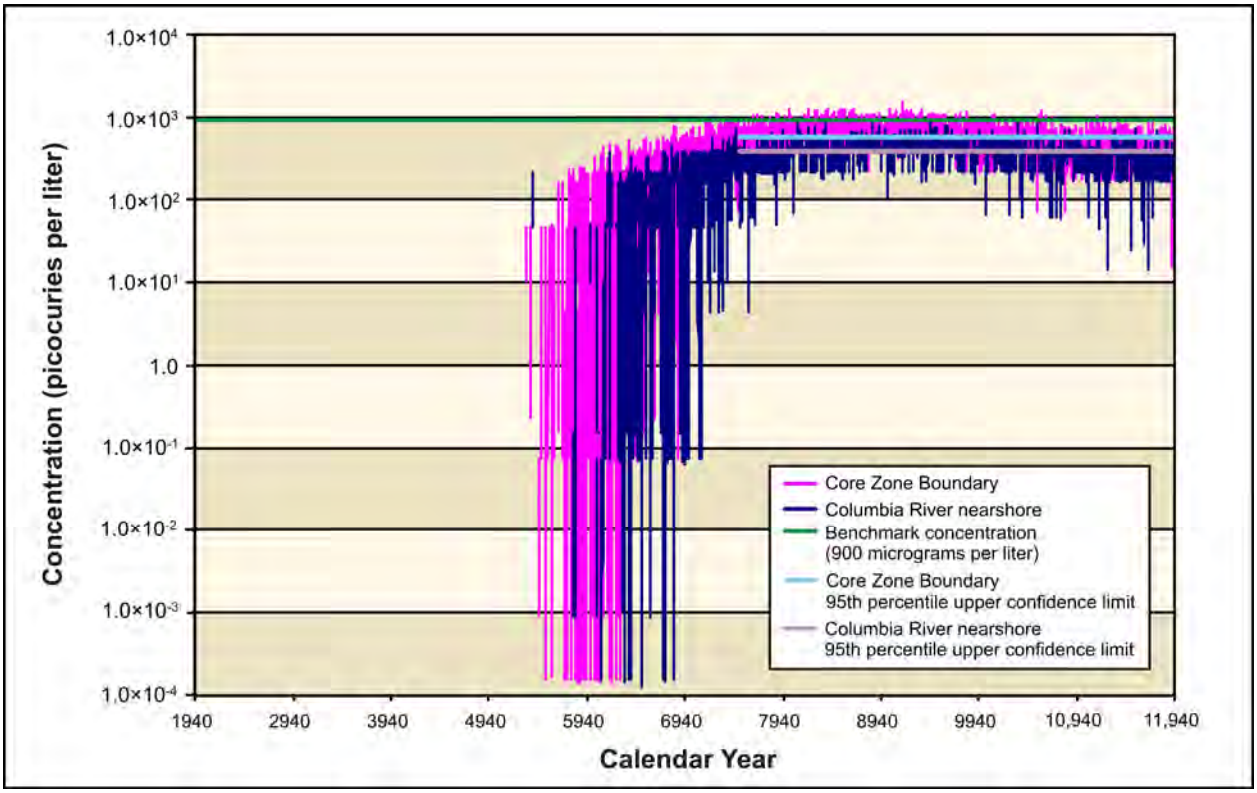


Figure 5–524. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Technetium-99 Concentration Versus Time

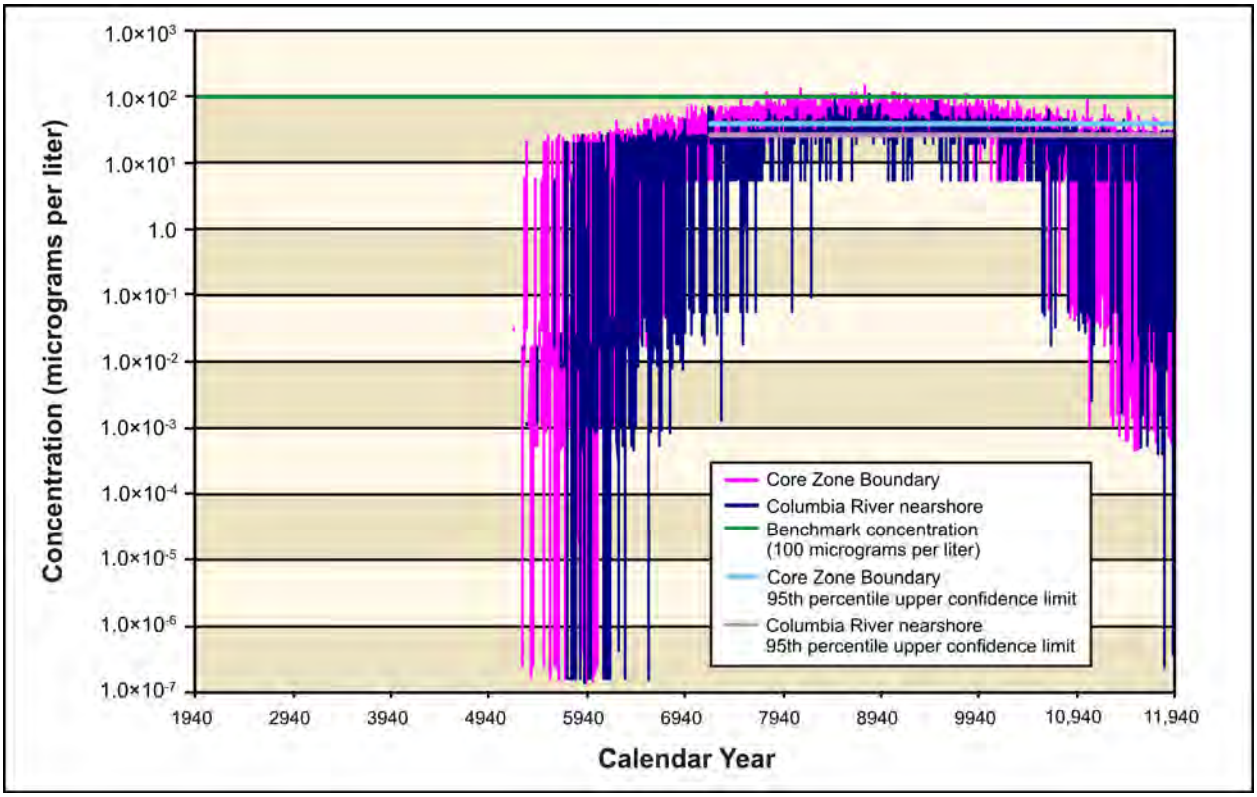


Figure 5–525. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Chromium Concentration Versus Time

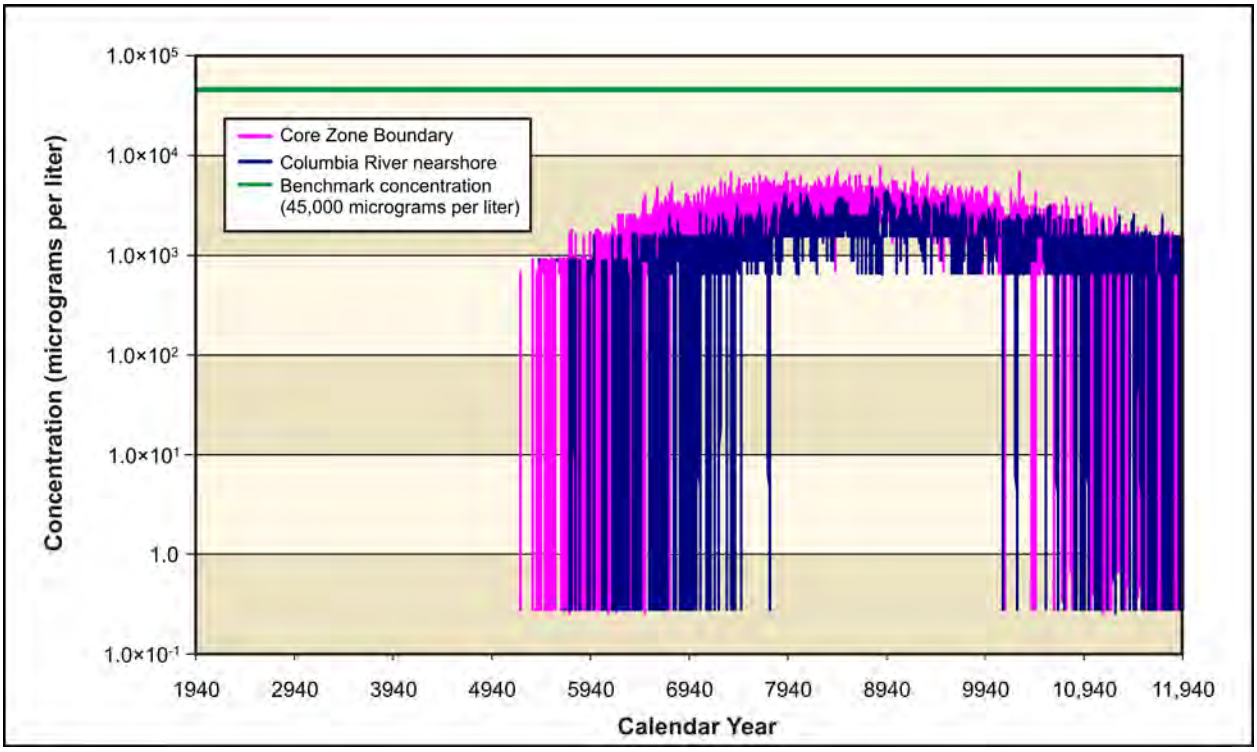


Figure 5–526. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Nitrate Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

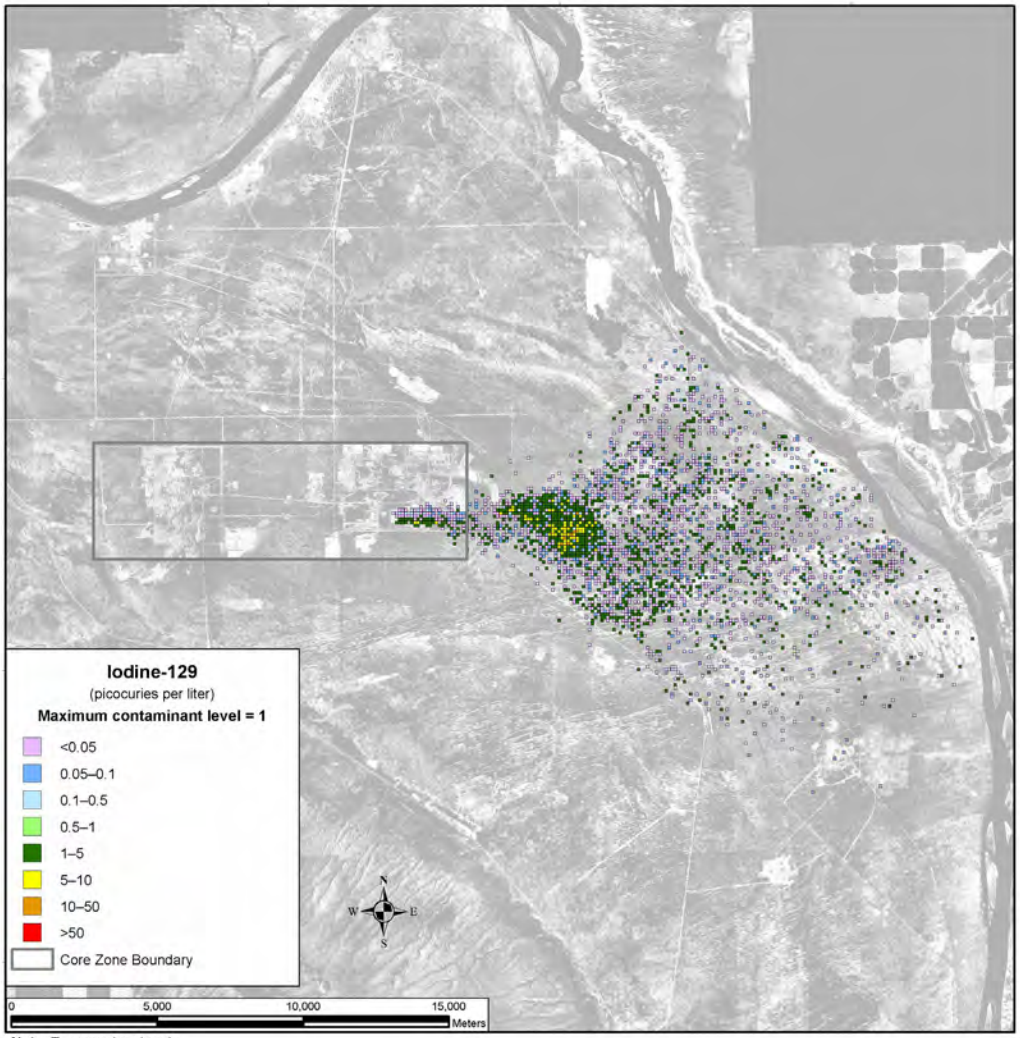
This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, in terms of the spatial distribution of groundwater concentration at selected times in this analysis period. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–527 through 5–534). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Figures 5–527 through 5–534 show groundwater releases that extend from the east edge of the Core Zone Boundary to the Columbia River. The iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity). Releases from IDF-East result in groundwater concentrations that extend from the release source east to the Columbia River. For each map, the concentrations that are greater than the benchmark concentration are indicated by the fully saturated colors (green, yellow, orange, and red) in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors (green, blue, indigo, and violet) in order of decreasing concentration. The concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

All plumes from IDF-East releases are initially contained in a narrow area moving eastward until they reach about one-third of the distance to the Columbia River nearshore boundary, where they spread out significantly and continue to the Columbia River. Figures 5–527 and 5–528 show the spatial distribution of iodine-129 groundwater concentration for CYs 7140 and 11,885, respectively. The CY 7140 data show that a release from IDF-East creates a plume outside of the east boundary between the Core Zone Boundary and the Columbia River nearshore. These data also show that there is an area east of the Core Zone Boundary where the concentration exceeds the benchmark concentration. By CY 11,885 (see Figure 5–528), the plume mass has continued to spread out and is still moving eastward toward the Columbia River. The CY 11,885 plume also shows areas where the concentrations exceed the benchmark concentration.

Figures 5–529 and 5–530 show a similar technetium-99 release moving east toward the Columbia River for CYs 7140 and 11,885. The plumes show areas where the concentration of technetium-99 exceeds the benchmark concentration. The CY 11,885 data show that the chromium is dissipating, but high-concentration areas remain.

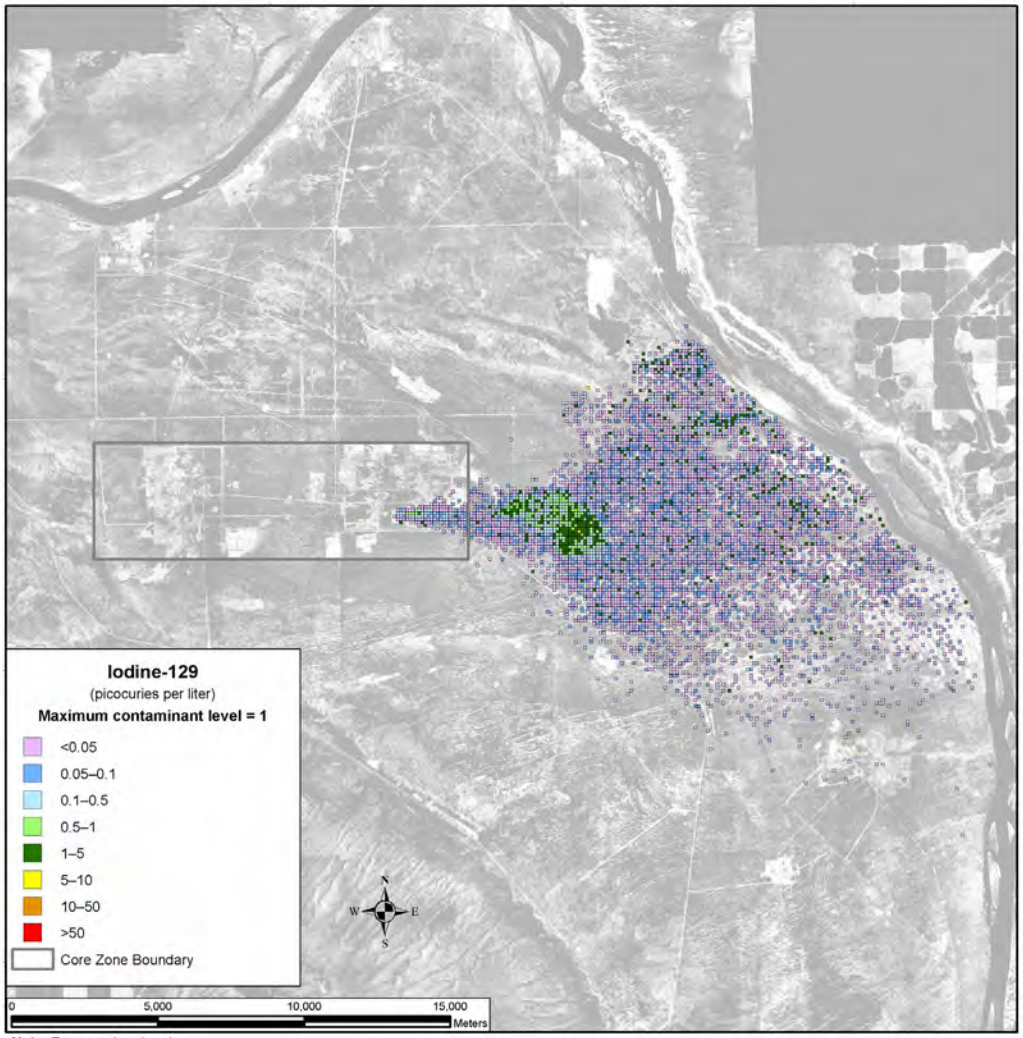
Figures 5–531 and 5–532 (CYs 7140 and 11,885 data) show a chromium plume with a small area where the concentration approaches the benchmark concentration. The CY 11,885 data show a reduced-size and reduced-concentration plume compared with the CY 7140 plume. The CY 11,885 data also shows that the chromium concentration continues between the release source and the Columbia River, but that the distribution is dissipating.

Figures 5–533 and 5–534 show the spatial distributions of groundwater concentrations of nitrate for CYs 7140 and 11,885. The nitrate release appears to approach the benchmark concentration in a small area east of the Core Zone Boundary. The CY 11,885 data show a nitrate plume significantly reduced in both area and concentration.



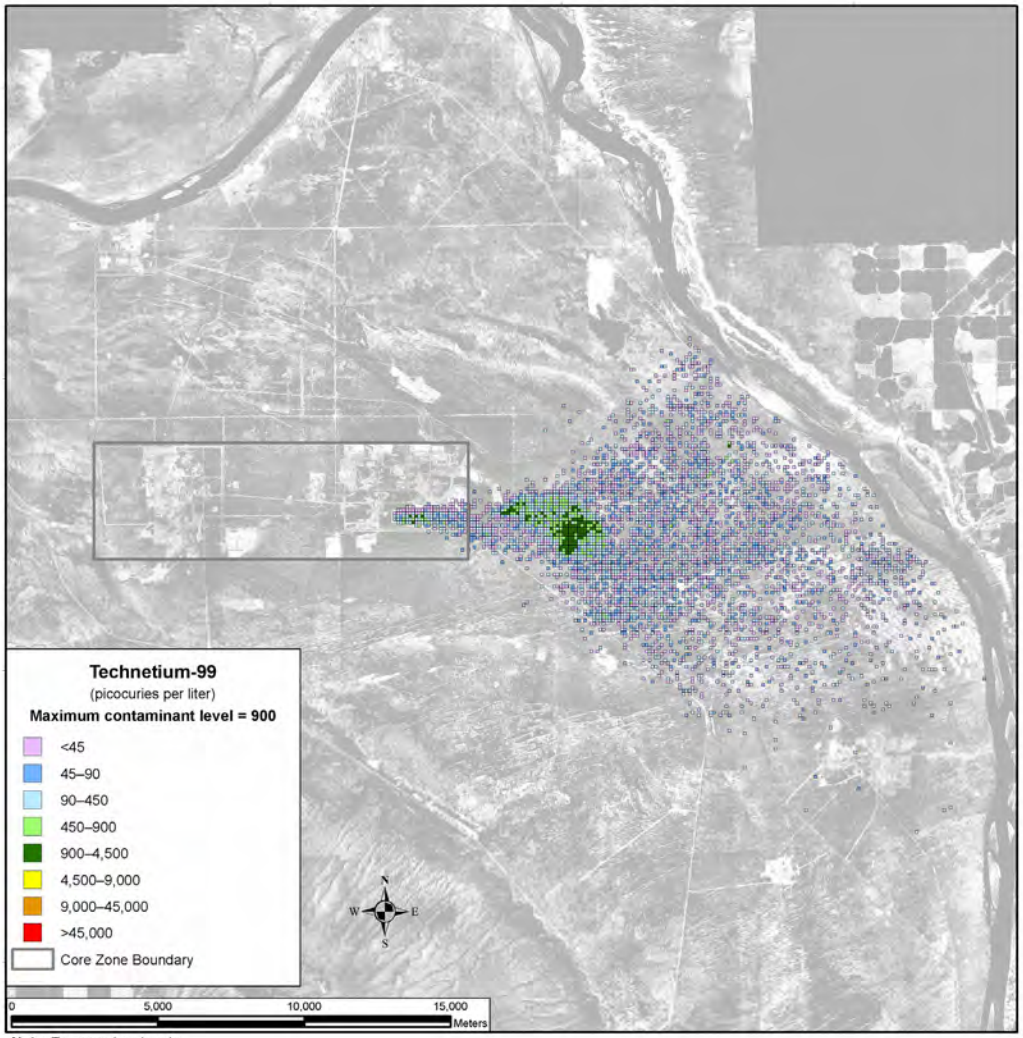
Note: To convert meters to feet, multiply by 3.281

Figure 5–527. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



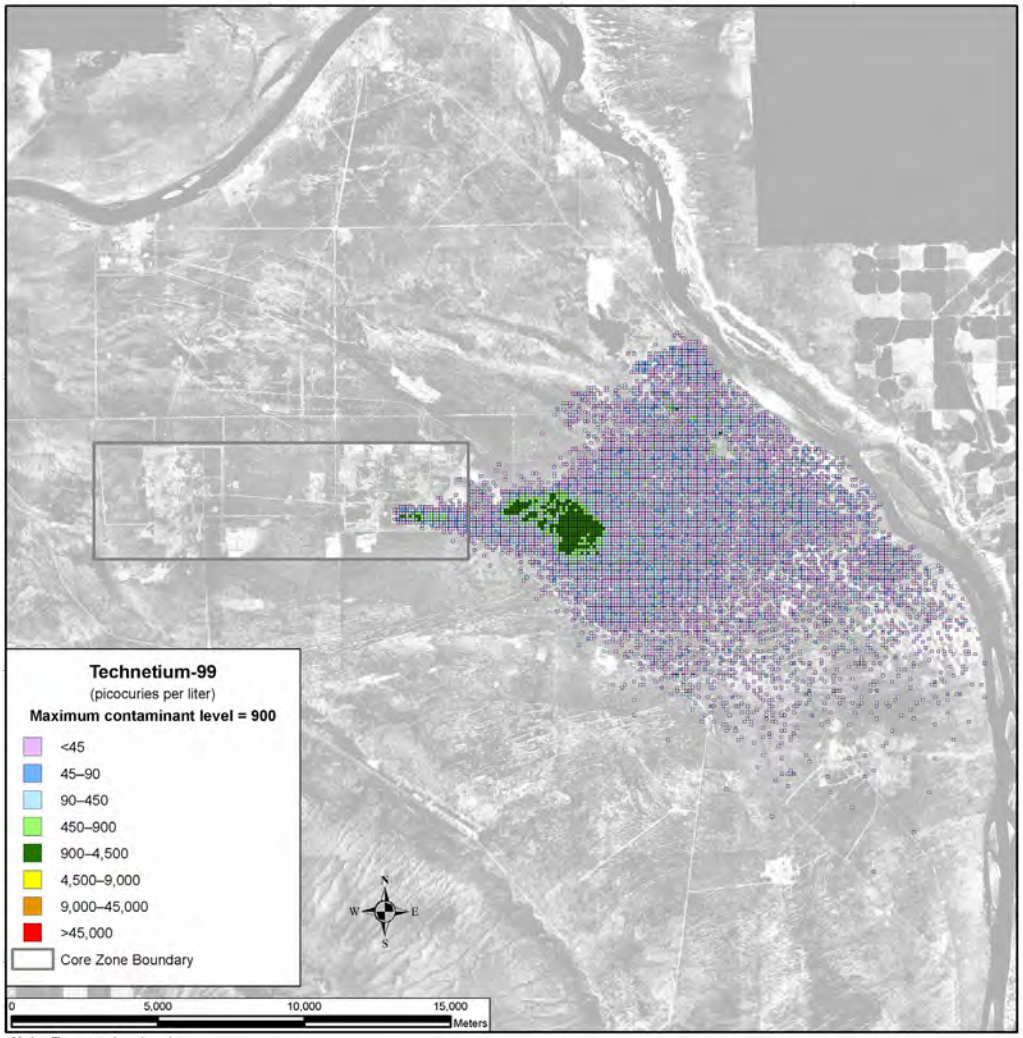
Note: To convert meters to feet, multiply by 3.281

Figure 5–528. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



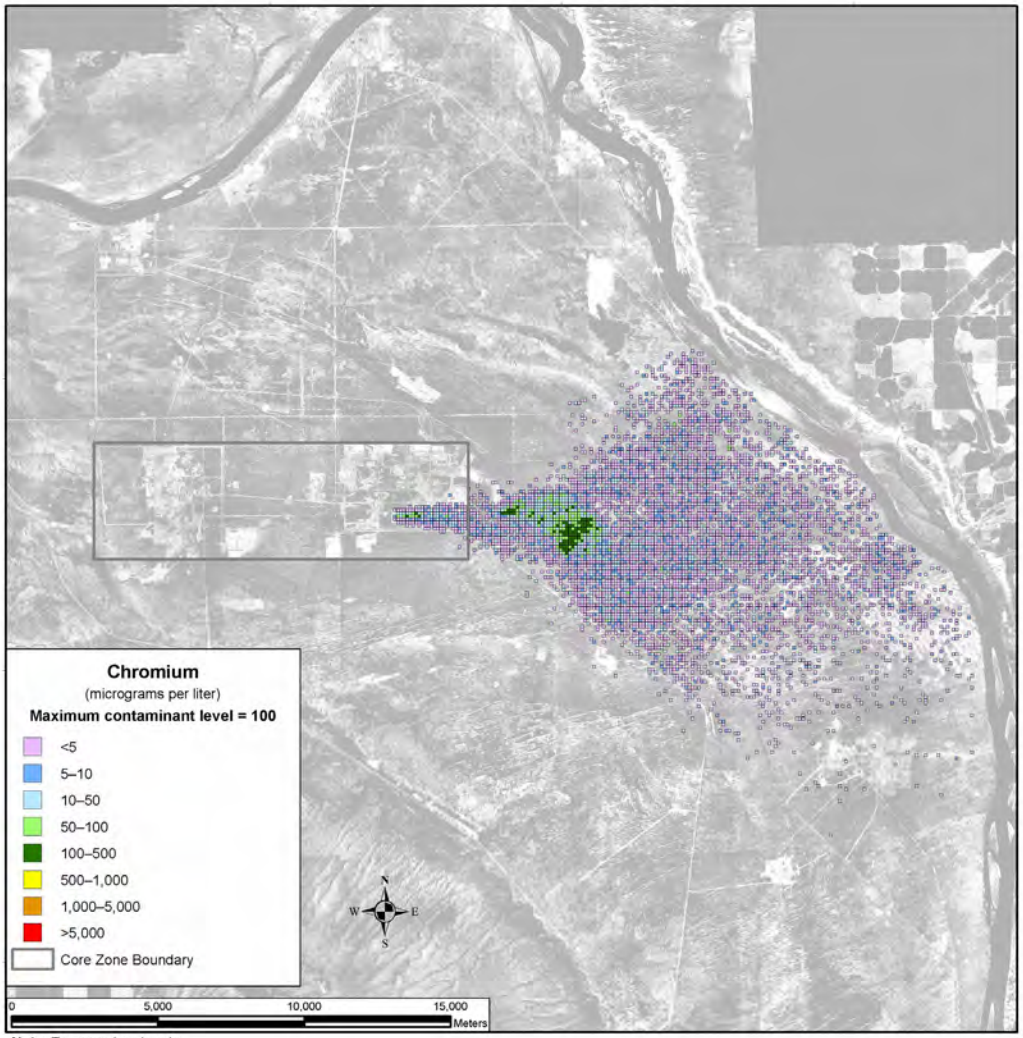
Note: To convert meters to feet, multiply by 3.281

Figure 5–529. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



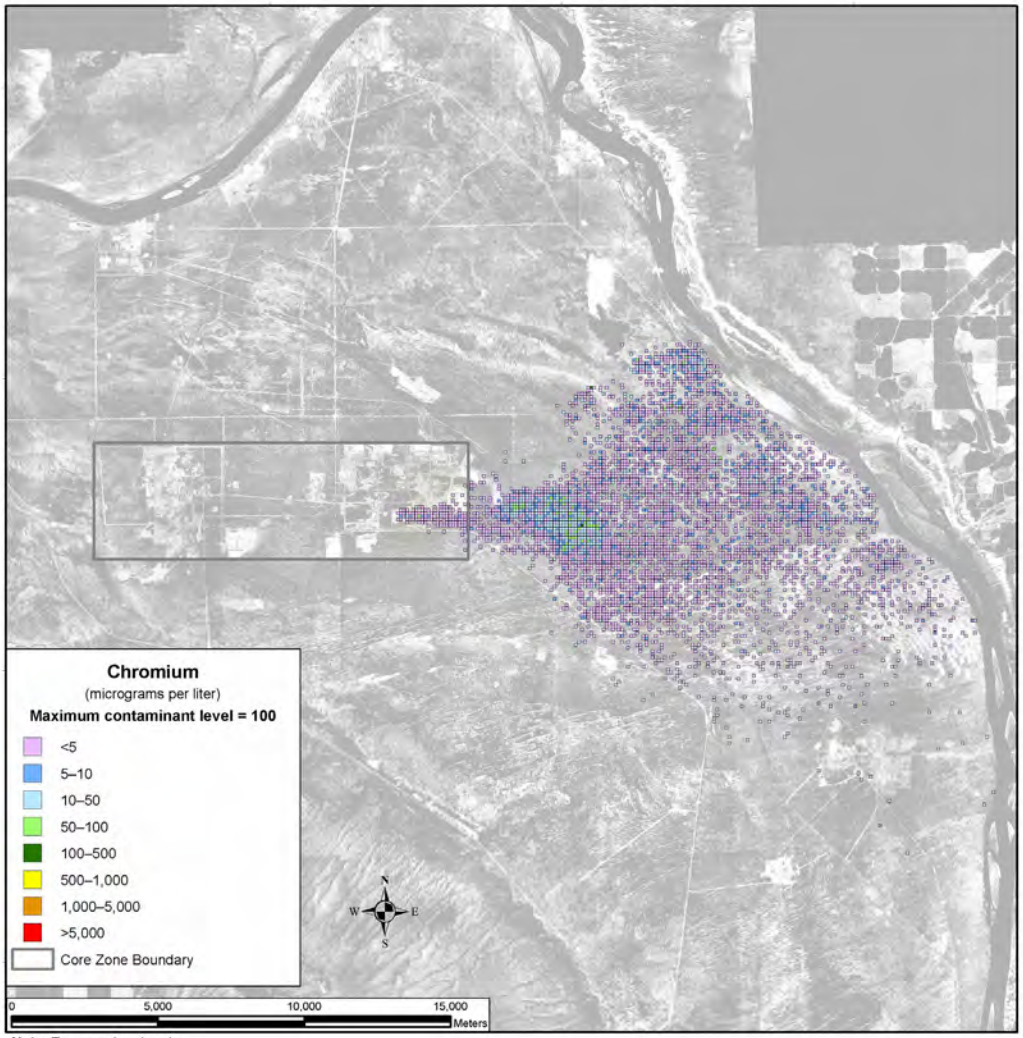
Note: To convert meters to feet, multiply by 3.281

Figure 5–530. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



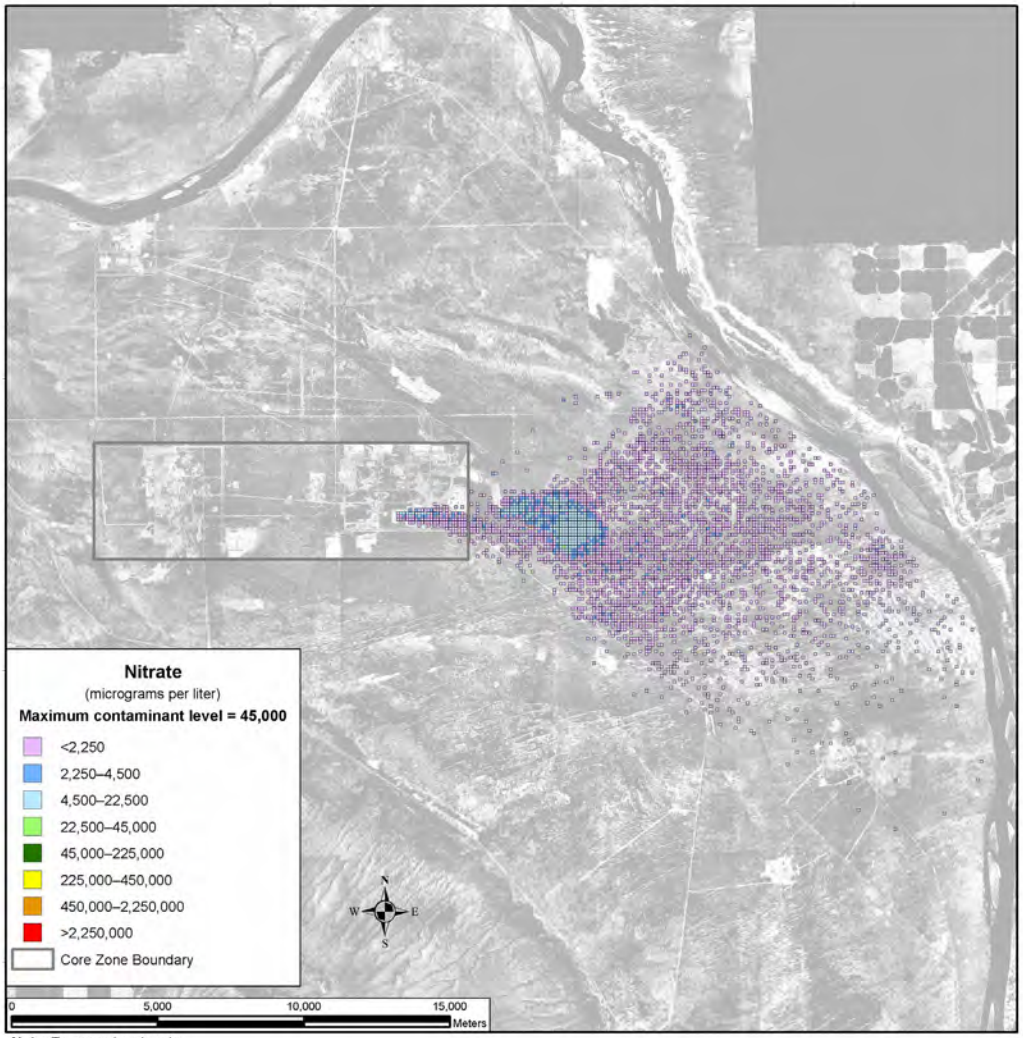
Note: To convert meters to feet, multiply by 3.281

Figure 5–531. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



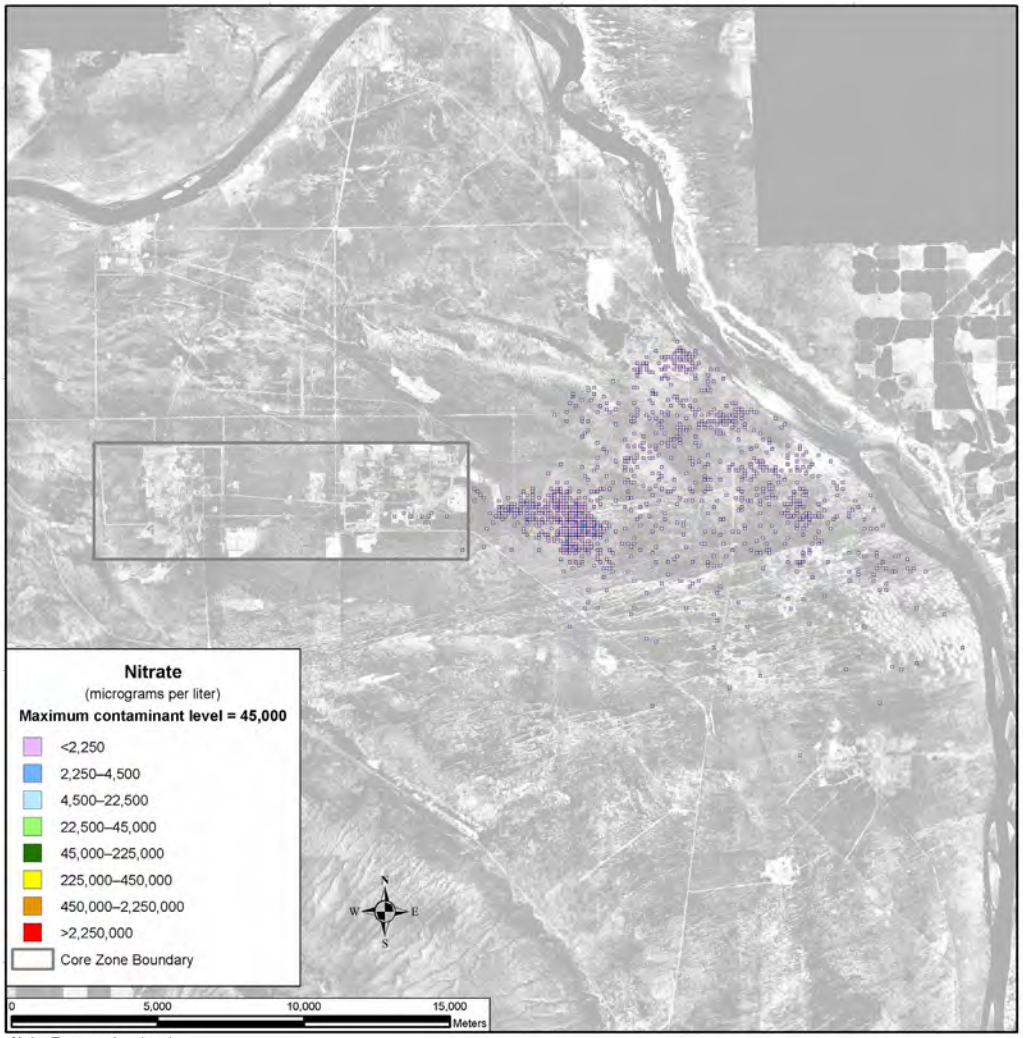
Note: To convert meters to feet, multiply by 3.281

Figure 5–532. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–533. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–534. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

For Waste Management Alternative 2, Disposal Group 1, Subgroup 1-F, in general, the predominant contributor is the iodine-129 inventory at IDF-East that is available for release to the environment at the start of the post-disposal period. The technetium-99, chromium, and nitrate concentrations do not appear to exceed benchmark standards during the period of analysis. These COPCs have concentrations at the Columbia River nearshore that are about one order of magnitude smaller than the benchmark concentrations. In general, the intensities are highest and the areas of these groundwater plumes largest between CYs 7000 and 9000, with concentrations declining through CY 11,885.

5.3.1.2.1.7 Disposal Group 1, Subgroup 1-G

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 1-G covers disposal of waste generated under Tank Closure Alternative 6C and FFTF Decommissioning Alternative 2 or 3, as well as onsite- and offsite-generated waste. Waste would be converted to IHLW and ILAW glass. IHLW would be stored on site, while ILAW glass would be disposed of at IDF-East. For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continue through CY 2050, when the disposal facilities would be operationally closed. During the disposal period, the materials in these permitted, operational facilities would not be available for release to the environment.

- The post-disposal period was assumed to start in CY 2051 and continue through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in IDF-East and the RPPDF would become available for release to the environment. For the purpose of analyzing long-term groundwater impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, IDF-East and the RPPDF are assumed to be covered by a barrier that limits infiltration for the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G (IDF-East and RPPDF releases), in terms of the total amount of COPCs released to the vadose zone, groundwater, and the Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figure 5–535 through 5–546). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility

IDF-East has five subtotals plotted representing releases including ETF-generated secondary waste, tank closure and waste management secondary waste, FFTF Decommissioning Alternative 3 waste, and onsite- and offsite-generated waste.

Figure 5–535 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–536, the chemical hazard drivers. For all five types of sources, the release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The predominant source of technetium-99 and iodine-129 is offsite-generated waste. For chemicals, the predominant source of chromium is tank closure secondary waste and for nitrate is offsite-generated waste. The predominant sources of fluoride and boron are waste management secondary waste and onsite-generated waste.

Figure 5–537 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–538 the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, nitrate, fluoride, and boron the amount released to groundwater is essentially equal to the amount released to the vadose zone. This means that there is less than one order of magnitude difference. Overall, about 90 percent of the radionuclide amount (curies) released to the vadose zone during the period of analysis reached the groundwater; approximately 100 percent of the chemical quantity (kilograms) reached the groundwater.

Figure 5–539 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–540, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For iodine-129, technetium-99, chromium, nitrate, fluoride, and boron the amount released to the Columbia River is essentially equal to the amount released to groundwater. Overall, about 97 percent of the radionuclide amount (curies) released to the groundwater during the period of analysis reached the river; approximately 99 percent of the chemical quantity (kilograms) reached the river.

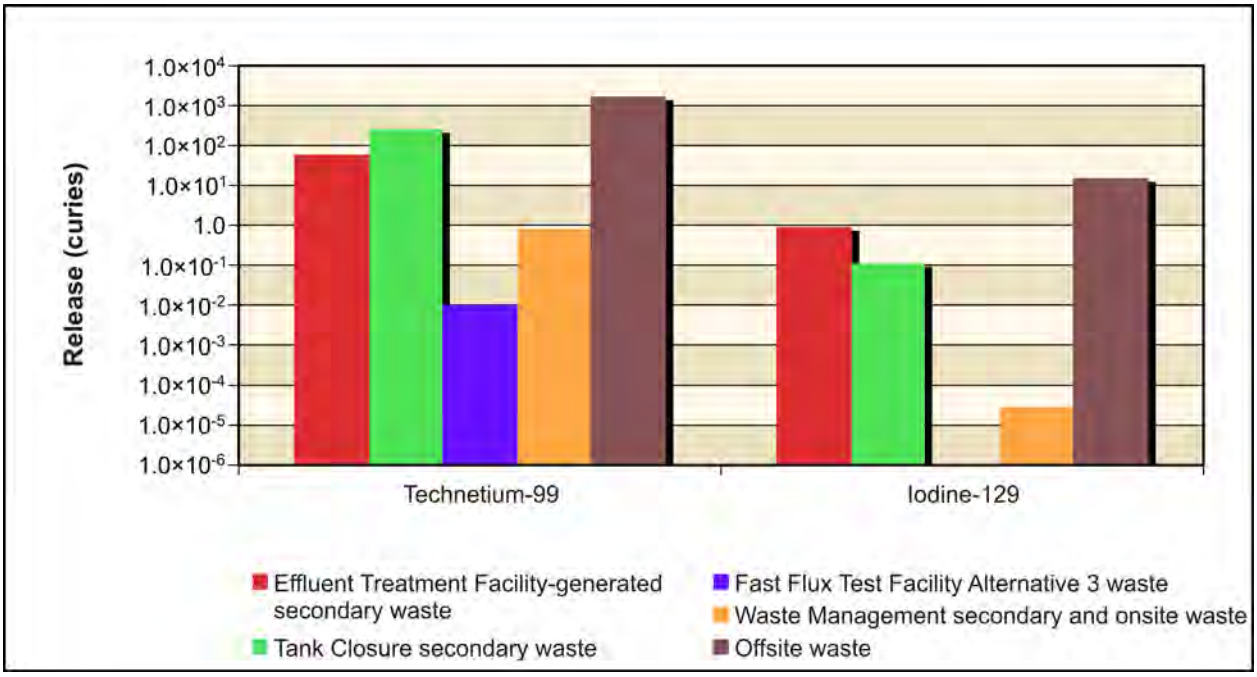


Figure 5–535. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

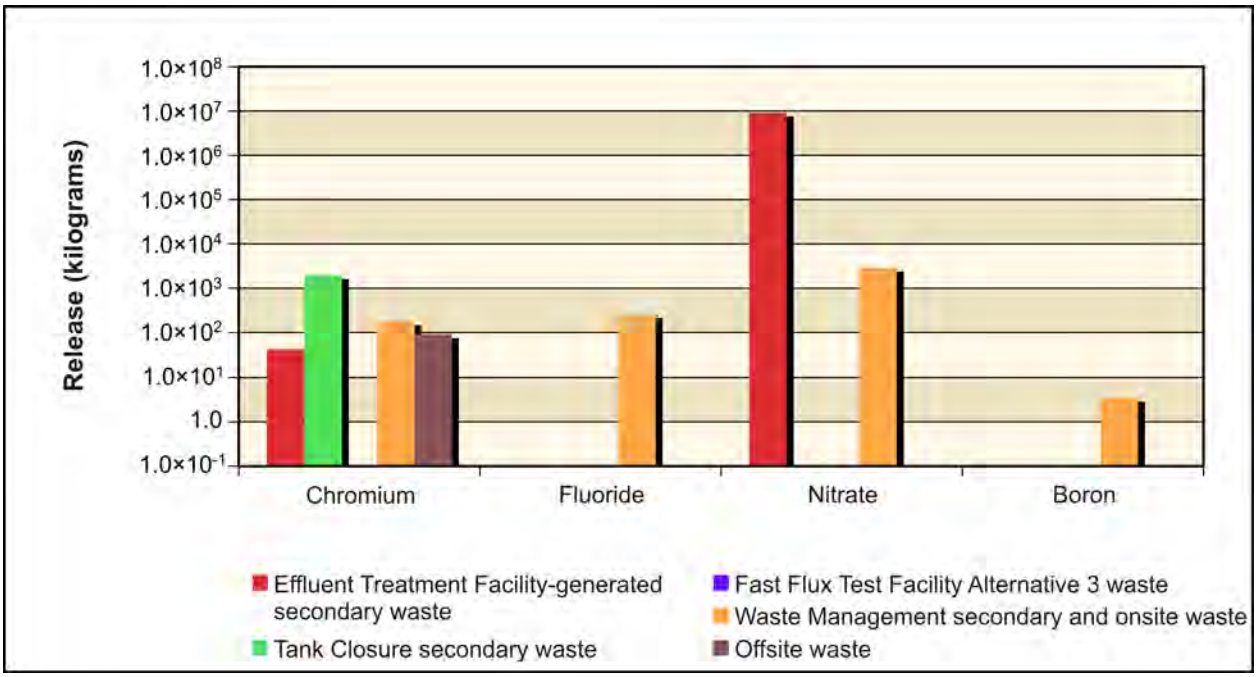


Figure 5–536. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

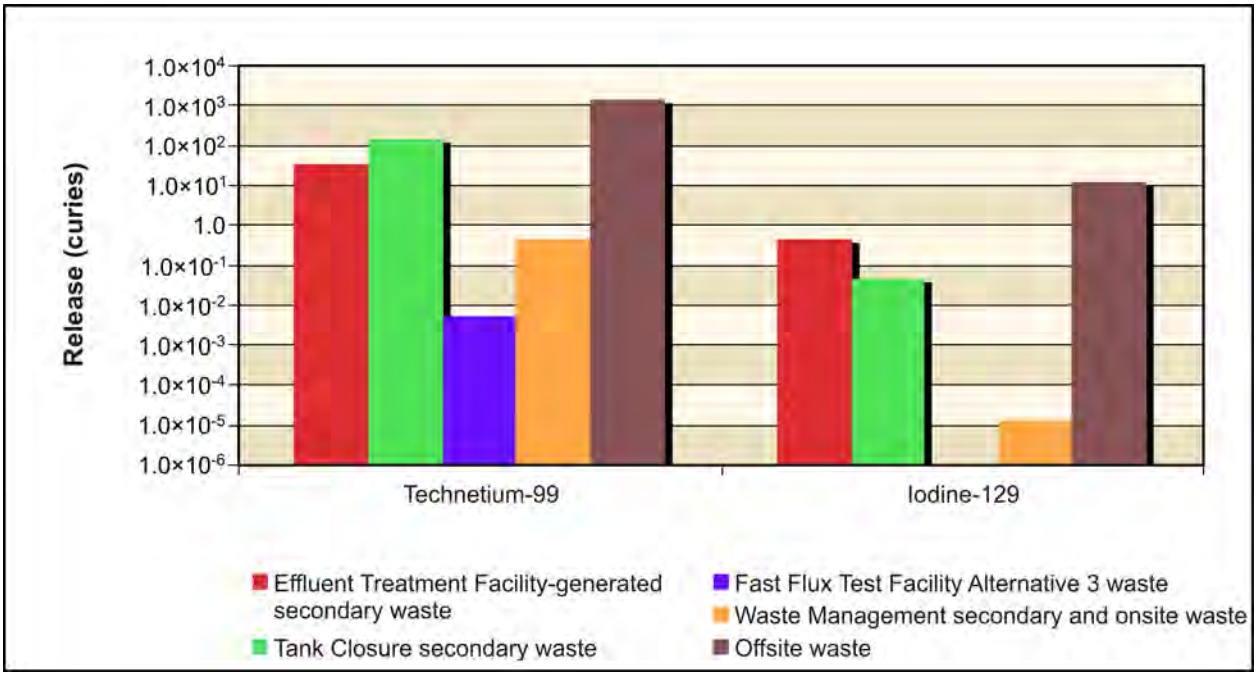


Figure 5–537. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

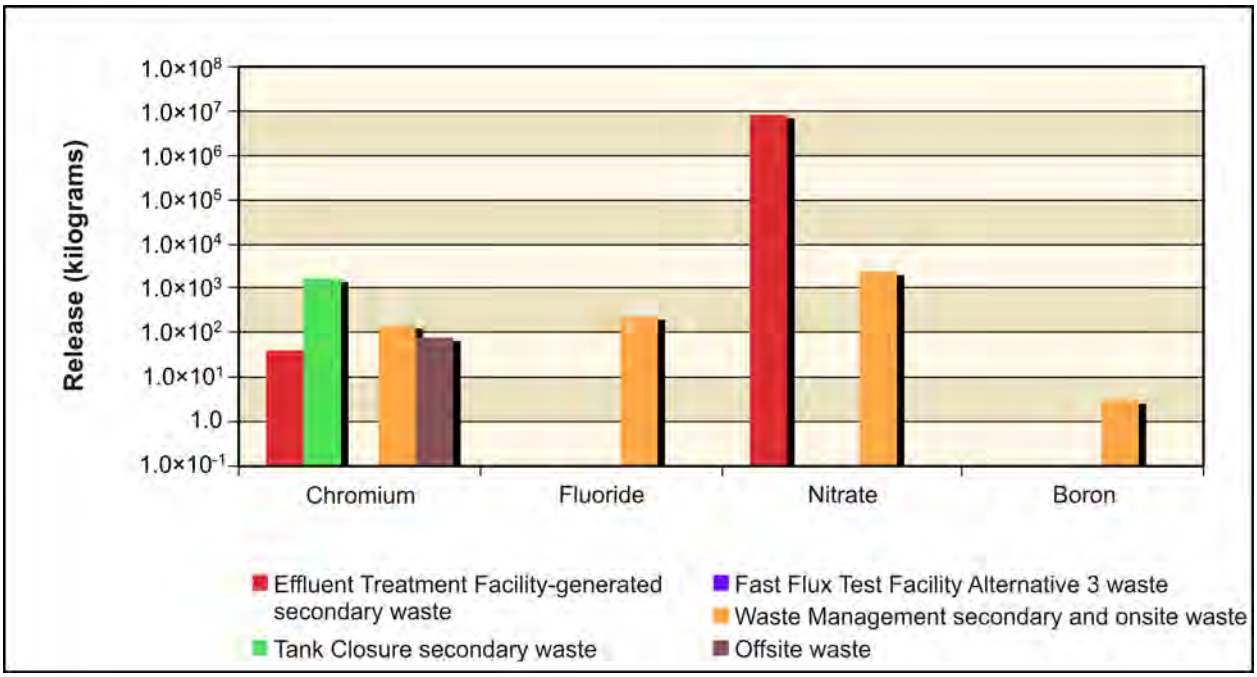


Figure 5–538. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

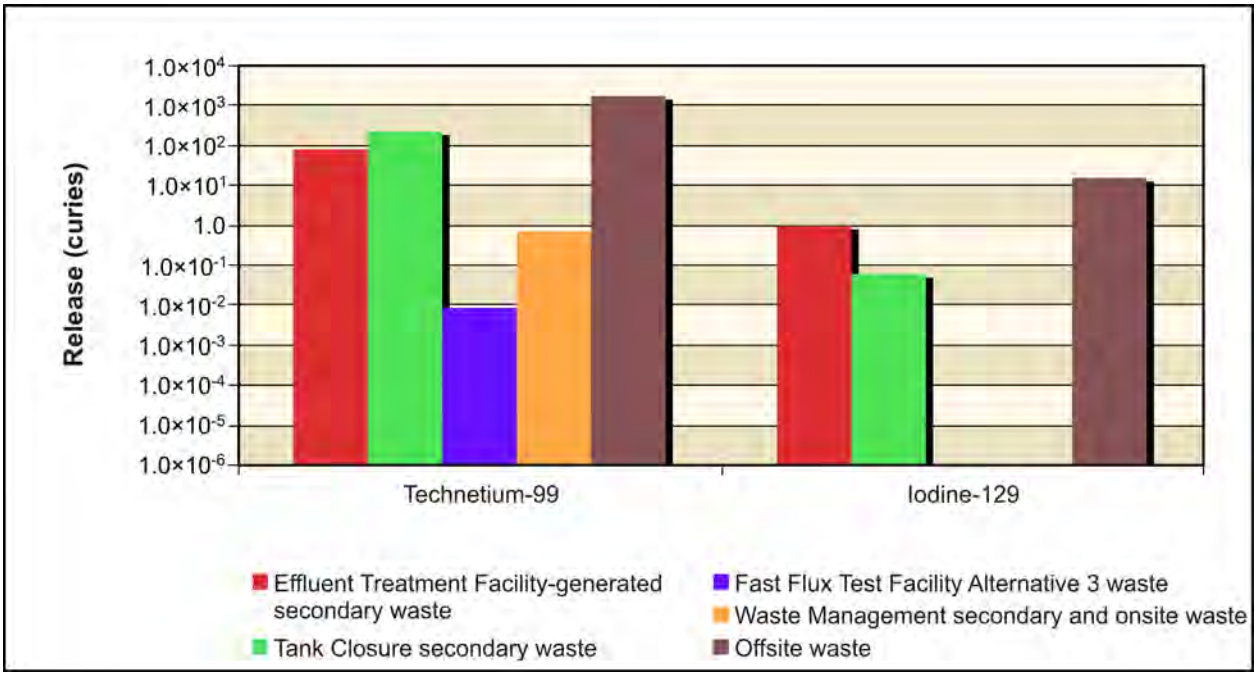


Figure 5–539. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

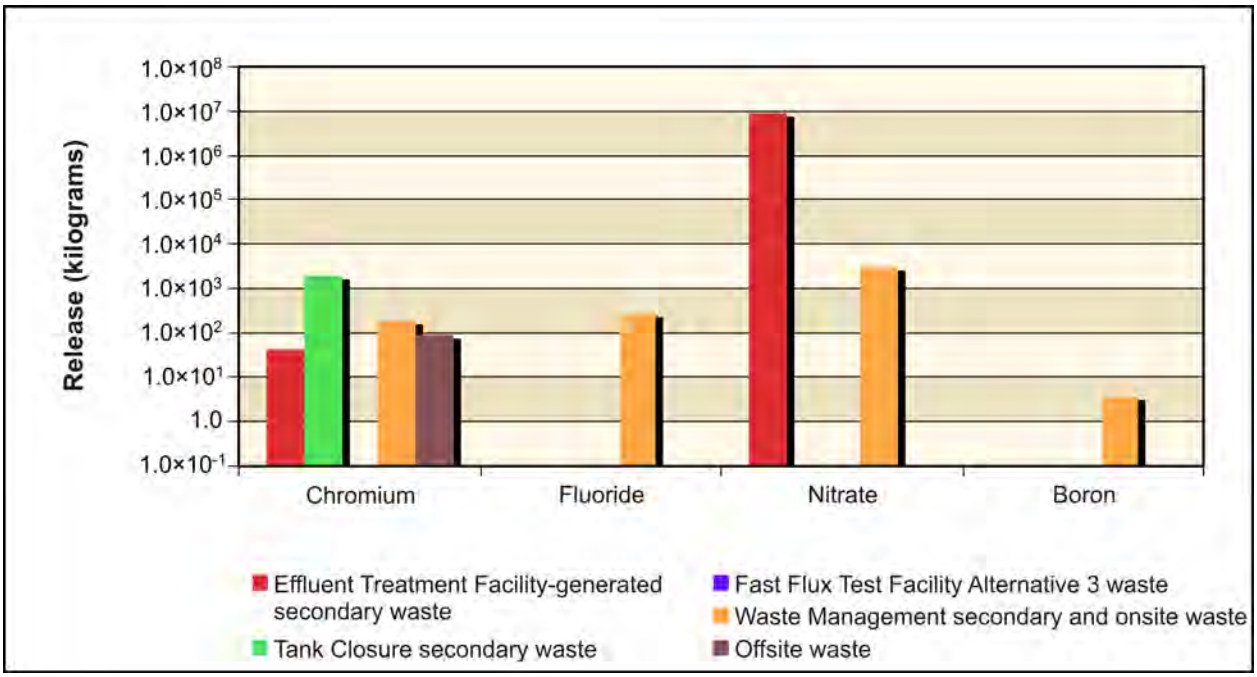


Figure 5–540. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

River Protection Project Disposal Facility

Figure 5–541 shows the estimated release at the RPPDF to the vadose zone for the radiological risk drivers and Figure 5–542, the chemical hazard drivers. Release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The vadose zone radiological sources from the RPPDF are technetium-99 (largest) and iodine-129 (smallest). The chemical hazard sources from the RPPDF are nitrate (largest) and chromium (smallest). Fluoride and boron are not released from the RPPDF.

Figure 5–543 shows the estimated release at the RPPDF to groundwater for the radiological risk drivers and Figure 5–544, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For iodine-129, technetium-99, chromium, and nitrate, the amount released to groundwater is essentially equal to the amount released to the vadose zone. Overall, about 100 percent of the radionuclide amount (curies) released to the vadose zone during the period of analysis reached the groundwater; approximately 100 percent of the chemical quantity (kilograms) reached the groundwater.

Figure 5–545 shows the estimated release at the RPPDF to the Columbia River for the radiological risk drivers and Figure 5–546, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For iodine-129, technetium-99, chromium, and nitrate the amount released to the Columbia River is essentially equal to the amount released to groundwater. Overall, 96 percent of the radionuclide amount (curies) released to the groundwater during the period of analysis reached the river; 96 percent of the chemical quantity (kilograms) reached the river.

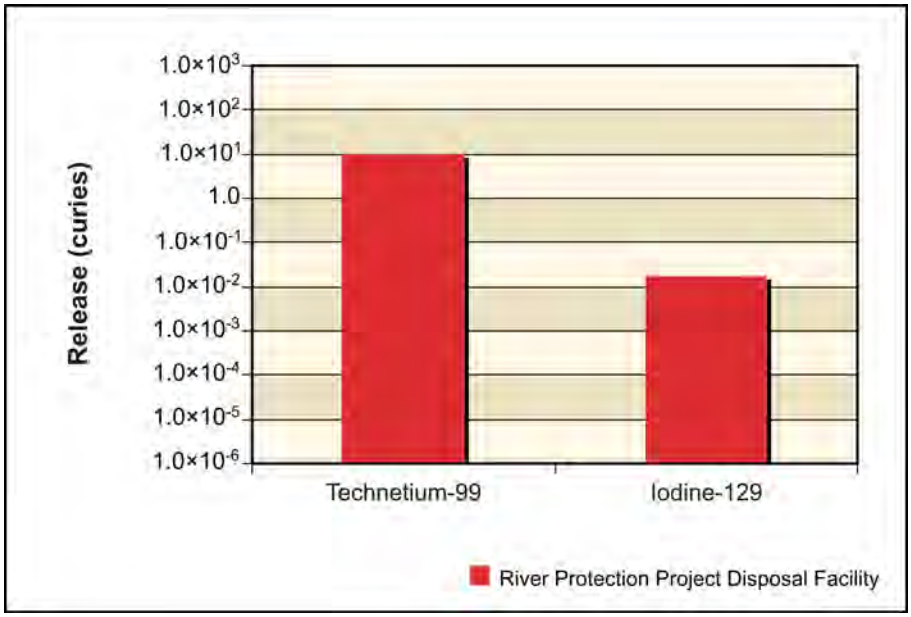


Figure 5–541. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases to River Protection Project Disposal Facility to Vadose Zone

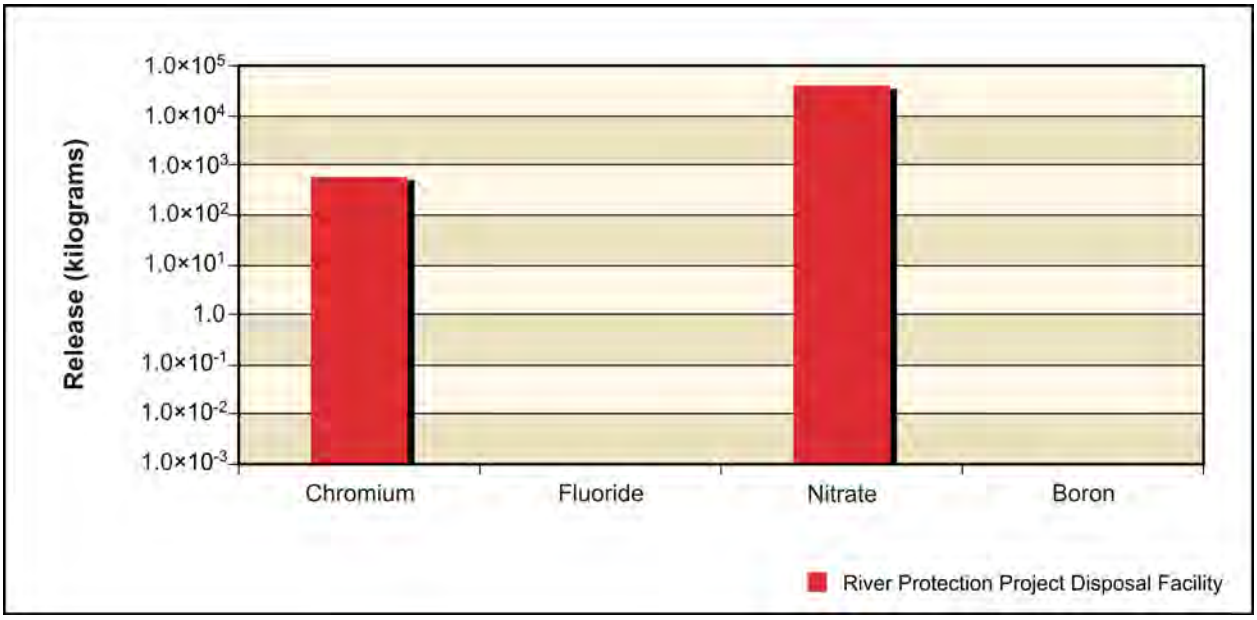


Figure 5–542. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to River Protection Project Disposal Facility to Vadose Zone

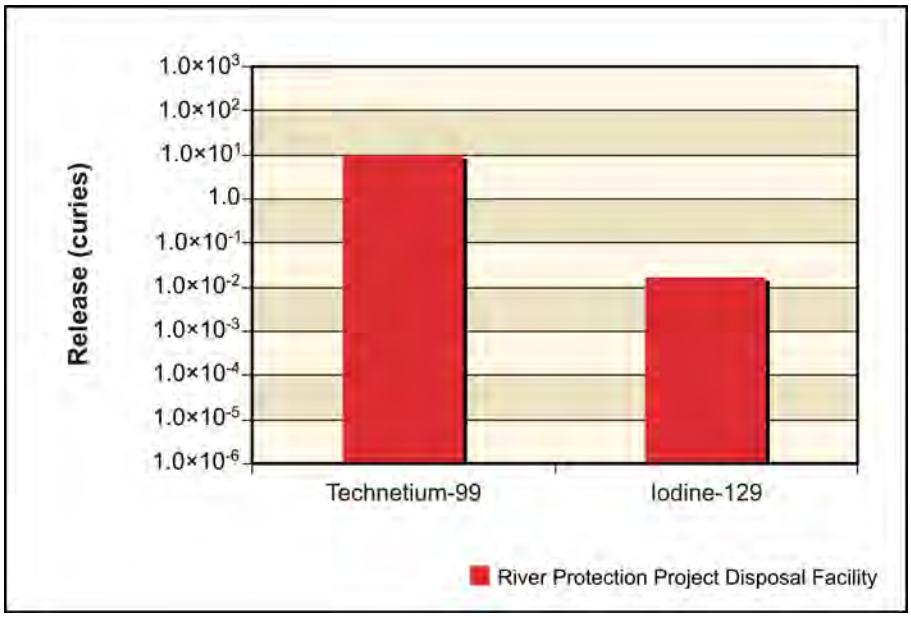


Figure 5–543. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases to River Protection Project Disposal Facility to Groundwater

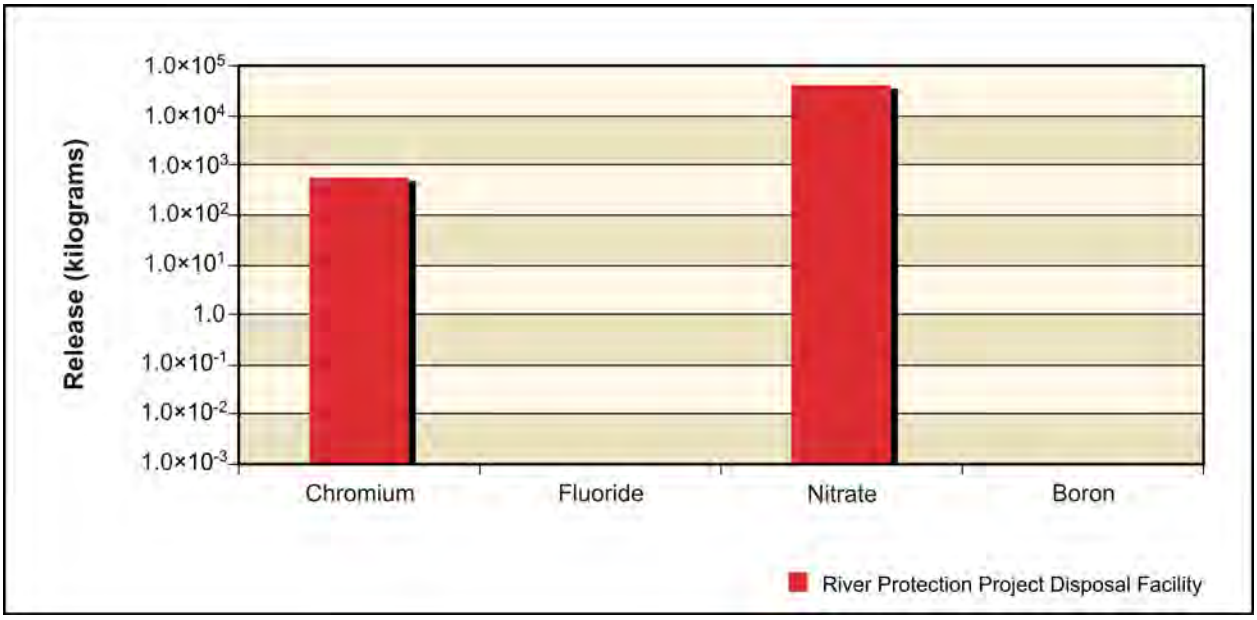


Figure 5–544. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to River Protection Project Disposal Facility to Groundwater

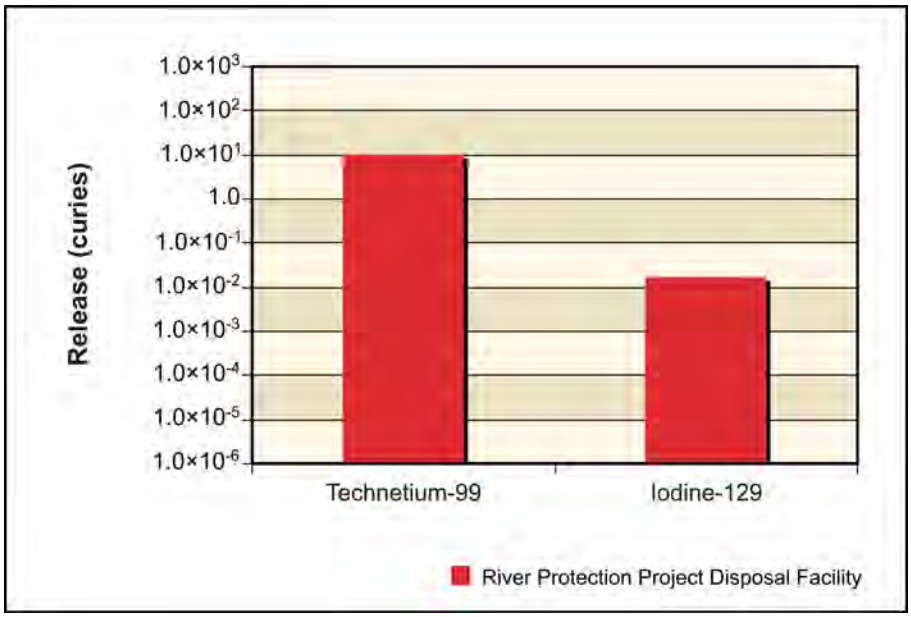


Figure 5–545. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Radiological Releases to River Protection Project Disposal Facility to Columbia River

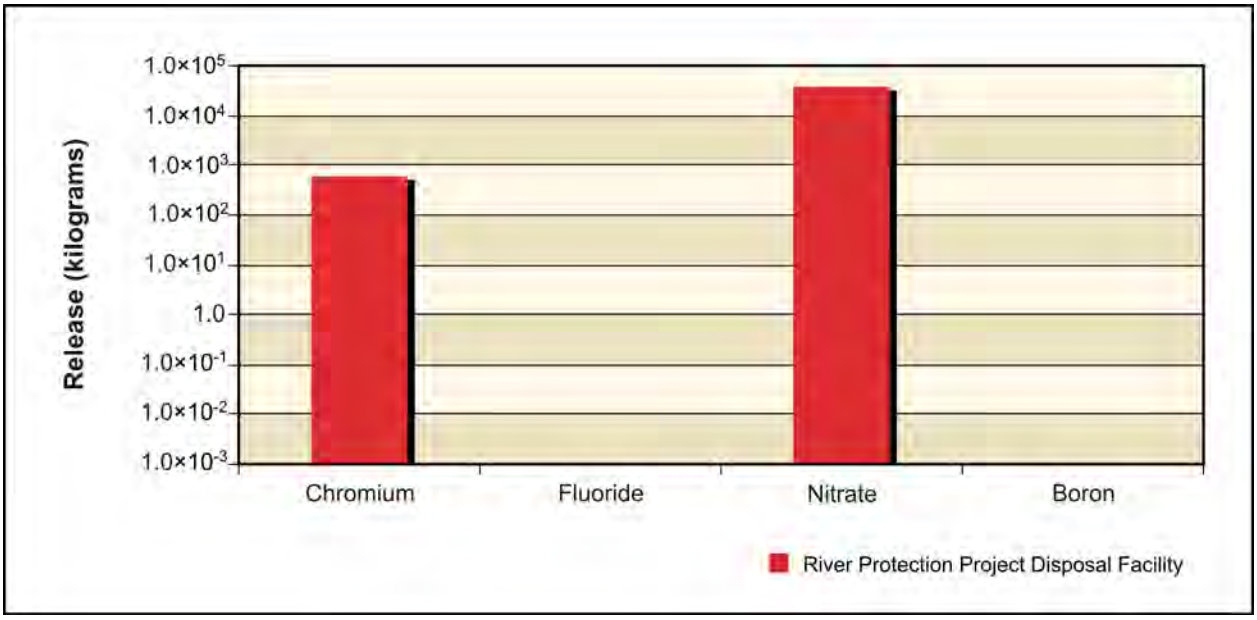


Figure 5–546. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chemical Releases to River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figure 5–547 through 5–551). The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Table 5–83 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–547 through 5–550 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate. Releases from IDF-East and the RPPDF cause groundwater concentrations to exceed benchmark concentrations at the Core Zone and Columbia River nearshore boundaries by less than one order of magnitude for iodine-129. Iodine-129 extends above the benchmark level during the later part of the period of analysis. Technetium-99, nitrate, and chromium do not exceed benchmark concentrations at the Core Zone or Columbia River nearshore boundaries.

Uranium-238 has no detectable release to the environment throughout the duration of the period of analysis. Figure 5–551 shows concentration versus time for total uranium.

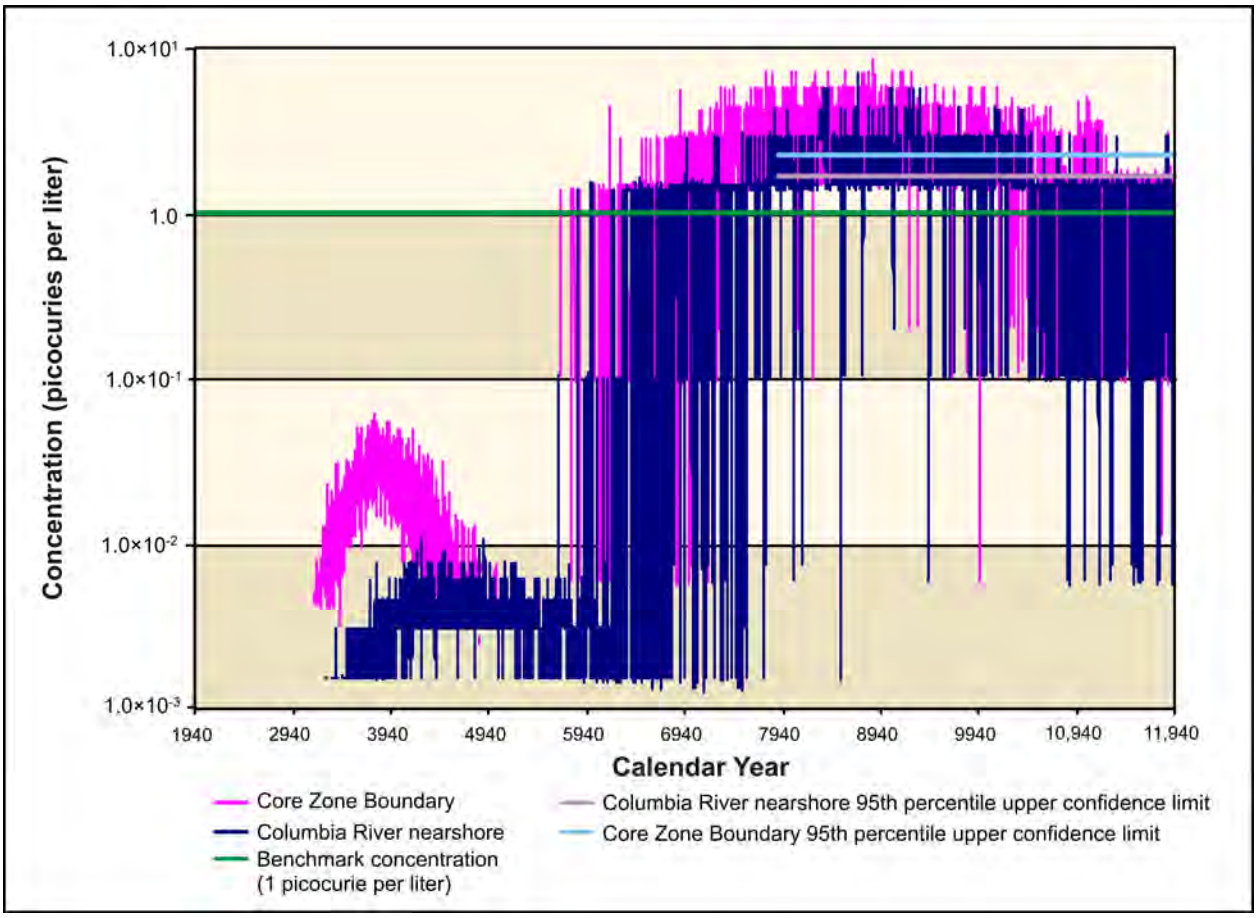


Figure 5–547. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Iodine-129 Concentration Versus Time

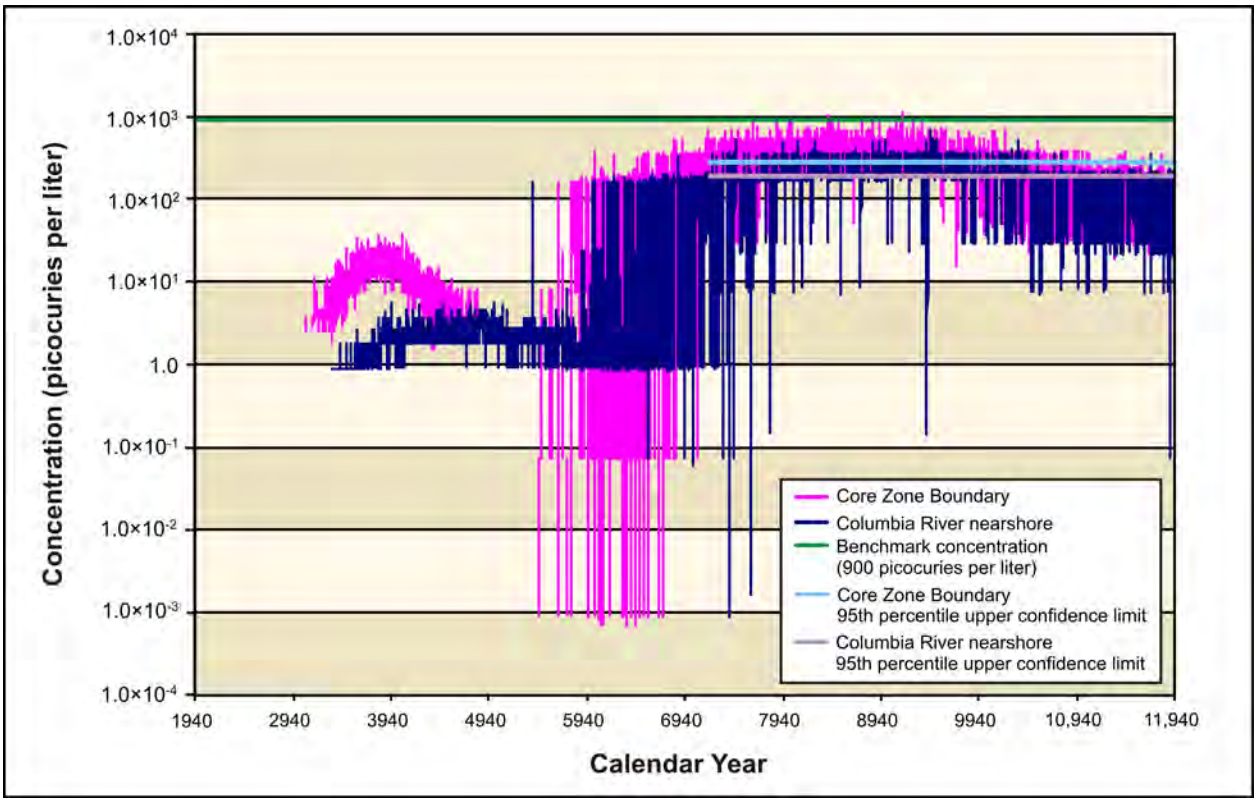


Figure 5–548. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Technetium-99 Concentration Versus Time

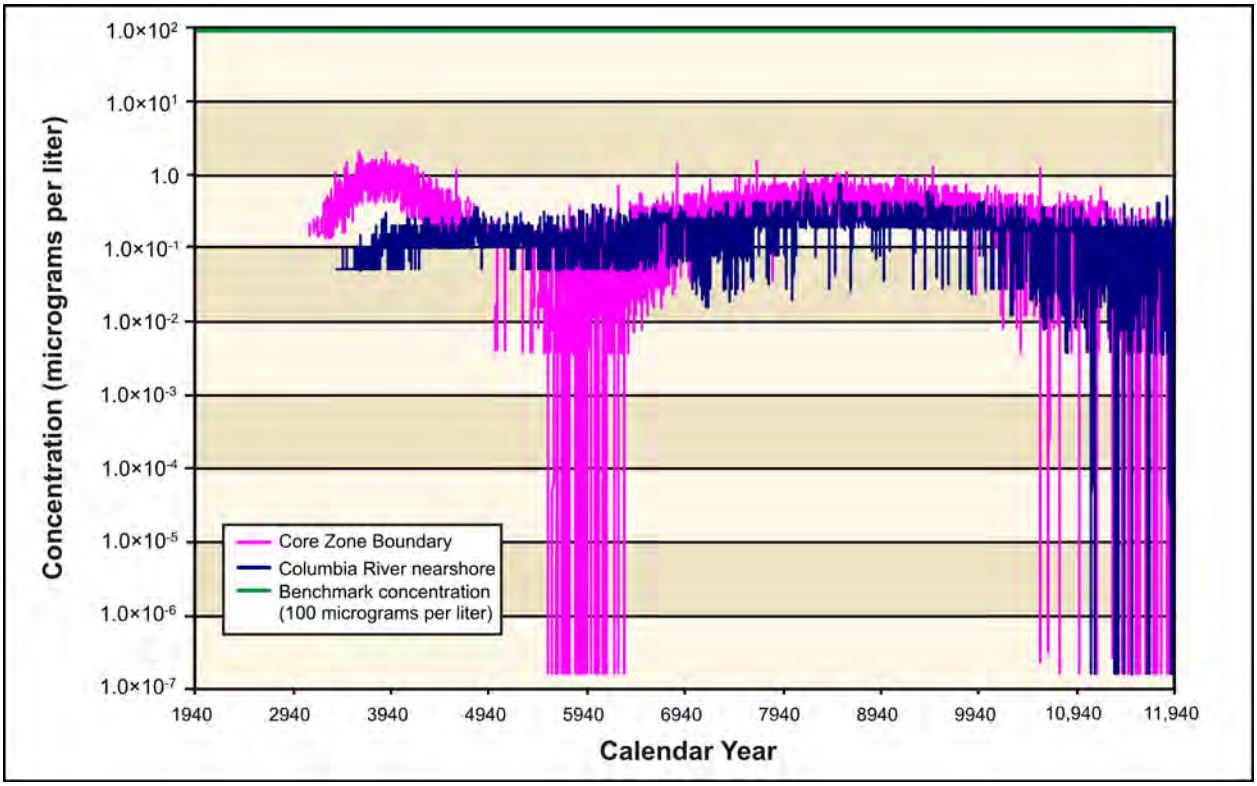


Figure 5–549. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Chromium Concentration Versus Time

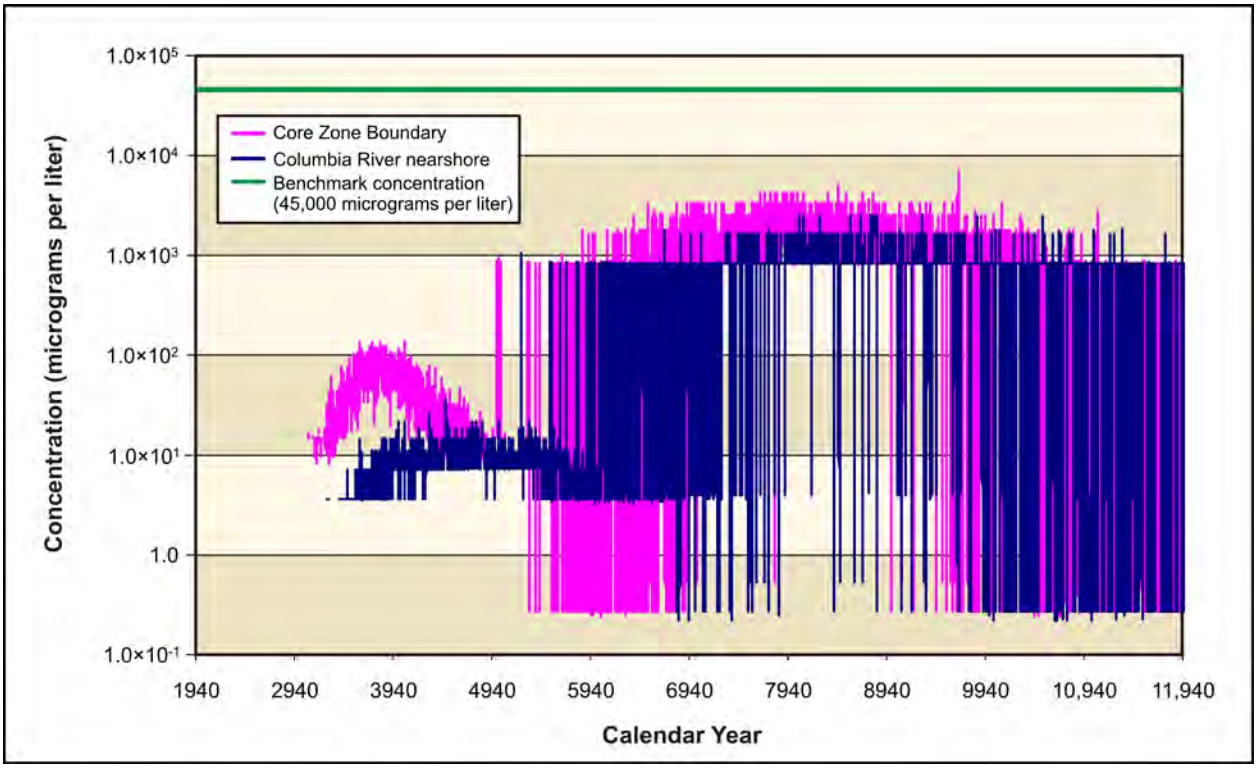


Figure 5–550. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Nitrate Concentration Versus Time

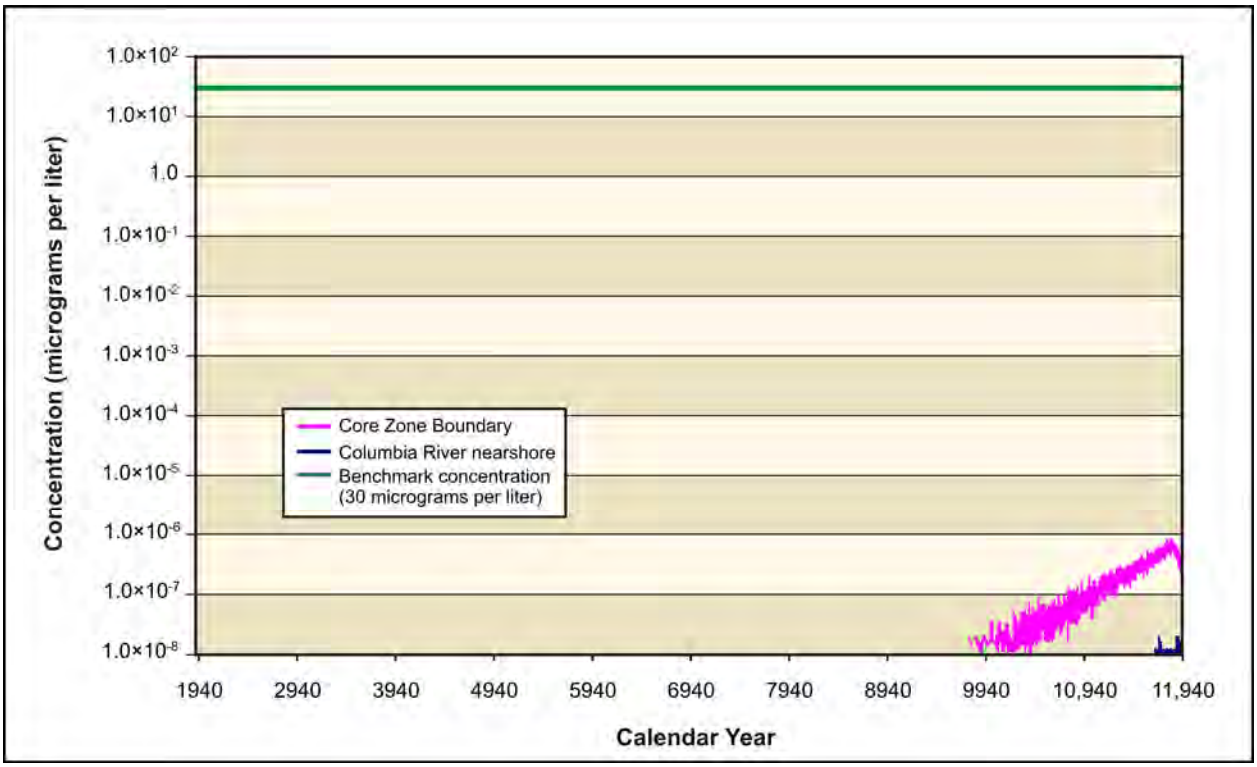


Figure 5–551. `Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Total Uranium Concentration Versus Time

Table 5–83. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,190**	33	**1,150**	674	900
	(9004)	(3825)	(9155)	(9451)	
Iodine-129	**19**	0.1	**9**	**7**	1
	(8739)	(3772)	(8858)	(8699)	
Chemical in micrograms per liter					
Chromium	4	2	2	1	100
	(8618)	(3856)	(3889)	(8528)	
Fluoride	0	0	1	0	4,000
	(8035)	(1940)	(7258)	(8913)	
Nitrate	14,200	149	5,630	2,440	45,000
	(8522)	(3811)	(9653)	(8827)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

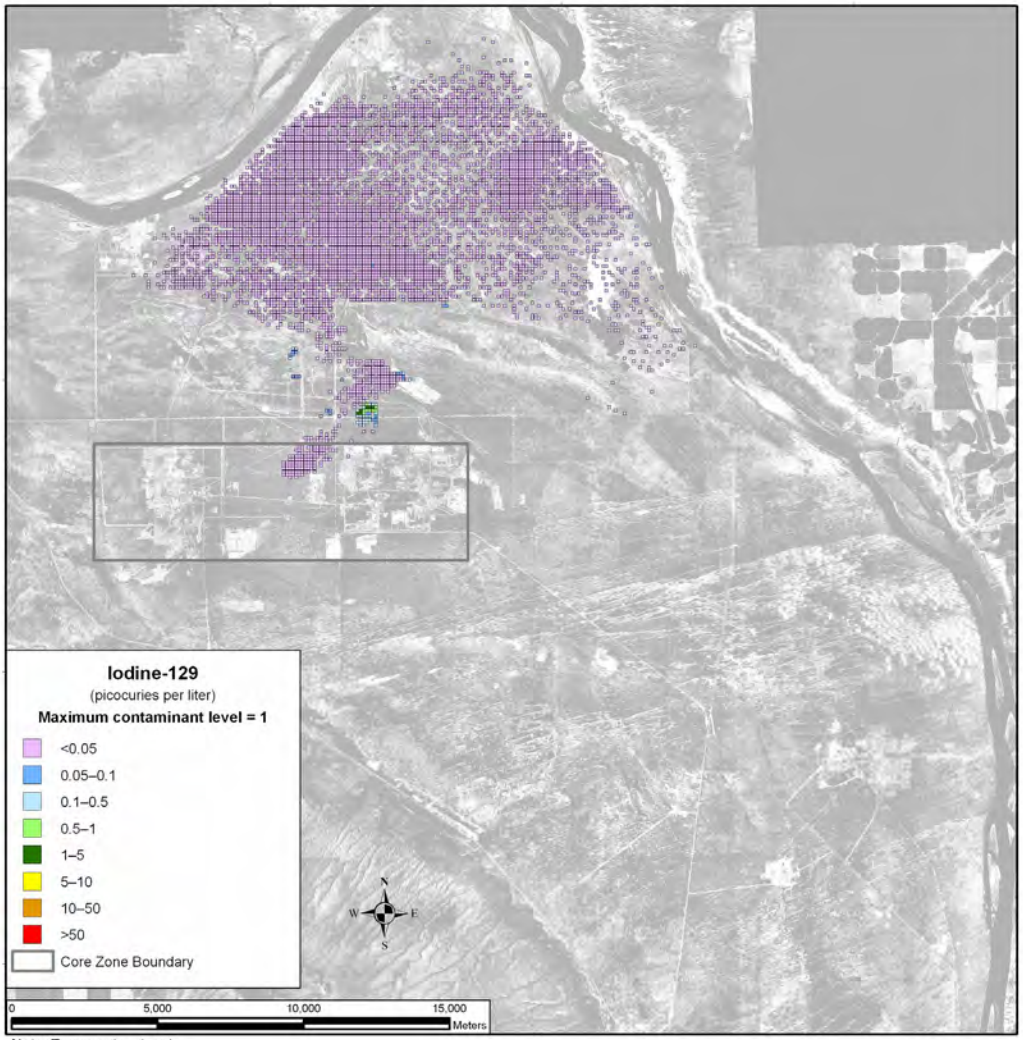
ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–552 through 5–564). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

Figure 5–552 shows the spatial distribution of groundwater concentration for iodine-129 during CY 3890. Releases from the RPPDF result in a groundwater plume heading north through Gable Mountain. This plume does not exceed iodine-129's benchmark concentration north of the Core Zone. During CY 7140, releases from IDF-East create a plume exceeding the benchmark, extending from the 200-East Area moving eastward towards the Columbia River (see Figure 5–553). Also by CY 7140, most of the RPPDF plume continues to move north and reaches the Columbia River. By CY 11,885 most of the mass in the IDF-East plume is still moving eastward toward the Columbia River, with only small, isolated pockets of high concentration exceeding the benchmark (see Figure 5–554). Technetium-99 (see Figures 5–555 through 5–557), chromium (see Figures 5–558 through 5–560), and nitrate (see Figures 5–561 through 5–563) show similar spatial distributions at selected times, except none of them exceed their benchmark concentrations. Iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity).

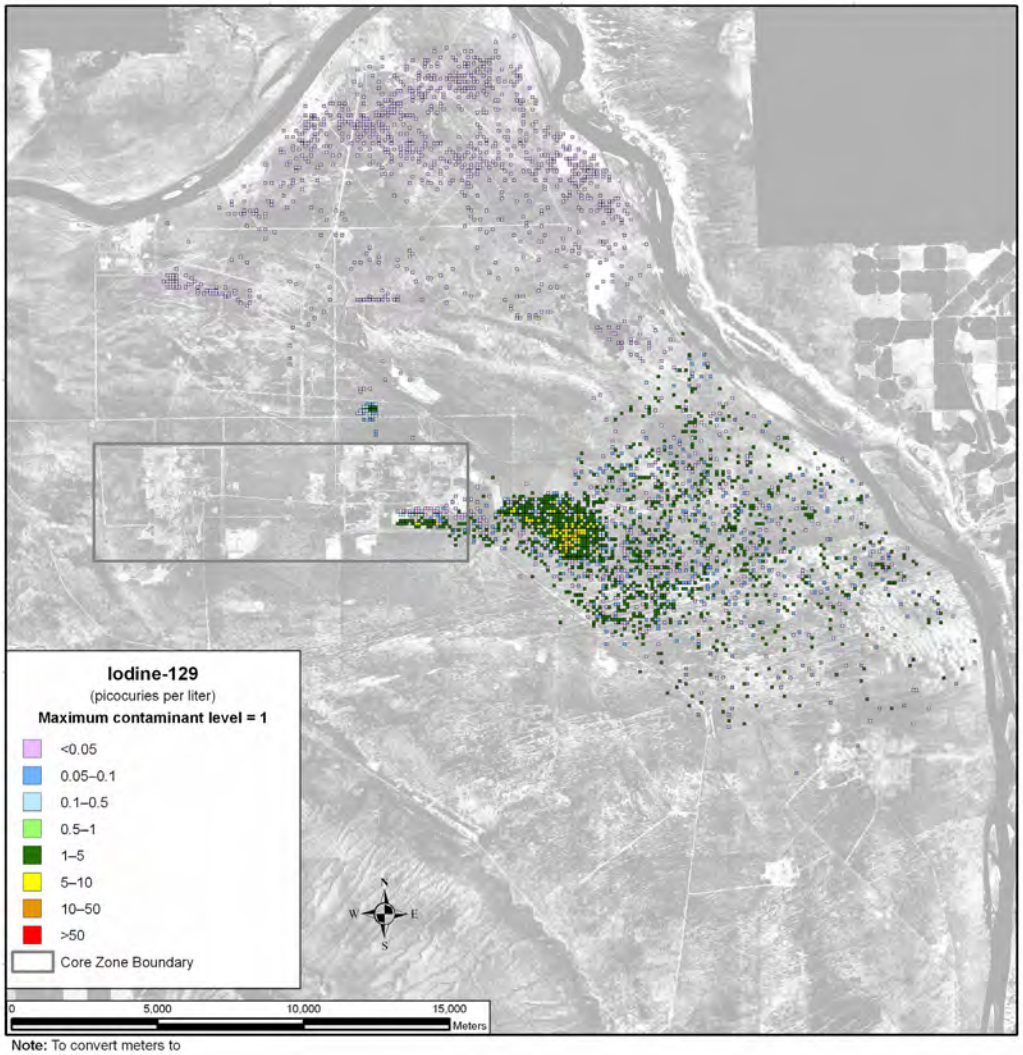
Total uranium shows a different spatial distribution over time. This COPC is not as mobile as those discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–564 shows the distribution of total uranium during CY 11,885. Releases from the RPPDF result in a groundwater plume that starts in the Core Zone and

moves north through Gable Mountain. However, this plume does not exceed the benchmark concentration during the period of analysis.



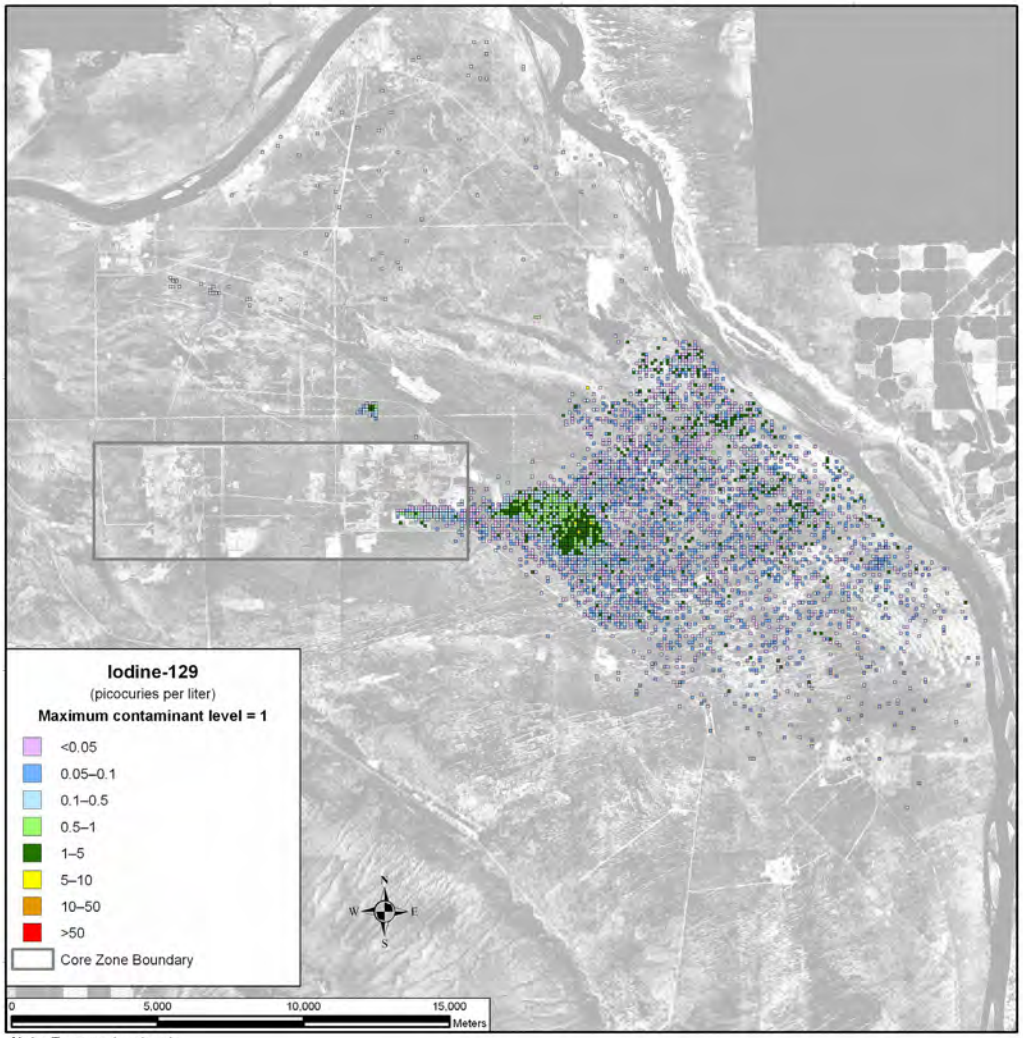
Note: To convert meters to feet, multiply by 3.281

Figure 5–552. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



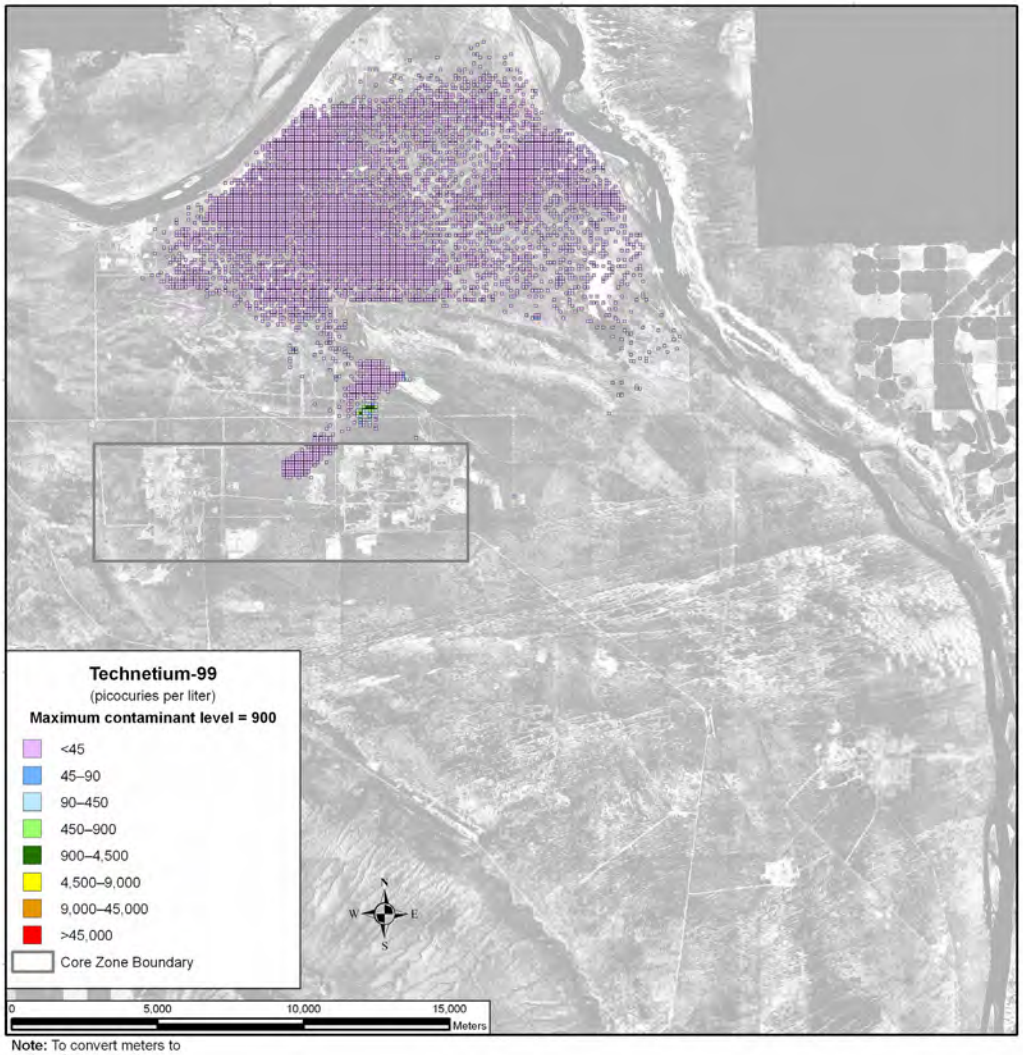
Note: To convert meters to feet, multiply by 3.281

Figure 5–553. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



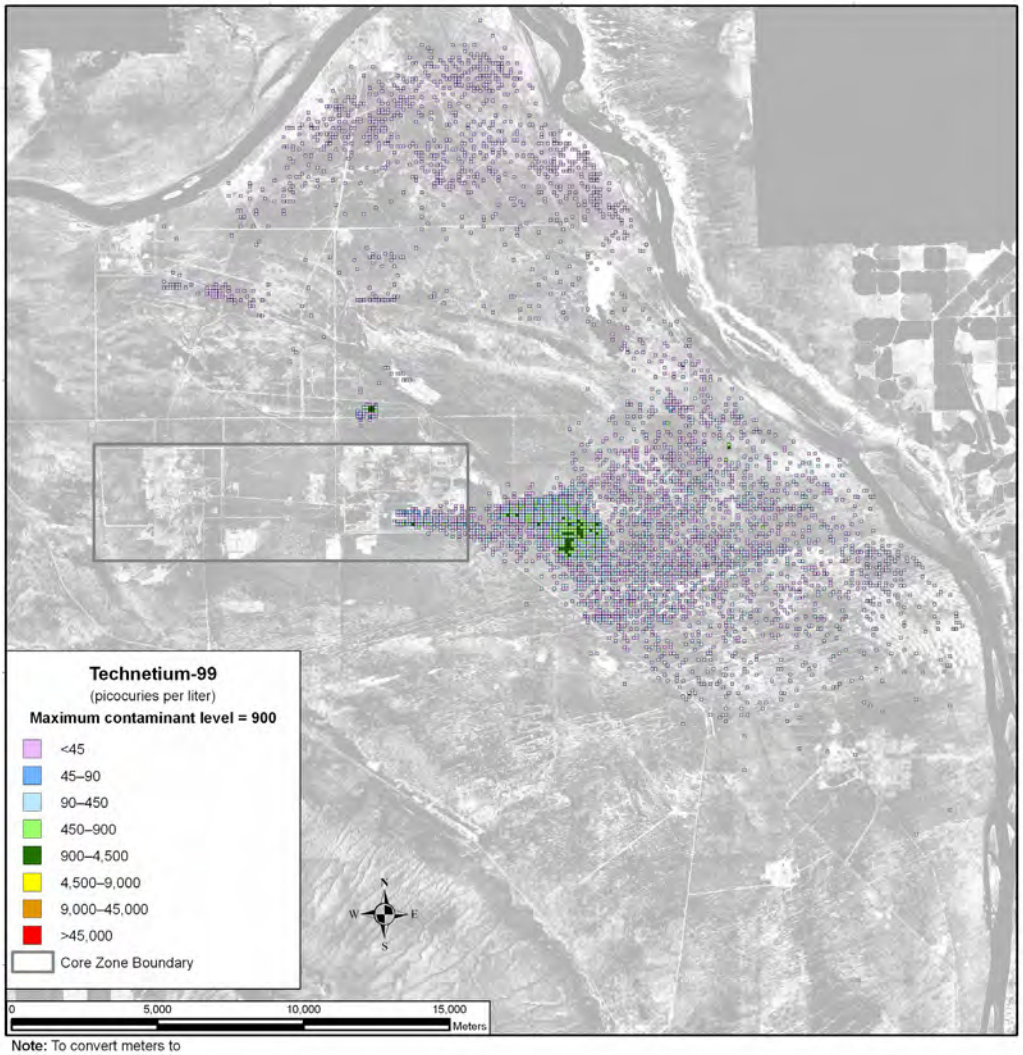
Note: To convert meters to feet, multiply by 3.281

Figure 5–554. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



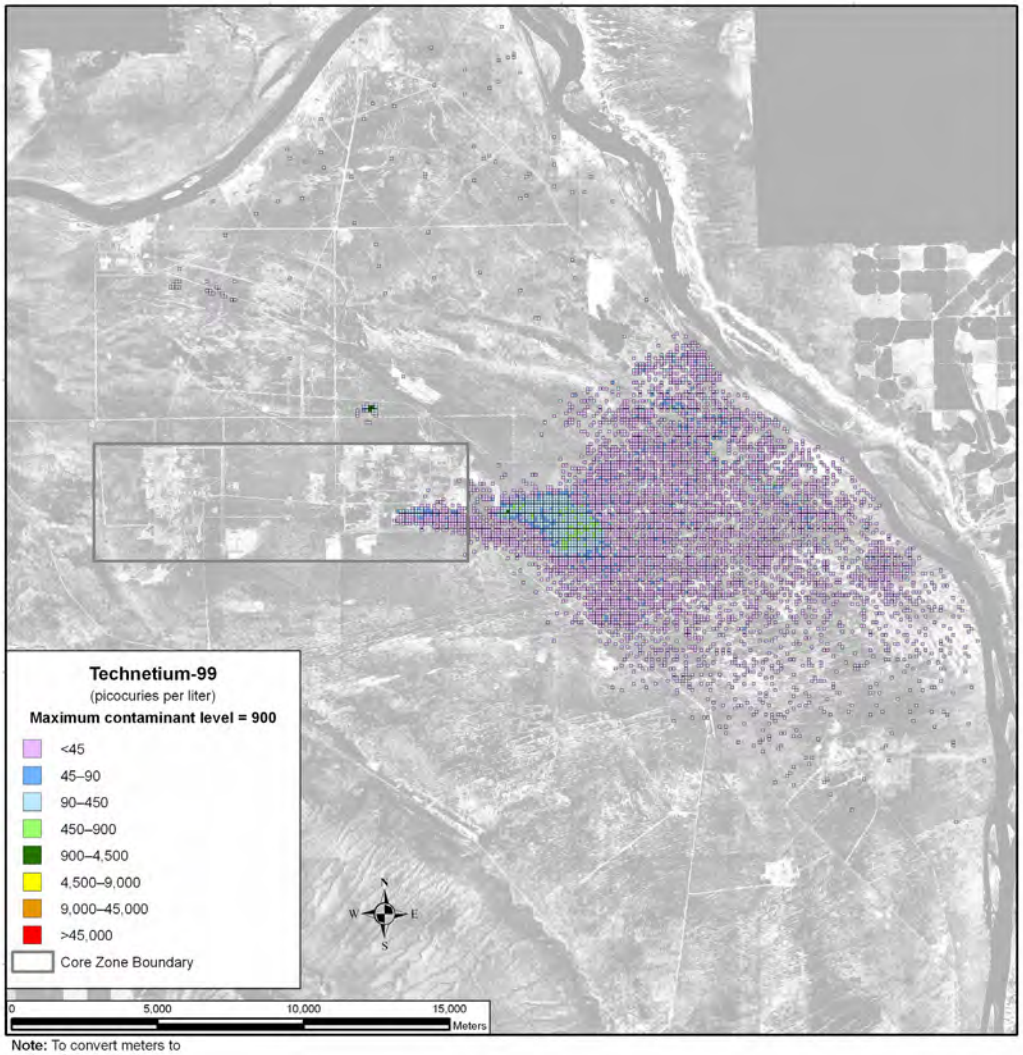
Note: To convert meters to feet, multiply by 3.281

Figure 5–555. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



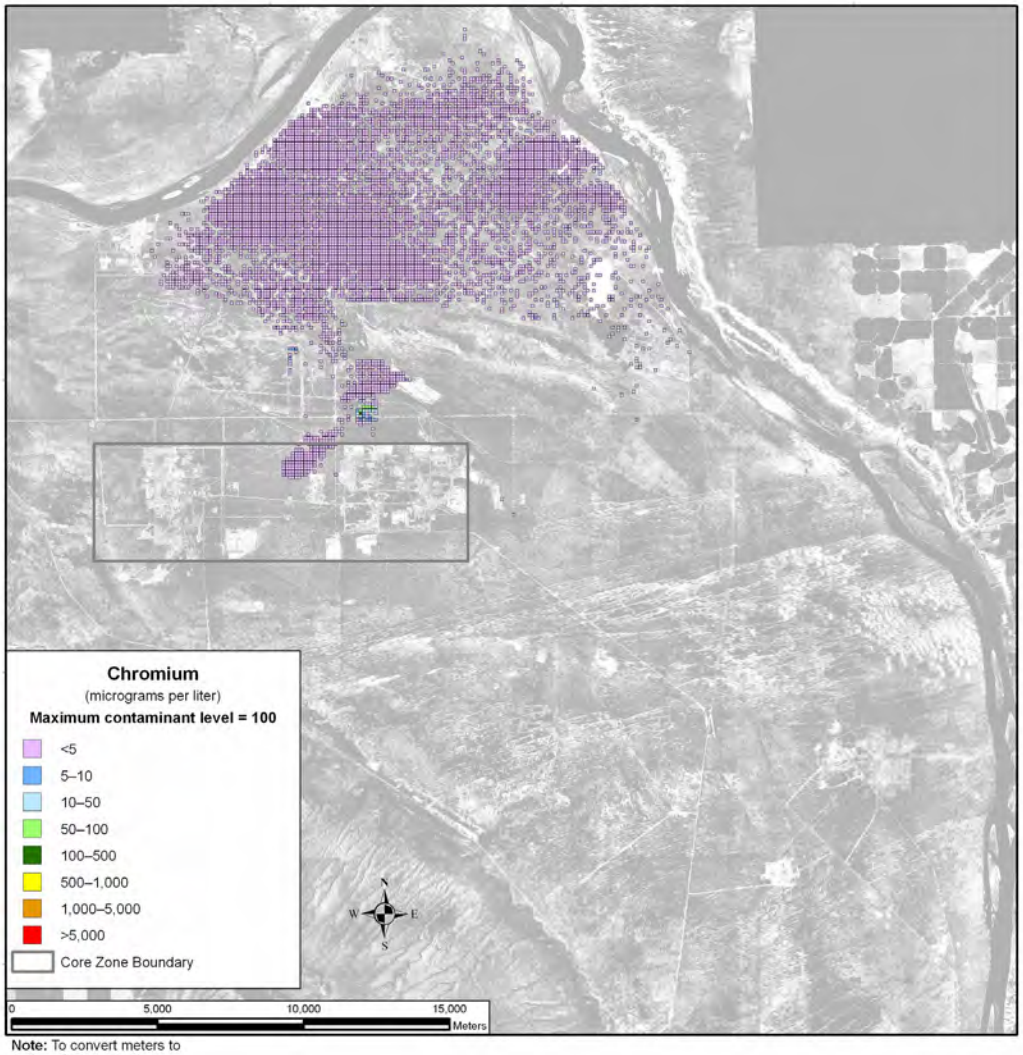
Note: To convert meters to feet, multiply by 3.281

Figure 5–556. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



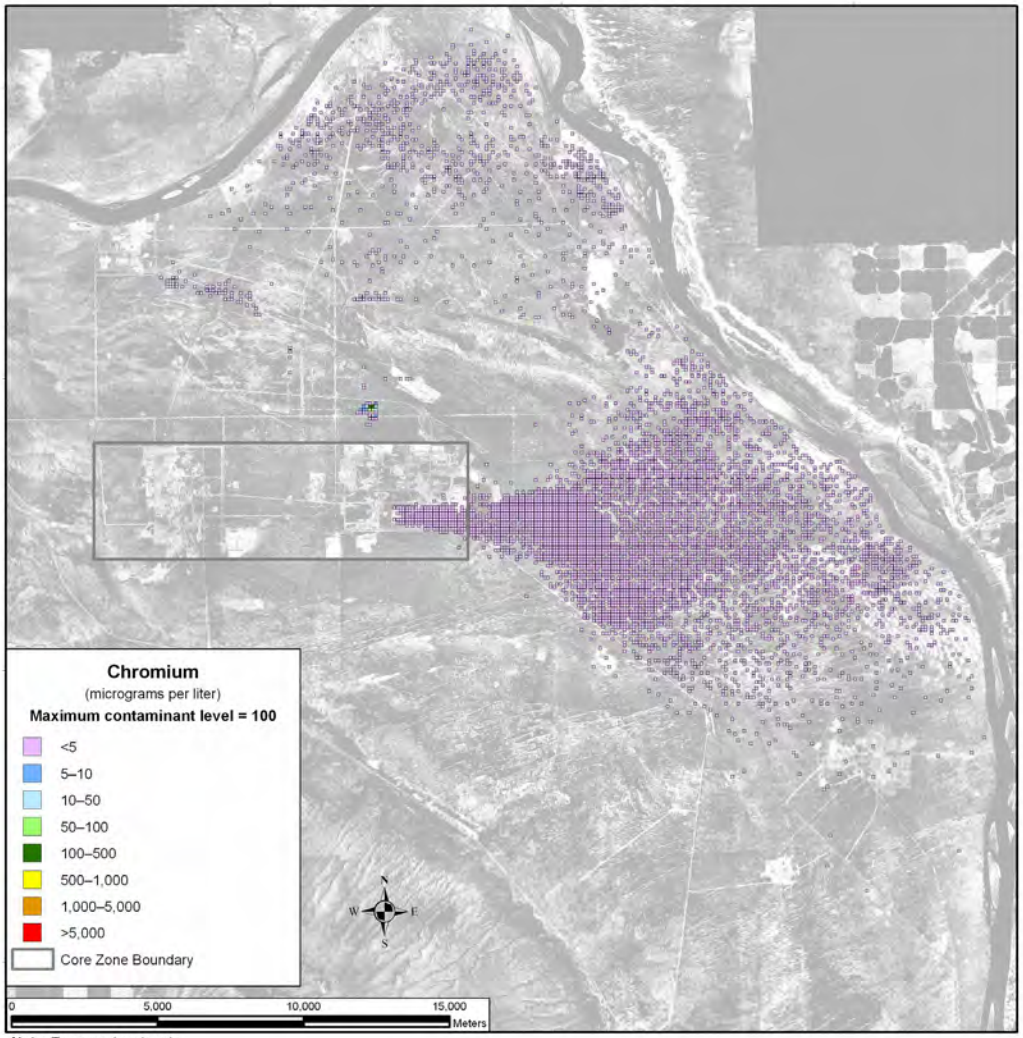
Note: To convert meters to feet, multiply by 3.281

Figure 5–557. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



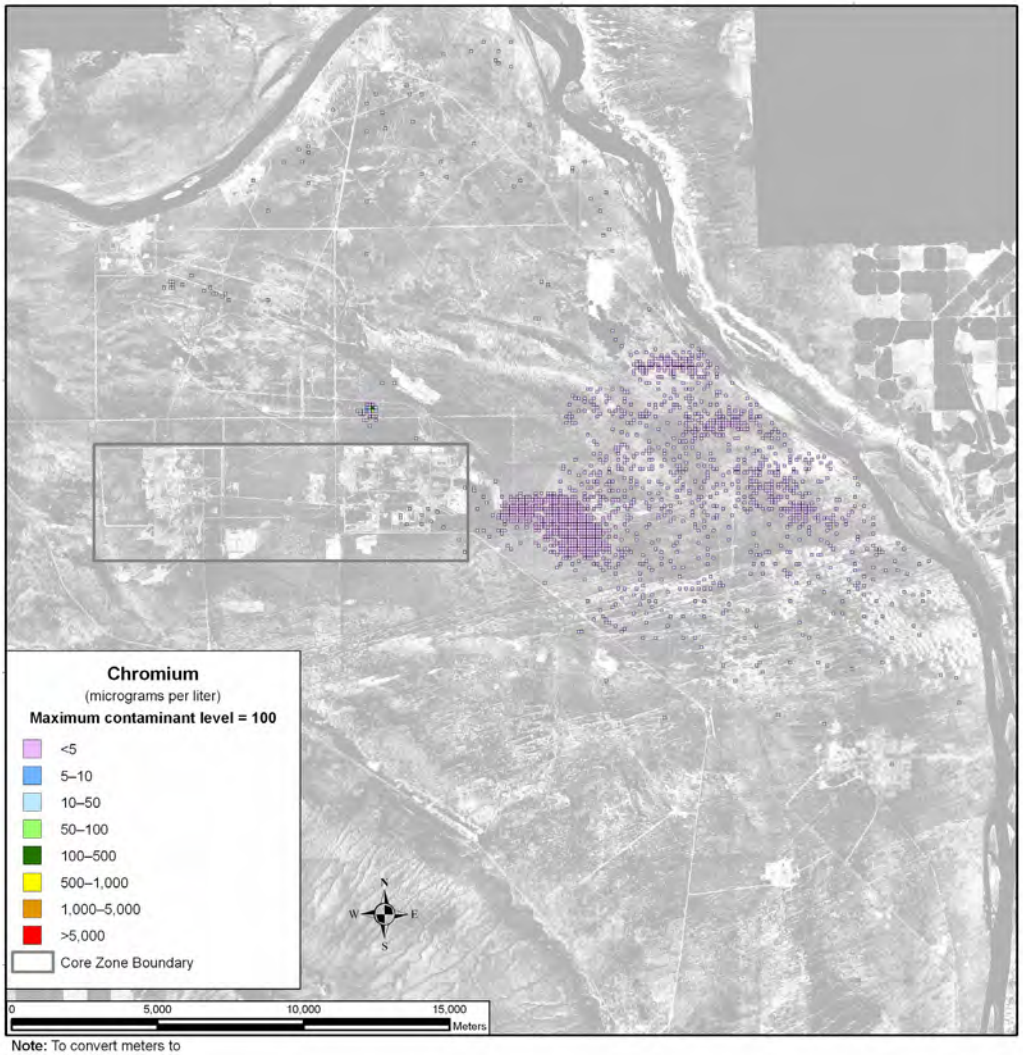
Note: To convert meters to feet, multiply by 3.281

Figure 5–558. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



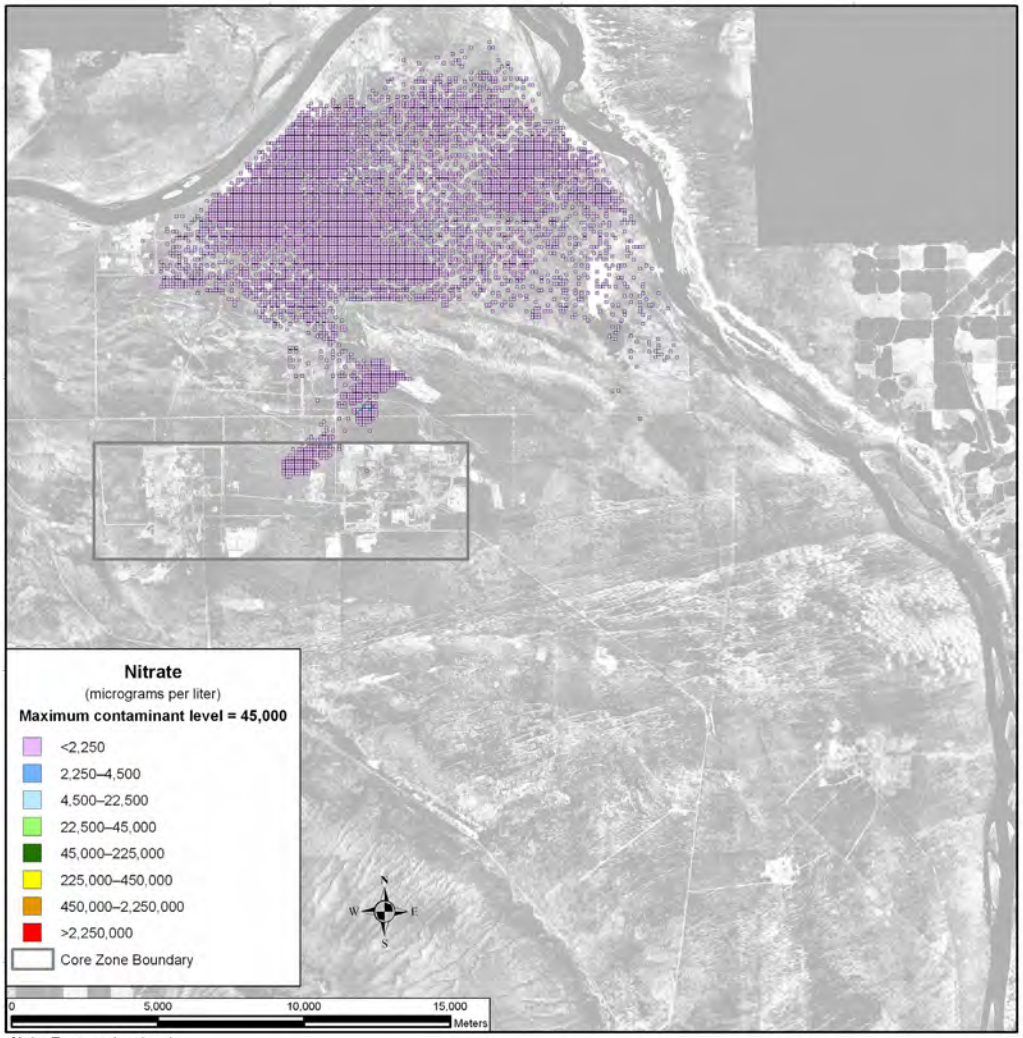
Note: To convert meters to feet, multiply by 3.281

Figure 5–559. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



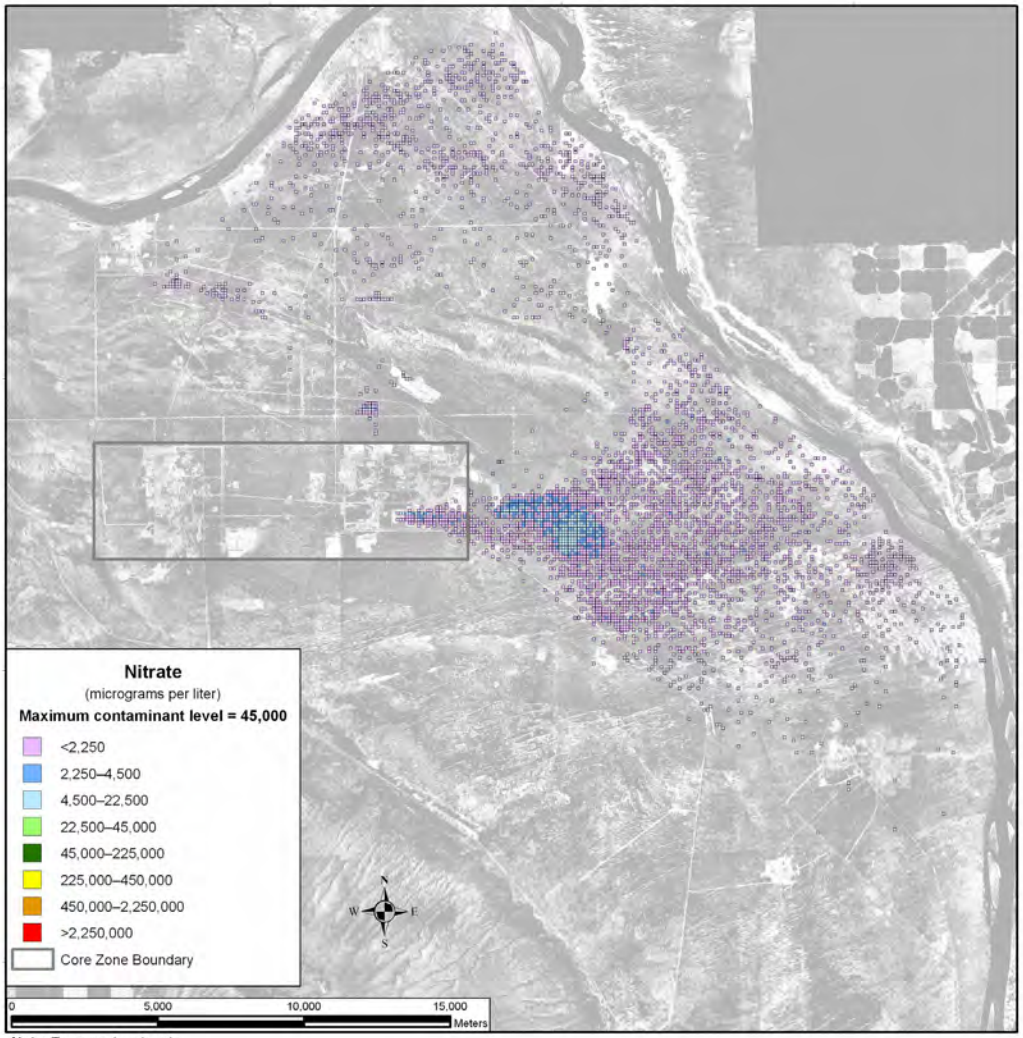
Note: To convert meters to feet, multiply by 3.281

Figure 5–560. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



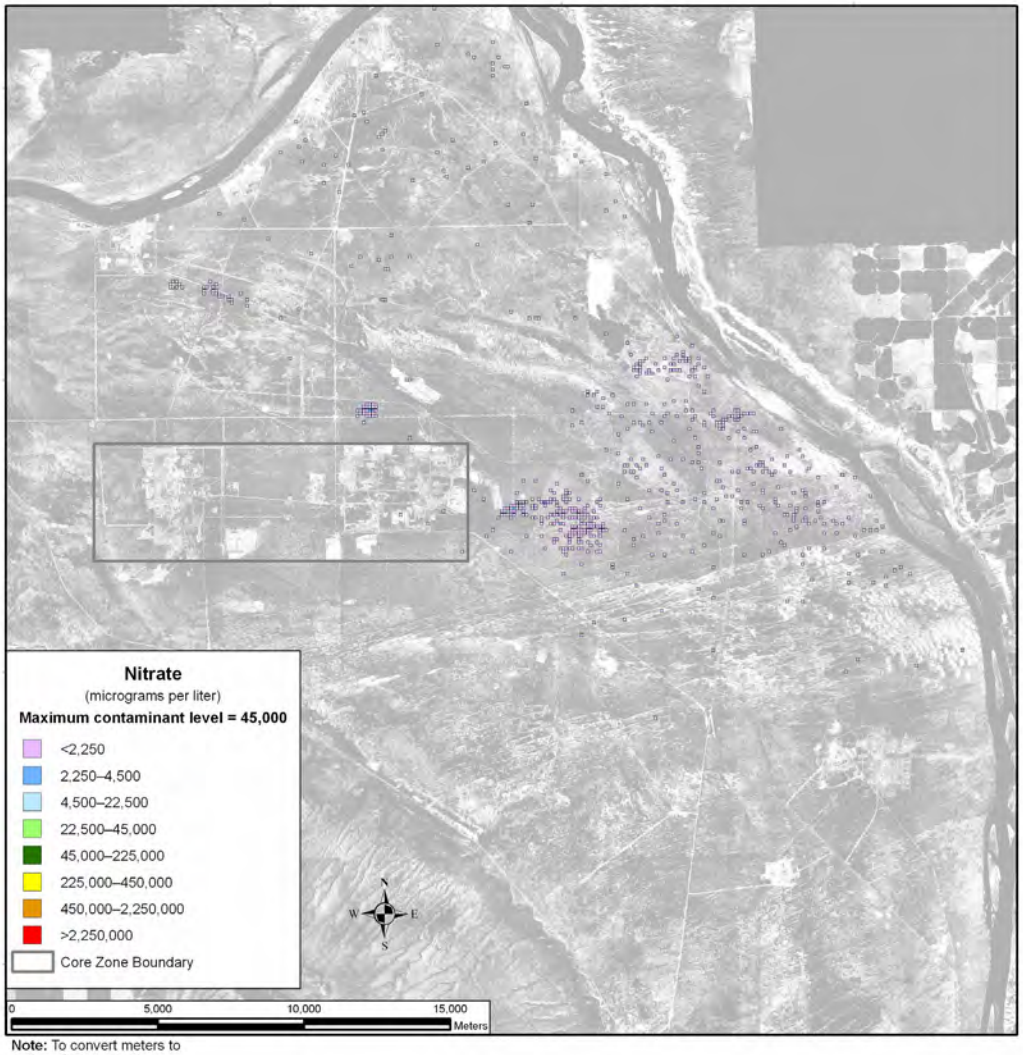
Note: To convert meters to feet, multiply by 3.281

Figure 5–561. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



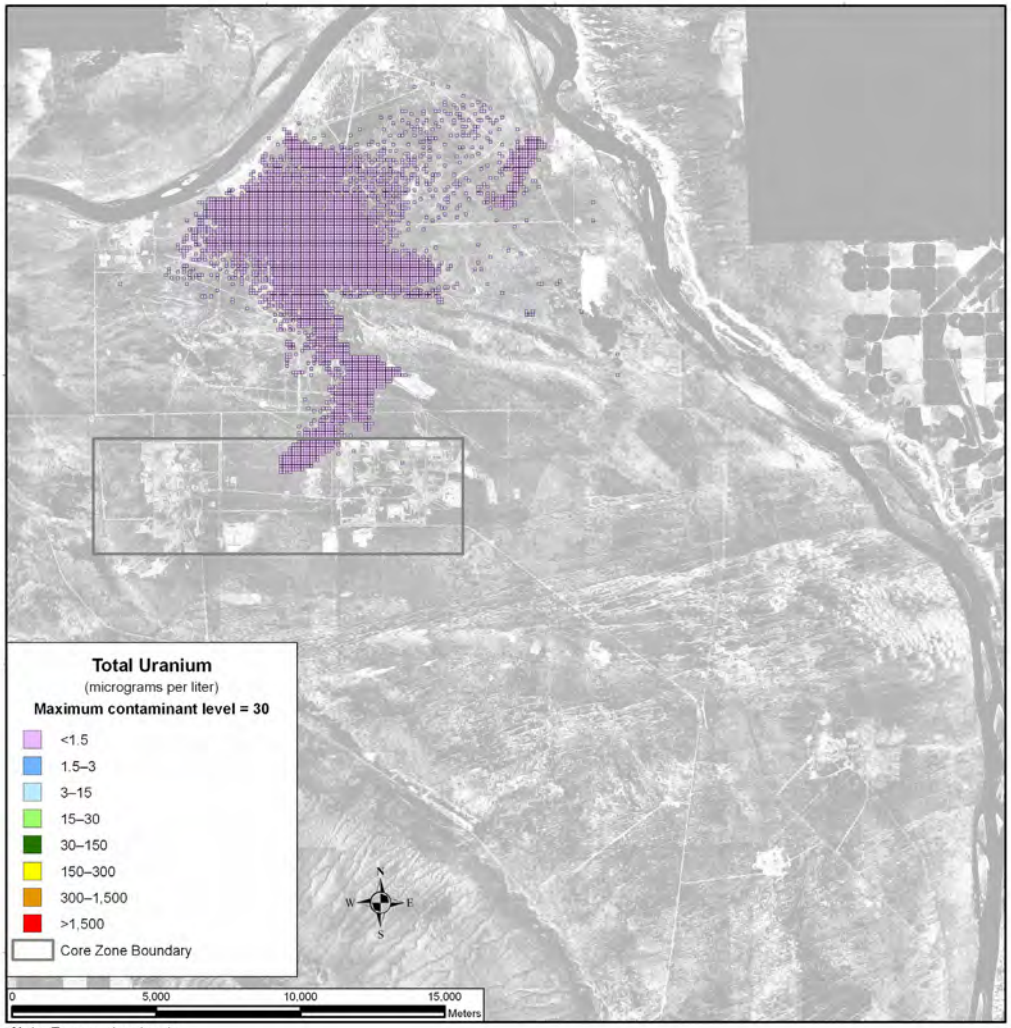
Note: To convert meters to feet, multiply by 3.281

Figure 5–562. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–563. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–564. Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 1, Subgroup 1-G, in general, the inventory remaining at IDF-East and the RPPDF, which are available for release to the environment at the start of the post-disposal period, are predominant contributors.

For the conservative tracers, concentrations slightly outside the Core Zone Boundary exceed benchmark standards by one order of magnitude during most of the period of analysis. Concentrations at the Columbia River are about one order of magnitude smaller. The intensities and areas of these groundwater plumes peak between CYs 7140 and 11,885.

For uranium-238 and total uranium, limited mobility is an important factor governing the timeframes and scale of groundwater impacts. The concentrations of these retarded species do not exceed the benchmark at the Core Zone Boundary or Columbia River.

5.3.1.2.2 Disposal Group 2

Disposal Group 2 is characterized by an operational completion date of CY 2100 for both IDF-East and the RPPDF. Under Disposal Group 2, IDF-East would have a large capacity (425,000 cubic meters [556,000 cubic yards]) and the RPPDF would have a larger capacity (8,370,000 cubic meters [10,900,000 cubic yards]). These capacities were designed to meet the waste generation volumes associated with Tank Closure Alternatives 2A and 6B, either FFTF Decommissioning Alternative 2 or 3, and onsite- and offsite-generated waste.

5.3.1.2.2.1 Disposal Group 2, Subgroup 2-A

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Subgroup 2-A covers disposal of waste generated under Tank Closure Alternative 2A and FFTF Decommissioning Alternative 2 or 3, as well as, onsite- and offsite-generated waste. Waste would be converted to IHLW and ILAW glass. IHLW would be stored on site, while ILAW glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods were identified for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, as follows:

- The disposal period was assumed to start with the onset of disposal operations in IDF-East in CY 2009 and continue through CY 2100, when the disposal facility would be operationally closed. During this disposal period, the materials in this permitted, operational facility would not be available for release to the environment due to engineered control of potential releases from materials placed in IDF-East.

- The post-disposal period for IDF-East was assumed to start in CY 2101. After CY 2101, the materials in IDF-East would become available for release to the environment. The post-disposal periods would continue through the 10,000-year period of analysis until CY 11,940. For the purpose of analyzing long-term groundwater impacts of Waste Management Alternative 2, IDF-East is assumed to be covered by a barrier that limits infiltration for the first 500 hundred years of the IDF-East post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A. Complete results are tabulated in Appendices M, N, and O. The discussion in this section of long-term impacts associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: boron, chromium, fluoride, and nitrate

The COPC drivers for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. No chemical risk is predicted. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, boron, chromium, fluoride, and nitrate) are all mobile (i.e., move with groundwater) and long-lived (relative to the 10,000-year period of analysis), or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, in terms of the total amounts of radionuclide and chemical COPCs released to the vadose zone, groundwater, and Columbia River during the 10,000-year period of analysis. Releases of radionuclides are totaled in curies; chemicals in kilograms (see Figures 5–565 through 5–570). Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility Figure 5–565 shows the estimated release at IDF-East to the vadose zone for the radiological risk drivers and Figure 5–566, the chemical COPCs hazard drivers. The predominant source of technetium-99 in the vadose zone is offsite-generated waste (77 percent), followed by tank closure secondary waste (19 percent), and ETF-generated secondary waste (4 percent). The sources of the iodine-129 release are offsite waste (85 percent) and ETF-generated secondary waste (14 percent). All of the fluoride and boron released to the vadose zone are from waste management secondary waste and onsite-generated waste. All of the nitrate released is from ETF-generated secondary waste. The predominant source of chromium (81 percent) is tank closure secondary waste, followed by waste management secondary and onsite-generated waste (8 percent), ILAW glass (5 percent), and offsite-generated waste (4 percent).

Figure 5–567 shows the estimated release at IDF-East to groundwater for the radiological risk drivers and Figure 5–568, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Nearly all of the chromium (96 percent) and essentially all (99 percent) of the fluoride, boron, and nitrate are released to the groundwater from the vadose zone. Most of the technetium-99 (89 percent) and iodine-129 (91 percent) are released to the groundwater from the vadose zone.

Figure 5–569 shows the estimated release at IDF-East to the Columbia River for the radiological risk drivers and Figure 5–570, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPCs. About 89 percent of the groundwater technetium-99 and 91 percent of the iodine-129 is released to the Columbia River. Almost all of the groundwater chromium (97 percent), fluoride (97 percent), nitrate (greater than 98 percent), and boron (97 percent) are released to the Columbia River.

Overall, 86 percent of the technetium-99 and 89 percent of the iodine-129 from the vadose zone are released to the Columbia River. Overall, almost all of the chromium (93 percent), fluoride (96 percent), nitrate (98 percent), and boron (96 percent) from the vadose zone are released to the Columbia River. There is essentially no release of uranium-238 or total uranium to the groundwater or to the Columbia River.

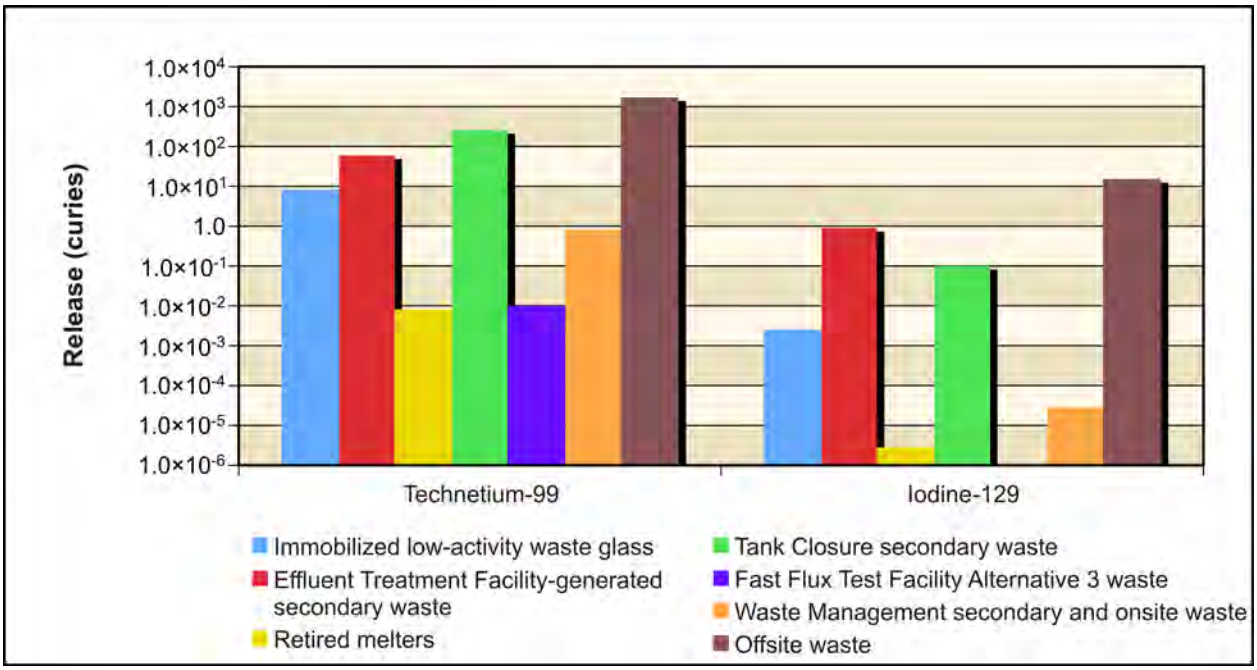


Figure 5–565. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

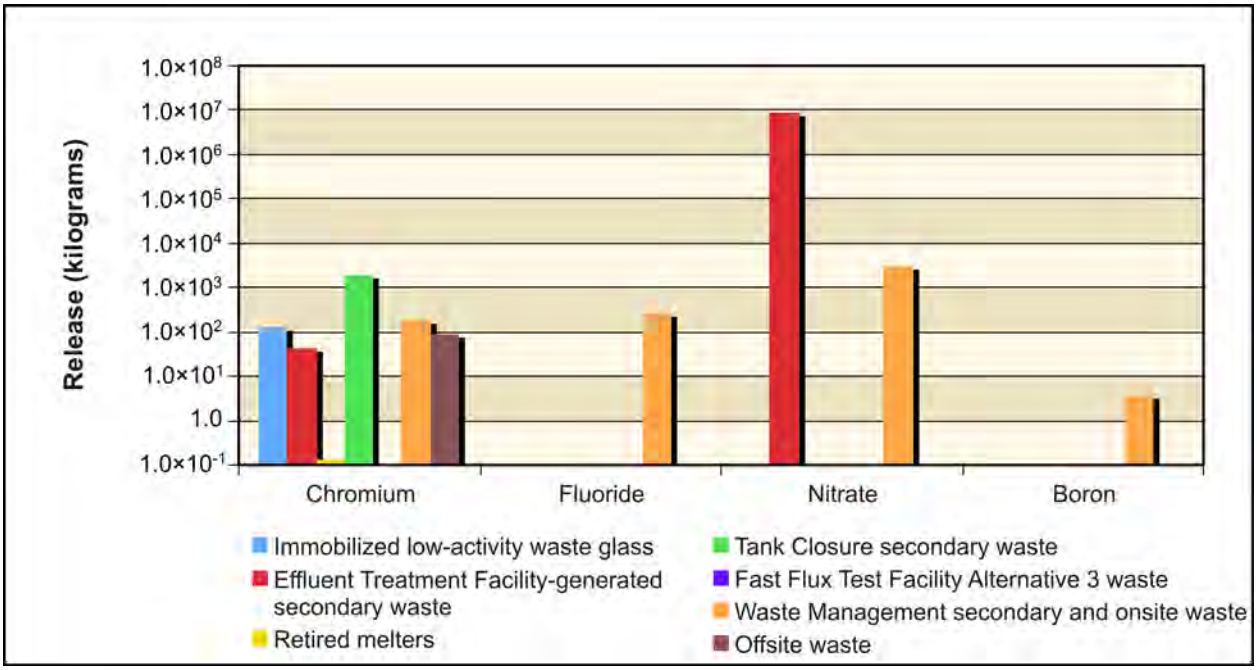


Figure 5–566. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

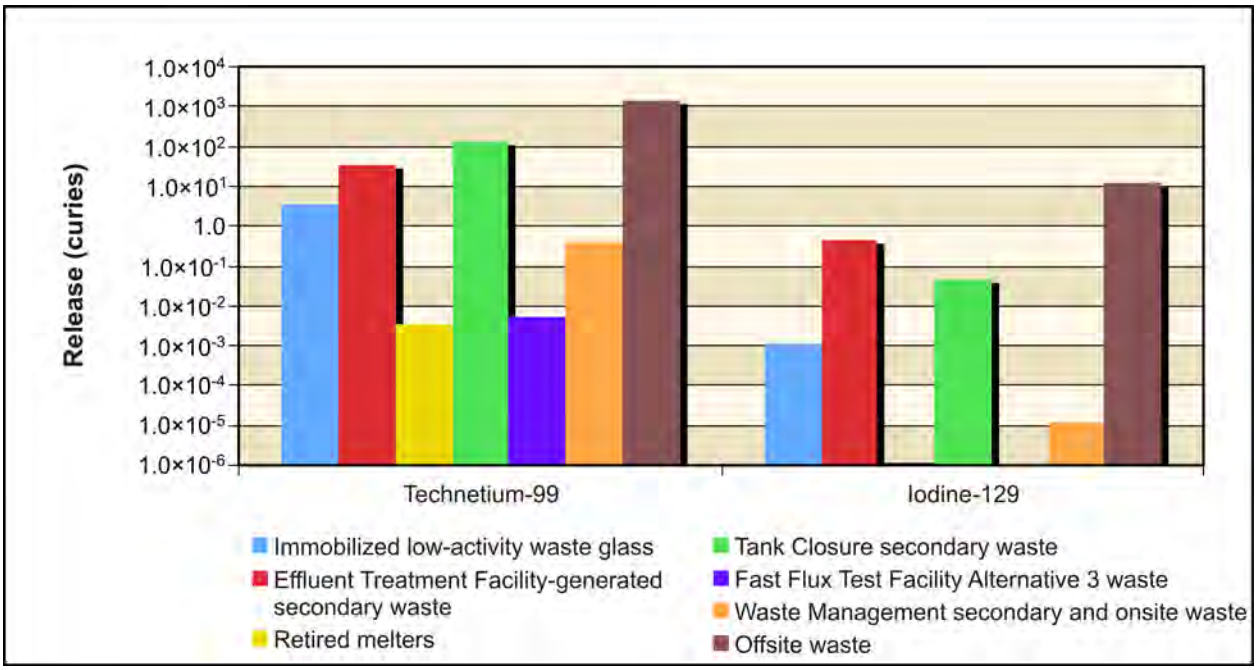


Figure 5–567. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

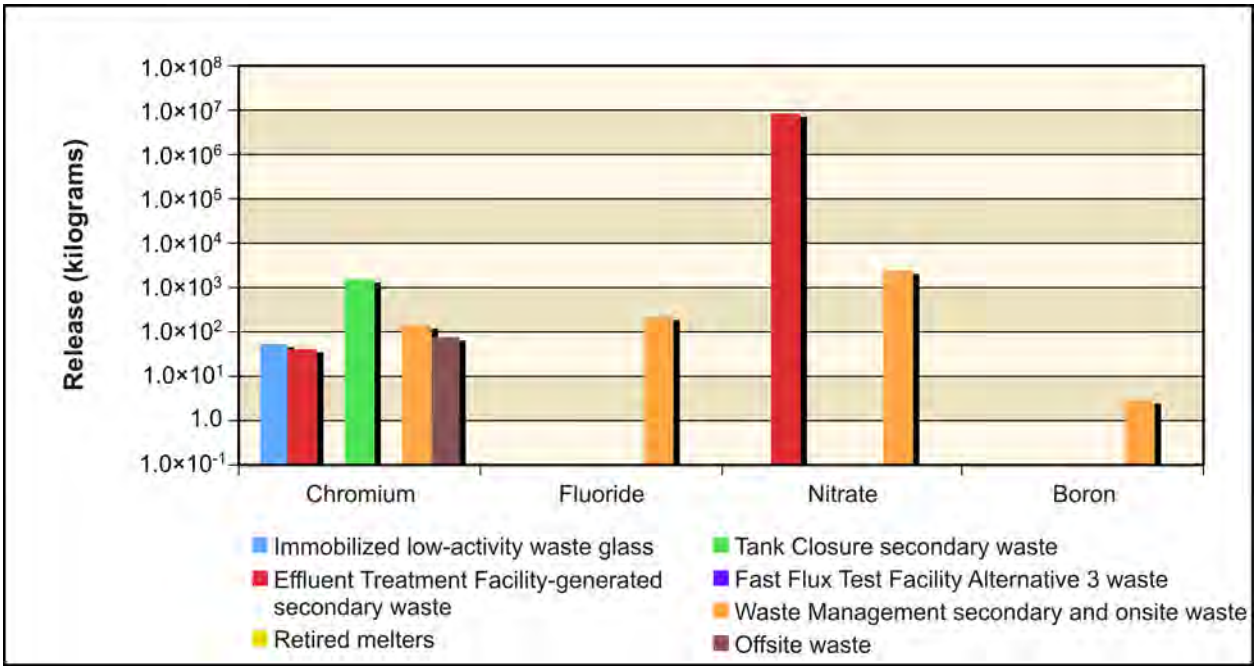


Figure 5–568. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

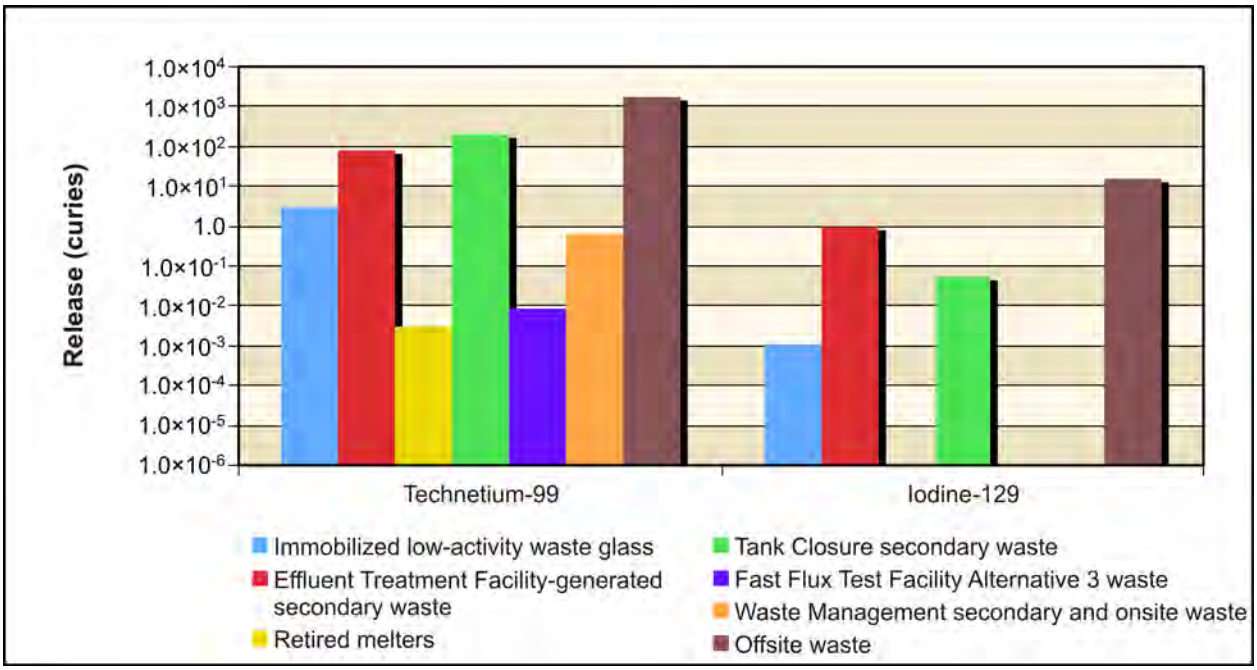


Figure 5–569. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

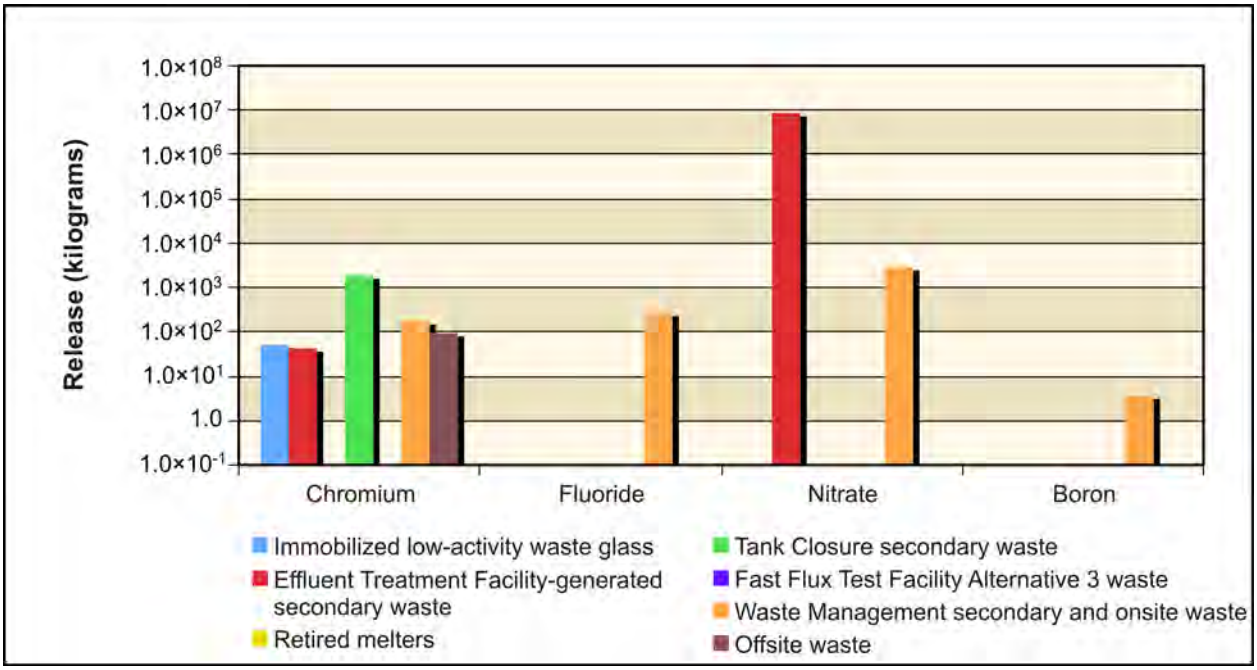


Figure 5–570. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the analysis of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, impacts in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–571 through 5–574). The benchmark concentration is also shown for each radionuclide and chemical. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Table 5–84 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Figures 5–571 through 5–574 show concentration versus time for iodine-129, technetium-99, chromium, and nitrate. During the later part of the analysis time period, the groundwater concentrations of iodine-129 from IDF-East exceed the benchmark concentrations at both the Core Zone and Columbia River nearshore boundaries. However, the iodine-129 concentrations are never greater than one order of magnitude above the benchmark concentration. After peaking, the iodine-129 concentrations continue to decrease through 11,940 (see Figure 5–571). The technetium-99 shows a similar response, with a peak near the latter quarter of the analysis period and then a continuing decline through 11,940 (see Figure 5–572). The technetium-99 concentrations at both the Core Zone and Columbia River nearshore boundaries never exceed the benchmark concentration. The chromium and nitrate concentrations show a similar trend (see Figures 5–573 and 5–574). The chromium concentrations approach but never exceed the benchmark concentration. The peak nitrate concentrations are always at least one order of magnitude less than the benchmark concentration.

There are no detectable releases of either uranium-238 or total uranium to the environment over the analysis period.

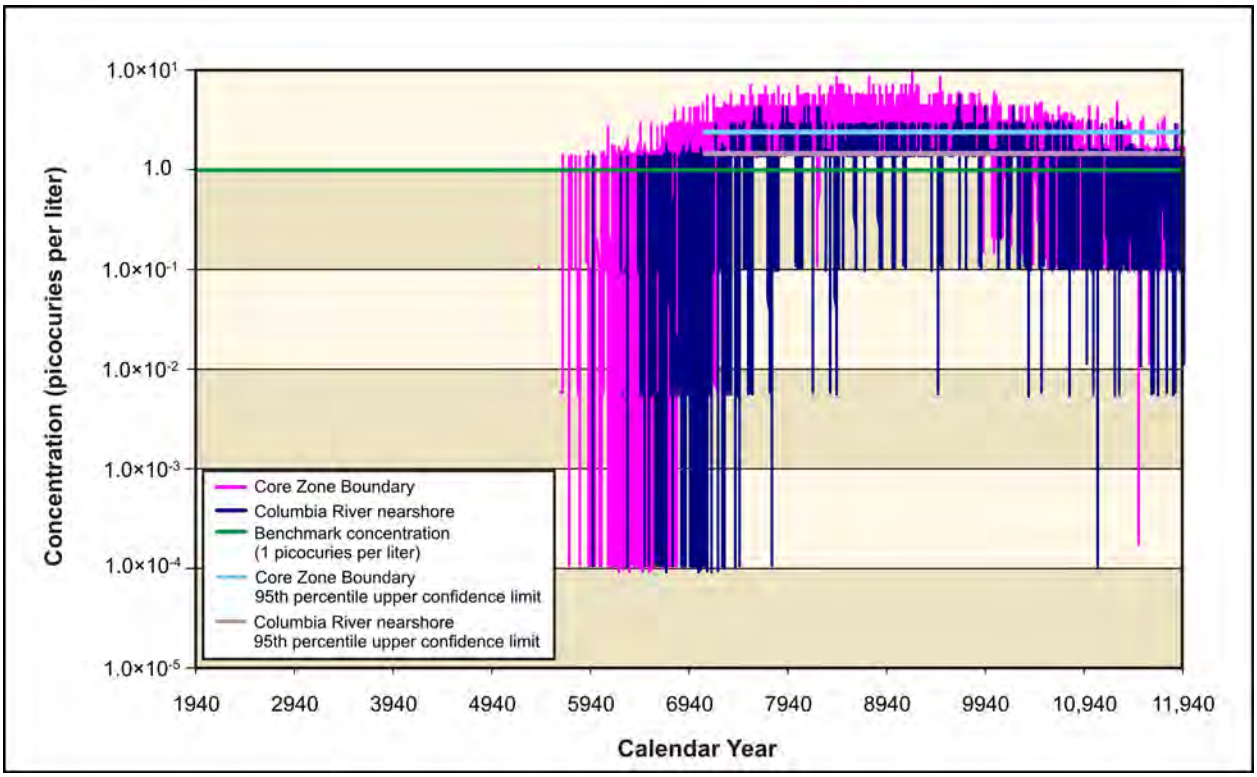


Figure 5–571. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Iodine-129 Concentration Versus Time

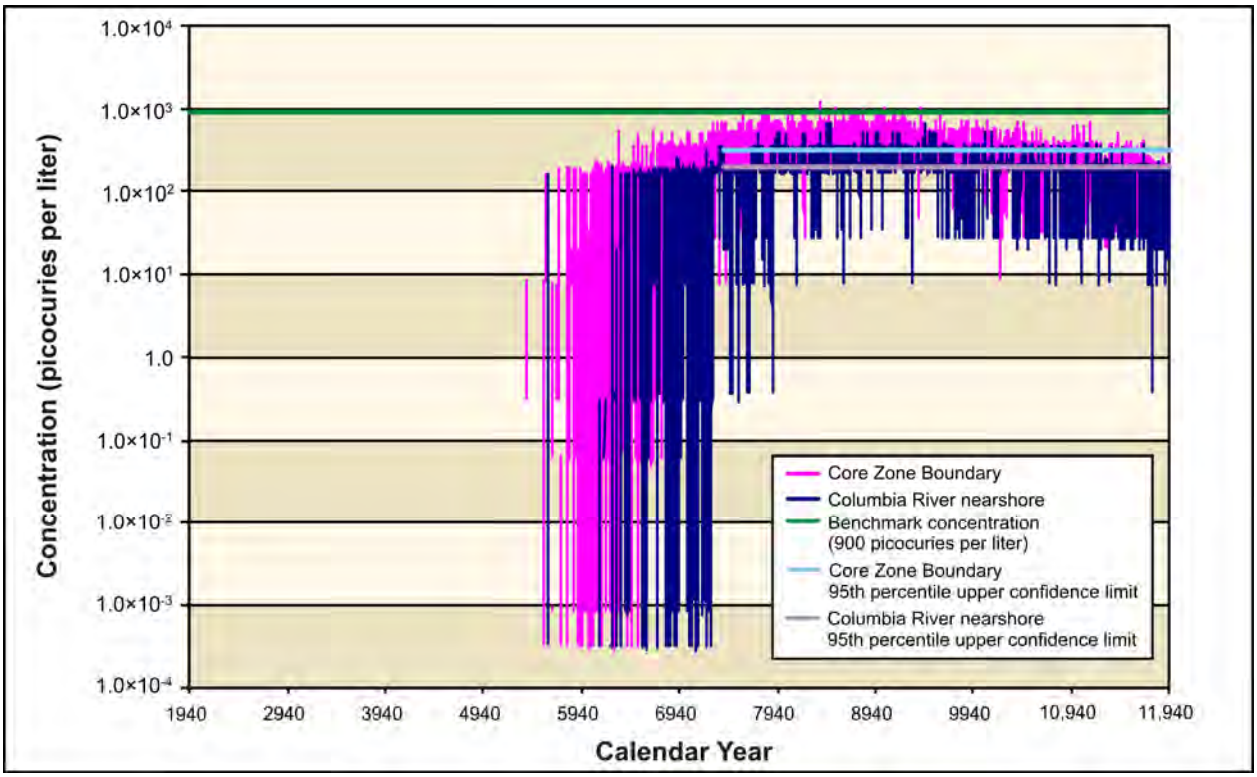


Figure 5–572. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Technetium-99 Concentration Versus Time

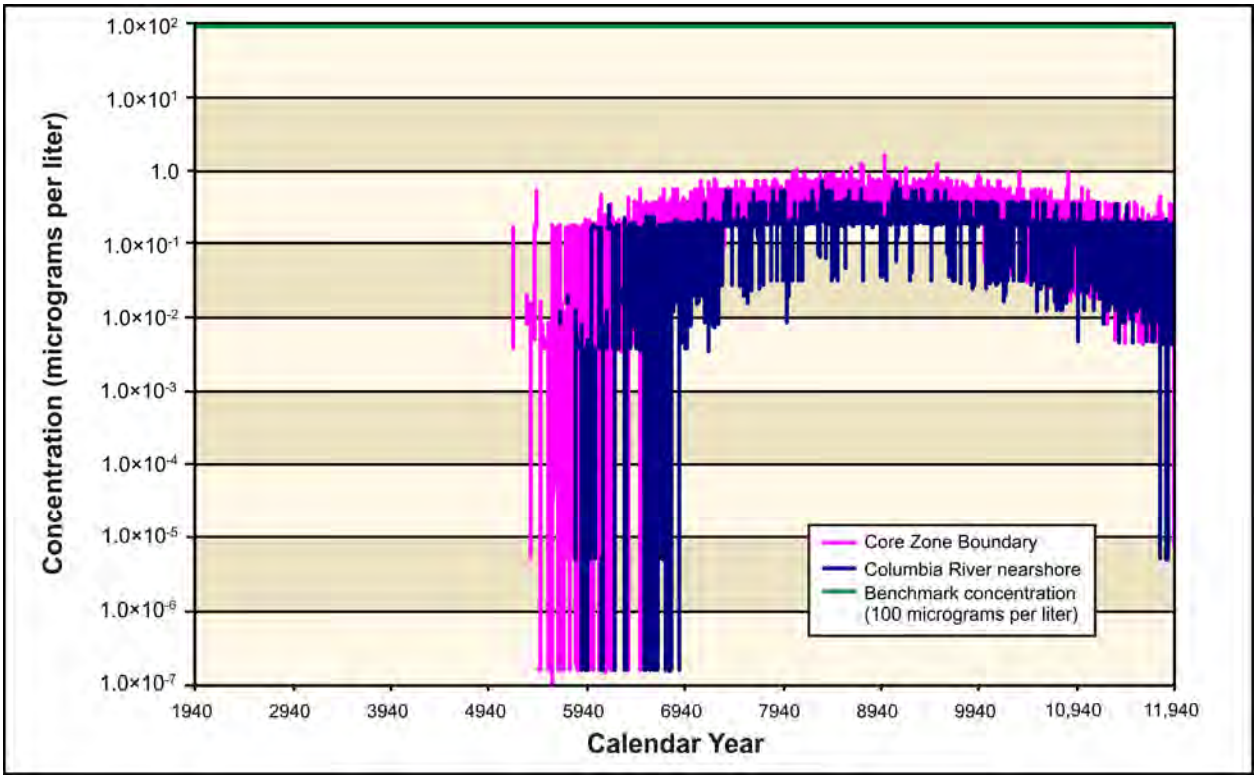


Figure 5–573. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Chromium Concentration Versus Time

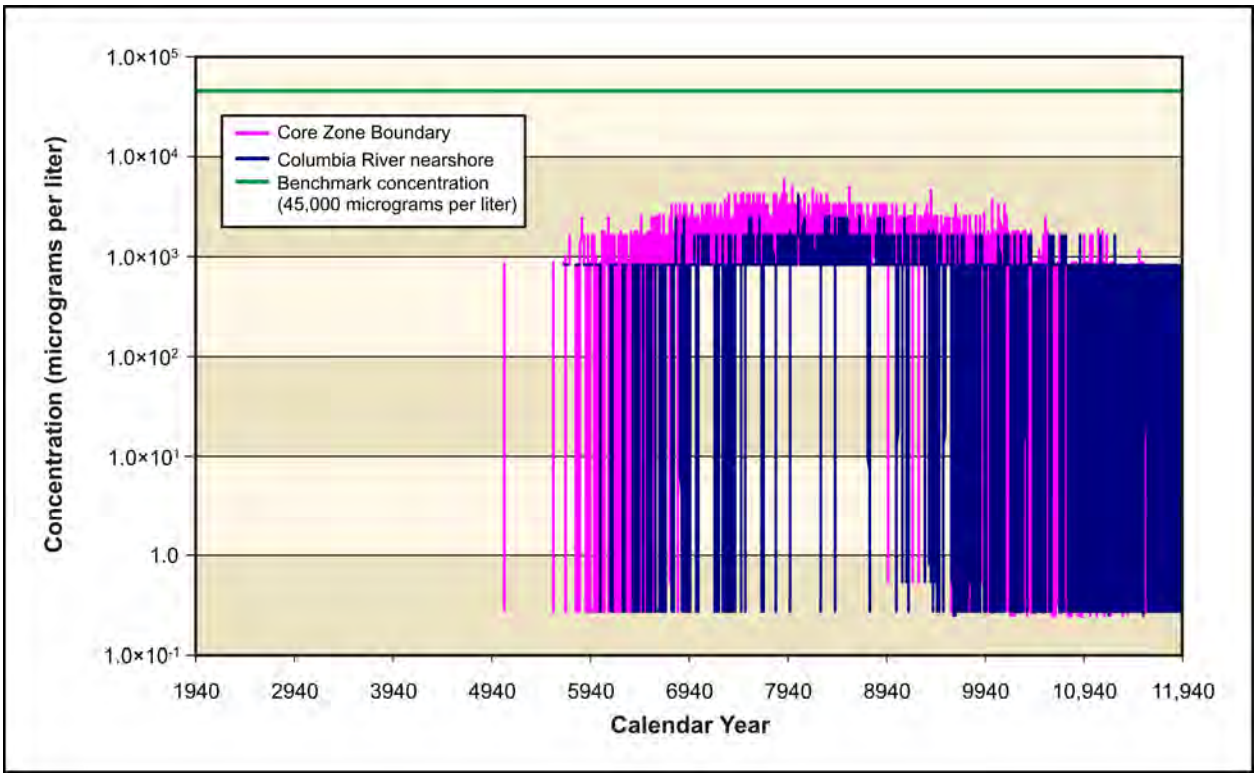


Figure 5–574. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Nitrate Concentration Versus Time

Table 5–84. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,820**	N/A	**1,150**	671	900
	(8580)		(8365)	(8478)	
Iodine-129	**24**	N/A	**10**	6	1
	(9058)		(9178)	(9652)	
Chemical in micrograms per liter					
Chromium	3	N/A	2	1	100
	(9308)		(8982)	(8354)	
Nitrate	15,500	N/A	5,700	4,070	45,000
	(8055)		(7905)	(8056)	

Note: corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; N/A=not applicable; RPPDF=River Protection Project Disposal Facility.

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, in terms of the spatial distribution of groundwater concentration at selected times in this analysis period. Concentrations of radionuclides are in picocuries per liter; chemicals in micrograms per liter (see Figures 5–575 through 5–582). Concentrations for each radionuclide and chemical are indicated by a color scale that is relative to the benchmark concentration.

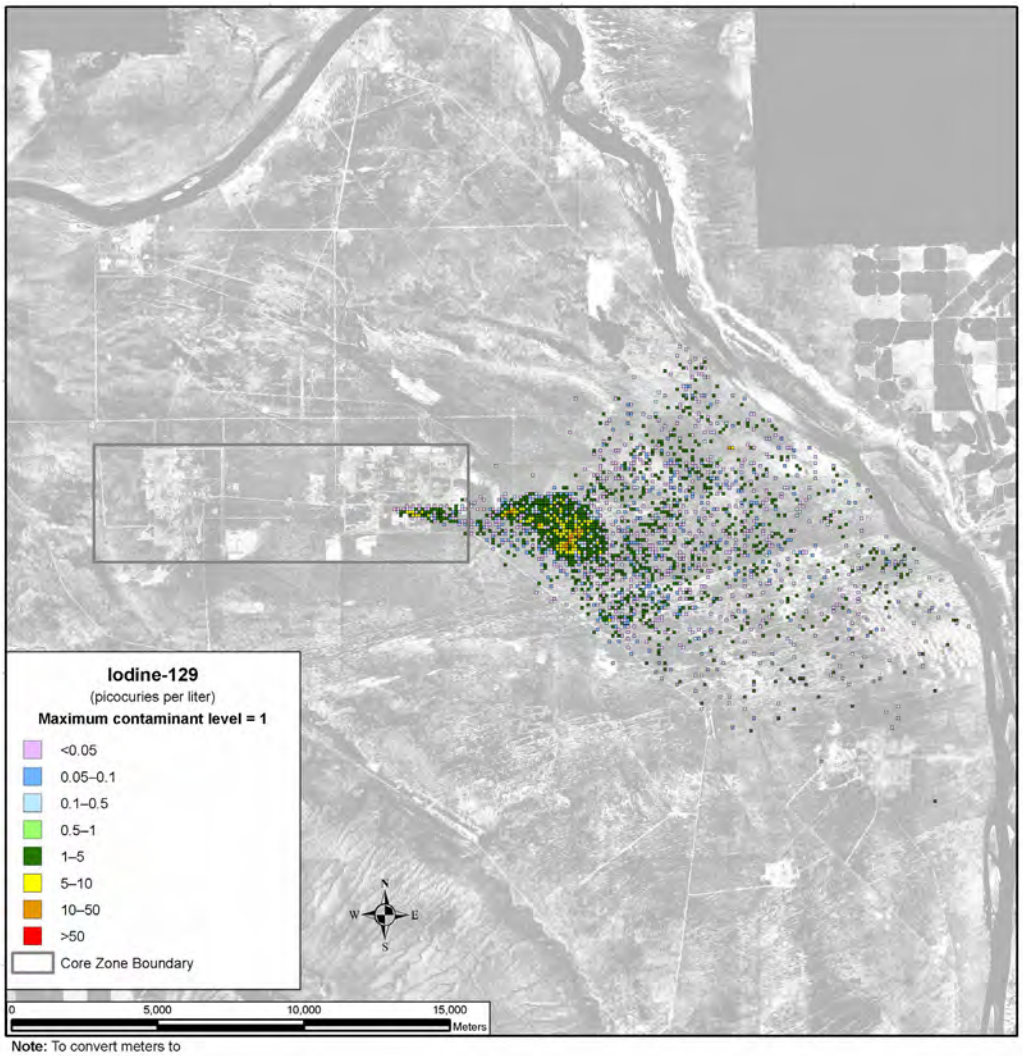
Figures 5–575 through 5–582 show that there are groundwater releases from IDF-East that extend to the Columbia River. The release distributions are confined in a narrow area until about a third of the distance to the Columbia River nearshore boundary, where they spread out significantly and continue to the Columbia River. The iodine-129, technetium-99, chromium, and nitrate are all conservative tracers (i.e., move at the rate of the pore water velocity) that are impacted by moisture content. For each distribution map, the concentrations that are greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red, in order of increasing concentration. Concentrations less than the benchmark concentration are indicated by the faded colors green, blue, indigo, and violet, in order of decreasing concentration. The concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

Figure 5–575 and 5–576 show the spatial distribution of groundwater concentration for iodine-129 during CYs 7140 and 11,885. These figures show a growing distribution in both size and concentration that is still present through CY 11,885. There are areas where concentration is above the benchmark concentration east of the Core Zone Boundary. However, over the period of analysis, most of the distribution concentration remains below the benchmark concentration.

Figures 5–577 and 5–578 show the technetium-99 release with a distribution from the release source to the Columbia River. There is also a small area east of the Core Zone Boundary where the technetium-99 concentration approaches (and potentially exceeds) the benchmark concentration. By CY 11,885 (see Figure 5–578), the distribution has increased over CY 7140 in size. Although most of the distribution is well below the benchmark concentration, this figure shows a distribution of technetium-99 through CY 11,885.

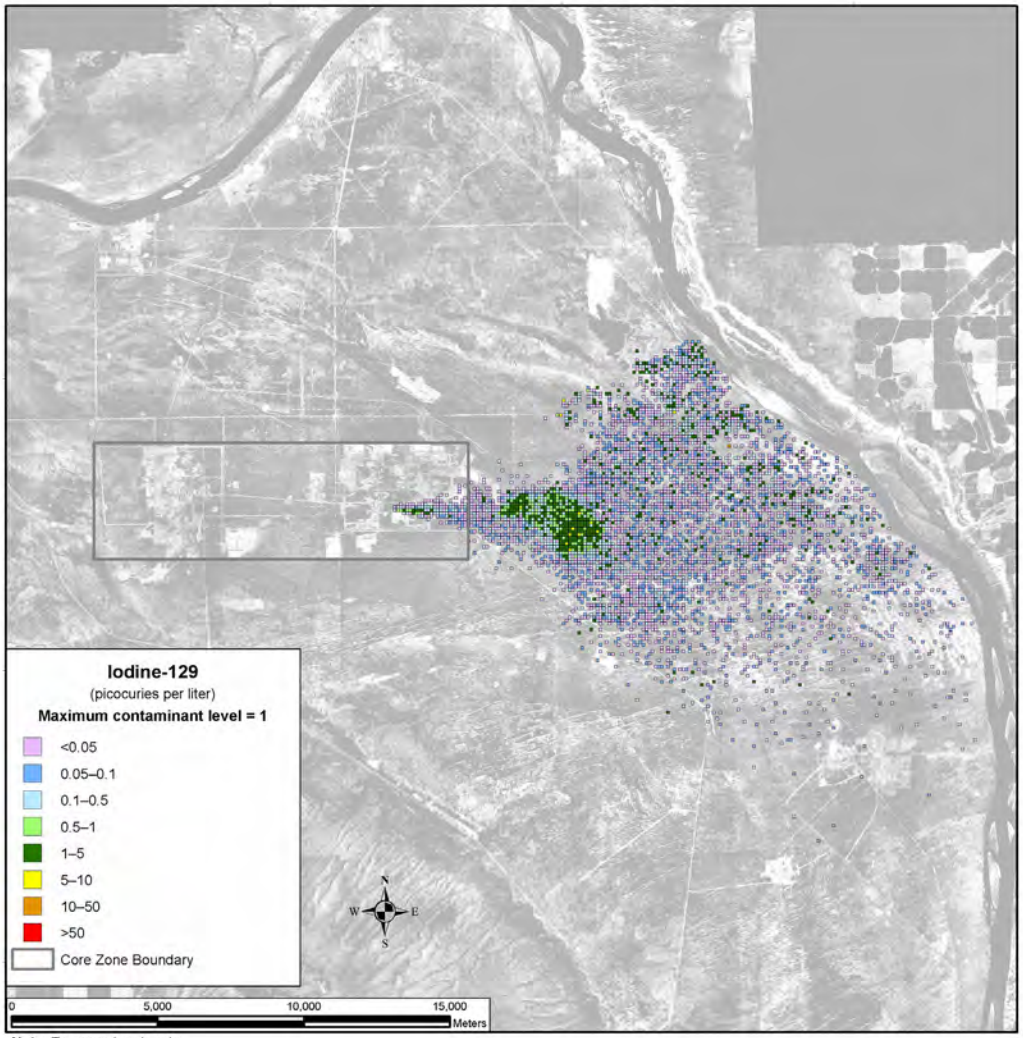
Figures 5–579 and 5–580 (CYs 7140 and 11,885) show a chromium release extending from the release source to the Columbia River. Comparisons of the CY 7140 and 11,885 distributions show about the same concentration and area for the releases. The concentration of chromium remains well below the benchmark concentration in both distributions.

Figures 5–581 and 5–582 show the spatial distribution of groundwater concentrations of nitrate for CYs 7140 and 11,885. There is an area east of the Core Zone Boundary where the nitrate release appears to approach the benchmark concentration. The CY 11,885 data show a significant reduction in concentration, especially for the isolated area of higher concentration. Most of the nitrate distribution is well below the benchmark concentration.



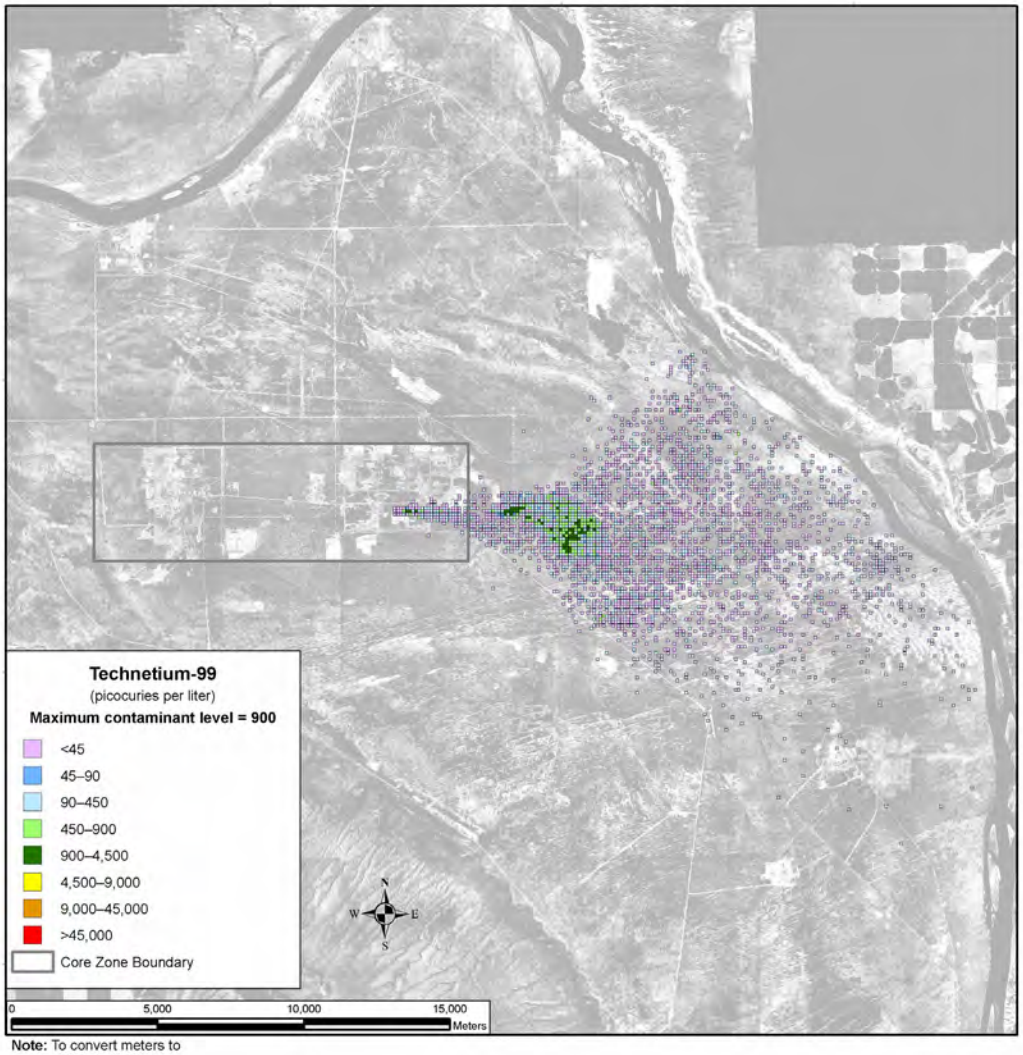
Note: To convert meters to feet, multiply by 3.281

Figure 5–575. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



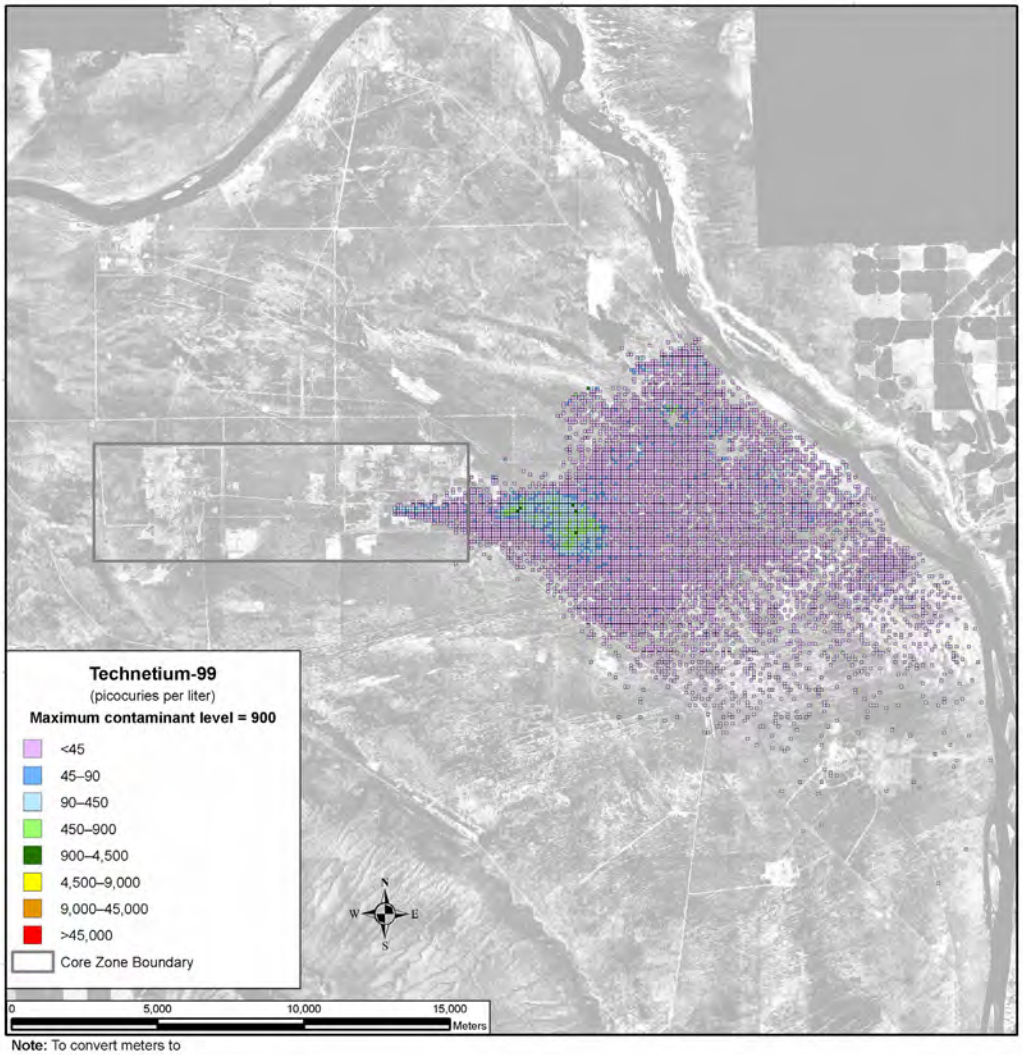
Note: To convert meters to feet, multiply by 3.281

Figure 5–576. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



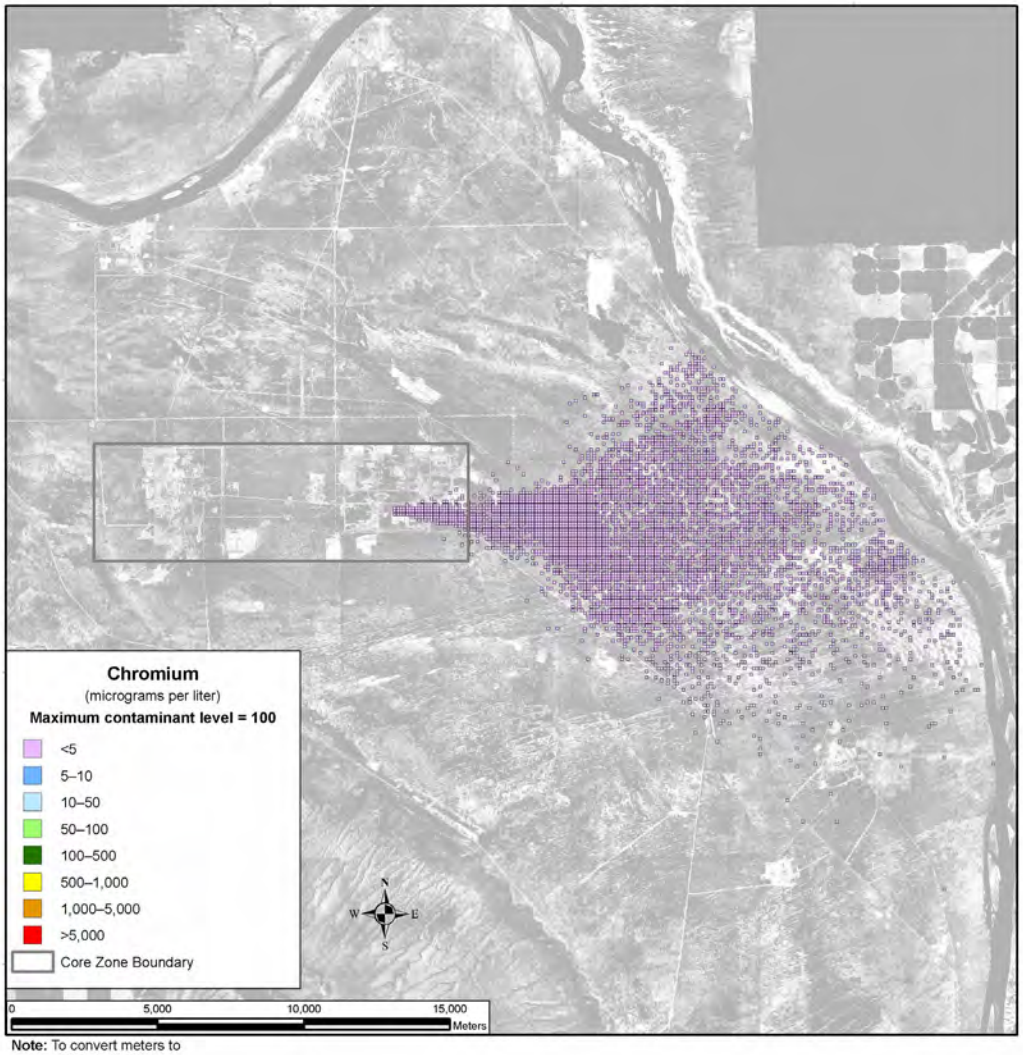
Note: To convert meters to feet, multiply by 3.281

Figure 5–577. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



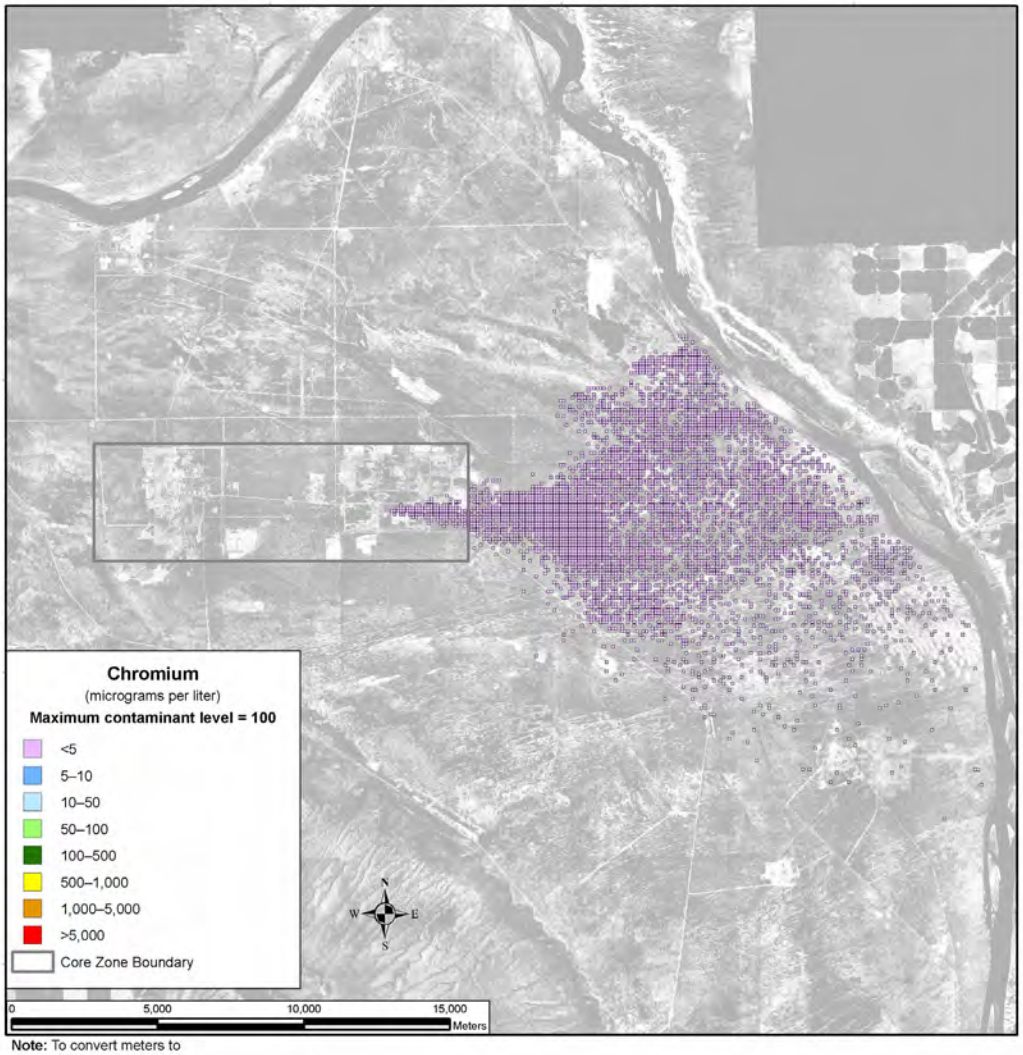
Note: To convert meters to feet, multiply by 3.281

Figure 5–578. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



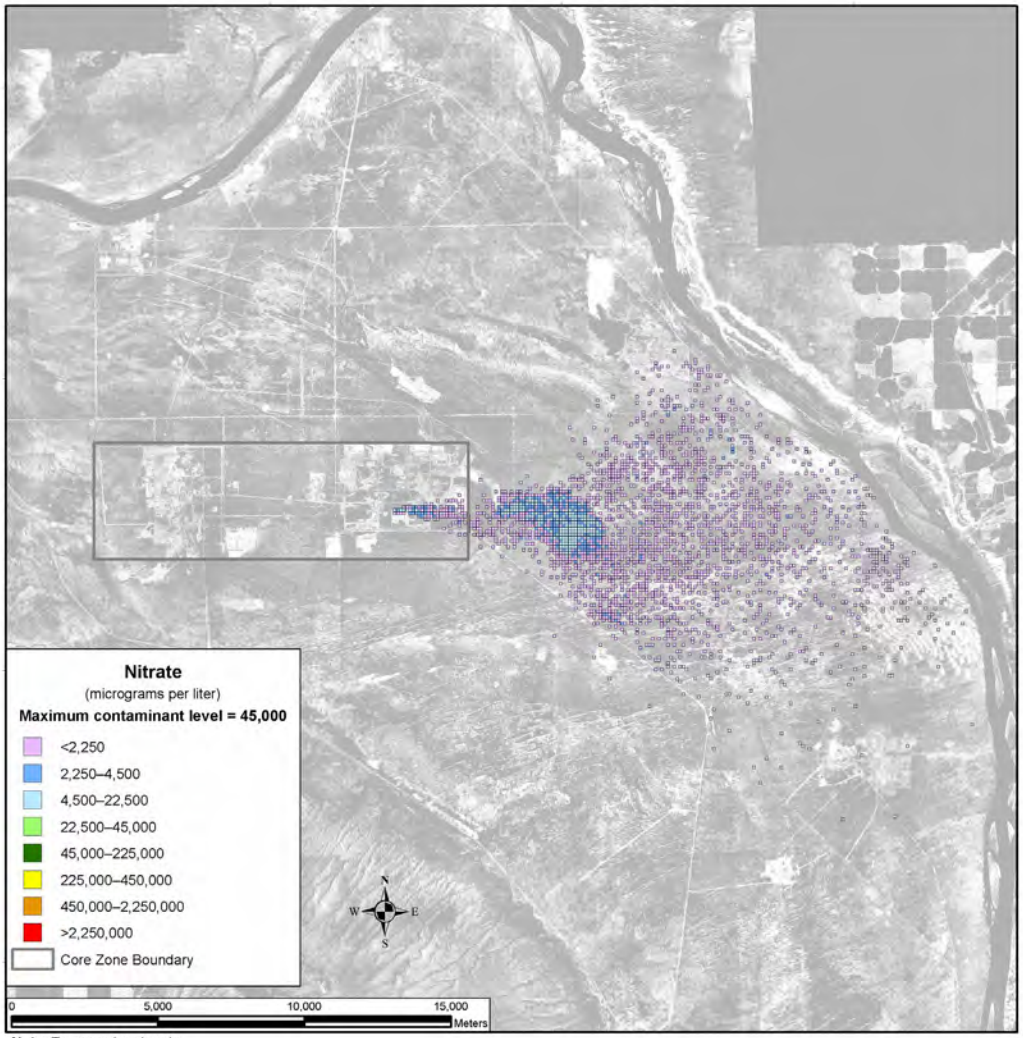
Note: To convert meters to feet, multiply by 3.281

Figure 5–579. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



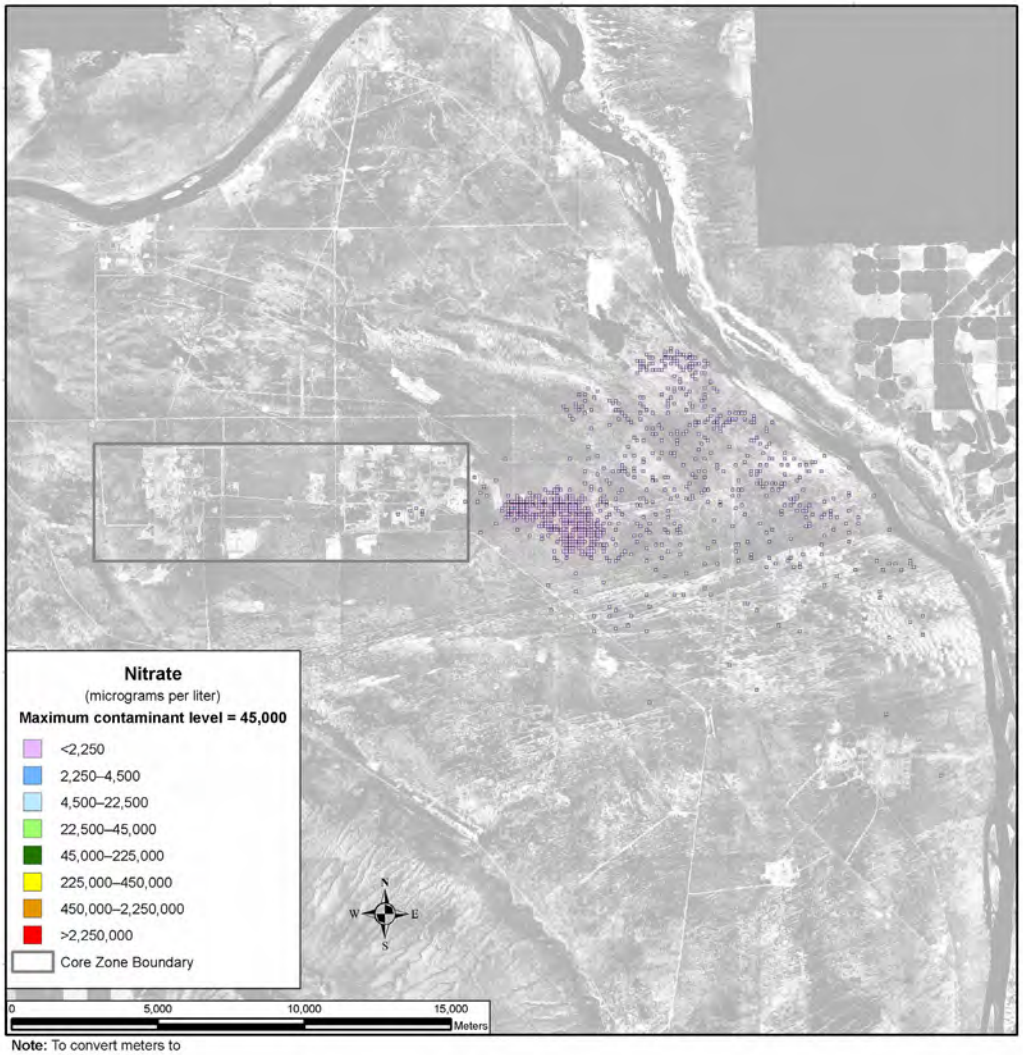
Note: To convert meters to feet, multiply by 3.281

Figure 5–580. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–581. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–582. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

Under Waste Management Alternative 2, Disposal Group 2, Subgroup 2-A, in general, the predominant contributor is the iodine-129 inventory at IDF-East that is available for release to the environment at the start of the post-disposal period. The technetium-99, chromium, and nitrate releases do not exceed benchmark concentrations during the period of analysis except in small, isolated areas (pockets). The release data show declining but significant concentrations through the end of this analysis period (CY 11,885).

5.3.1.2.2.2 Disposal Group 2, Subgroup 2-B, Base Case

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, includes Tank Closure Alternative 6B, Base Case; FFTF Decommissioning Alternative 2 or 3; and onsite- and offsite-generated waste. Waste would be converted to IHLW and ILAW glass. IHLW would be stored on site, while ILAW glass would be managed on site as high-level radioactive waste (HLW) pending disposition.

For the long-term groundwater impact analysis, two major periods have been identified for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, as follows:

- The disposal period starts with the onset of disposal operations for IDF-East and the RPPDF in CY 2009 and continues through CY 2100, when the disposal facilities will be operationally closed. During this disposal period, the materials in these permitted, operational facilities are assumed to be unavailable for release to the environment.

- The post-disposal period starts in CY 2101 and continues through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in IDF-East and the RPPDF become available for release to the environment. For the purpose of analyzing long-term groundwater impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, IDF-East and the RPPDF are assumed to be covered by a barrier limiting infiltration for the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case. Full results are tabulated in Appendices M, N, and O. This discussion of long-term impacts associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and acetonitrile

The COPC drivers for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis, and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. There is no chemical risk. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

The COPC drivers that are discussed in detail in this section (nitrate iodine-129, technetium-99, chromium, nitrate, and acetonitrile) are all mobile (i.e., they move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case (IDF-East and the RPPDF), in terms of the total amount released to the vadose zone, groundwater, and the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility

Figure 5–583 shows the release to the vadose zone for the radiological risk drivers and Figure 5–584, the chemical hazard drivers. For all seven types of sources, the inventories in the waste forms are a major factor in the quantities released to the vadose zone. The predominant source of technetium-99 in the vadose zone is offsite-generated waste (77 percent), followed by tank closure secondary waste (19 percent), and ETF-generated secondary waste (4 percent). The sources of the iodine-129 release are offsite-generated waste (85 percent) and ETF-generated secondary waste (14 percent). The chromium release is from the tank closure secondary waste (86 percent), waste management secondary waste and onsite-generated waste (8 percent), with some from offsite-generated waste (4 percent) and ETF-generated secondary waste (2 percent). All of the nitrate released is from ETF-generated secondary waste. There is no acetonitrile from any of the waste forms in IDF-East.

Figure 5–585 shows the release to groundwater for the radiological risk drivers and Figure 5–586, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Most of the vadose zone technetium-99 (89 percent), iodine-129 (91 percent), chromium (>99 percent), and nitrate (>99 percent) is released to groundwater during the period of analysis.

Figure 5–587 shows the release to the Columbia River for the radiological risk drivers and Figure 5–588, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. Most of the technetium-99 (97 percent), iodine-129 (97 percent), chromium (97 percent), and nitrate (>99 percent) in the groundwater is released to the Columbia River over the period of analysis.

Overall, most of the technetium-99 (86 percent), iodine-129 (89 percent), chromium (96 percent), and nitrate (98 percent) from the vadose zone is released to the Columbia River. These releases are identical to those of Waste Management Alternative 2, Disposal Group 2-B, Option Case, for these COPCs.

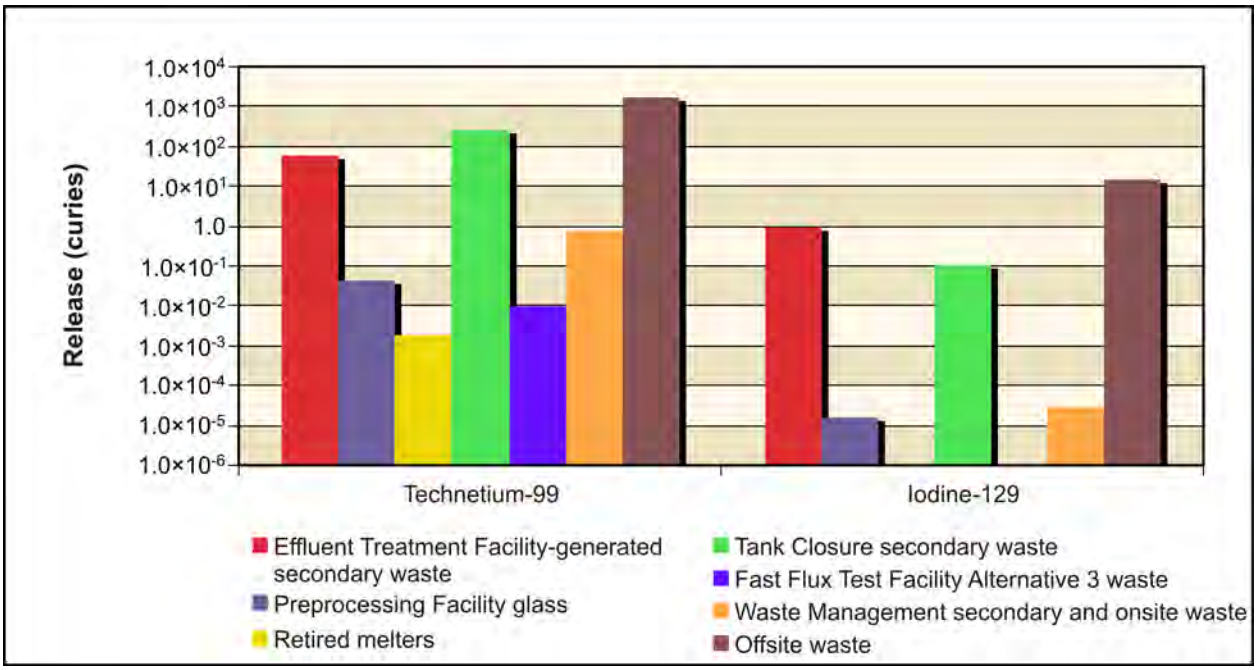


Figure 5–583. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

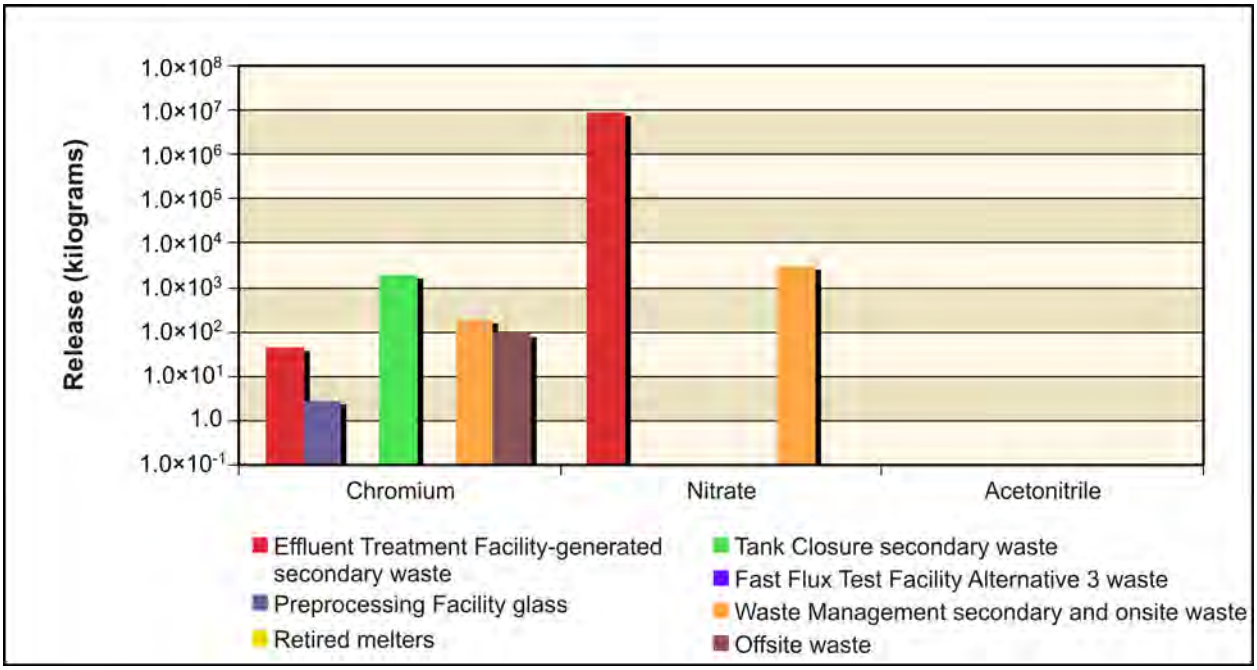


Figure 5–584. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

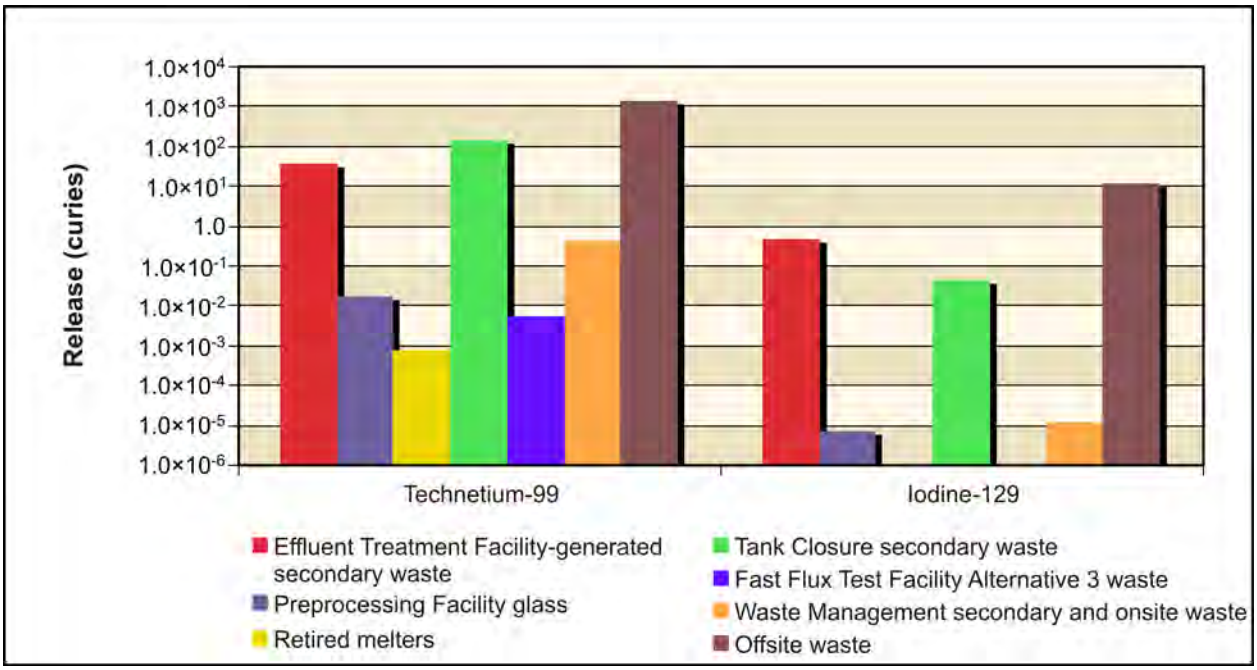


Figure 5–585. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

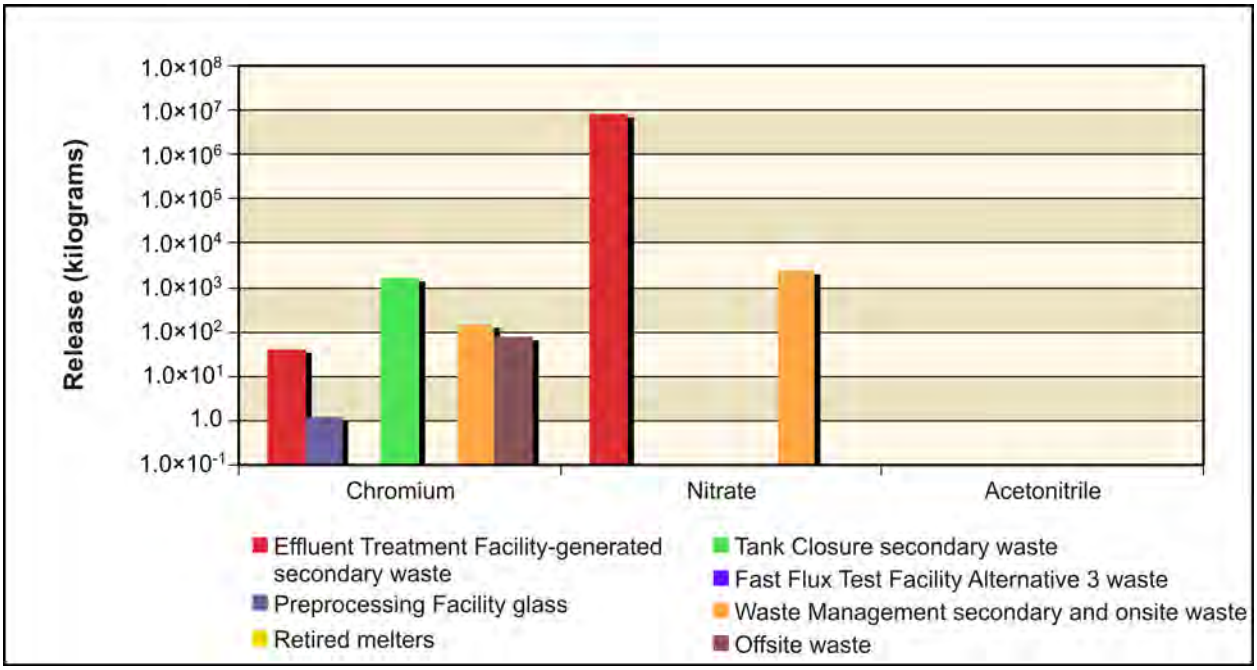


Figure 5–586. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

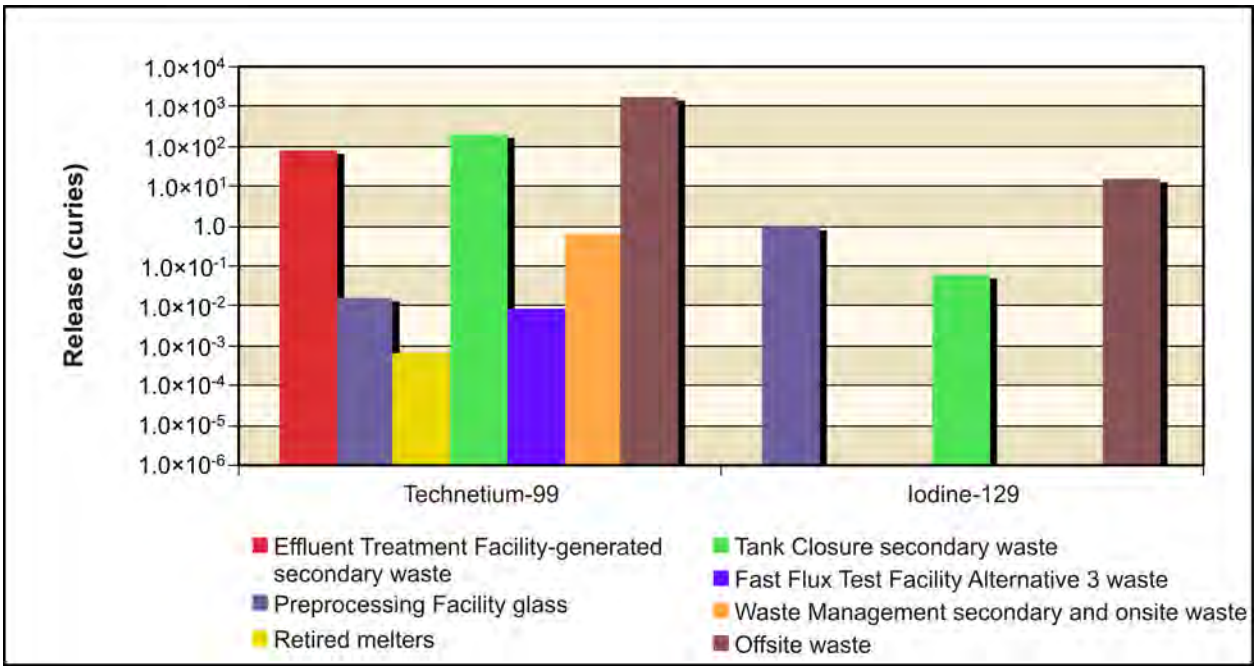


Figure 5–587. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

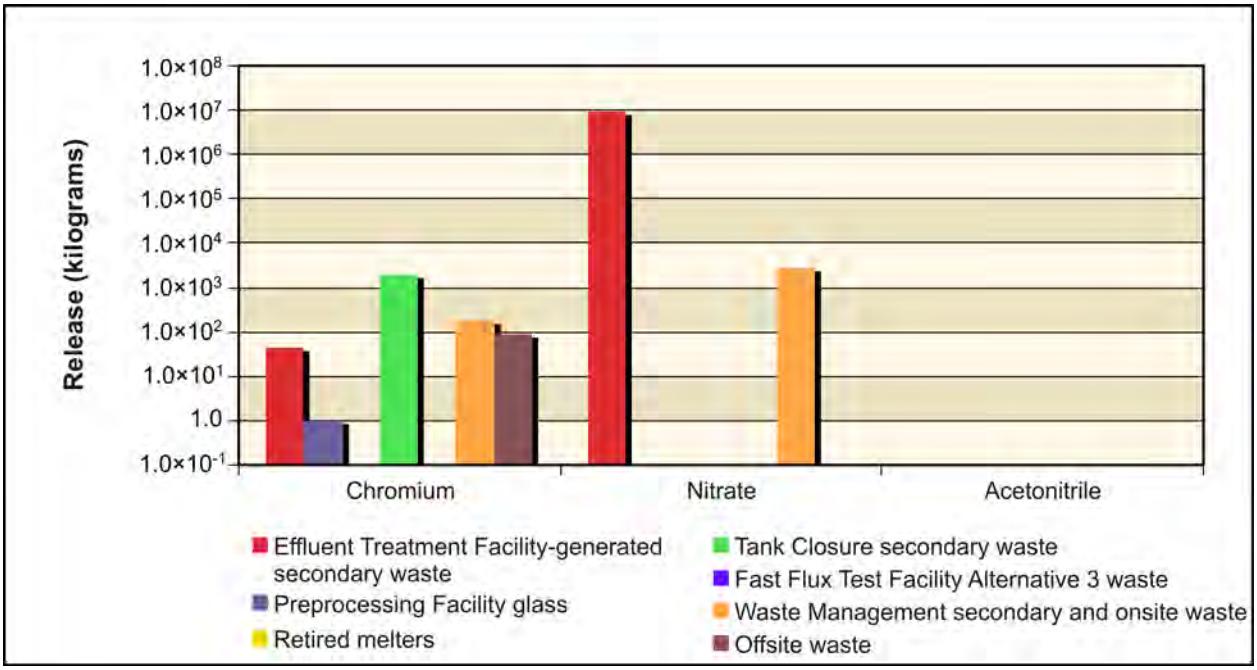


Figure 5–588. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

River Protection Project Disposal Facility

Figure 5–589 shows the release to the vadose zone for the radiological risk drivers and Figure 5–590, the chemical hazard drivers. Release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The predominant releases from the RPPDF are technetium-99 and iodine-129, with technetium-99 being the predominant radionuclide released. The chemical releases from the RPPDF include nitrate (largest), chromium, and acetonitrile (smallest).

Figure 5–591 shows the release to groundwater for the radiological risk drivers and Figure 5–592, the chemical hazard drivers. In addition to the inventory considerations discussed in the previous paragraph, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For technetium-99, iodine-129, chromium, nitrate, and acetonitrile, the amount released to groundwater is essentially equal to the amount released to the vadose zone.

Figure 5–593 shows the release to the Columbia River for the radiological risk drivers and Figure 5–594, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. For iodine-129, technetium-99, chromium, nitrate, and acetonitrile, the amount released to the Columbia River is essentially equal to the amount released to groundwater.

Overall, about 96 percent of the radionuclides and chemicals released by the RPPDF to the vadose zone are released to the Columbia River during the period of analysis. Identical results were observed for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case.

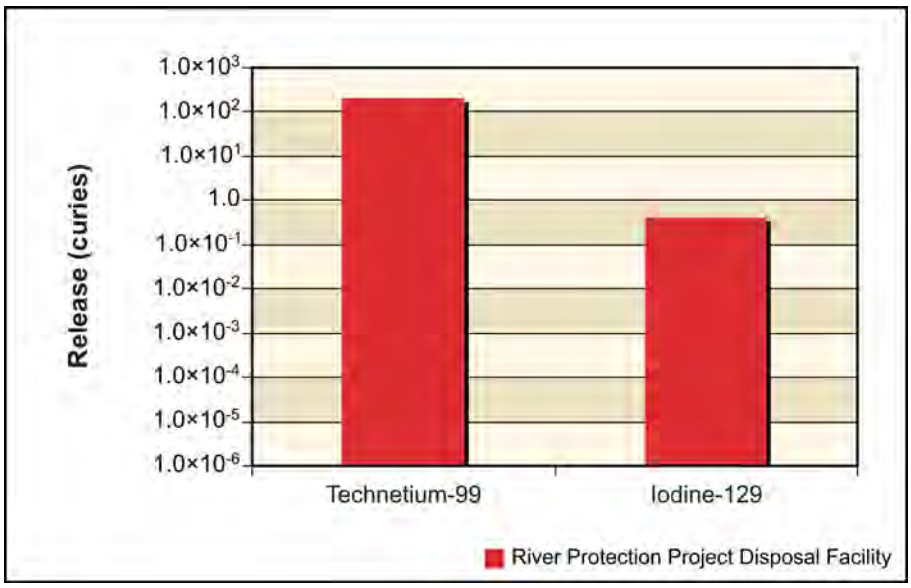


Figure 5–589. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

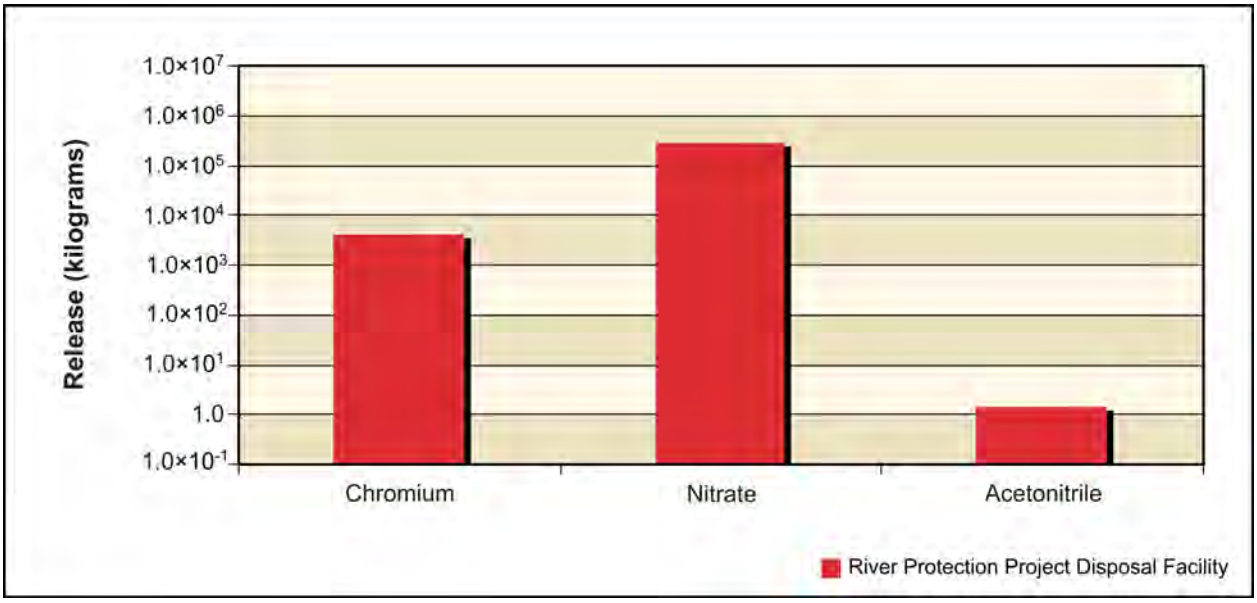


Figure 5–590. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

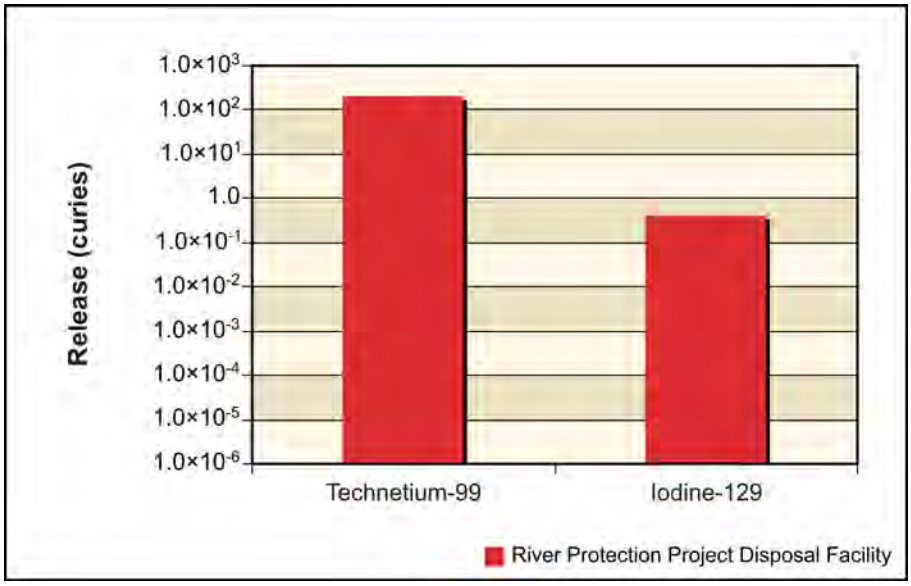


Figure 5–591. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at River Protection Project Disposal Facility to Groundwater

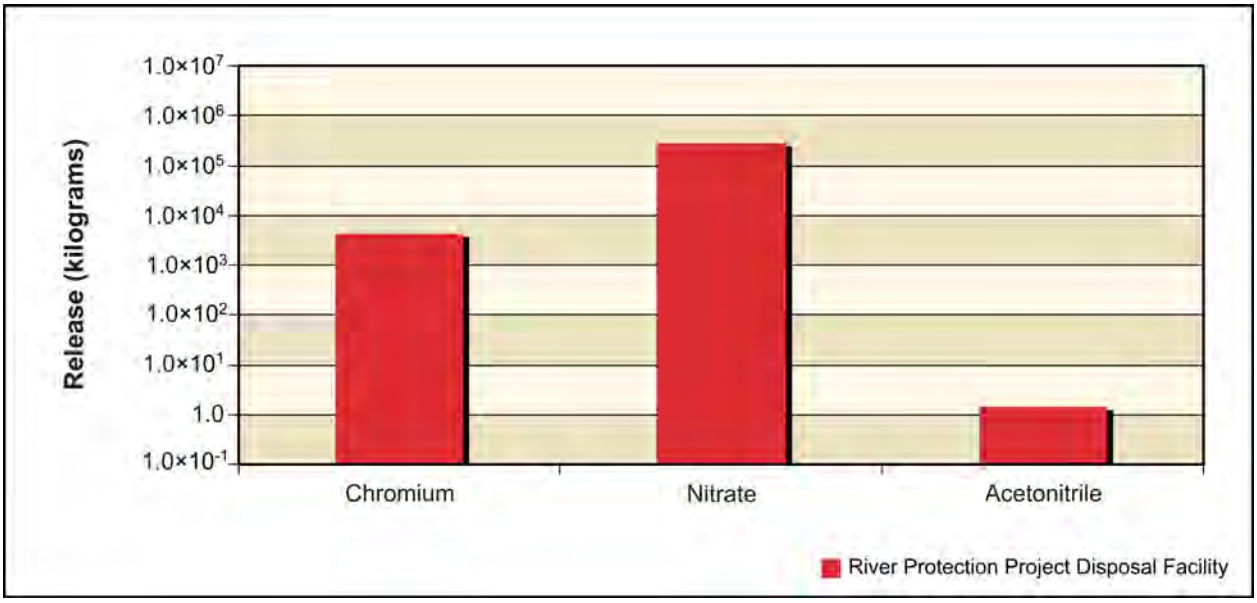


Figure 5–592. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at River Protection Project Disposal Facility to Groundwater

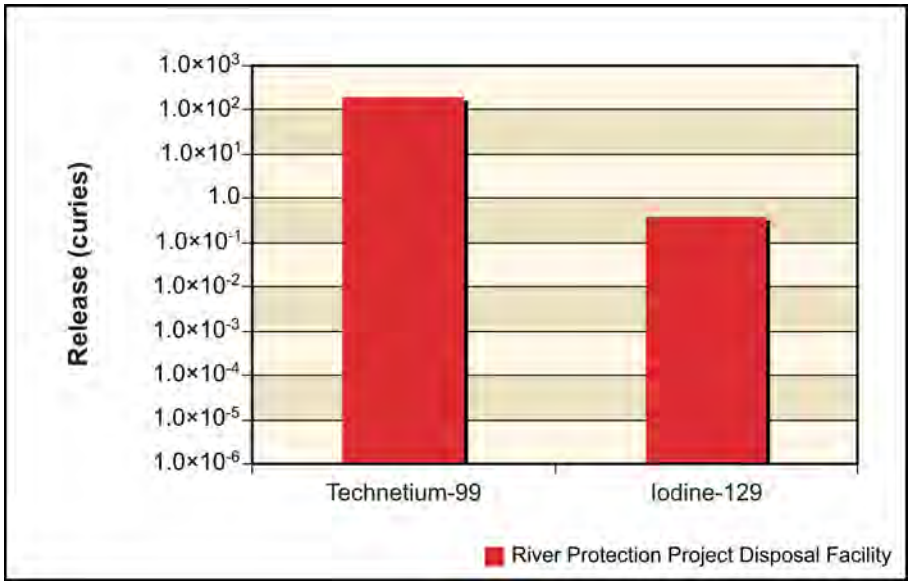


Figure 5–593. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Radiological Releases at River Protection Project Disposal Facility to Columbia River

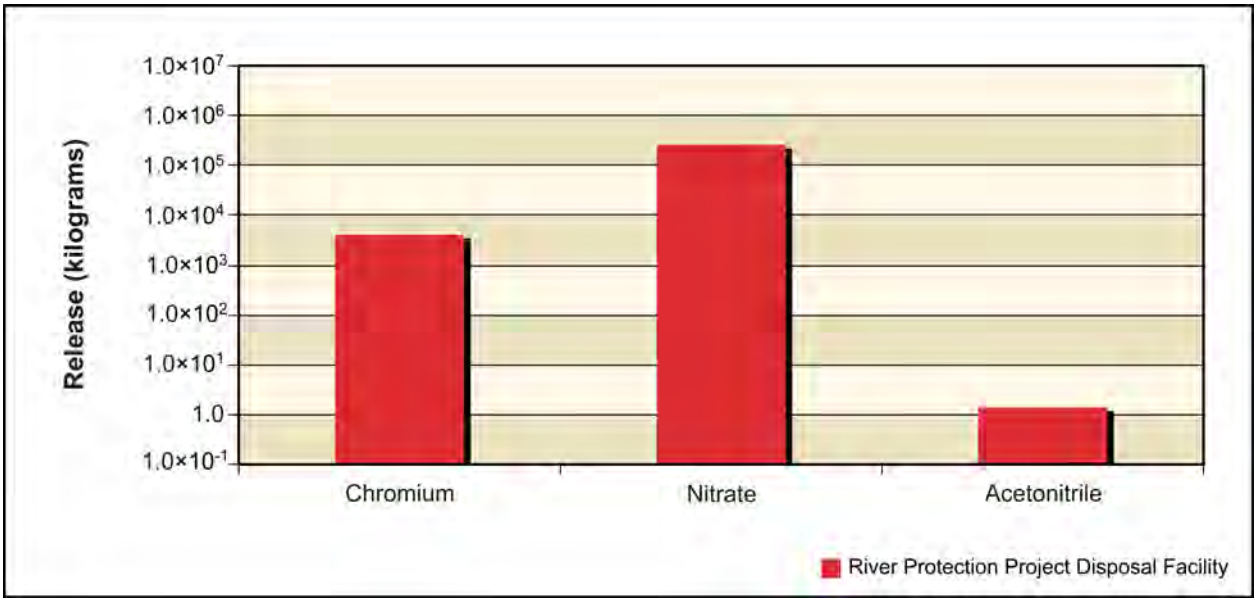


Figure 5–594. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. The benchmark concentration of each radionuclide and chemical is also shown. The concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Table 5–85 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River nearshore.

Table 5–85. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,890**	283	**1,140**	703	900
	(8580)	(3889)	(8365)	(8477)	
Iodine-129	**24**	0.5	**10**	**6**	1
	(9058)	(4089)	(9188)	(9652)	
Chemical in micrograms per liter					
Chromium	3	6	11	2	100
	(8281)	(3868)	(11232)	(5035)	
Nitrate	16,600	353	5,750	3,310	45,000
	(8162)	(3996)	(8245)	(7837)	

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

Figures 5–595 through 5–598 show concentration versus time for technetium-99, iodine-129, nitrate, and chromium, respectively. The releases of technetium-99 from IDF-East and the RPPDF do not exceed the benchmark concentrations at the Core Zone Boundary or the Columbia River nearshore (see Figure 5–595). The technetium-99 concentrations at both boundaries remain fairly constant for most of the analysis period and then decrease into CY 11,940.

Figure 5–596 shows iodine-129 exceeding benchmark concentrations starting about CY 5940 and continuing through CY 11,940 for both the Core Zone Boundary and the Columbia River nearshore. Figures 5–597 and 5–598 show that the nitrate and chromium releases do not reach the benchmark concentrations over the period of analysis. The nitrate and chromium concentrations at the Core Zone Boundary and the Columbia River nearshore are always at least one order of magnitude lower than their benchmark concentrations.

Figure 5–599 shows concentration versus time for total uranium. Uranium-238 has no detectable release to the environment. Total uranium concentrations, while very low, continue to increase during the period of analysis and beyond. The total uranium concentration never approaches closer than six orders of magnitude to the benchmark concentration during the period of analysis (through CY 11,940).

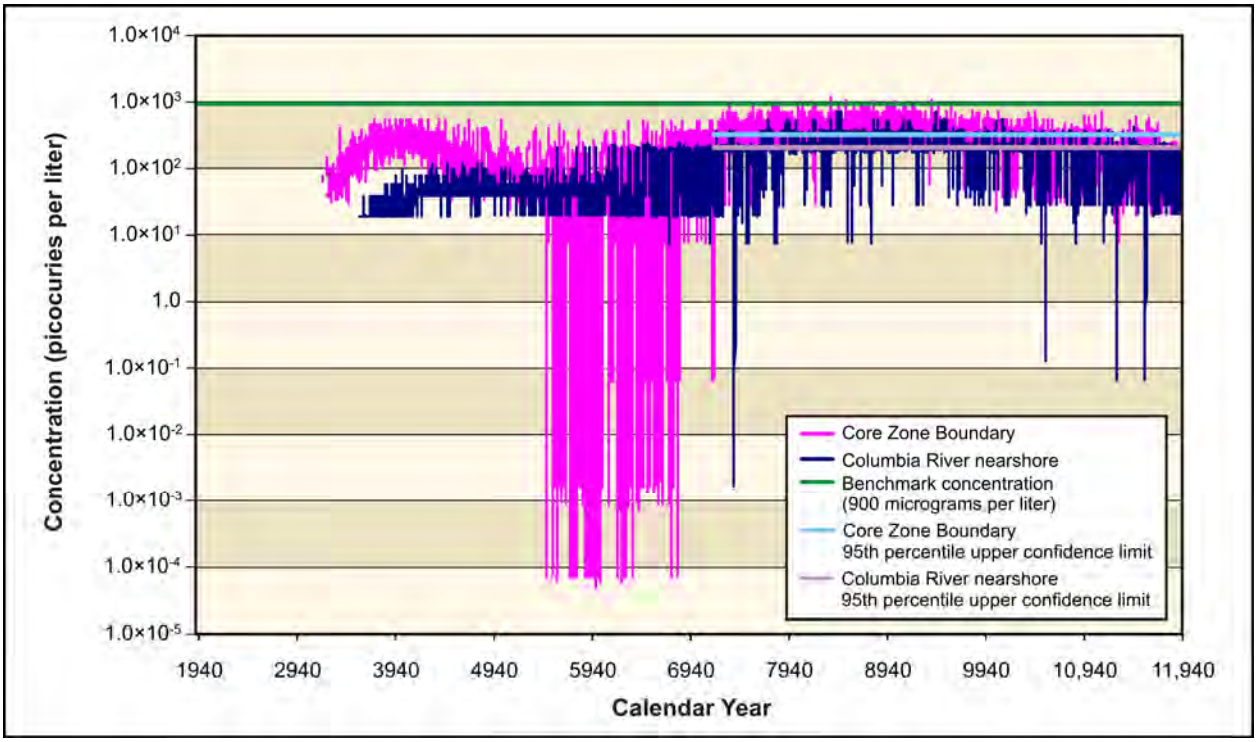


Figure 5–595. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Technetium-99 Concentration Versus Time

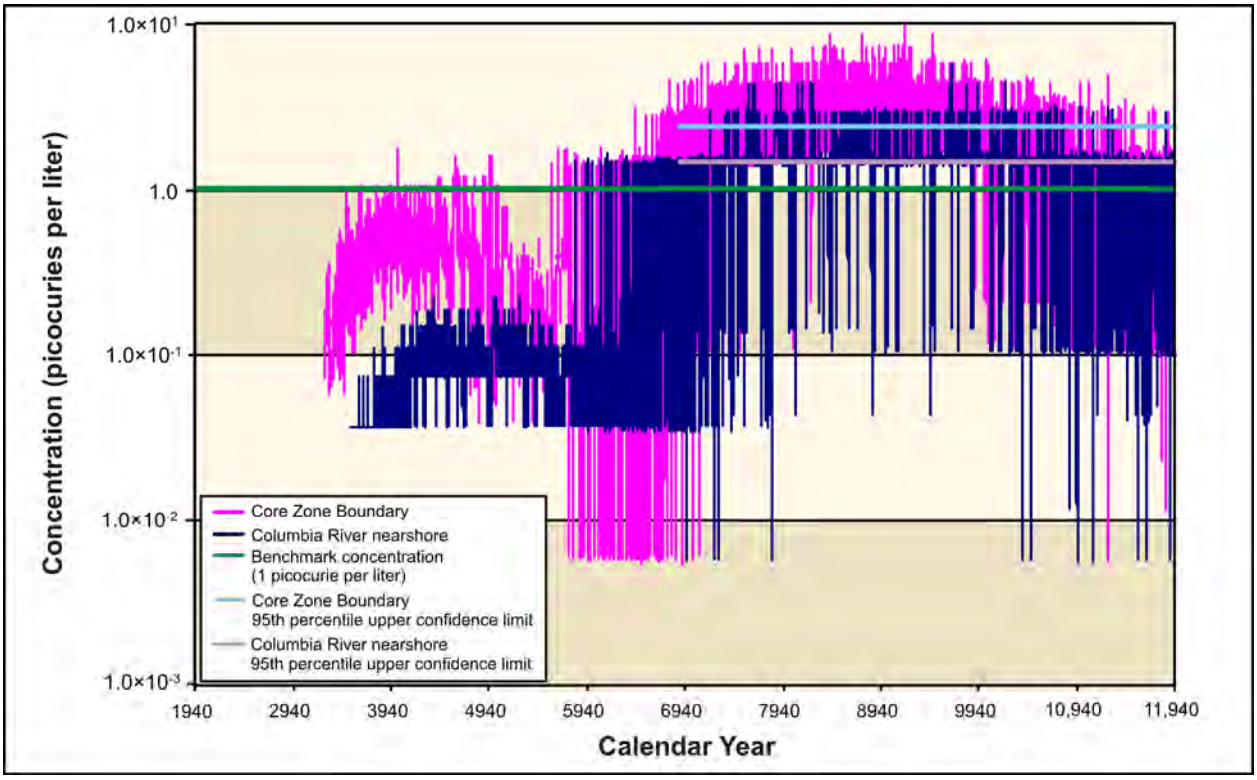


Figure 5–596. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Iodine-129 Concentration Versus Time

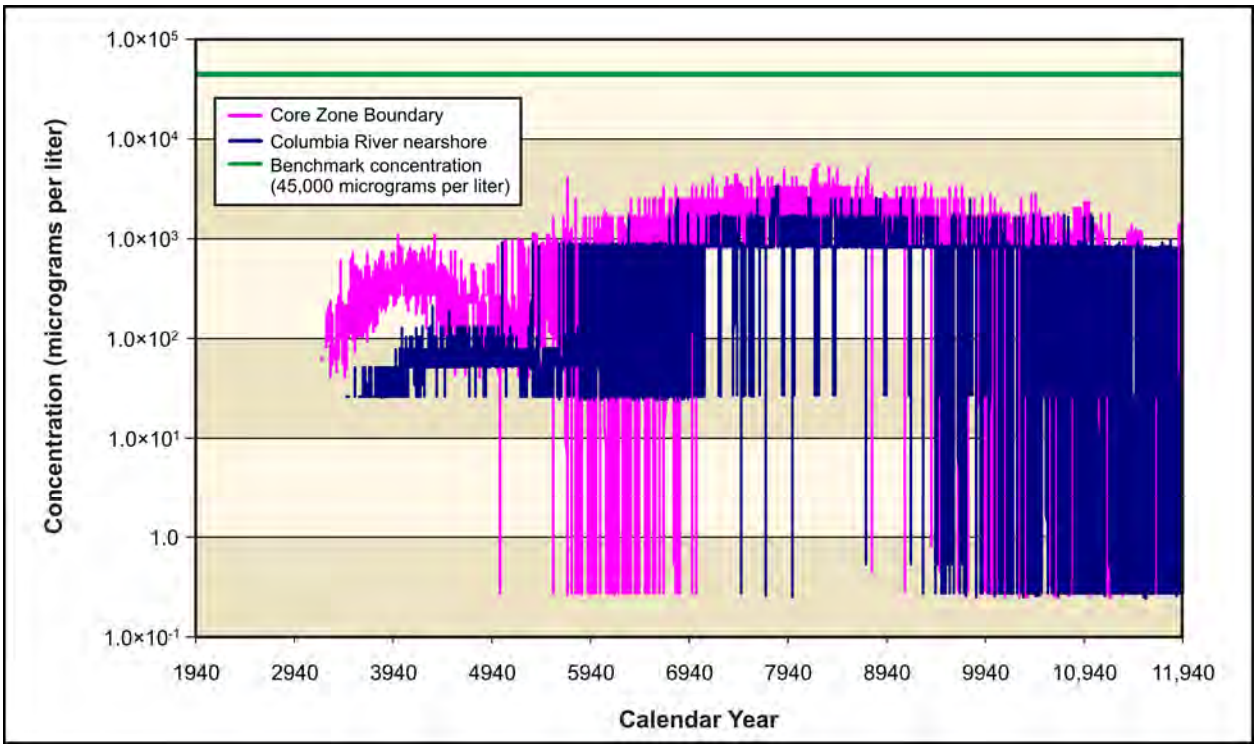


Figure 5–597. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Nitrate Concentration Versus Time

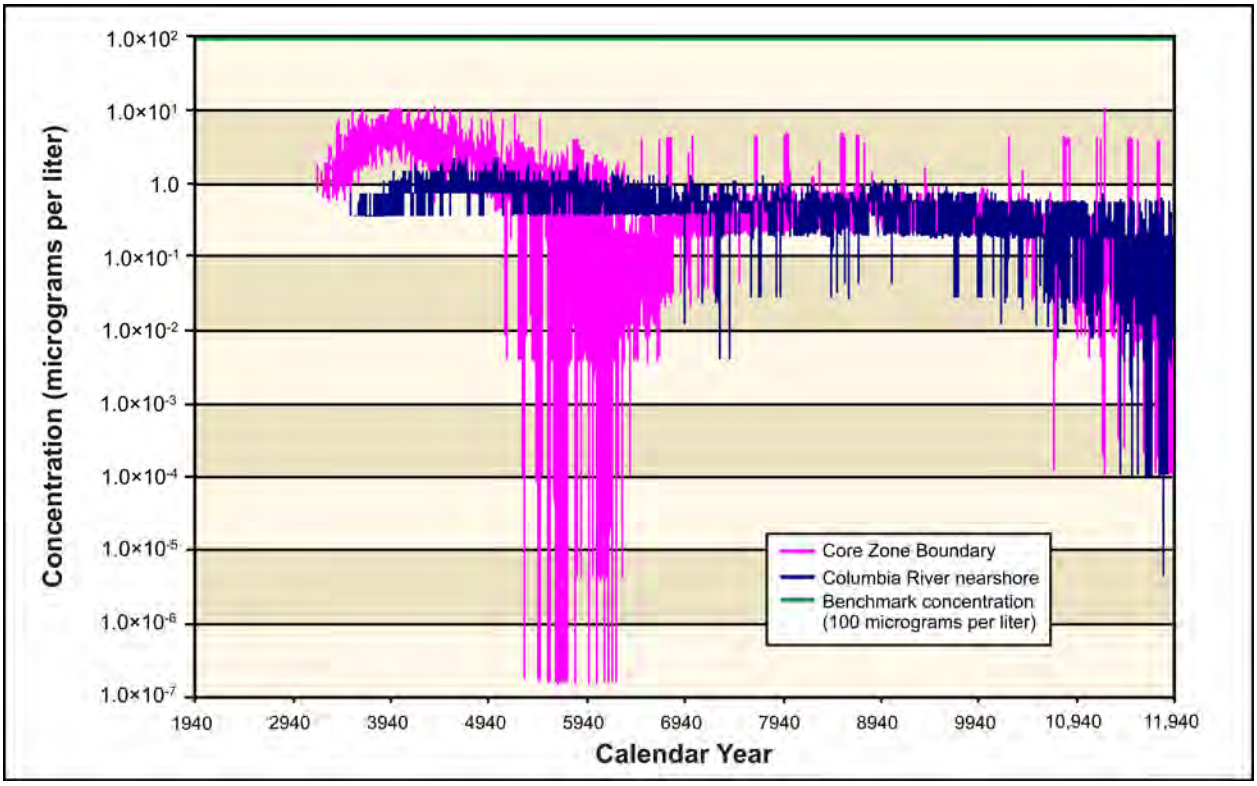


Figure 5–598. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Chromium Concentration Versus Time

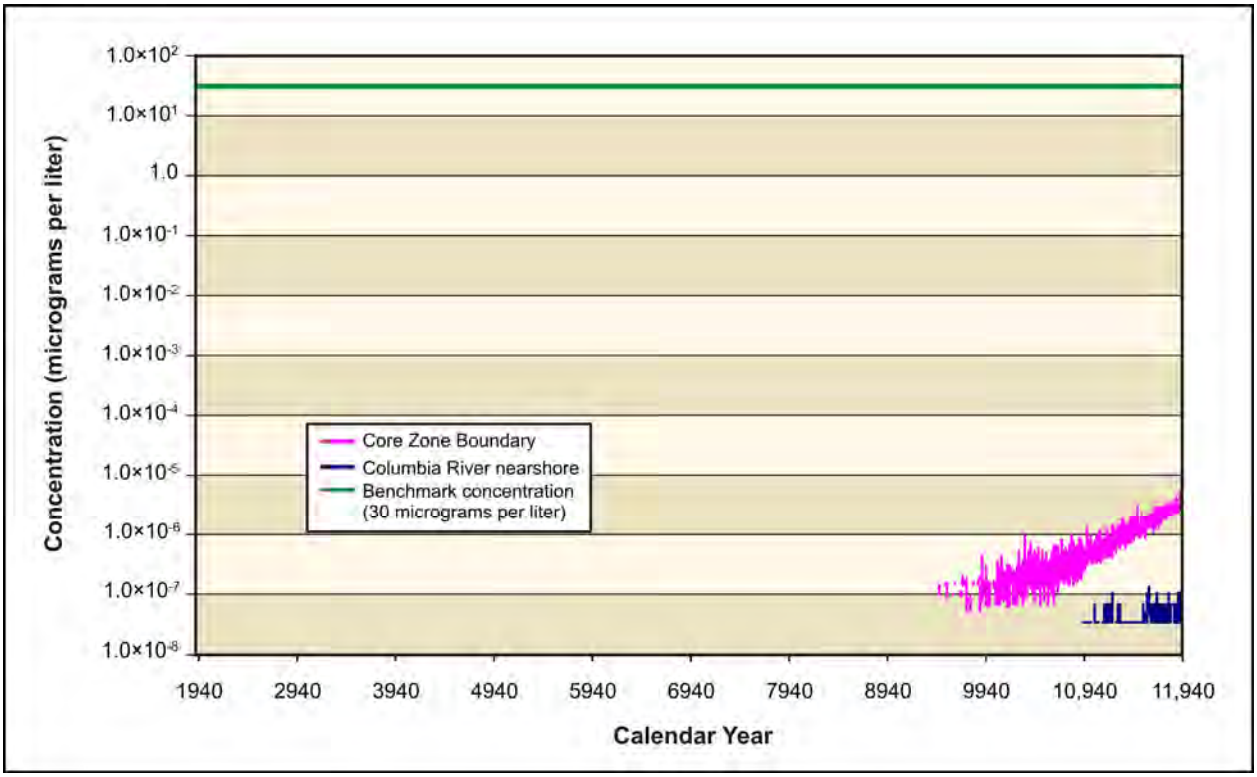


Figure 5–599. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Total Uranium Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, in terms of the spatial distribution of groundwater concentrations at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully-saturated colors green, yellow, orange, and red in order of increasing concentration; concentrations lower than the benchmark concentration by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

Figures 5–600 through 5–611 show concentration distributions at CYs 3890, 7140, and 11,885 for technetium-99, iodine-129, nitrate, and chromium. Figure 5–612 shows the concentration distribution for total uranium at CY 11,885. These groundwater releases from IDF-East that extend from the east of the Core Zone Boundary to the Columbia River and from the RPPDF north from the Core Zone Boundary to the Columbia River. The releases from the RPPDF remain in a fairly narrow area until about halfway to the Columbia River nearshore, where the plume spreads out and continues to the shoreline. The IDF-East plume is contained in a narrow area until it reaches about one-third of the distance to the Columbia River nearshore, where it spreads out and continues to the shoreline.

Figure 5–600 (CY 3890) shows that the technetium-99 release from the RPPDF exceeds the benchmark concentrations in small areas north of the Core Zone Boundary. Figure 5–601 (CY 7140) shows that the RPPDF technetium-99 distribution has nearly dissipated, but that areas of higher technetium-99 concentration remain. This figure also shows that the release from IDF-East extends from the release site to the Columbia River. By CY 11,885 (see Figure 5–602), the RPPDF-released technetium-99 has nearly

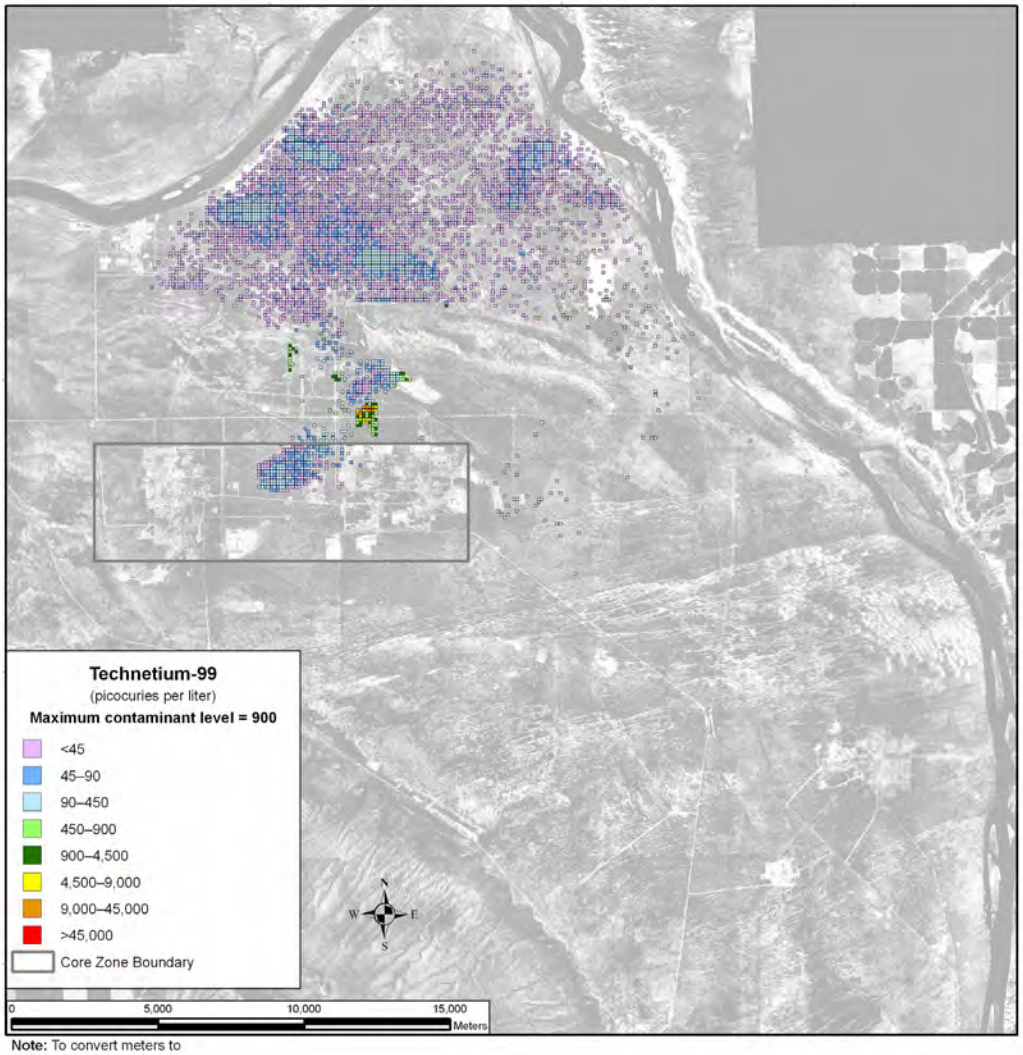
dissipated, with the exception of a small, isolated area of high concentration. The IDF-East technetium-99 release has increased significantly, and the concentration in groundwater continues in a widely distributed plume through CY 11,885. Those concentrations, however, remain below the benchmark concentration.

Figures 5–603 through 5–605 show similar concentration distribution for iodine-129, the RPPDF plume extending north from the Core Zone Boundary and the IDF-East plume extending east. Figure 5–603 shows an RPPDF plume at CY 3890 and but no IDF-East plume, the IDF-East release having occurred in later years. Figure 5–604 shows a dissipated RPPDF iodine-129 distribution and a significant IDF-East plume extending from the release site to the Columbia River. There is an area east of the Core Zone Boundary in which the iodine-129 concentration exceeds the benchmark concentration. Figure 5–605 (CY 11,885) shows almost no RPPDF iodine-129 but a small area (pocket) of high-concentration iodine-129 remains. This indicates that the IDF-East iodine-129 release to the Columbia River continues through CY 11,885, and that in smaller areas the concentrations approach or exceed the benchmark concentration.

Figures 5–606 through 5–608 show chromium releases from the RPPDF and IDF-East that produce plume maps (time, space, and concentration) similar to those of the technetium-99 and iodine-129 releases. These also show a delayed (relative to the RPPDF release) release of chromium from IDF-East. However, areas of higher nitrate concentrations from both releases do not exceed benchmark concentrations. A small area of higher nitrate concentration from the RPPDF nitrate release appears to be maintained through CY 11,885.

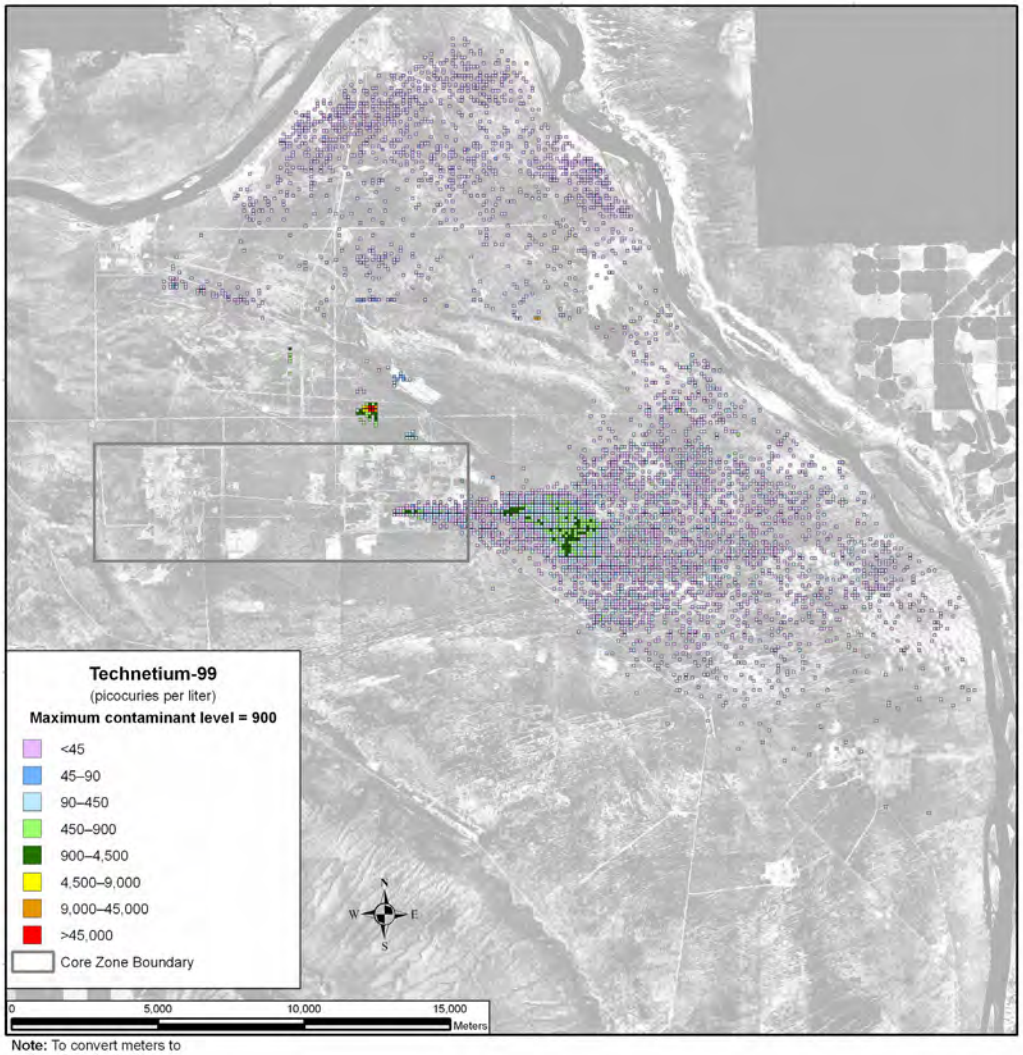
The nitrate release shown in Figures 5–609 through 5–611 is nearly identical to the chromium release (time and space ranges). The IDF-East nitrate release never reaches the benchmark concentration. In CY 7140, the RPPDF shows a small area in which a high nitrate concentration is maintained, but this appears to dissipate by CY 11,885.

Figure 5–612 shows the concentration distribution for total uranium released from the RPPDF for CY 11,885. The released total uranium produces a fairly even distribution between the release source and the Columbia River nearshore. As total uranium is not as mobile as the other COPCs, the total uranium release results in a fairly homogeneous distribution between the release source and the Columbia River. The concentration is consistently well below the benchmark concentration and there are no areas of higher levels, as were observed for other COPCs. The distribution and consistency of the CY 11,885 total uranium distribution would indicate that the released total uranium plume will remain well past CY 11,885.



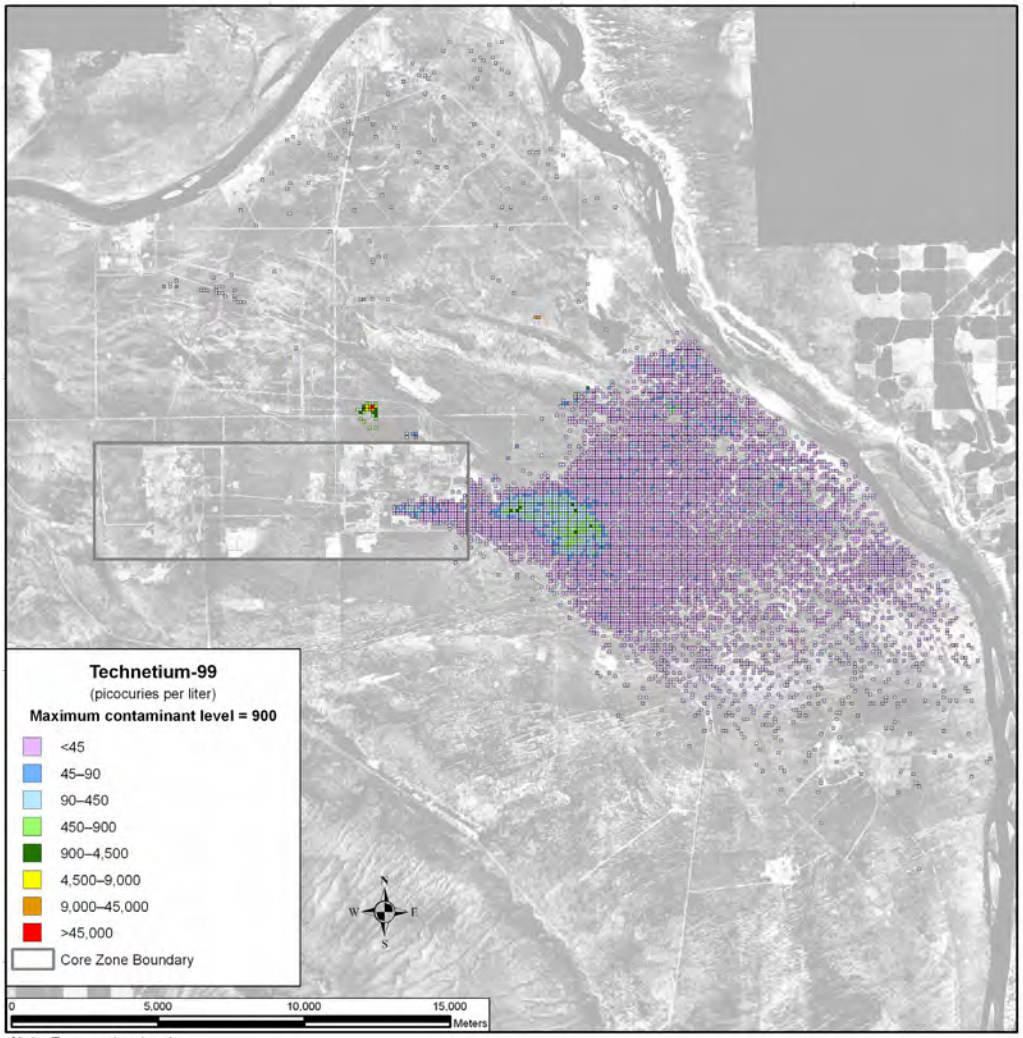
Note: To convert meters to feet, multiply by 3.281

Figure 5–600. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



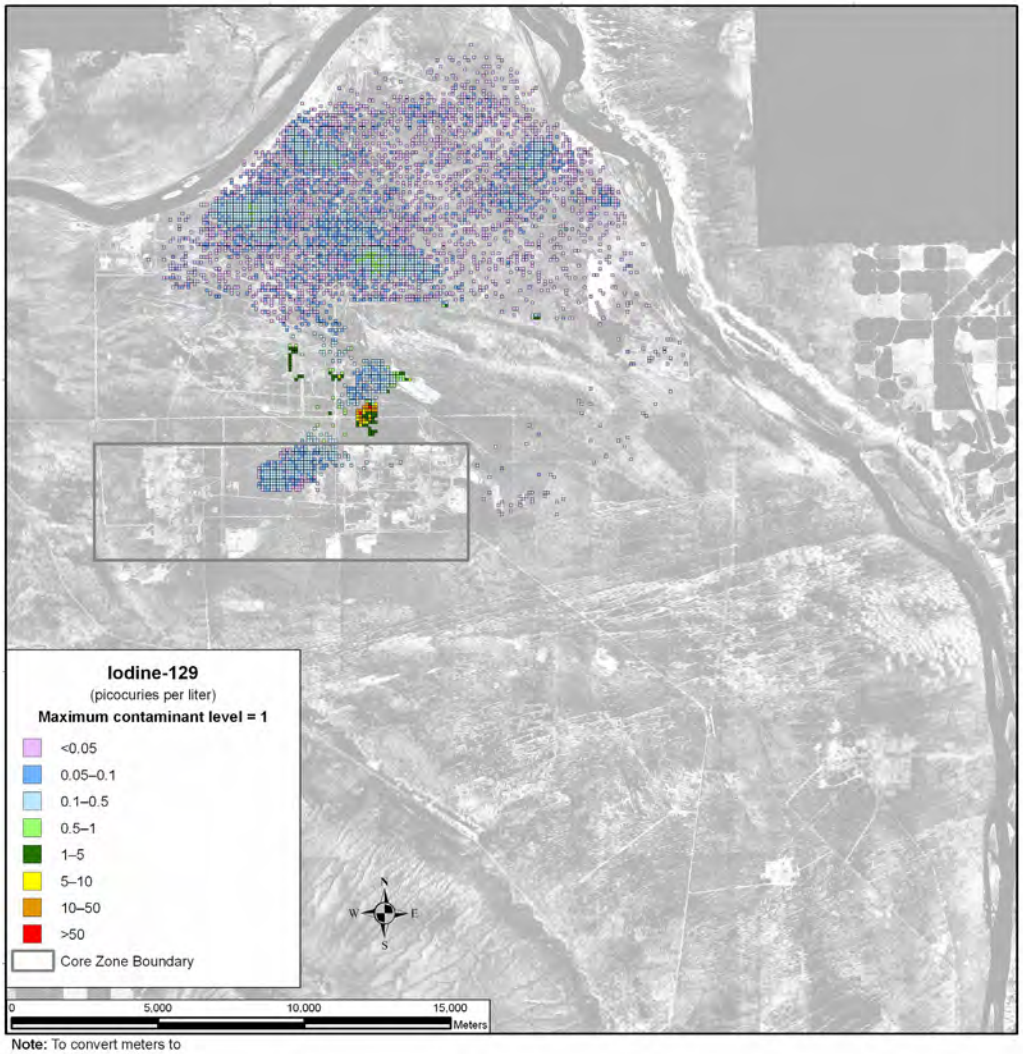
Note: To convert meters to feet, multiply by 3.281

Figure 5–601. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



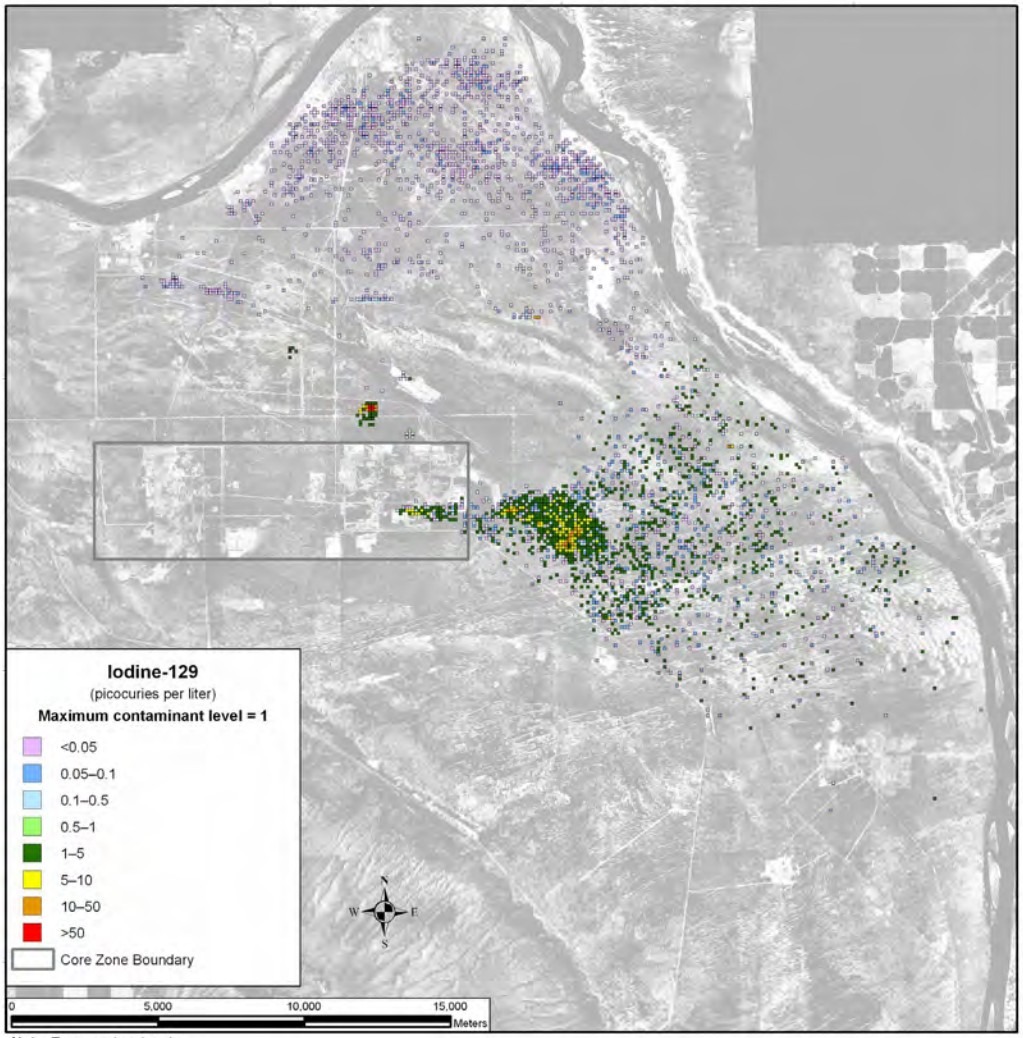
Note: To convert meters to feet, multiply by 3.281

Figure 5–602. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



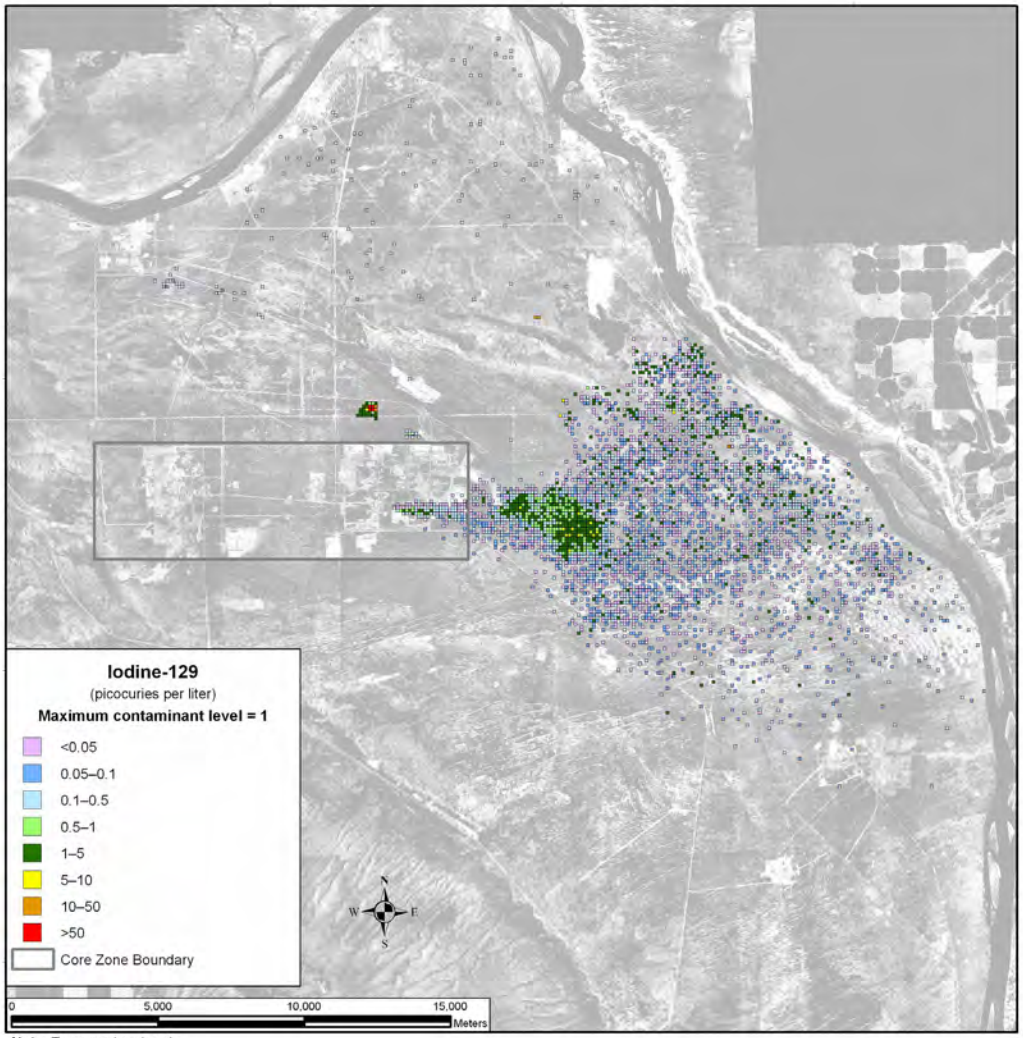
Note: To convert meters to feet, multiply by 3.281

Figure 5–603. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



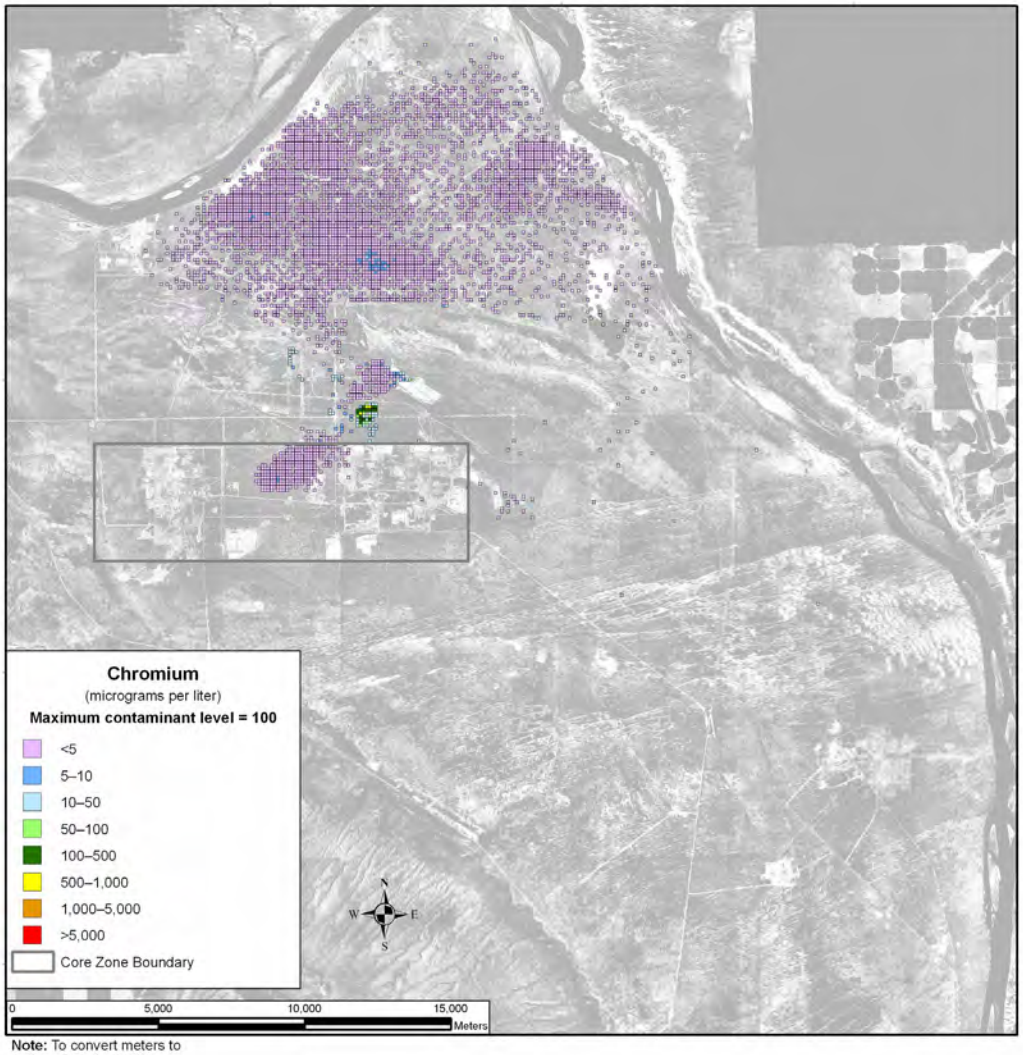
Note: To convert meters to feet, multiply by 3.281

Figure 5–604. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



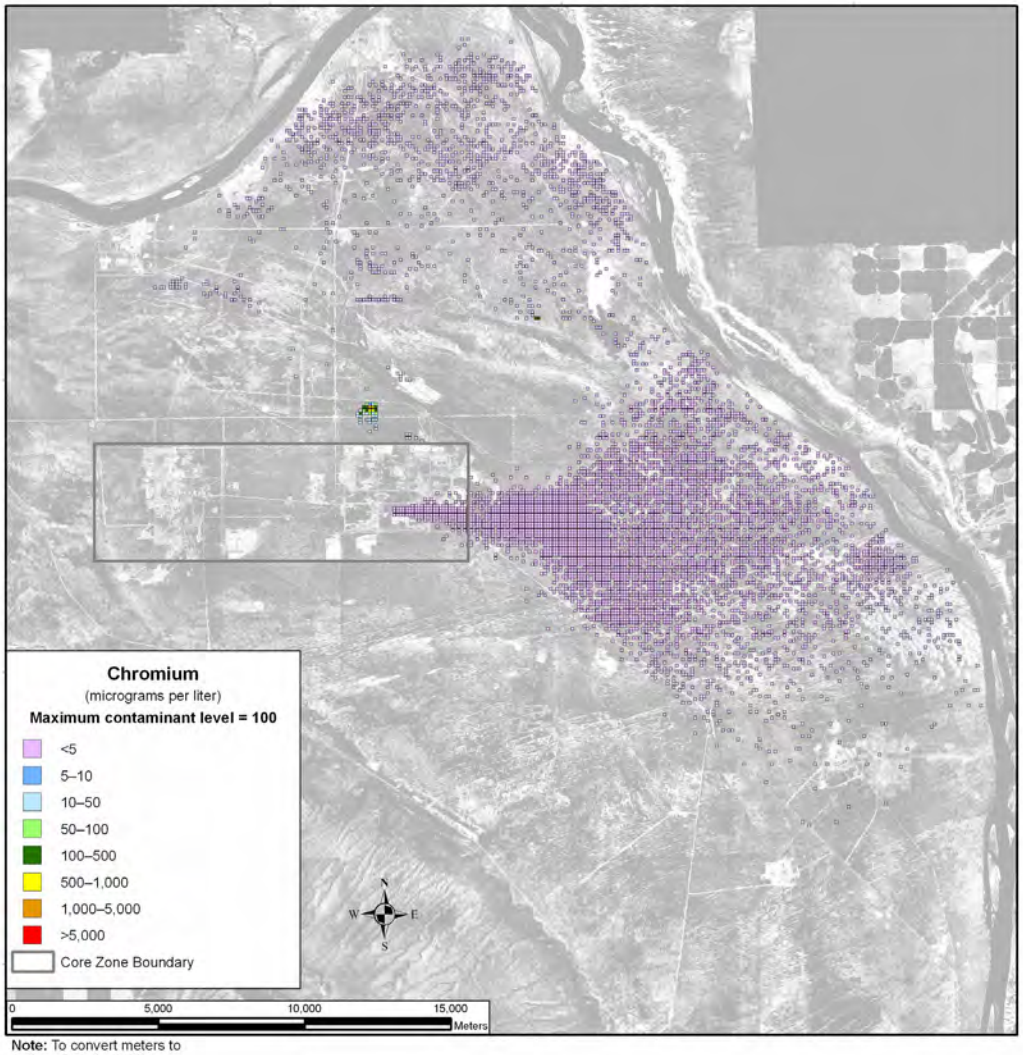
Note: To convert meters to feet, multiply by 3.281

Figure 5–605. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



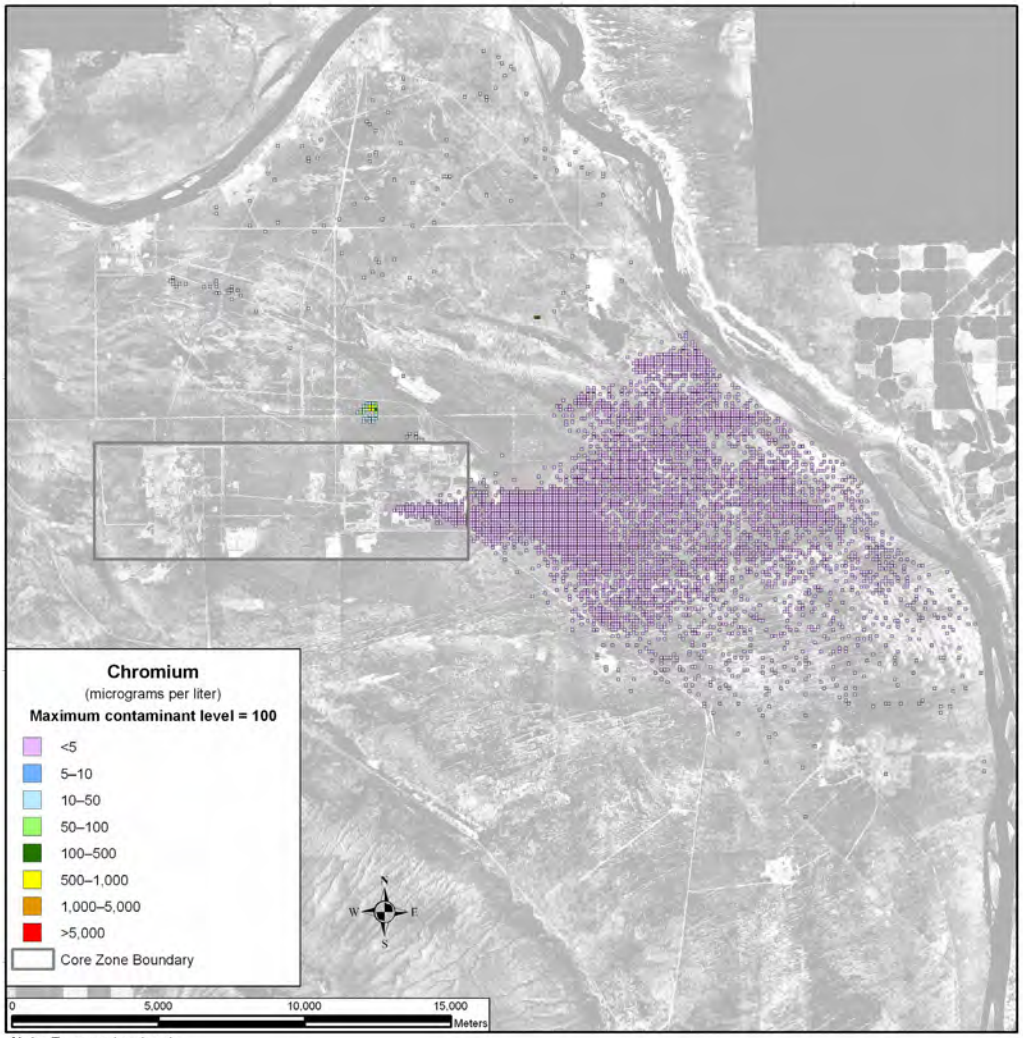
Note: To convert meters to feet, multiply by 3.281

Figure 5–606. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



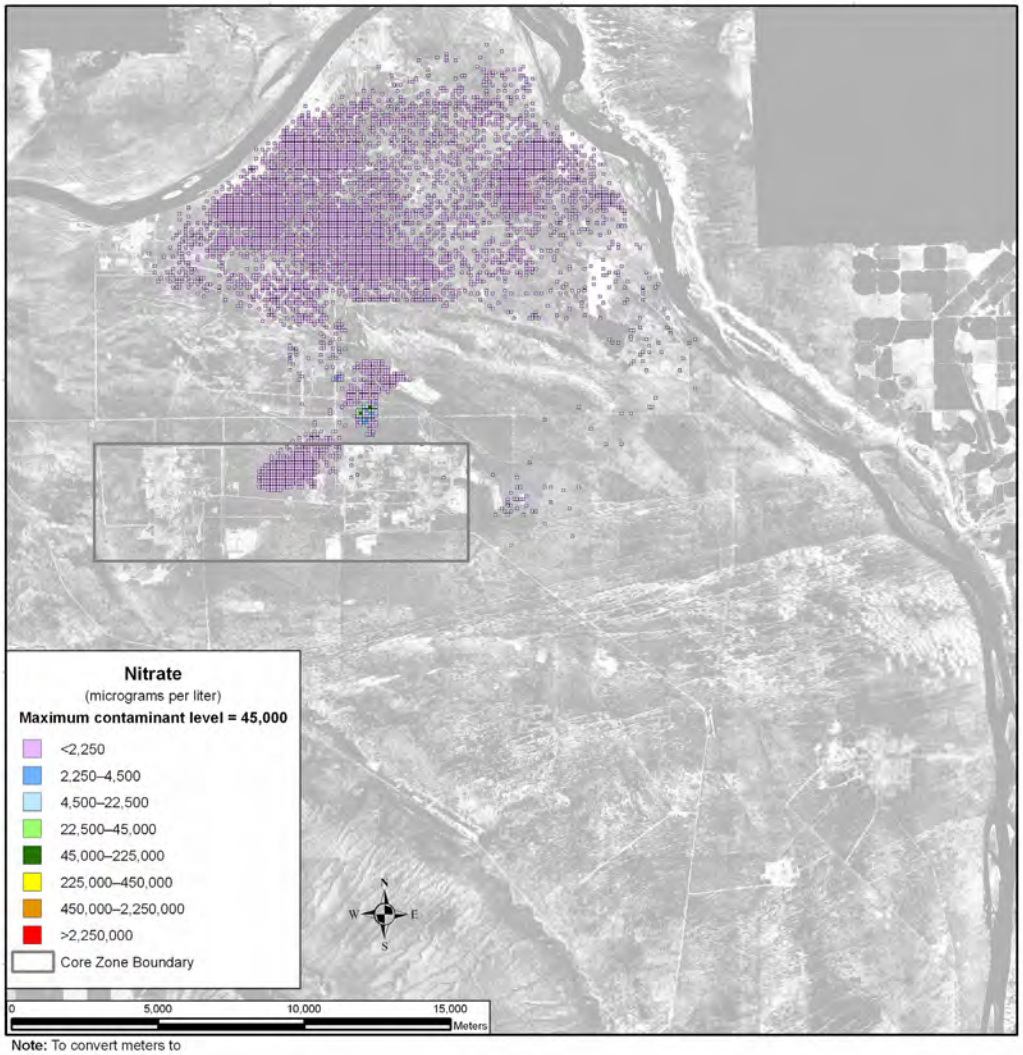
Note: To convert meters to feet, multiply by 3.281

Figure 5–607. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



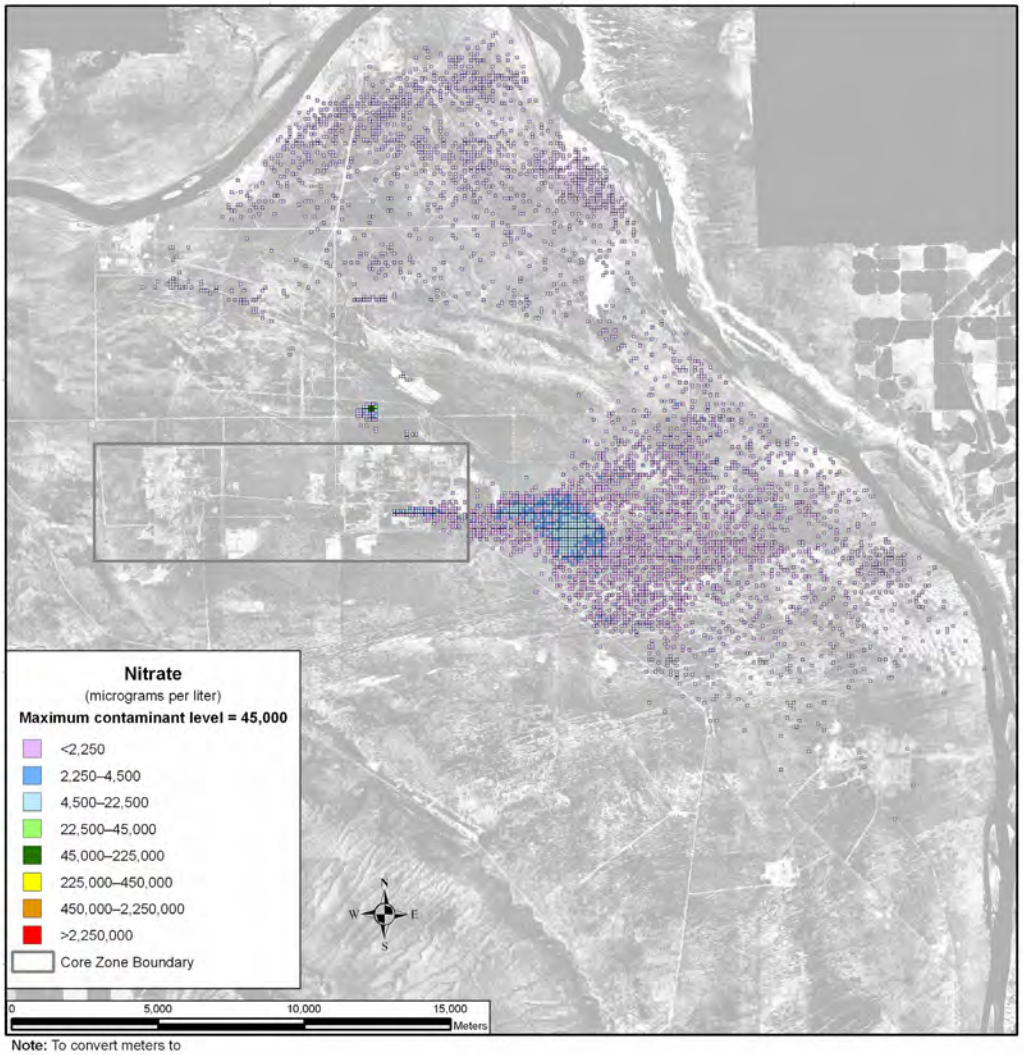
Note: To convert meters to feet, multiply by 3.281

Figure 5–608. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



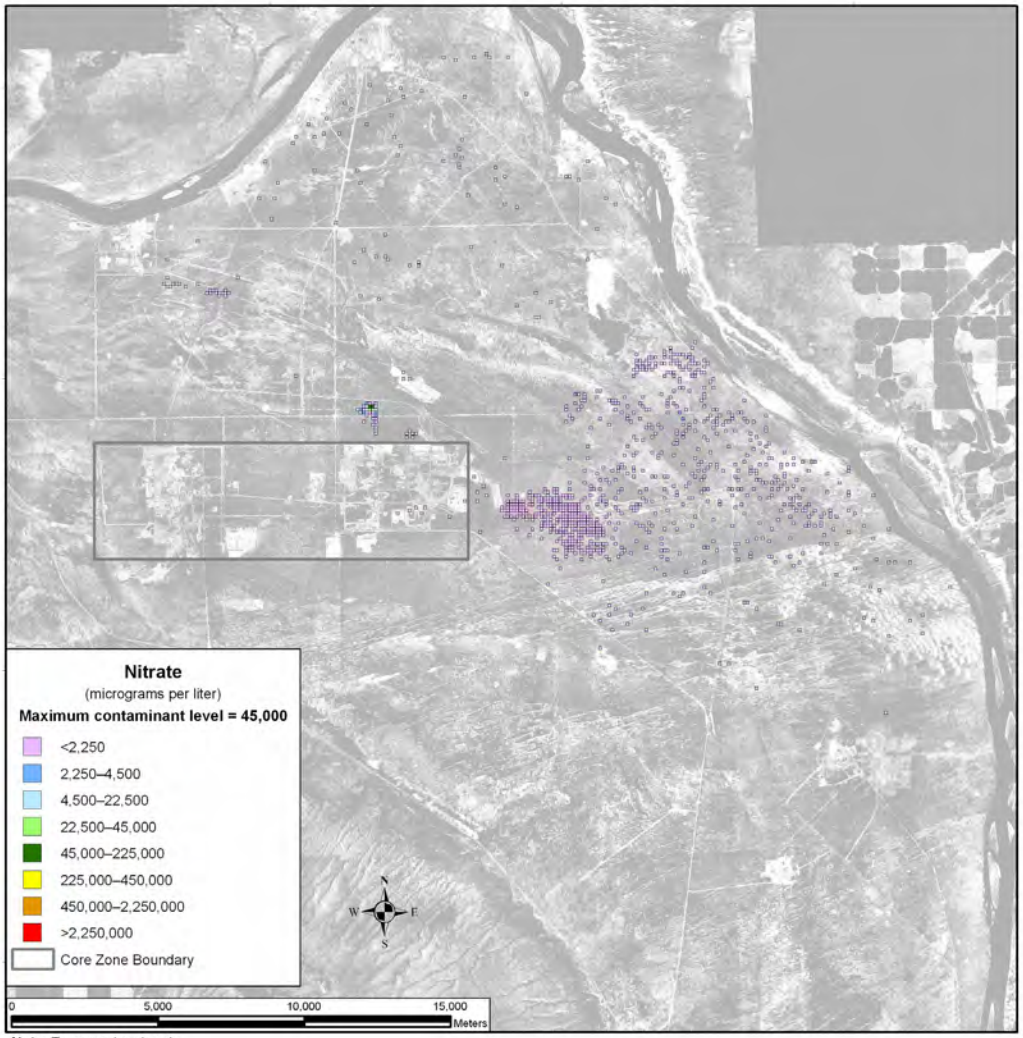
Note: To convert meters to feet, multiply by 3.281

Figure 5–609. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



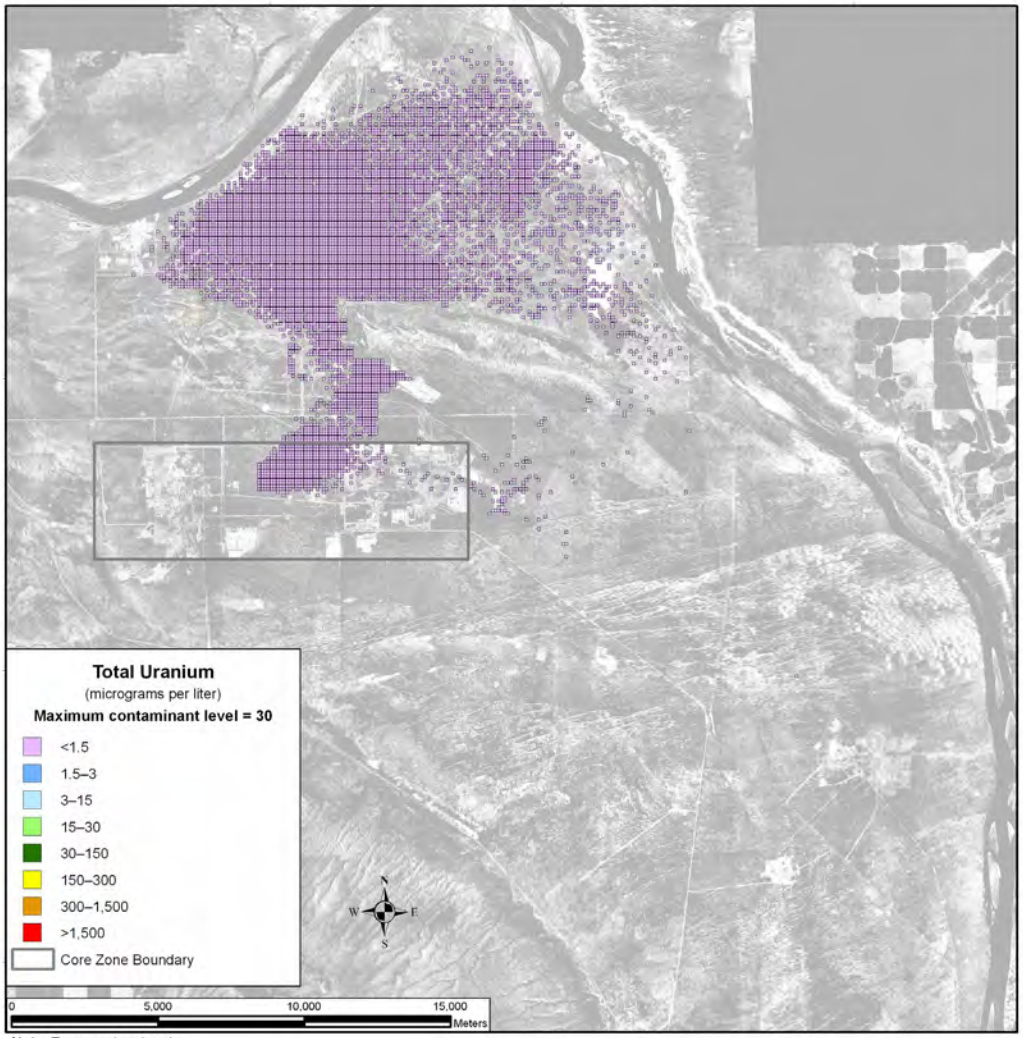
Note: To convert meters to feet, multiply by 3.281

Figure 5–610. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–611. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–612. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

For Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, released iodine-129 is the major source of this risk. The analysis indicates that the concentrations of the COPCs at these points decrease to levels significantly below the benchmark concentrations through CY 11,885.

As for the conservative tracers, there are small, isolated areas near the outer Core Zone Boundary in which high concentrations appear not to dissipate; they remain high through the end of the period of analysis. The release of total uranium appears fairly homogeneous between the release source and the Columbia River nearshore. Although the concentration in this plume is well below the benchmark, total uranium remains in the environment and trends shows an increasing concentration through the end of this analysis period (CY 11,885).

5.3.1.2.2.3 Disposal Group 2, Subgroup 2-B, Option Case

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, includes Tank Closure Alternative 6B, Option Case; FFTF Decommissioning Alternative 2 or 3; and onsite- and offsite-generated waste. Summaries of the actions and timelines for Waste Management Alternative 2 are provided in Chapter 2, Section 2.5.

For the long-term groundwater impact analysis, two major periods have been identified for Waste Management Alternative 2, Disposal Group 1, Subgroup 1-E:

- The disposal period starts with the onset of disposal operations for IDF-East and the RPPDF in CY 2009 and continues through CY 2100. During this disposal period, the materials in these permitted, operational facilities are assumed to be unavailable for release to the environment.

- The post-disposal period starts in CY 2101 and continues through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in IDF-East and the RPPDF become available for release to the environment. For the purpose of analyzing long-term groundwater impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, IDF-East and the RPPDF are assumed to be covered by a barrier limiting infiltration for the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case. Full results are tabulated in Appendices M, N, and O. This discussion of long-term impacts associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, is focused on the following COPC drivers:

- Radiological risk drivers: iodine-129 and technetium-99
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, and acetonitrile

The COPC drivers for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis, and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. There is no chemical risk. The chemical hazards drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, chromium, nitrate, and acetonitrile) are all mobile (i.e., they move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. They are essentially conservative tracers. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2 Subgroup 2-B, Option Case, in terms of the total amount released to the vadose zone, groundwater, and the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over 10 orders of magnitude.

200-East Area Integrated Disposal Facility

IDF-East has seven subtotals plotted representing releases from ETF-generated secondary waste, Preprocessing Facility (PPF) glass, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, waste management secondary and onsite-generated waste, and offsite-generated waste.

Figure 5–613 shows the release to the vadose zone for the radiological risk drivers and Figure 5–614, chemical hazard drivers. The inventories in the waste forms are a major factor in the quantities released to the vadose zone. The predominant source of technetium-99 in the vadose zone is offsite-generated waste (77 percent), followed by tank closure secondary waste (19 percent), and ETF-generated secondary waste (4 percent). The sources of the iodine-129 release are offsite-generated waste (85 percent) and ETF-generated secondary waste (14 percent). The chromium release is from the tank closure secondary waste (85 percent), waste management secondary and onsite-generated waste (8 percent) offsite-generated waste (4 percent), ETF-generated secondary waste (2 percent), and PPF glass (1 percent). All of the nitrate released is from ETF-generated secondary waste. There is no acetonitrile from any of the waste forms in IDF-East.

Figure 5–615 shows the release to groundwater for the radiological risk drivers and Figure 5–616, the chemical hazard drivers. In addition to the waste form inventory, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. Most of the vadose zone technetium-99 (89 percent), iodine-129 (91 percent) and all of the chromium and nitrate are released to groundwater during the period of analysis.

Figure 5–617 shows the release to the Columbia River for the radiological risk drivers and Figure 5–618, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. Most of the groundwater technetium-99 (97 percent), iodine-129 (97 percent), chromium (97 percent), and nitrate (>99 percent) are released to the Columbia River over the period of analysis.

Overall, most of the vadose zone technetium-99 (86 percent), iodine-129 (89 percent), chromium (96 percent), and nitrate (98 percent) from IDF-East is released to the Columbia River. These releases are identical to those for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

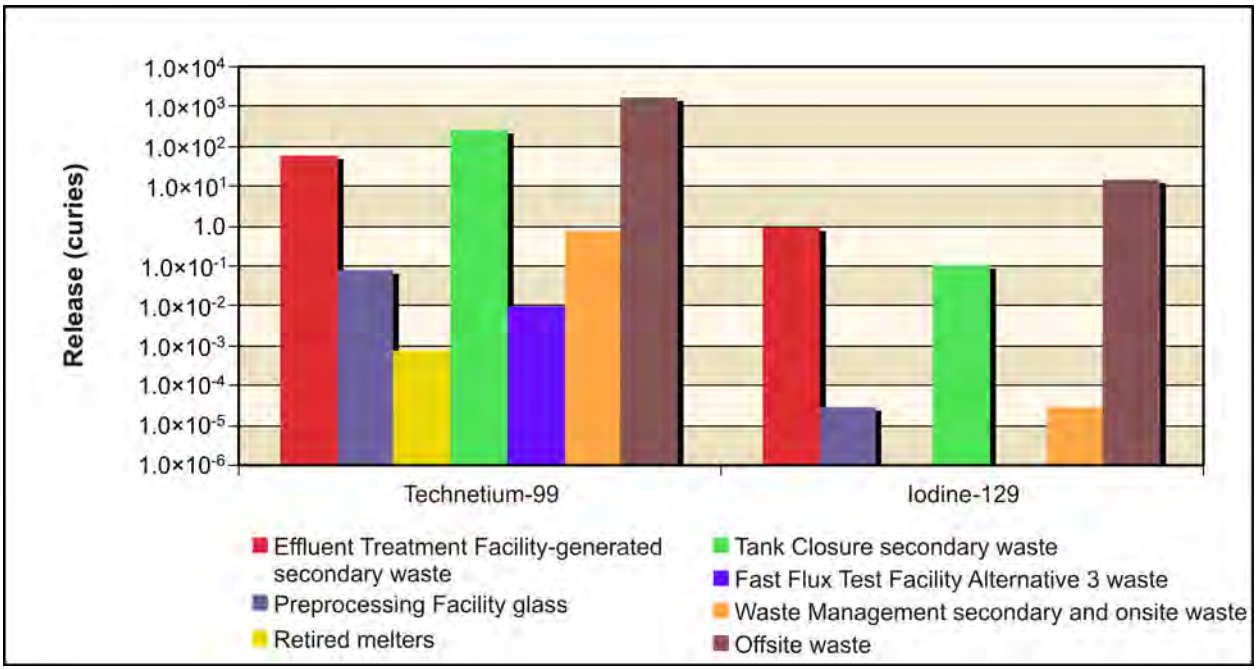


Figure 5–613. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

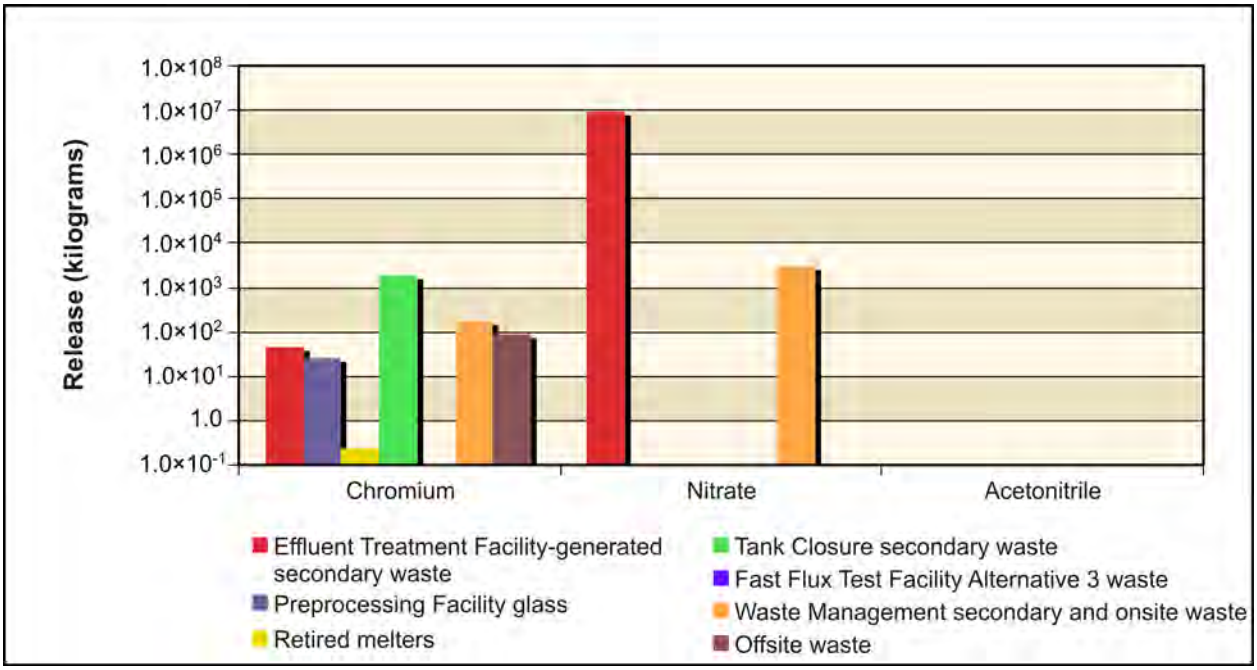


Figure 5–614. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

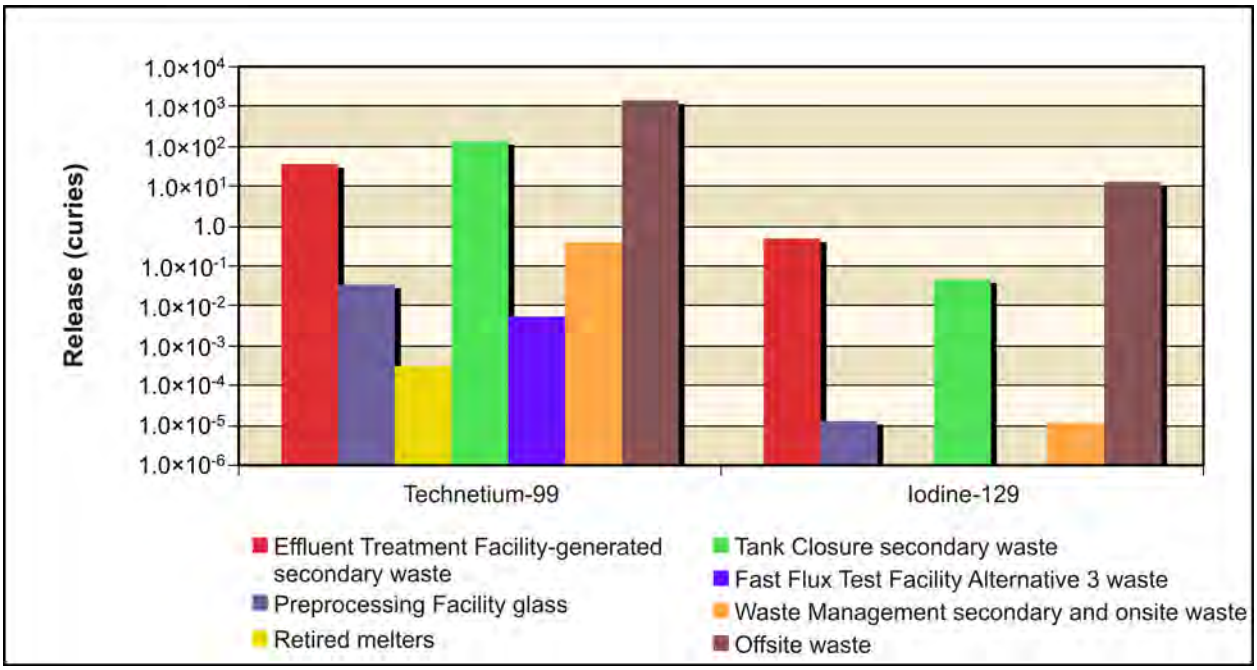


Figure 5–615. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

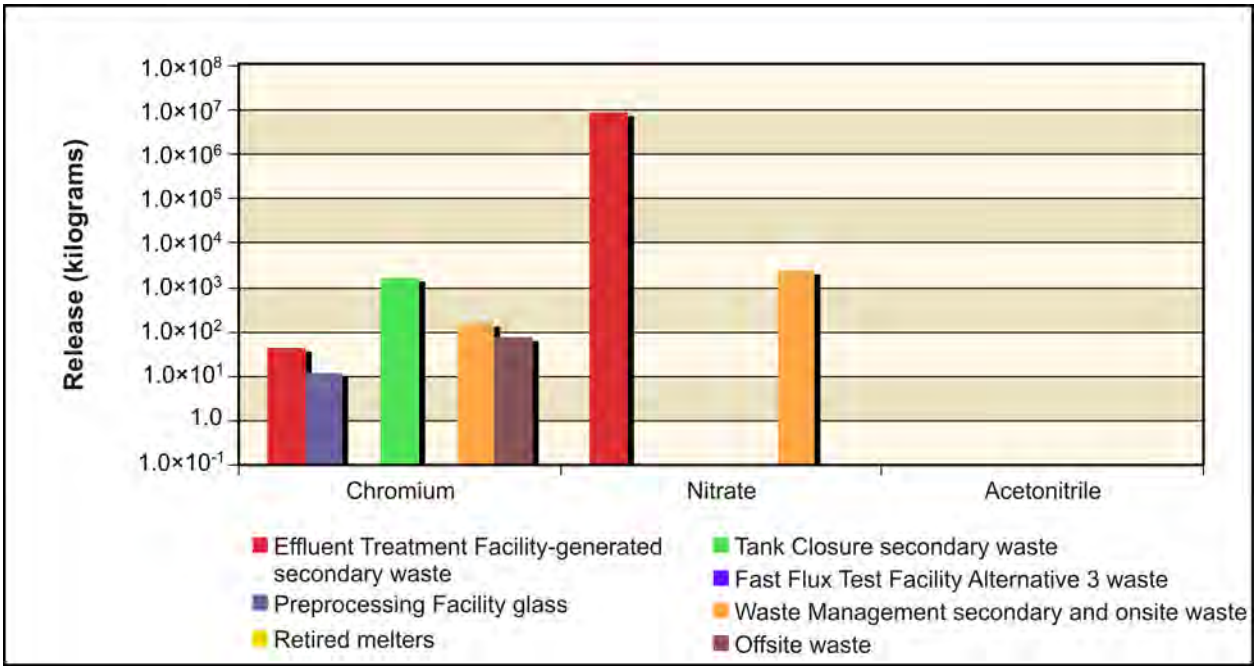


Figure 5–616. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

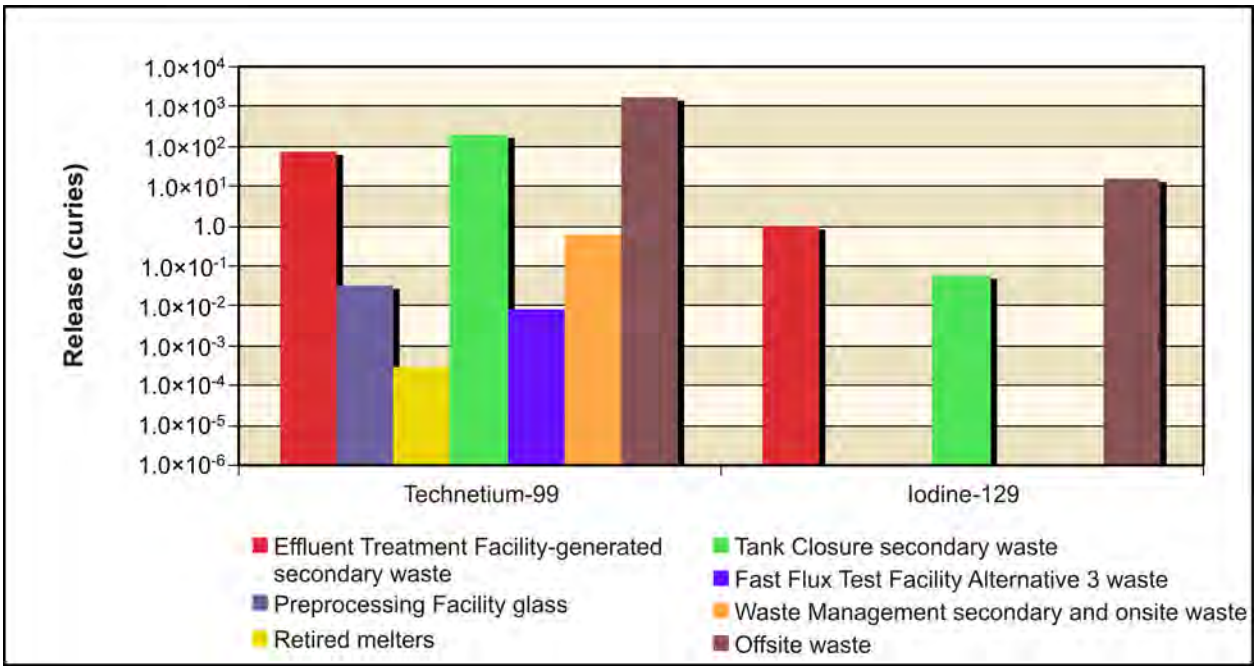


Figure 5–617. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

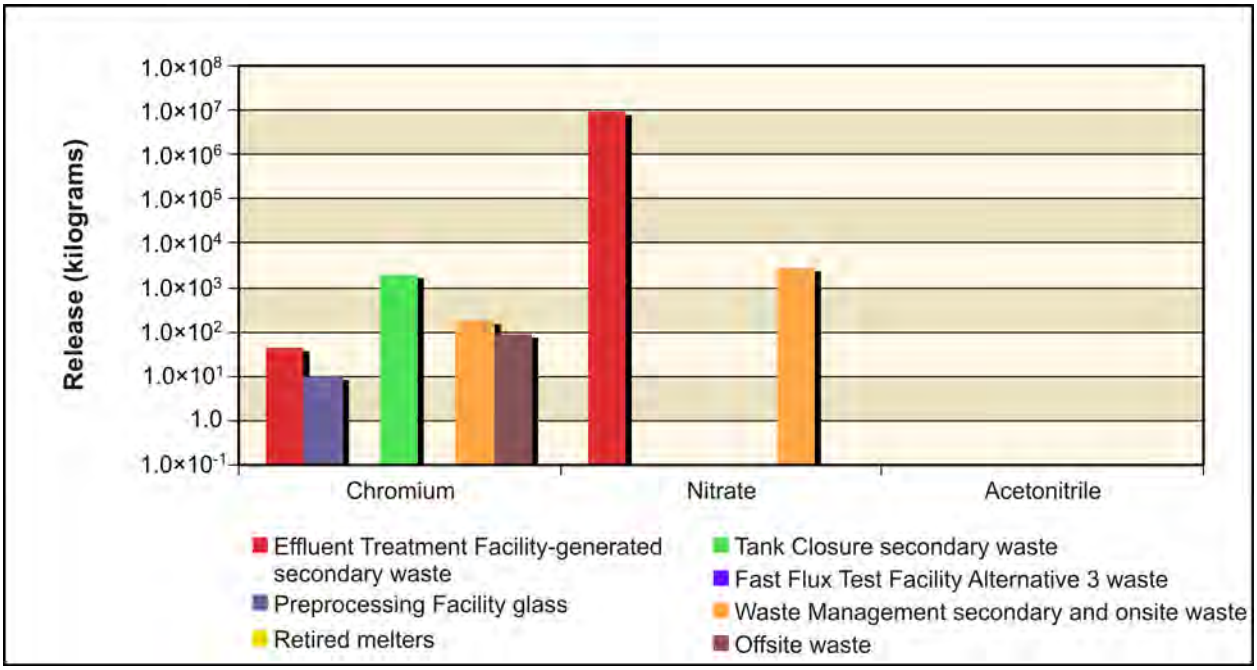


Figure 5–618. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

River Protection Project Disposal Facility

Figure 5–619 shows the release to the vadose zone for the radiological risk drivers and Figure 5–620, the chemical hazard drivers. Release to the vadose zone is controlled by the inventory (i.e., 100 percent of the inventory was released during the post-disposal period). The predominant releases from the RPPDF are technetium-99 and iodine-129, with technetium-99 being the predominant radionuclide released. The chemical releases from the RPPDF include nitrate (largest), chromium, and acetonitrile (smallest).

Figure 5–621 shows the release to groundwater for the radiological risk drivers and Figure 5–622, the chemical hazard drivers. In addition to the inventory, release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. All of the RPPDF vadose zone technetium-99, iodine-129, chromium, nitrate, and acetonitrile is released to groundwater.

Figure 5–623 shows the release to the Columbia River for the radiological risk drivers and Figure 5–624, the chemical hazard drivers. Release to the Columbia River is controlled by the transport properties of the COPC drivers. All of the RPPDF groundwater iodine-129, technetium-99, chromium, nitrate, and acetonitrile, is released to the Columbia River.

Overall, about 95 percent of the RPPDF vadose zone radionuclides and chemicals are released to the Columbia River during the period of analysis. This release is almost identical to that identified for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

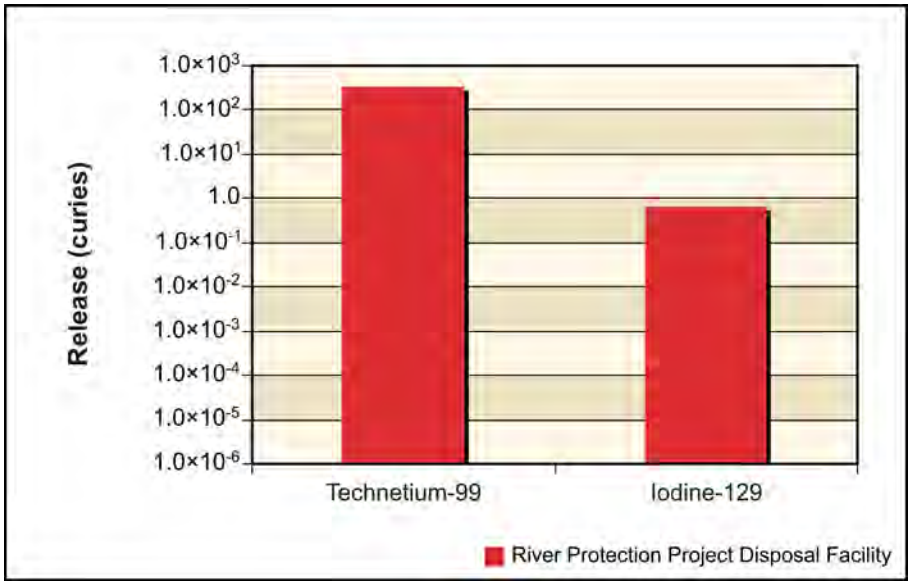


Figure 5–619. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

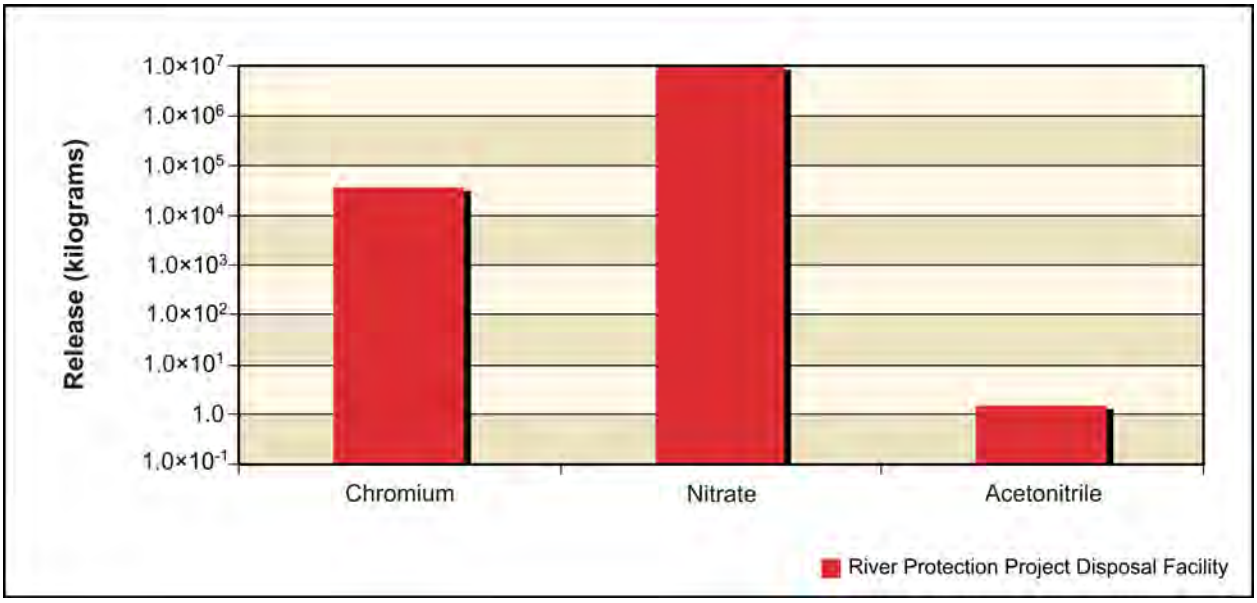


Figure 5–620. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

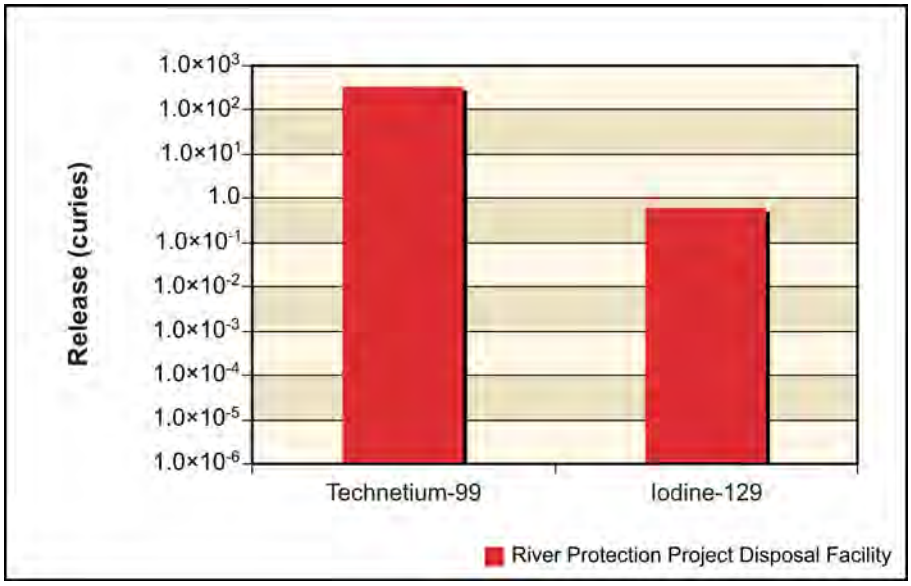


Figure 5–621. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at River Protection Project Disposal Facility to Groundwater

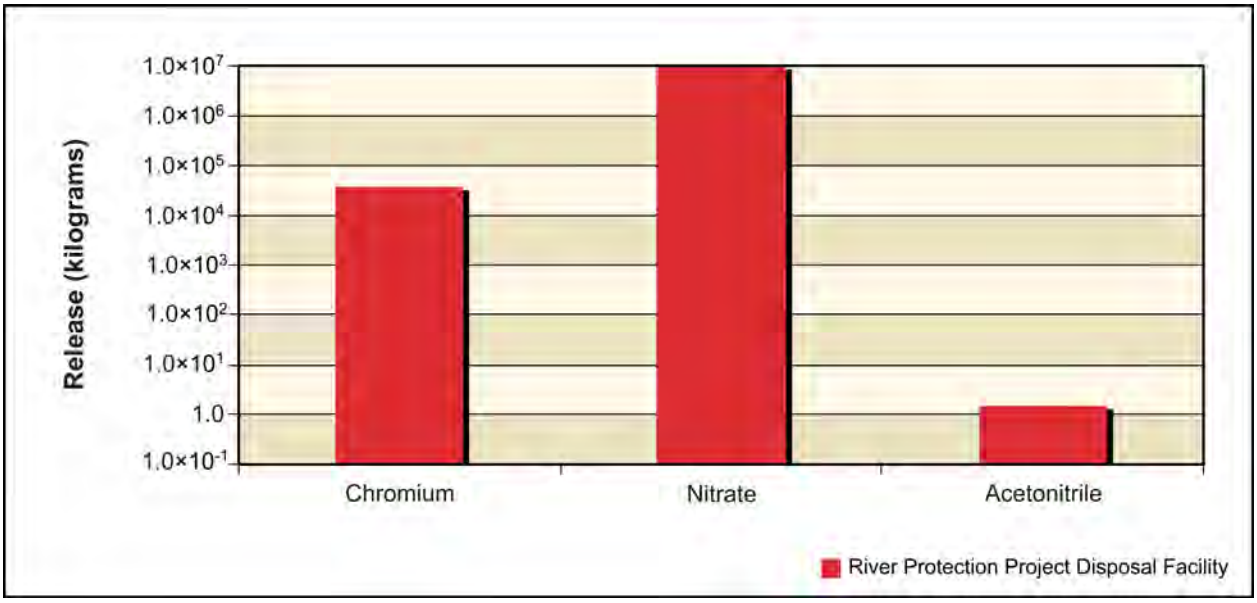


Figure 5–622. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at River Protection Project Disposal Facility to Groundwater

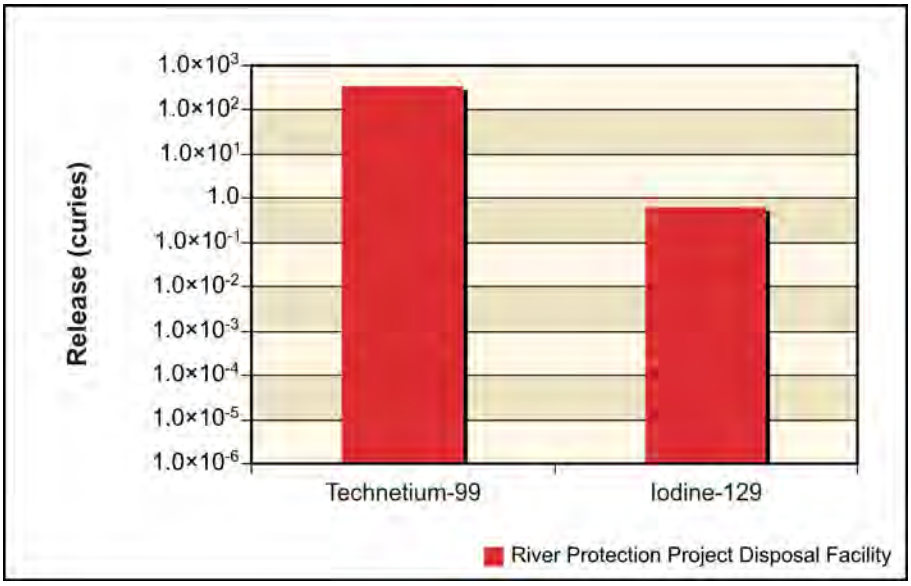


Figure 5–623. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Radiological Releases at River Protection Project Disposal Facility to Columbia River

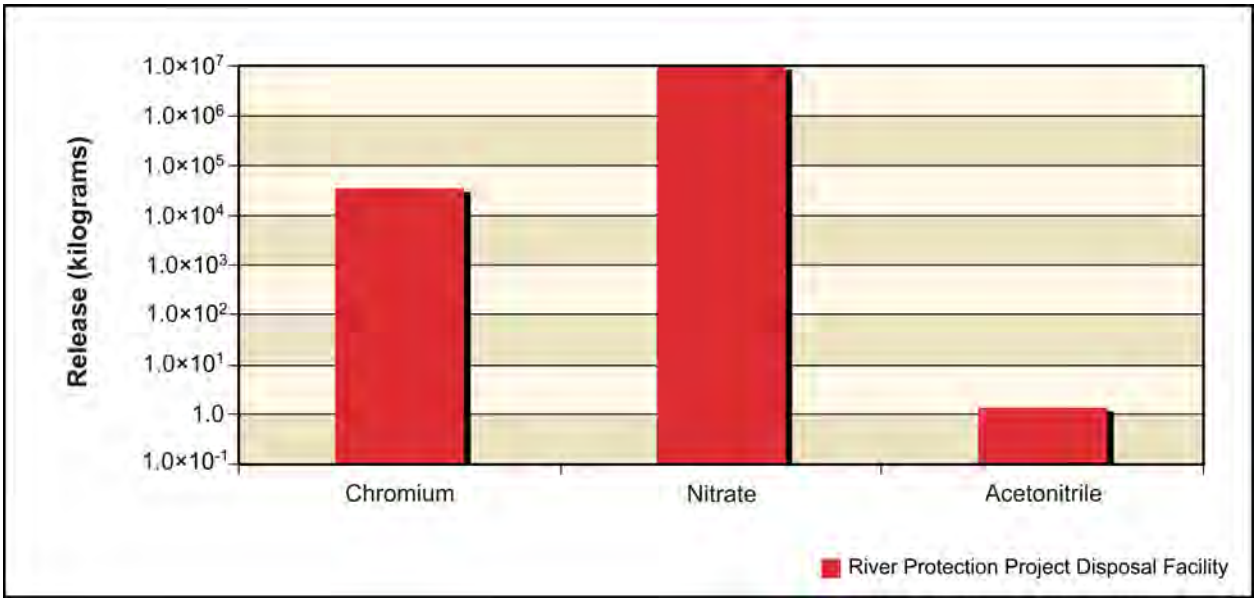


Figure 5–624. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, in terms of groundwater concentration versus time at the Core Zone Boundary, and the Columbia River nearshore. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. The benchmark concentration of each radionuclide and chemical is also shown. The concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on several of these graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval is likely (95 percent of the time) to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Table 5–86 lists the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary and Columbia River nearshore.

Table 5–86. Waste Management Alternative 2, Disposal Group 2, Subgroup 2B, Option Case, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**2,890** (8580)	340 (4213)	**1,350** (4466)	717 (8477)	900
Iodine-129	**24** (9058)	0.6 (4176)	**10** (9188)	**6** (9652)	1
Chemical in micrograms per liter					
Chromium	3 (8281)	33 (4118)	97 (10533)	17 (5522)	100
Nitrate	16,600 (8162)	9,070 (3962)	28,400 (9305)	5,700 (4618)	45,000

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.
Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

Figures 5–625 through 5–628 show concentration versus time for technetium-99, iodine-129, nitrate, and chromium, respectively. With the exception of nitrate, the concentrations versus time are essentially identical to those for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

The concentration of technetium-99 (see Figure 5–625) is below the benchmark at the Core Zone Boundary and the Columbia River nearshore. The technetium-99 concentrations remains fairly constant for most of the analysis period and then decreases through CY 11,940, staying within about one order of magnitude from the benchmark. Figure 5–626 shows iodine-129 exceeding benchmark concentrations starting at about CY 5940 and continuing through CY 11,940 at both the Core Zone Boundary and the Columbia River nearshore. This concentration peaks during the last one-third of the analysis period and then declines, reaching the benchmark concentration at about CY 11,940.

Nitrate concentrations at the Core Zone Boundary and Columbia River nearshore peak near the start of the analysis period (see Figure 5–627). Both concentrations then decrease through CY 11,885, always at least one order of magnitude below the benchmark concentration. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, shows a similar nitrate release, but with a peak about three-quarters of the way through the analysis period and then a decline to the benchmark concentration at about CY 11,885.

Figure 5–628 shows that the chromium concentrations at the Core Zone Boundary and the Columbia River nearshore always remain just below the benchmark concentration. In Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, the chromium is below the benchmark by at least one order of magnitude.

Figure 5–629 shows concentration versus time for total uranium. Uranium-238 has no detectable release to the environment. Total uranium concentrations, while very low, continue to increase during the period of analysis and beyond. The total uranium concentrations remain at least six orders of magnitude below the benchmark concentration throughout the analysis period (through CY 11,940). These release concentrations are basically identical to those for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

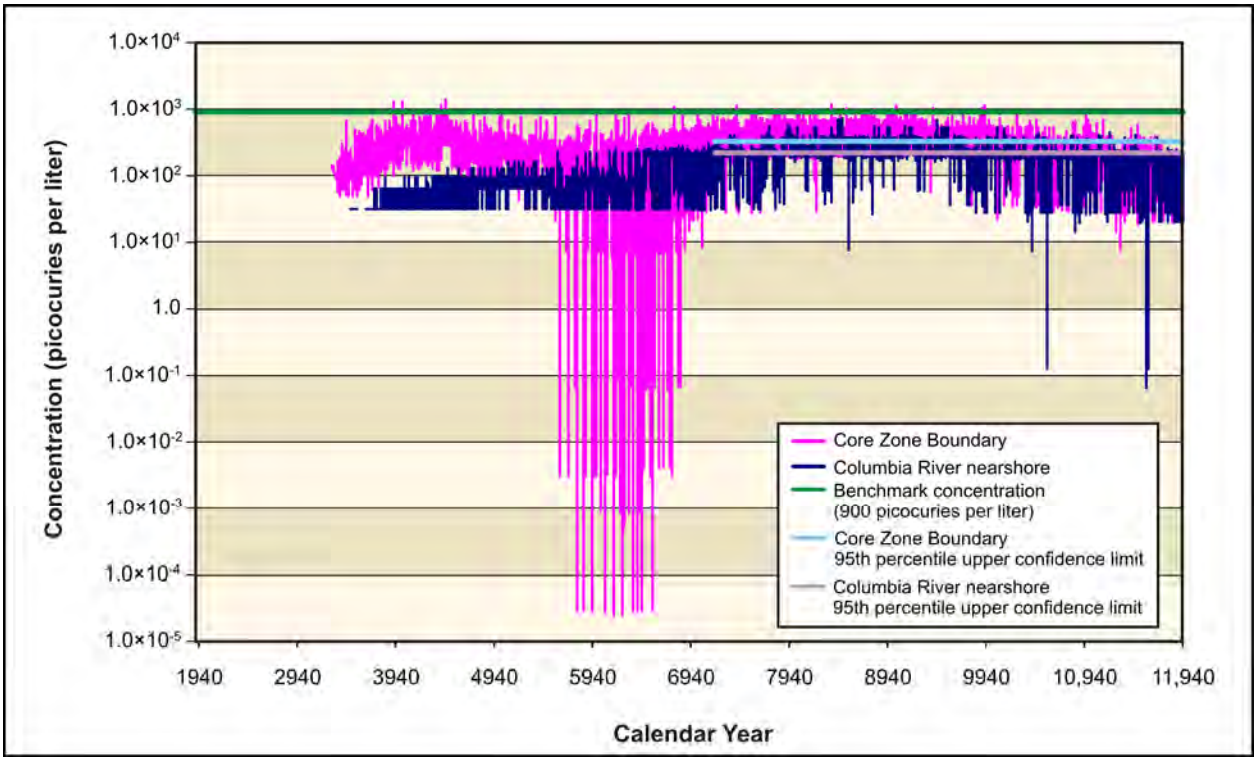


Figure 5–625. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Technetium-99 Concentration Versus Time

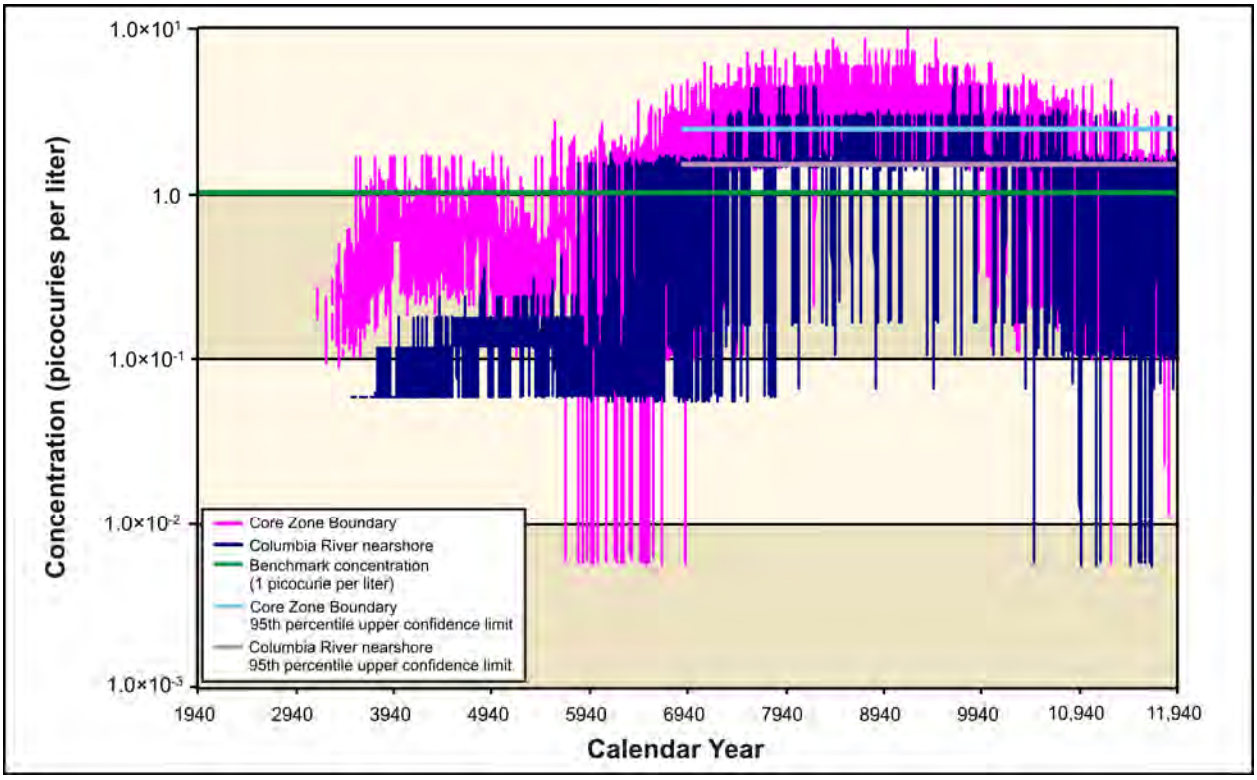


Figure 5–626. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Iodine-129 Concentration Versus Time

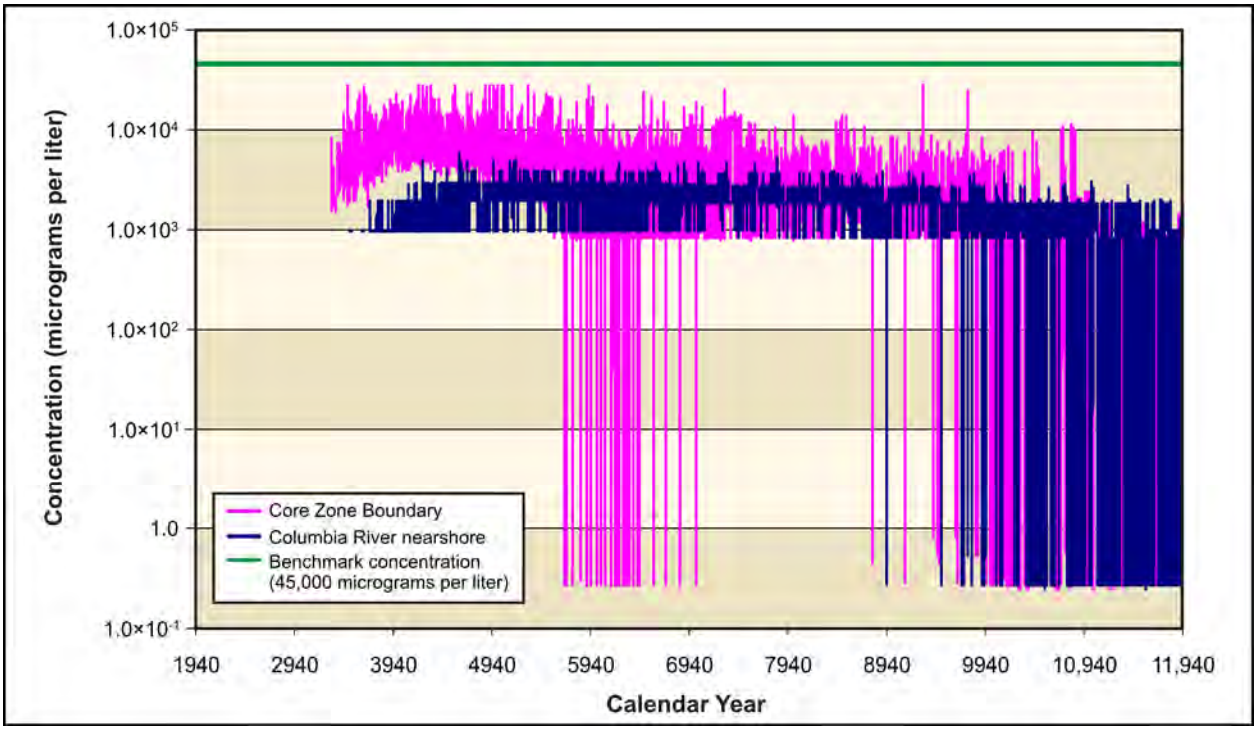


Figure 5–627. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Nitrate Concentration Versus Time

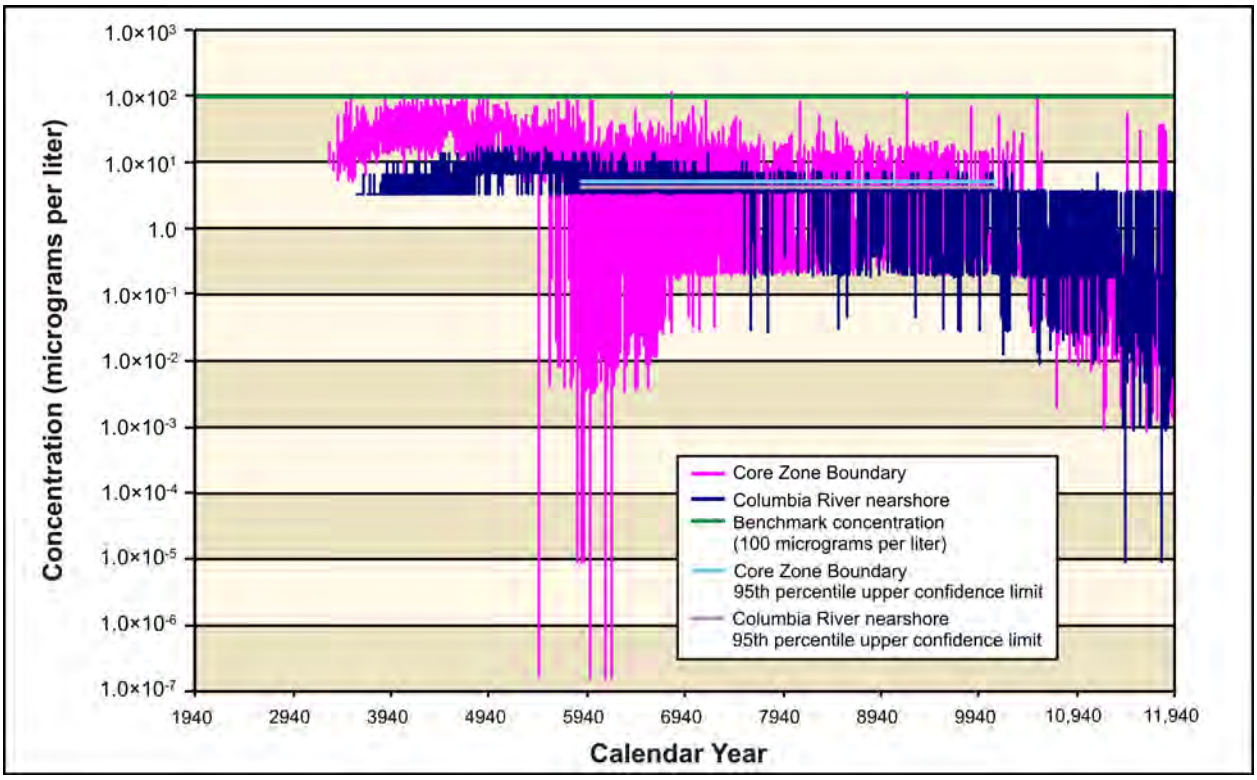


Figure 5–628. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Chromium Concentration Versus Time

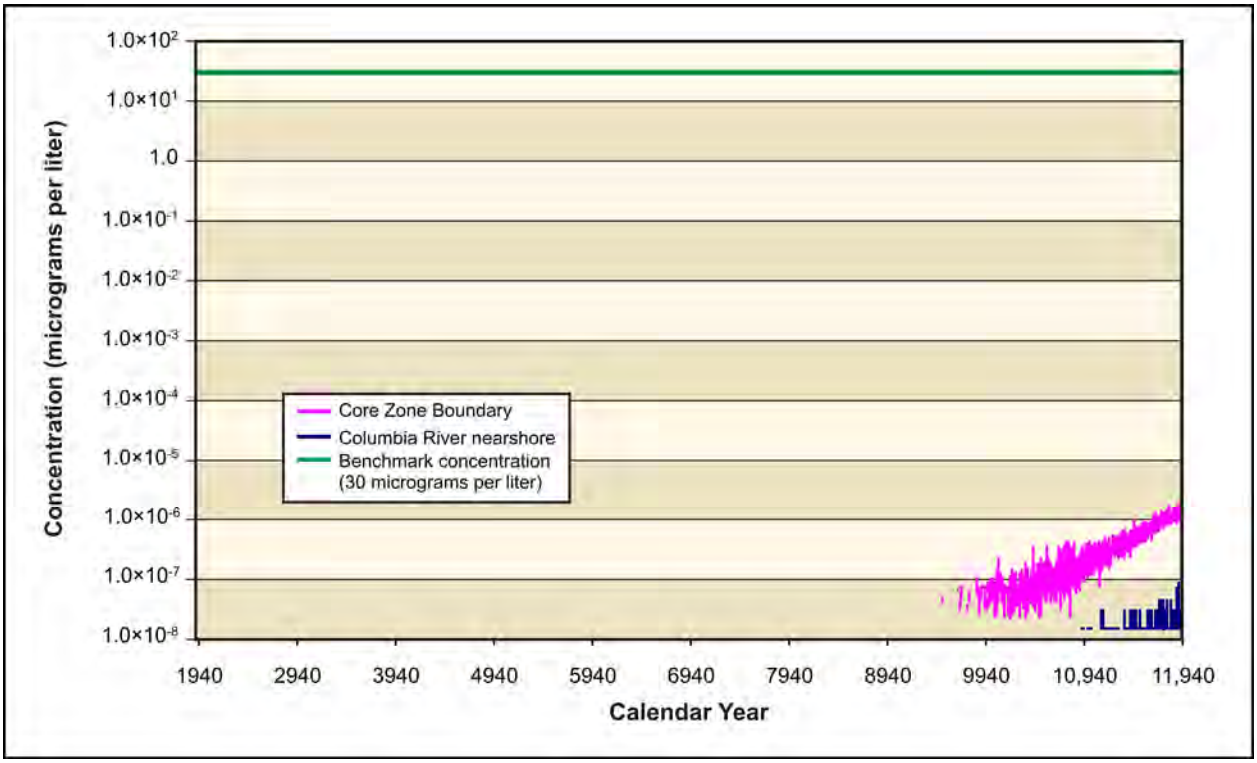


Figure 5–629. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Total Uranium Concentration Versus Time

ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, in terms of the spatial distribution of groundwater concentrations at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration; concentrations lower than the benchmark concentration, by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations.

Figures 5–630 through 5–641 show concentration distributions at CYs 3890, 7140, and 11,885 for technetium-99, iodine-129, nitrate, and chromium. Figure 5–642 shows the concentration distribution of total uranium at CY 11,885. These data show that groundwater releases extend from IDF-East east to the Columbia River and from the RPPDF north to the Columbia River. The RPPDF release remains in a fairly narrow channel until about halfway to the Columbia River, where it spreads out. The IDF-East release is also contained in a narrow area until it reaches one-third the distance to the Columbia River, where it begins to spread.

Figure 5–630 (CY 3890) shows a technetium-99 releases from the RPPDF that exceeds the benchmark concentrations in small areas just outside the Core Zone Boundary. Figure 5–631 (CY 7140) shows a nearly dissipated RPPDF technetium-99 distribution, as well as several very small areas in which the concentration exceeds the benchmark. It also shows several areas in which the technetium-99 released from IDF-East approaches and potentially exceeds the technetium-99 benchmark concentration. By CY 11,885 (see Figure 5–632), the technetium-99 from the RPPDF is nearly dissipated, though there

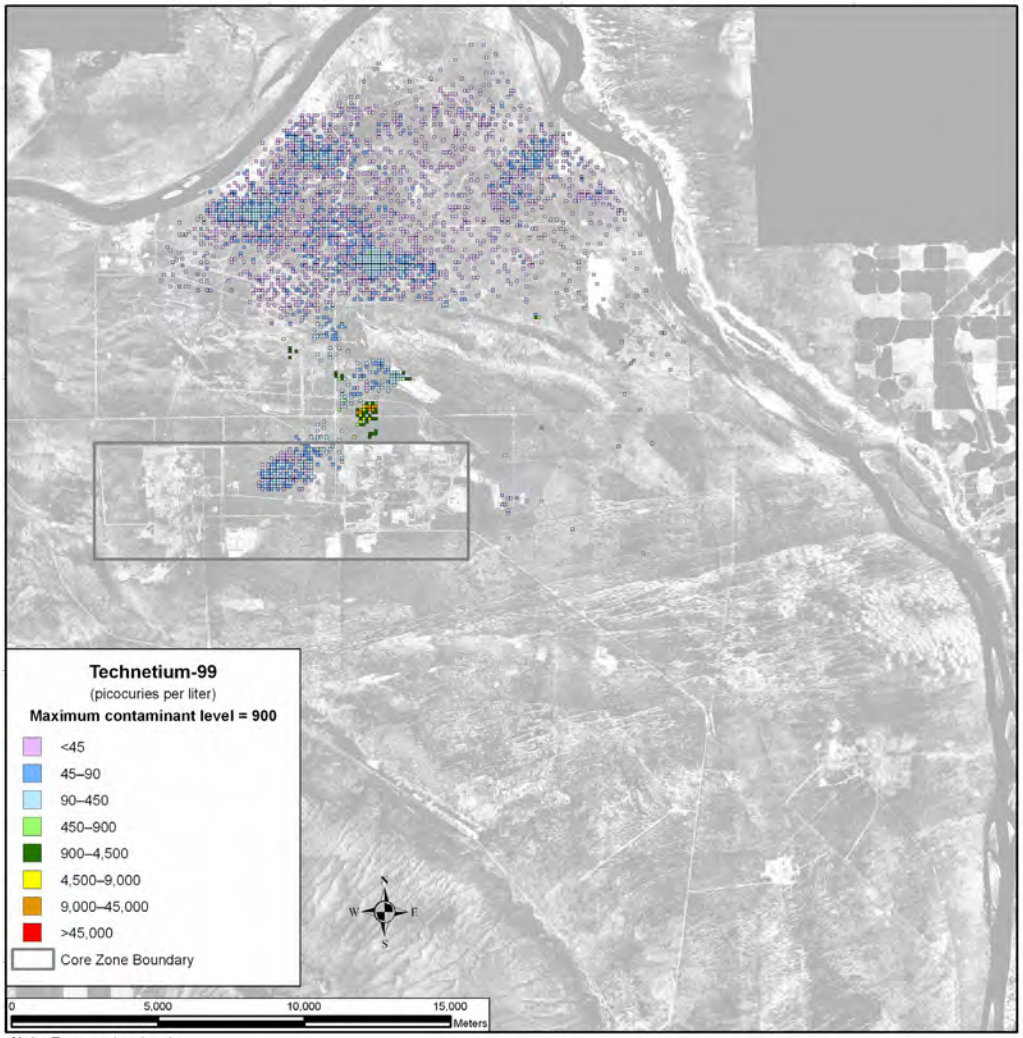
remains a small, isolated area of high concentration. The IDF-East technetium-99 release continues through CY 11,882, but most of the concentrations remain below the benchmark.

Figures 5–633 through 5–635 show similar concentration distributions of iodine-129 from the RPPDF and IDF-East, the RPPDF plume extending to the north from the Core Zone and the IDF-East plume to the east. Figure 5–633 shows an RPPDF plume at CY 3890 and but no IDF-East plume; it only becomes visible later. Figure 5–634 shows the dissipation of the RPPDF iodine-129 plume and a significant IDF-East plume. A small area (pocket) of high-concentration RPPDF iodine-129 remains and an area of IDF-East iodine-129 in concentrations higher than the benchmark has developed to the east of the Core Zone Boundary. Figure 5–635 (CY 11,885) shows a nearly dissipated RPPDF iodine-129 plume and the small higher-concentration area. It also shows an expanded IDF-East iodine-129 distribution and an area in which the iodine-129 exceeds the benchmark concentration. The spatial distributions of technetium-99 and iodine-129 over the analysis period are nearly identical to those of Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

Figures 5–636 through 5–638 show plume maps (time, space, and concentration) for nitrate releases from the RPPDF and IDF-East that are similar to those for technetium-99 and iodine-129 releases. In isolated areas north of the Core Zone Boundary, the RPPDF-released nitrate concentrations exceed the benchmark concentrations, a circumstance not observed in Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, nitrate releases. There is also a small area of high nitrate concentration from the RPPDF release that appears to continue through CY 11,885.

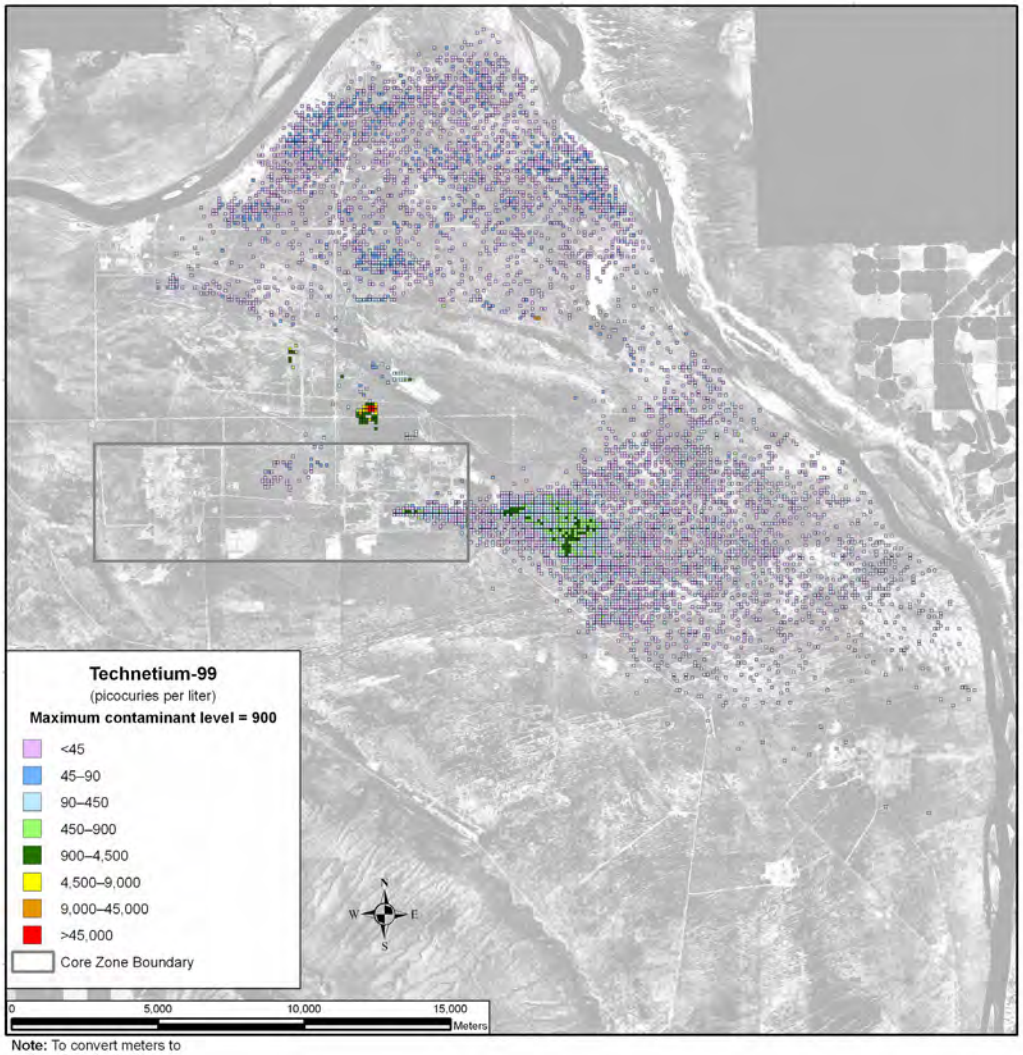
The chromium release shown in Figures 5–639 through 5–641 is nearly identical to the nitrate release in time and spatial ranges. The RPPDF release distribution includes a small area in which the chromium concentration exceeds the benchmark through CY 11,885. The IDF-East chromium release never reaches the benchmark, but the distribution continues through CY 11,885. In Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case, the nitrate high-concentration areas dissipate more rapidly and are below the benchmark concentration by CY 11,885.

Figure 5–642 shows the concentration distribution for total uranium released from the RPPDF for CY 11,885. The released total uranium produces a fairly homogeneous distribution between the release source and the Columbia River nearshore. The distribution concentration is consistently below the benchmark concentration. The retardation of total uranium yields a fairly consistent distribution between the point of release and the Columbia River. This indicates that the total uranium distribution will remain past CY 11,885. Identical results were observed for Waste Management Alternative 2, Disposal Group 2 Subgroup 2-B, Base Case.



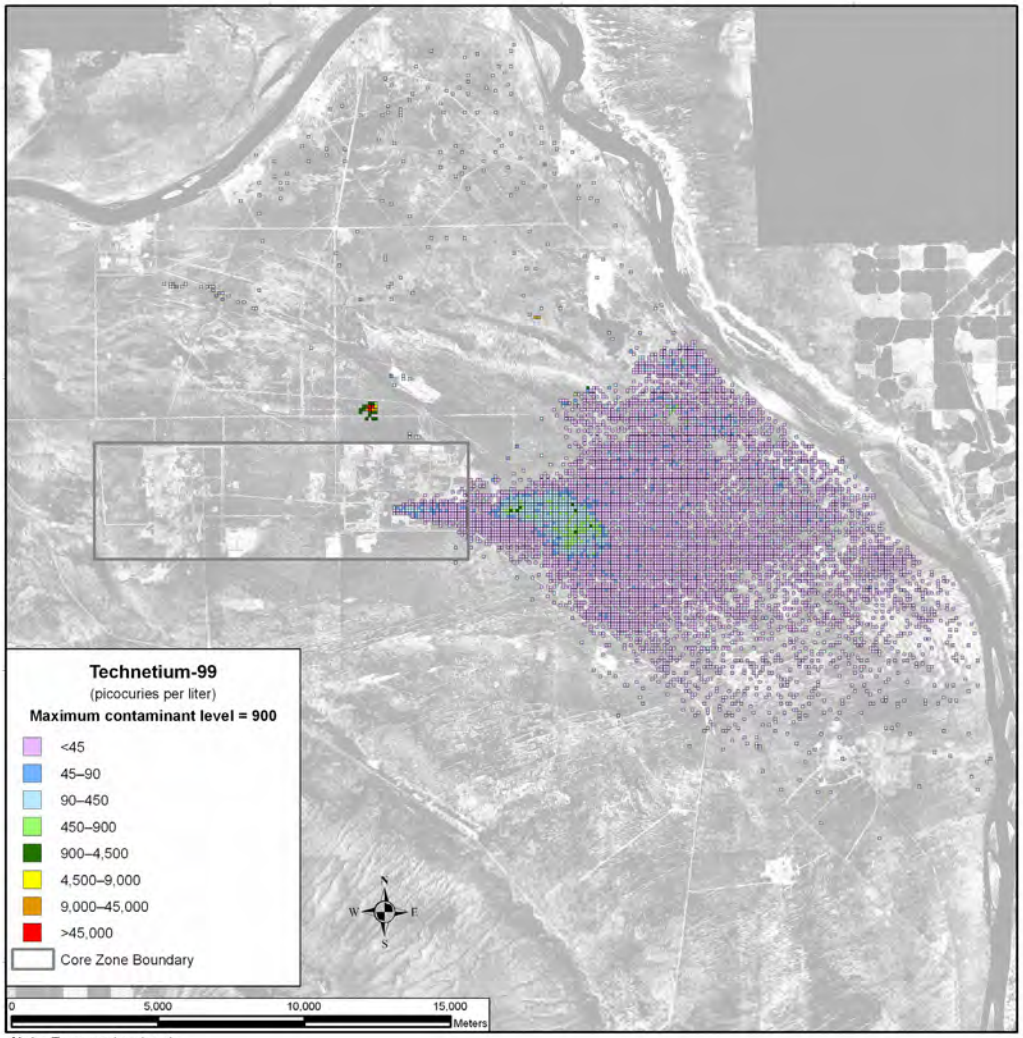
Note: To convert meters to feet, multiply by 3.281

Figure 5–630. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



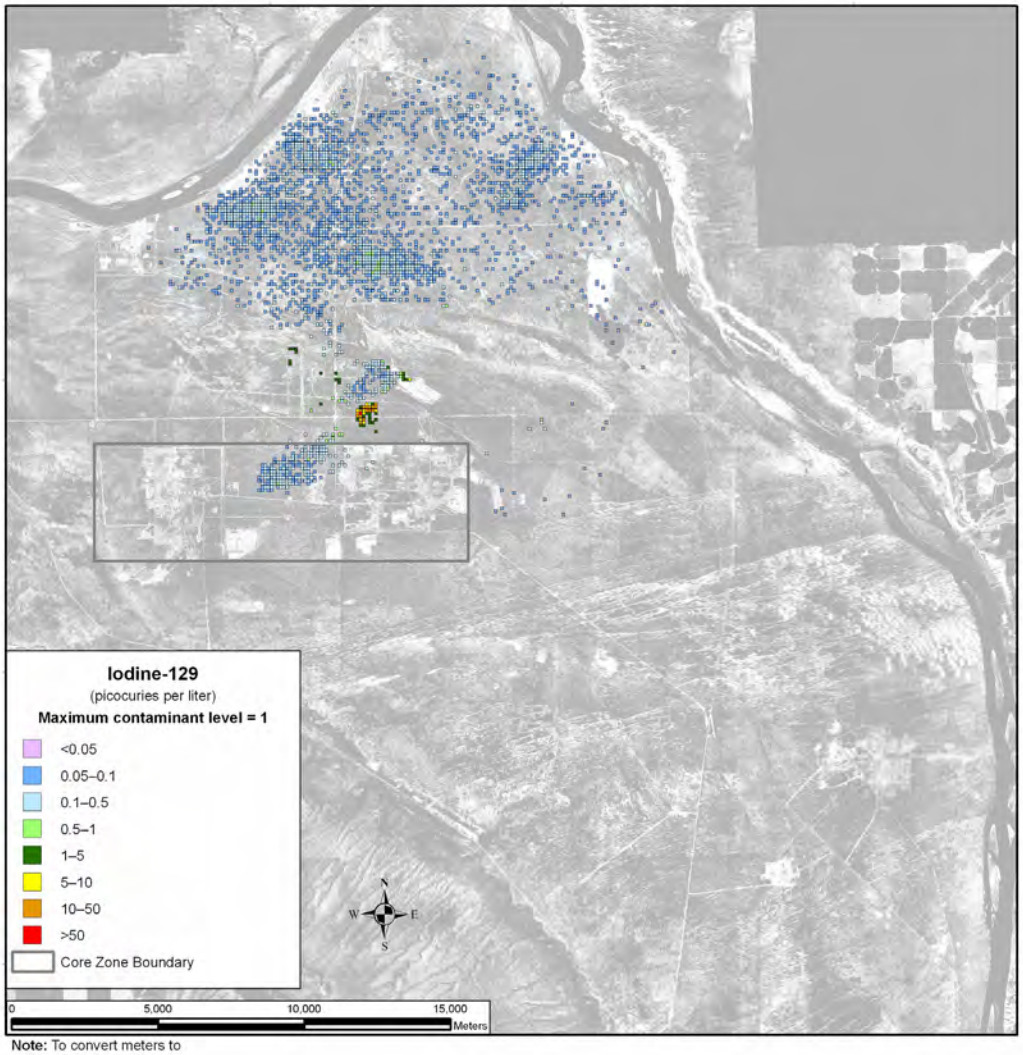
Note: To convert meters to feet, multiply by 3.281

Figure 5–631. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



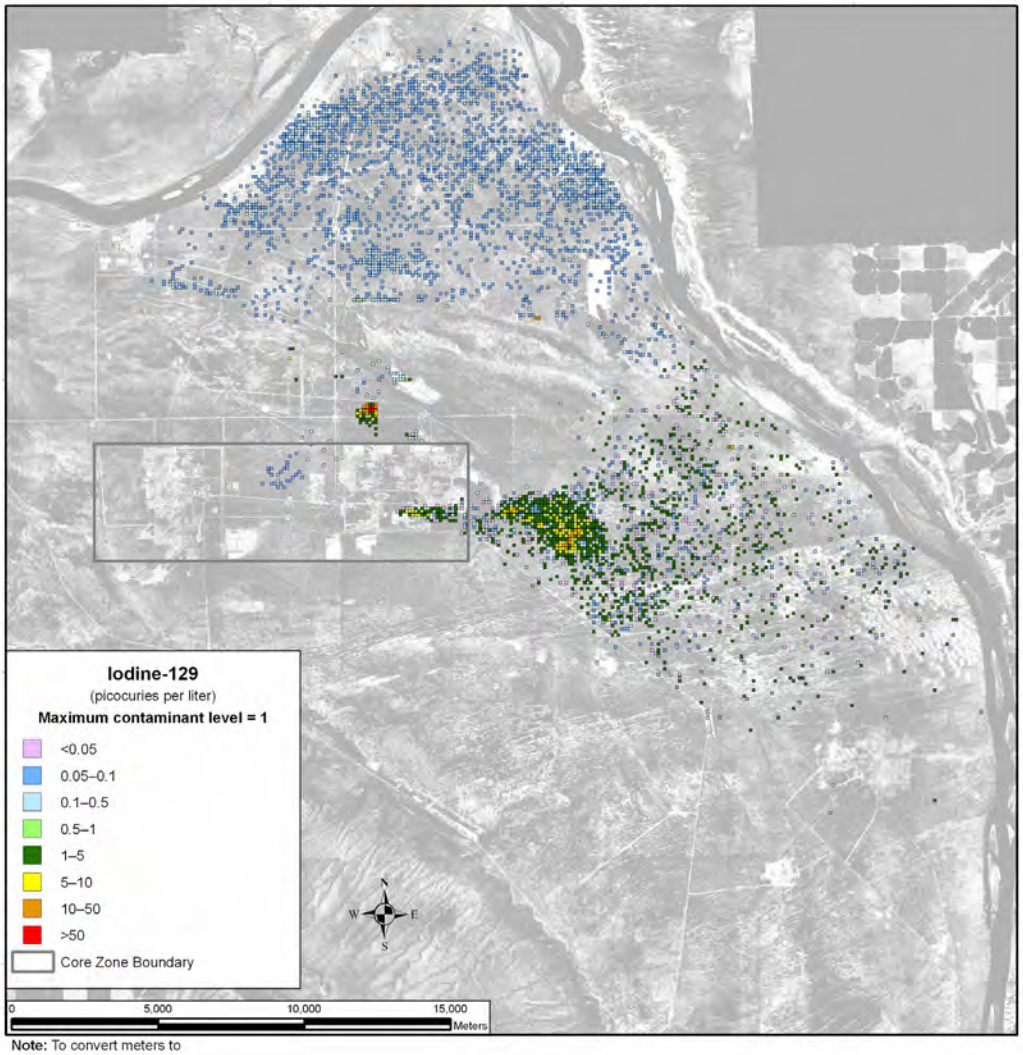
Note: To convert meters to feet, multiply by 3.281

Figure 5–632. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



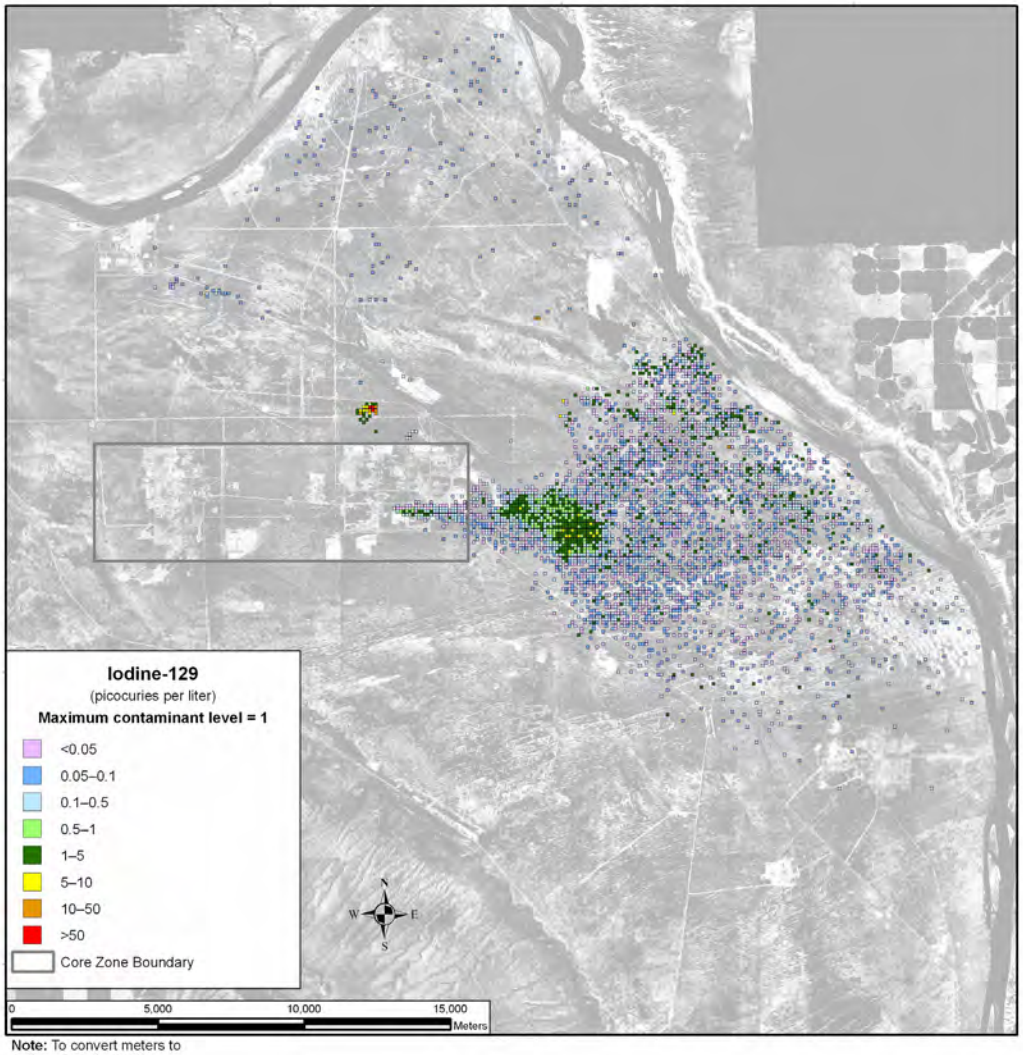
Note: To convert meters to feet, multiply by 3.281

Figure 5–633. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



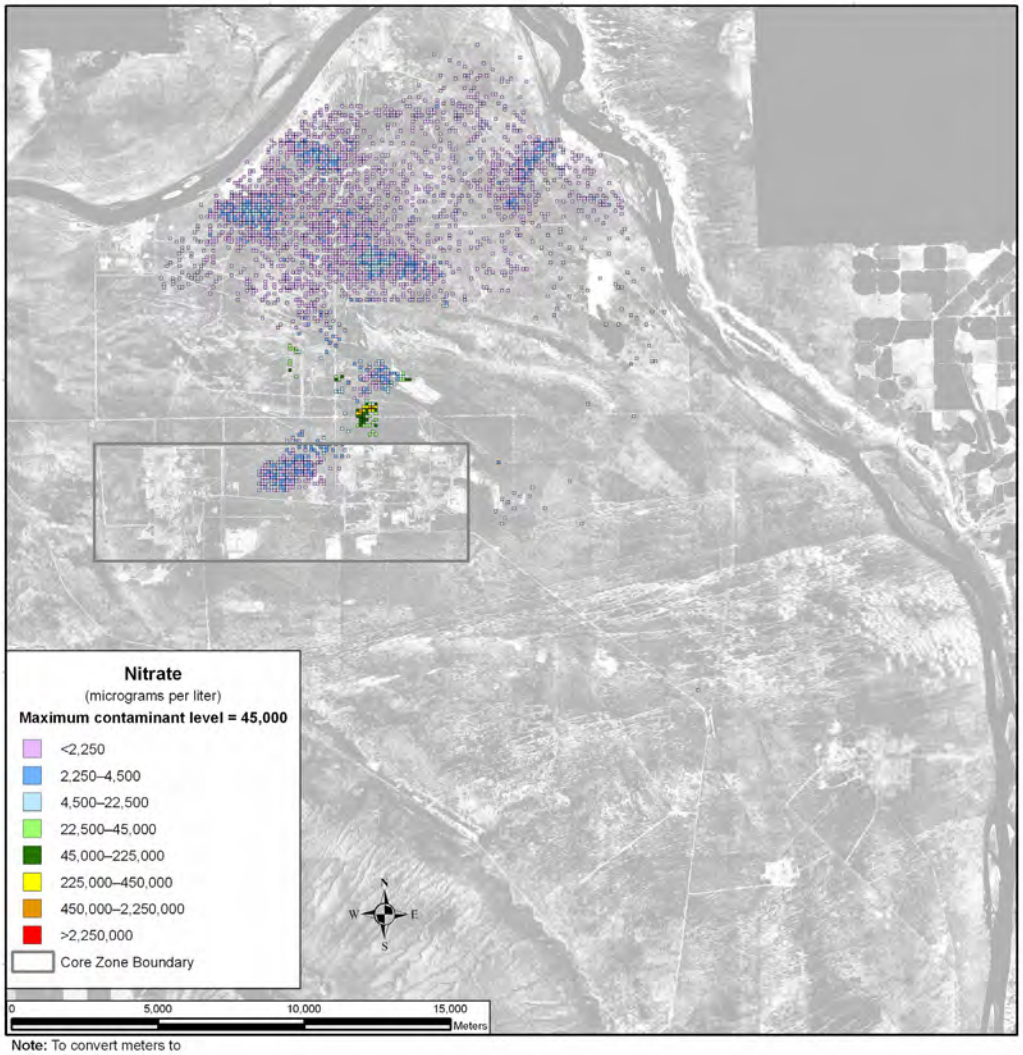
Note: To convert meters to feet, multiply by 3.281

Figure 5–634. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



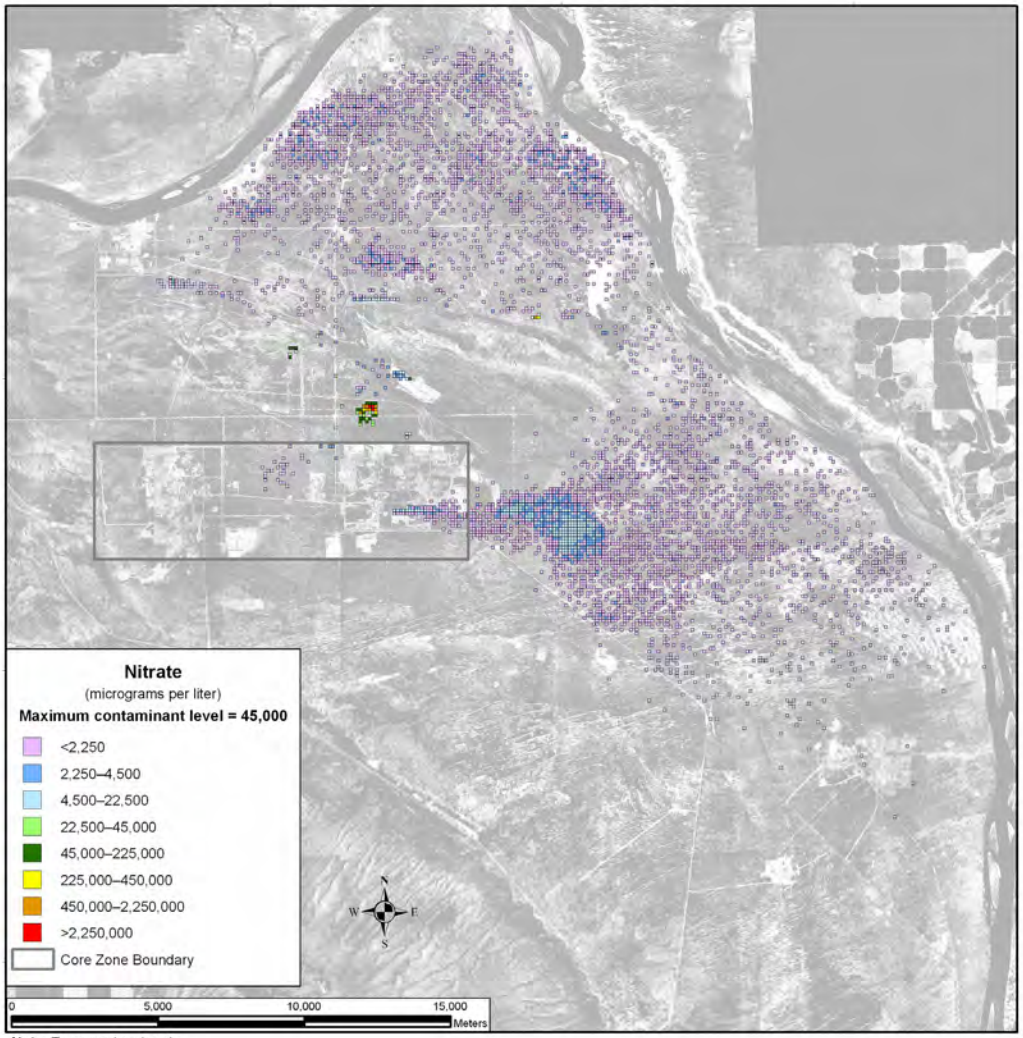
Note: To convert meters to feet, multiply by 3.281

Figure 5–635. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



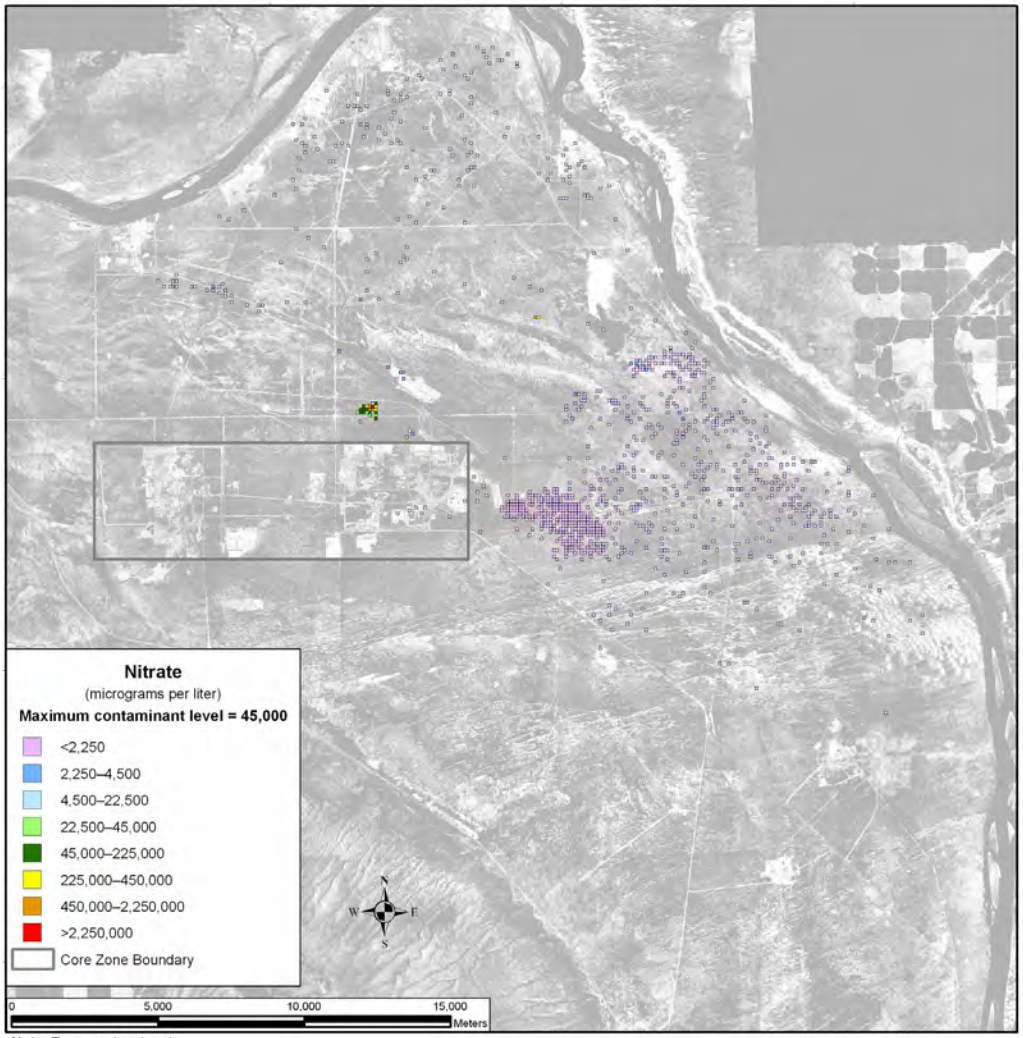
Note: To convert meters to feet, multiply by 3.281

Figure 5–636. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



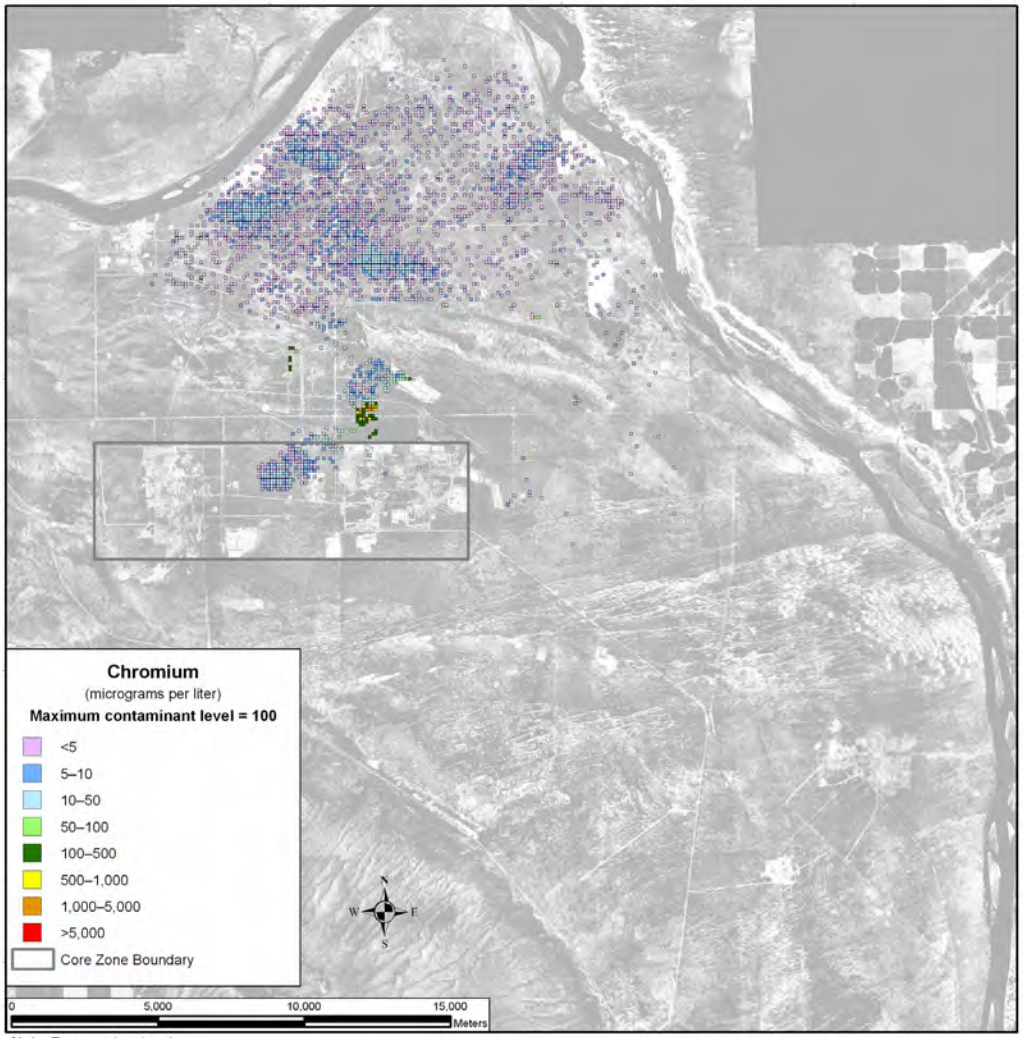
Note: To convert meters to feet, multiply by 3.281

Figure 5–637. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



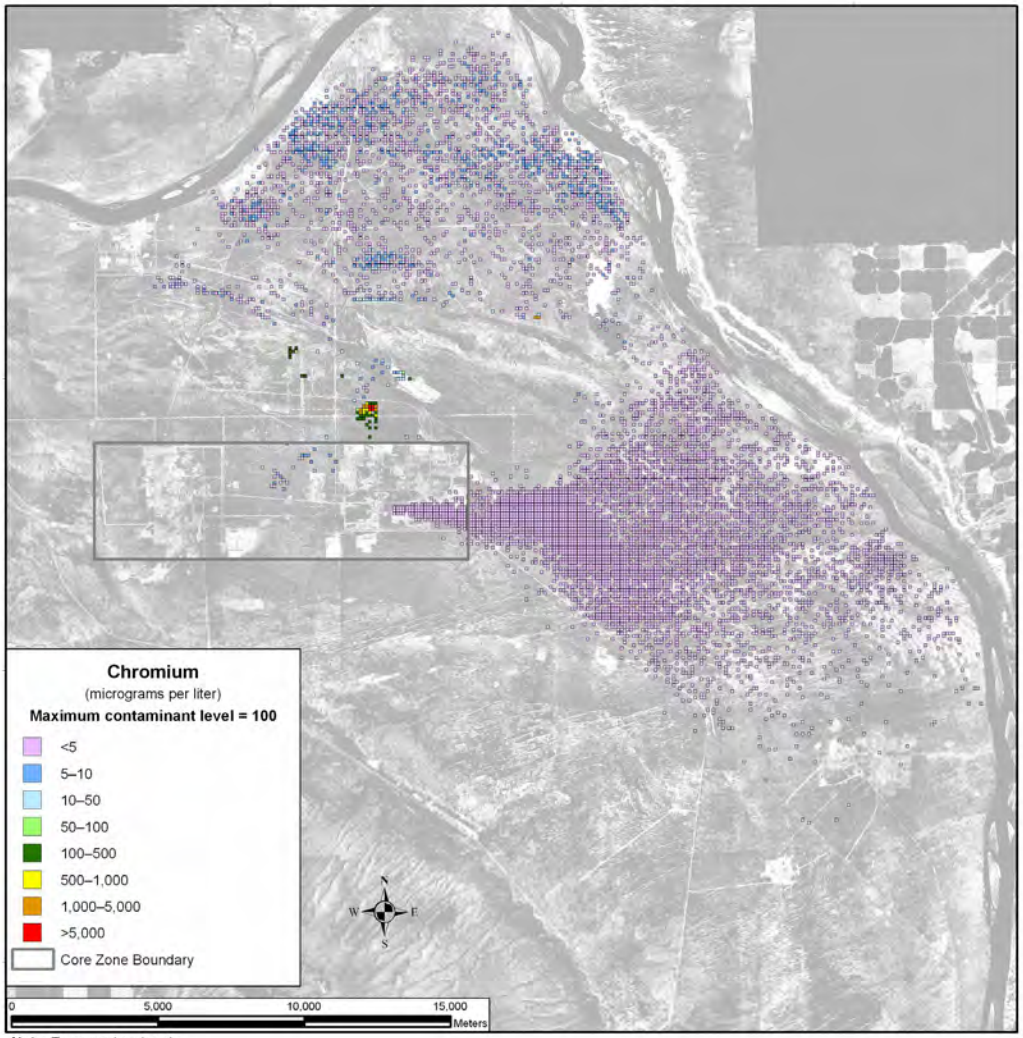
Note: To convert meters to feet, multiply by 3.281

Figure 5–638. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



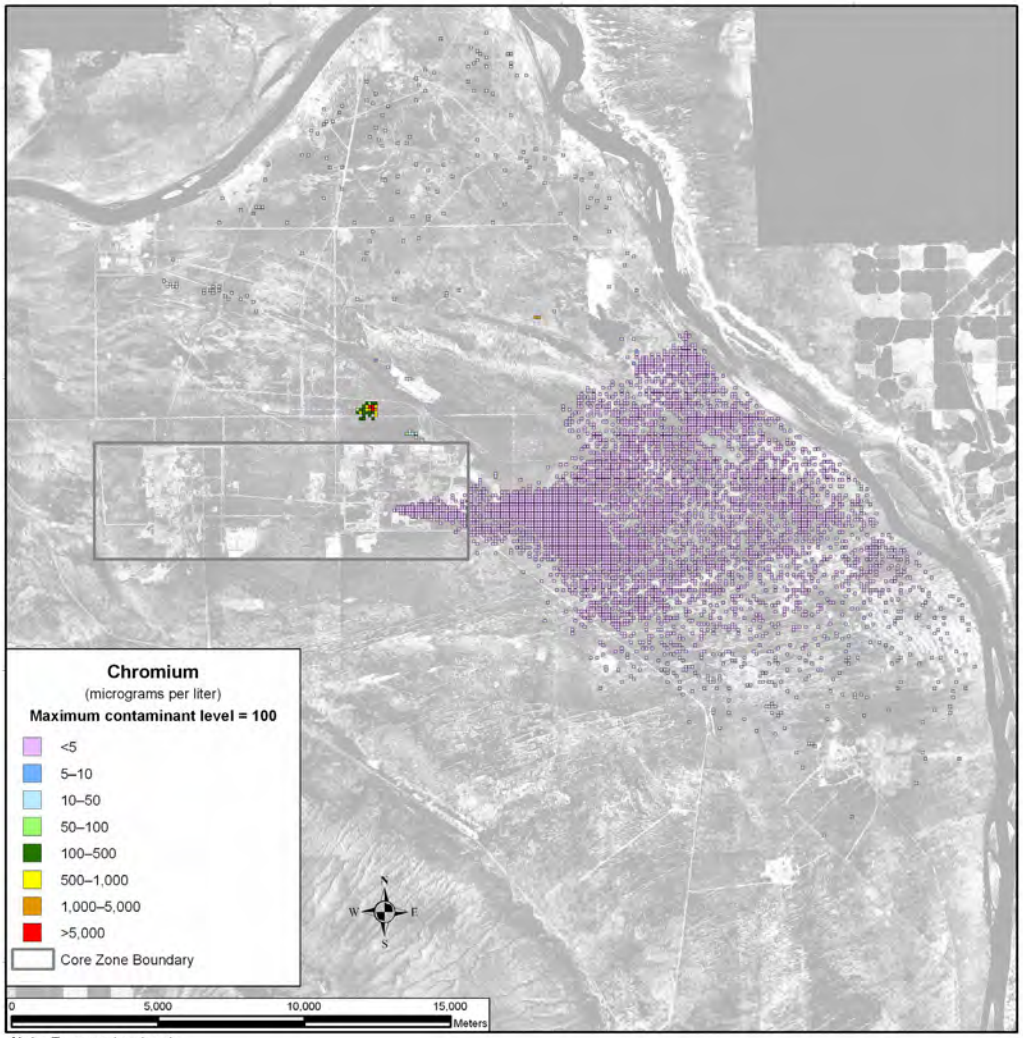
Note: To convert meters to feet, multiply by 3.281

Figure 5–639. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



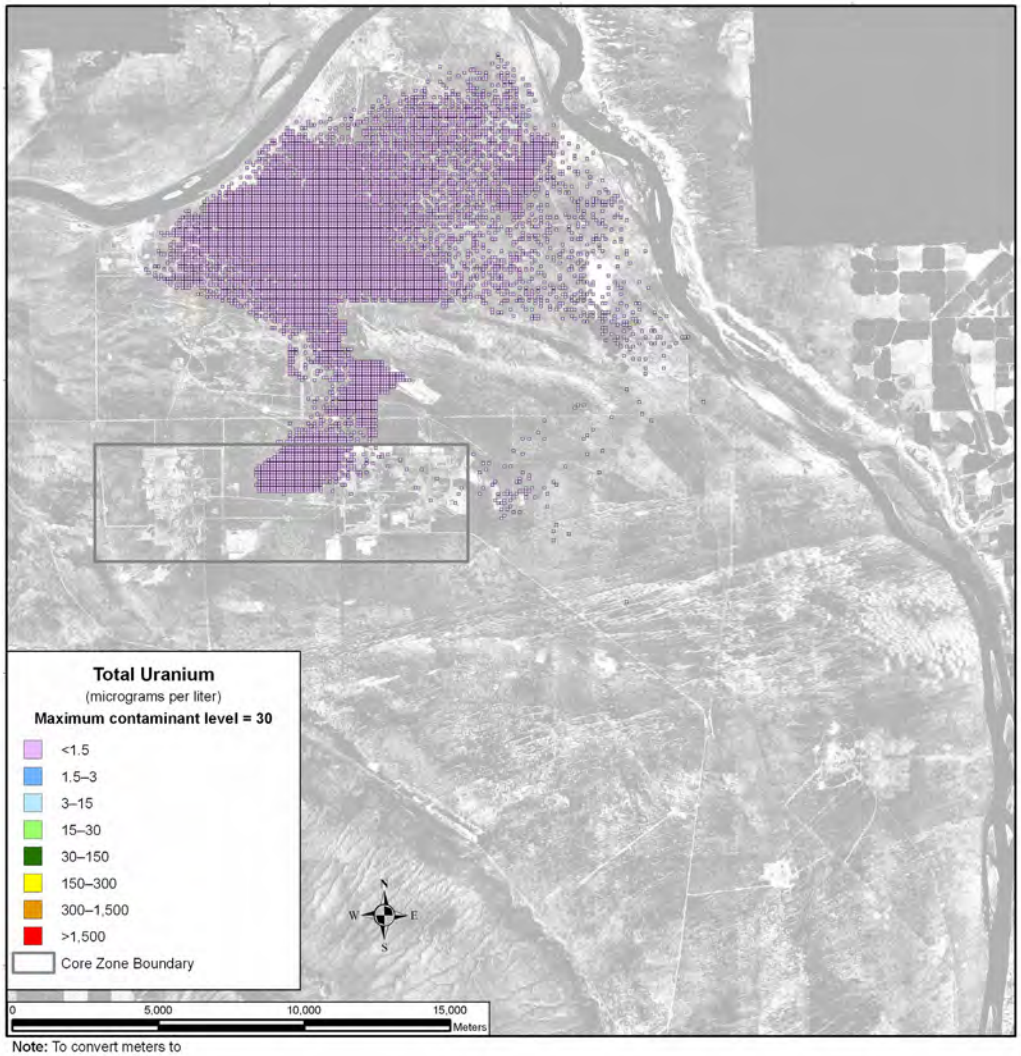
Note: To convert meters to feet, multiply by 3.281

Figure 5–640. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



Note: To convert meters to feet, multiply by 3.281

Figure 5–641. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–642. Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

For Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Option Case, in general, the analysis indicates that the concentrations of the COPCs at Core Zone Boundary and the Columbia River nearshore decrease to levels significantly below the benchmark concentrations.

In small, isolated areas near the outer Core Zone Boundary, there are high concentrations of the conservative tracers that remain high (i.e., they appear not to dissipate) through the end of the period of analysis. A fairly homogeneous plume of released uranium lies between the release source and the Columbia River nearshore. Although the concentrations of total uranium are both two orders of magnitude lower than the benchmark concentrations during this analysis period, the trend appears to show a continuing increase through the end of that period.

Except for isolated areas with nitrate and chromium, the spatial and time distributions are nearly identical to those for Waste Management Alternative 2, Disposal Group 2, Subgroup 2-B, Base Case.

5.3.1.2.3 Disposal Group 3

Disposal Group 3 is characterized by an operational completion date of CY 2165 for both IDF-East and the RPPDF. In Disposal Group 3, IDF-East has a large capacity (425,000 cubic meters [556,000 cubic yards]) and the RPPDF an even larger capacity (8,370,000 cubic meters [10,900,000 cubic yards]). These capacities are designed to meet the waste generation volumes associated with Tank Closure Alternative 6A, Base and Option Cases; FFTF Decommissioning Alternative 2 or 3; and onsite- and offsite-generated waste.

ACTIONS AND TIMEFRAMES INFLUENCING GROUNDWATER IMPACTS

Disposal Group 3 covers Tank Closure Alternative 6A, Base and Option Cases; FFTF Decommissioning Alternative 2 or 3; and onsite- and offsite-generated waste. For both the Base and Option Cases, waste will be converted to IHLW and PPF glass. IHLW would be stored on site, while PPF glass would be disposed of at IDF-East.

For the long-term groundwater impact analysis, two major periods have been identified for Waste Management Alternative 2, Disposal Group 3:

- The disposal period starts with the onset of disposal operations in IDF-East and the RPPDF in CY 2009 and continues through CY 2165 when these facilities will be operationally closed. During the disposal period, the materials in these permitted, operational facilities are unavailable for release to the environment.

- The post-disposal period starts in CY 2166 and continues through the 10,000-year period of analysis until CY 11,940. At the start of this period, materials in the facilities become available for release to the environment. For purposes of analyzing long-term groundwater impacts of Waste Management Alternative 3, Disposal Group 3, IDF-East and RPPDF are assumed to be covered by a barrier limiting infiltration during the first 500 years of the post-disposal period.

COPC DRIVERS

A total of 40 COPCs were analyzed for Waste Management Alternative 2, Disposal Group 3. Full results are tabulated in Appendices M, N, and O. This discussion of long-term impacts associated with Waste Management Alternative 2 is focused on the following COPC drivers:

- Radiological risk drivers: technetium-99 and iodine-129
- Chemical risk drivers: none
- Chemical hazard drivers: chromium, nitrate, total uranium, and acetonitrile

The COPC drivers for Waste Management Alternative 2, Disposal Group 3 were selected by evaluating the risk or hazard associated with all 40 COPCs during the year of peak risk or hazard at the Core Zone Boundary during the 10,000-year period of analysis and selecting the major contributors. This process is described in Appendix Q. The radiological risk drivers listed above account for essentially 100 percent of the radiological risk. There is no chemical risk. The chemical hazard drivers above account for over 99 percent of the chemical hazard associated with Waste Management Alternative 2, Disposal Group 3.

The COPC drivers that are discussed in detail in this section (iodine-129, technetium-99, chromium, and nitrate) are all mobile (i.e., they move with groundwater) and long-lived (relative to the 10,000-year period of analysis) or stable. They are essentially conservative tracers. Total uranium was added to the list because it begins to appear toward the end of the period of analysis. Total uranium is long-lived or stable, but is not as mobile as the other COPC drivers; it moves about seven times more slowly than groundwater. Acetonitrile was added because of its appearance in the RPPDF. The other COPCs that were analyzed do not significantly contribute to drinking water risk at the Core Zone Boundary during the period of analysis because of high retardation factors (i.e., retention in the vadose zone), short half-lives (i.e., rapid radioactive decay), or a combination of both factors.

ANALYSIS OF RELEASE AND MASS BALANCE

This section presents the impacts of Alternative 2, Disposal Group 3, Base and Option Cases, in terms of the total amount released to the vadose zone, groundwater, and the Columbia River. Releases of radionuclides are totaled in curies; chemicals, in kilograms. Both are totaled over the 10,000-year period of analysis. Note that the release amounts are plotted on a logarithmic scale to facilitate visual comparison of releases that vary over eight orders of magnitude.

200-East Area Integrated Disposal Facility

Seven subtotals are plotted for IDF-East representing releases from ETF-generated secondary waste, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, offsite-generated waste, steam reforming waste, retired melters, and waste management secondary and onsite-generated waste. Figure 5–643 shows the release to the vadose zone at IDF-East in the Base Case for the radiological risk drivers and Figure 5–644, the chemical hazard drivers. Technetium-99 is significantly released to the vadose zone from each on the subtotaled sources, with offsite-generated waste and tank closure secondary waste contributing the most. Iodine-129 has significant releases from five of the subtotaled sources, with offsite-generated waste and ETF-generated secondary waste contributing the most. Chromium has six significant sources, with ETF-generated secondary waste and tank closure secondary waste providing the most releases. Nitrate is only significantly released from ETF-generated secondary waste and waste management secondary waste, and onsite-generated waste.

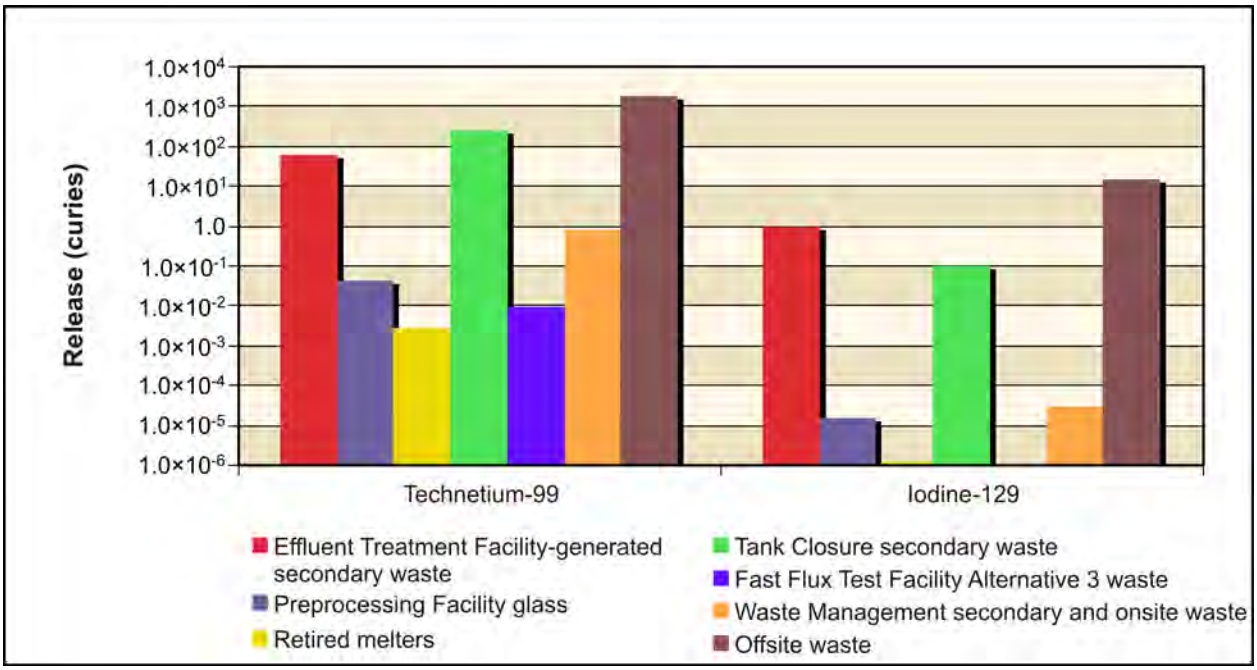


Figure 5–643. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

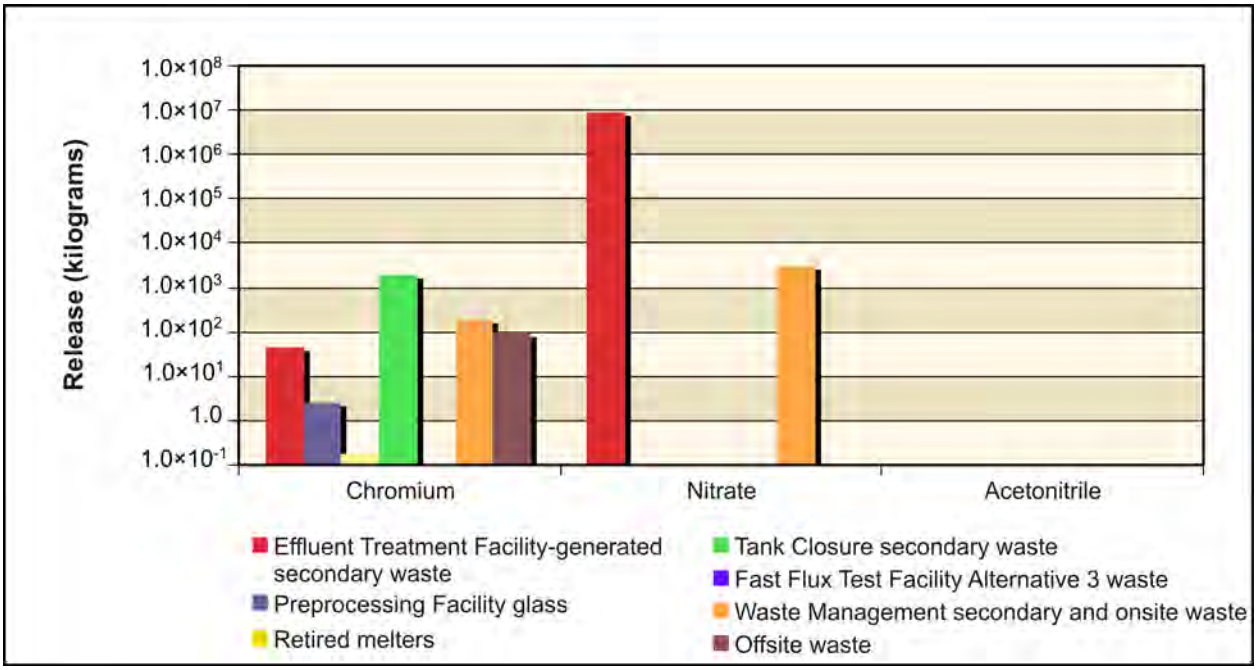


Figure 5–644. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

Figure 5–645 shows the release to the vadose zone at IDF-East in the Option Case for the radiological risk drivers and Figure 5–646, the chemical hazard drivers. The radiological risk drivers and the chemical hazard drivers released to the vadose zone in the Option Case are essentially identical to those in the Base Case.

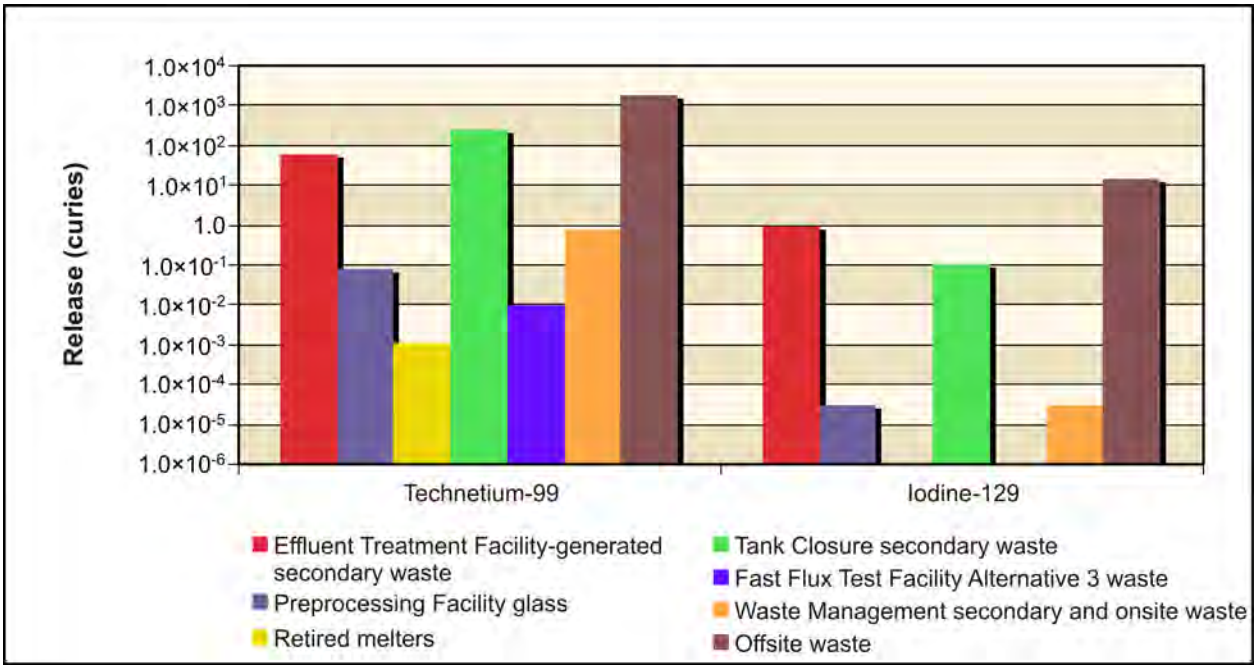


Figure 5–645. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

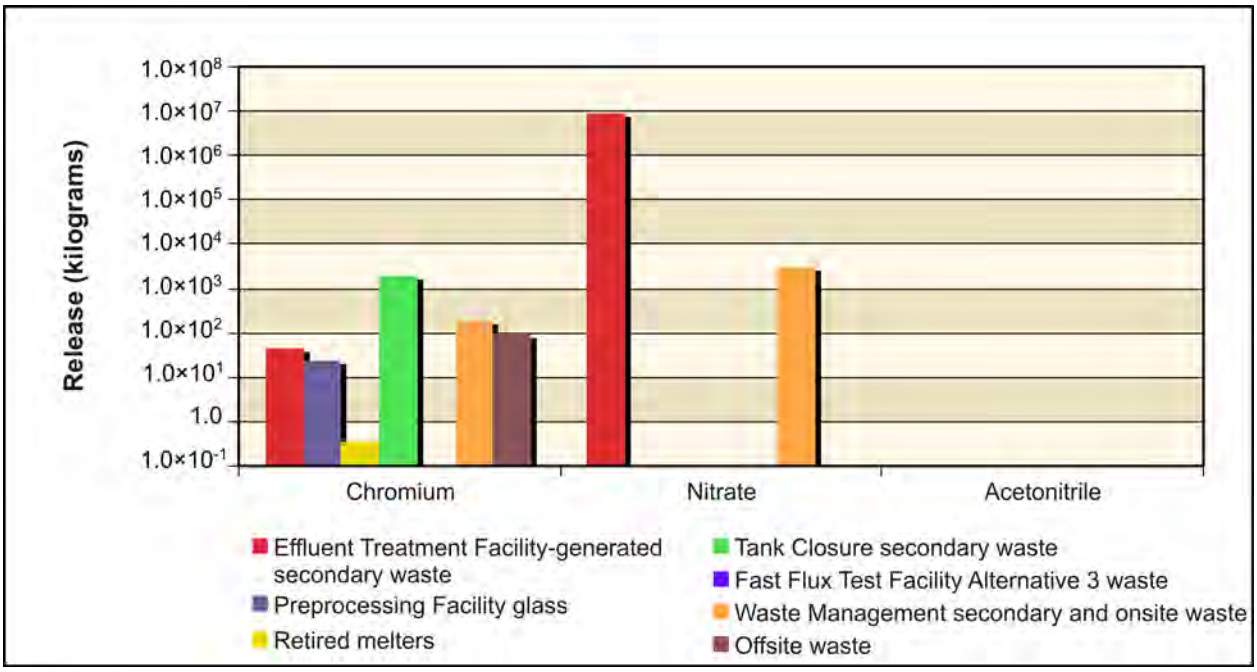


Figure 5–646. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Vadose Zone

Figure 5–647 shows the release to groundwater at IDF-East in the Base Case for the radiological risk drivers and Figure 5–648, the chemical hazard drivers. Release to groundwater is controlled by the transport properties of the COPC drivers and by the rate of moisture movement through the vadose zone. For the conservative tracers (technetium-99, iodine-129, chromium, and nitrate), the amount released to groundwater is typically equal to the amount released to the vadose zone. Ninety-five to 100 percent of the technetium-99 released to the vadose zone released from ETF-generated secondary waste and offsite-generated waste reaches groundwater. Forty to 60 percent of the technetium-99 released to the vadose zone from other sources—i.e., PPF glass, retired melters, tank closure secondary waste, FFTF Decommissioning Alternative 3 waste, and waste management secondary and onsite-generated waste—reaches groundwater. For iodine-129 from offsite-generated waste, releases to groundwater and to the vadose zone are essentially equal. Only about 40 percent of the iodine-129 released to the vadose zone—i.e., releases from ETF-generated secondary waste, PPF glass, tank closure secondary waste, and waste management secondary and onsite-generated waste—reaches groundwater. Chromium released to groundwater from ETF-generated secondary waste, tank closure secondary waste, waste management secondary and onsite-generated waste, and offsite-generated waste is essentially equal to that released to the vadose zone. About 45 percent of the chromium released from PPF glass and retired melters to the vadose zone is transferred to the groundwater. Finally, nitrate released to groundwater from ETF-generated secondary waste, waste management secondary waste, and onsite-generated waste is essentially equal to that released to the vadose zone.

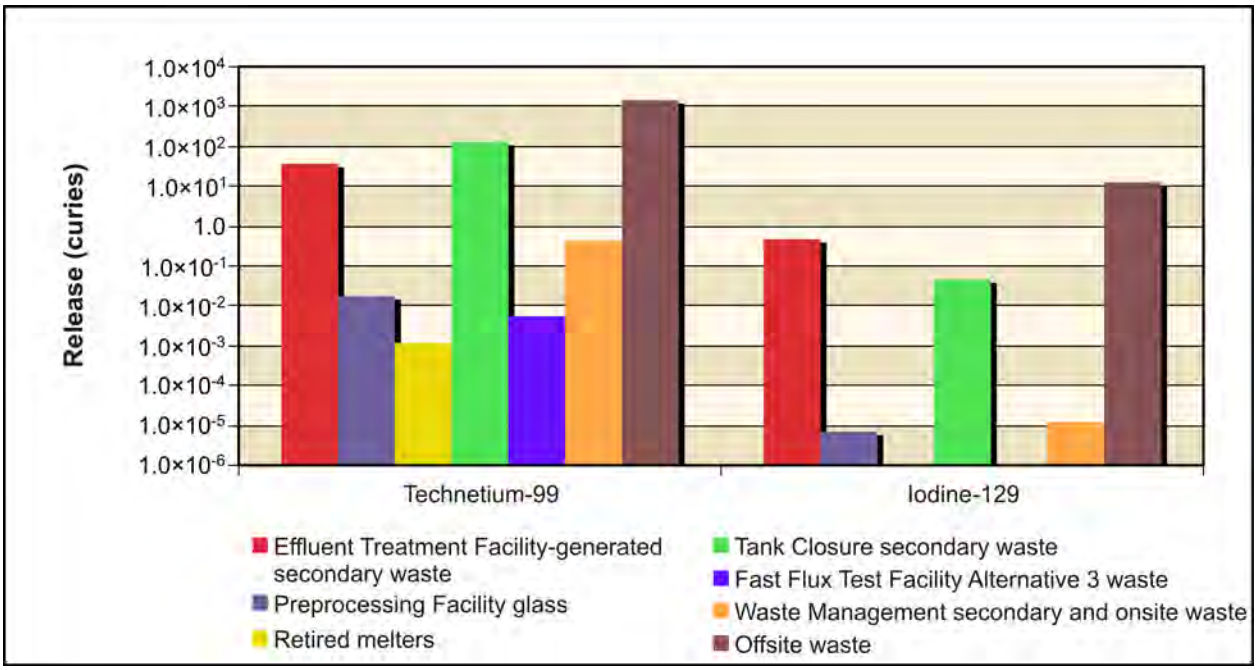


Figure 5–647. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

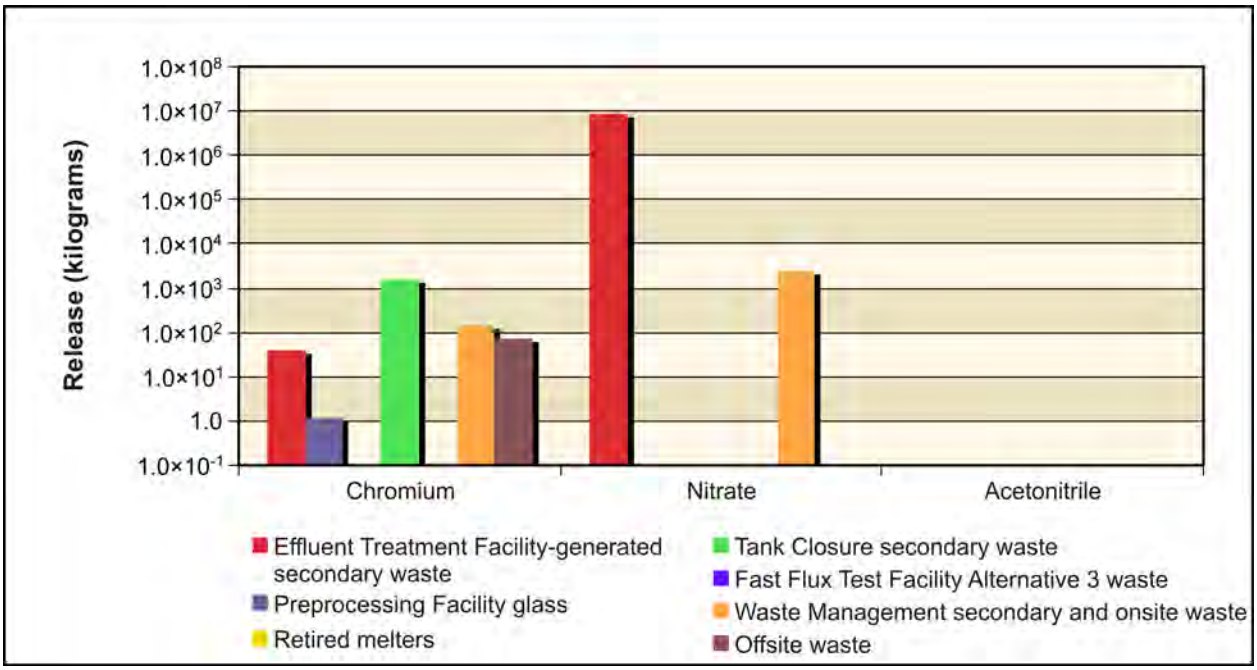


Figure 5–648. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

Figure 5–649 shows the release to groundwater at IDF-East in the Option Case for the radiological risk drivers and Figure 5–650, the chemical hazard drivers. The releases of radiological risk drivers and the chemical hazard drivers to groundwater in the Option Case are essentially identical to those in the Base Case.

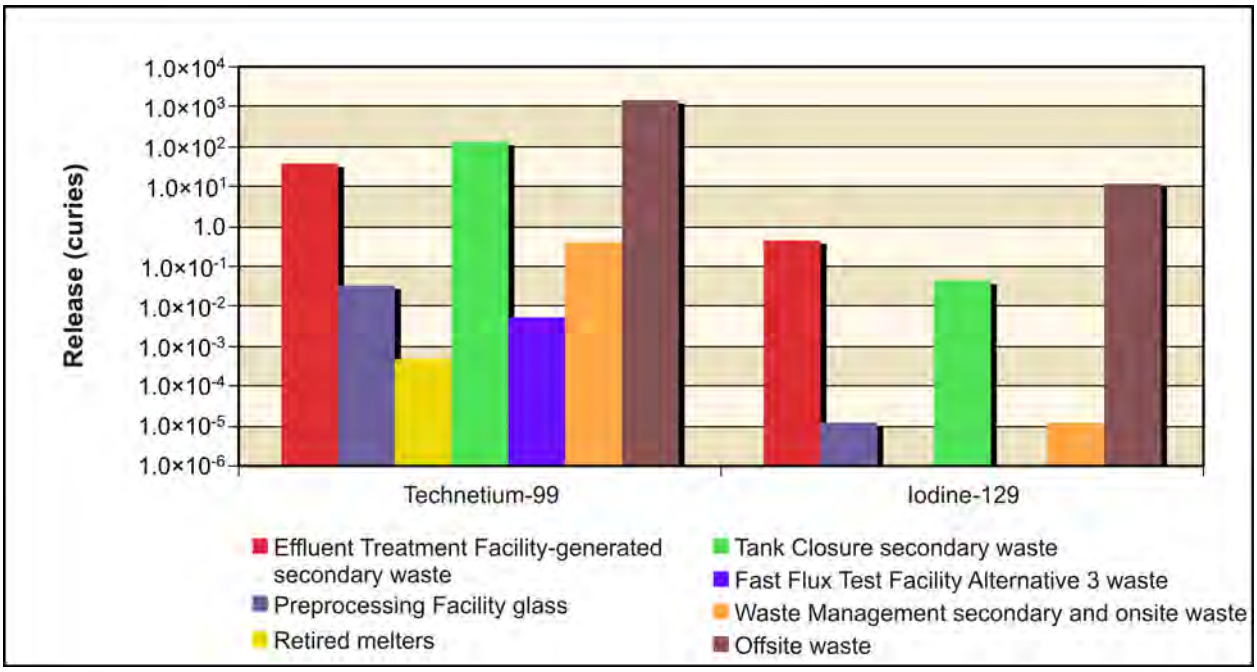


Figure 5–649. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Groundwater

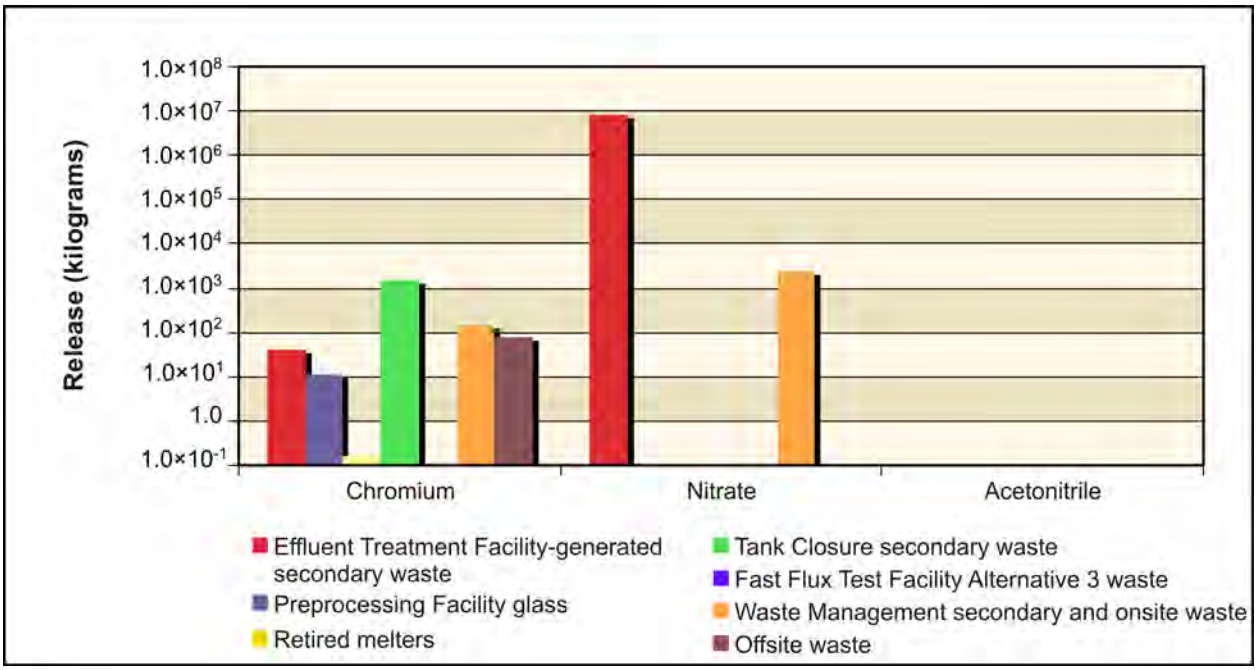


Figure 5–650. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Groundwater

Figure 5–651 shows the release to the Columbia River at IDF-East in the Base Case for the radiological risk drivers and Figure 5–652, the chemical hazard drivers. For the conservative tracers (technetium-99, iodine-129, chromium, and nitrate), the amount released to the Columbia River is typically essentially equal to the amount released to the vadose zone. Ninety to 97 percent of the technetium-99 released to groundwater from ETF-generated secondary-waste, PPF glass, retired melters, FFTF Decommissioning Alternative 3 waste, waste management secondary and onsite-generated waste, and offsite-generated waste reaches the Columbia River. Only about 60 percent of the technetium-99 released to groundwater from the tank closure secondary waste reaches the river. Ninety to 97 percent of the iodine-129 released to groundwater from ETF-generated secondary waste and offsite-generated waste reaches the Columbia River. Only about 25 percent of the iodine-129 released from the tank closure secondary waste to groundwater is transferred to the river. Essentially none of the iodine-129 released to groundwater from PPF glass, waste management secondary waste, and onsite-generated is transferred to the river. As for chromium, 90 to 98 percent of the amount released from ETF-generated secondary waste, PPF glass, retired melters, tank closure secondary waste, waste management secondary and onsite-generated waste, and offsite-generated waste is released to the Columbia River. The amount of nitrate released to the Columbia River from ETF-generated secondary waste, waste management secondary waste, and onsite-generated waste is essentially equal to that released to the groundwater.

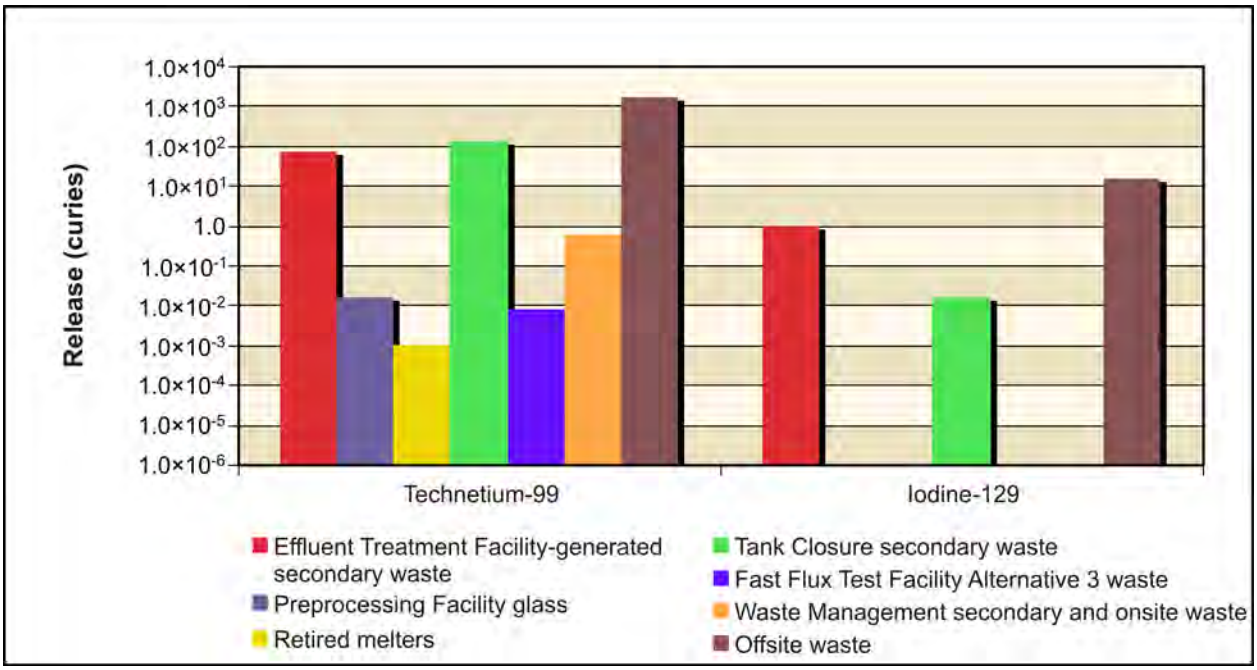


Figure 5–651. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

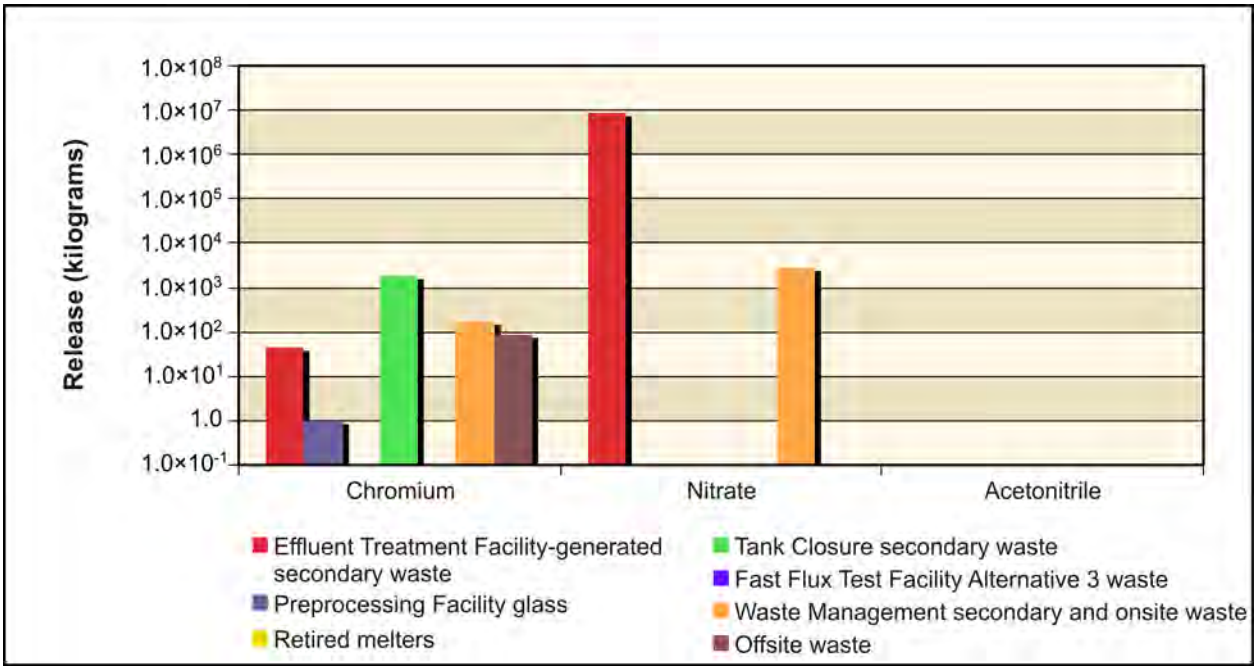


Figure 5–652. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

Figure 5–653 shows the release to the Columbia River at IDF-East in the Option Case for the radiological risk drivers and Figure 5–654, the chemical hazard drivers. For the IDF, the radiological risk drivers and the chemical hazard drivers released to the Columbia River in the Option Case are essentially identical to those in the Base Case.

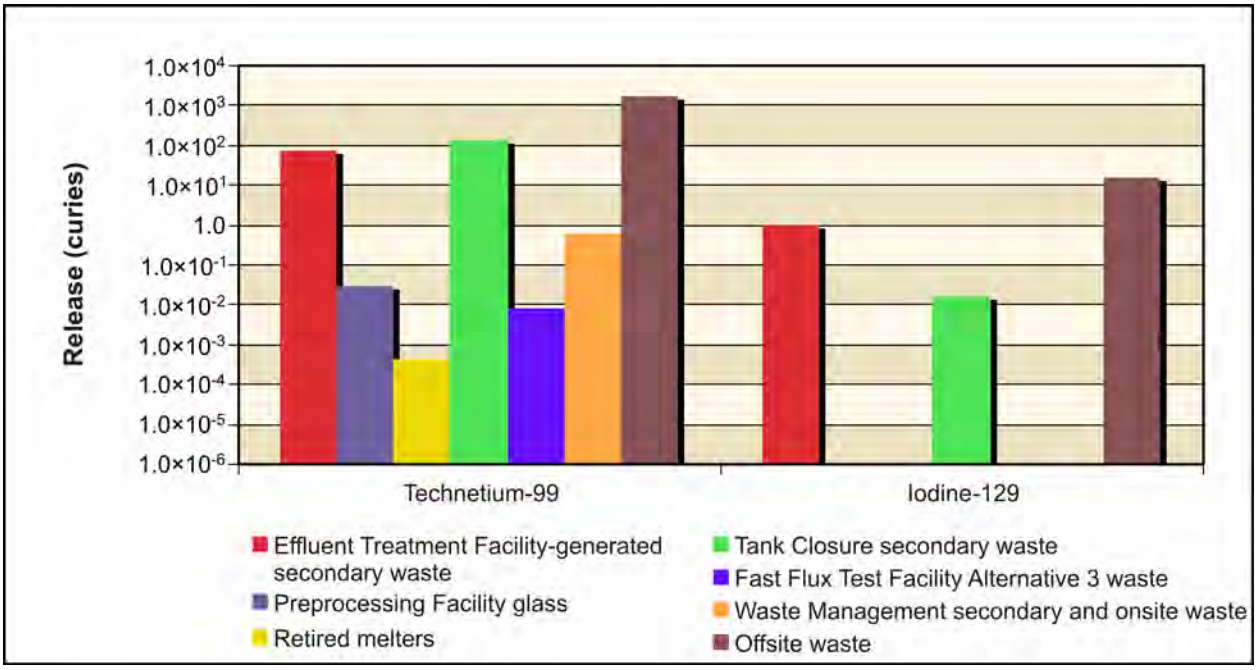


Figure 5–653. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at 200-East Area Integrated Disposal Facility to Columbia River

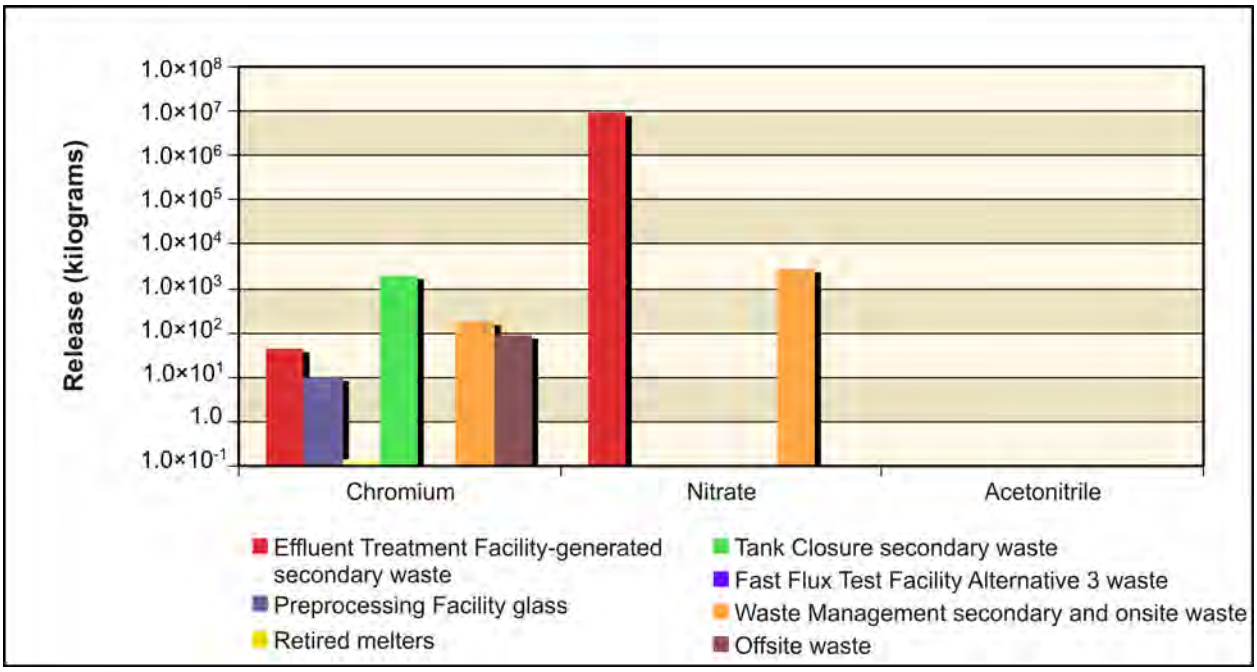


Figure 5–654. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at 200-East Area Integrated Disposal Facility to Columbia River

River Protection Project Disposal Facility

Figure 5–655 shows the release to the vadose zone at the RPPDF in the Base Case for the radiological risk drivers and Figure 5–656, the chemical hazard drivers. The only constituents significantly released to the vadose zone from the RPPDF were technetium-99, iodine-129, chromium, and nitrate.

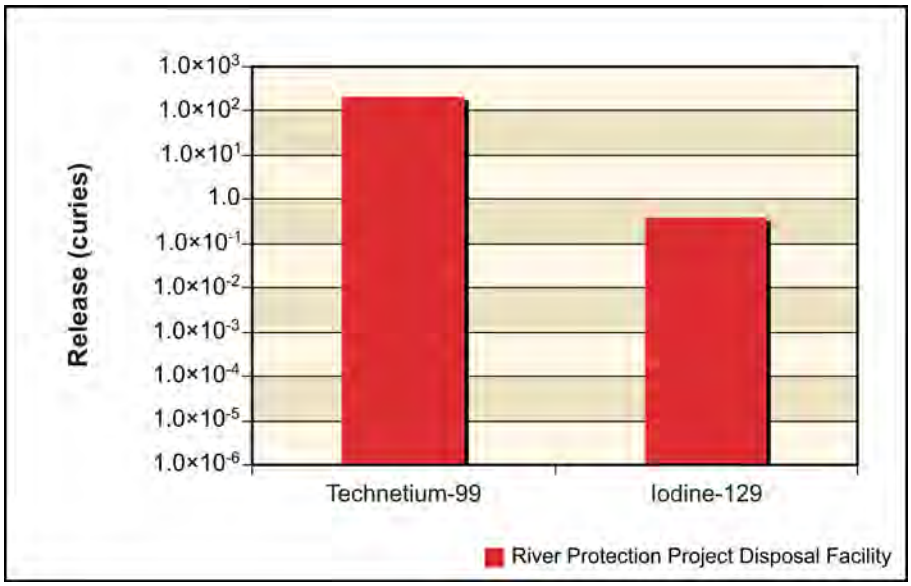


Figure 5–655. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

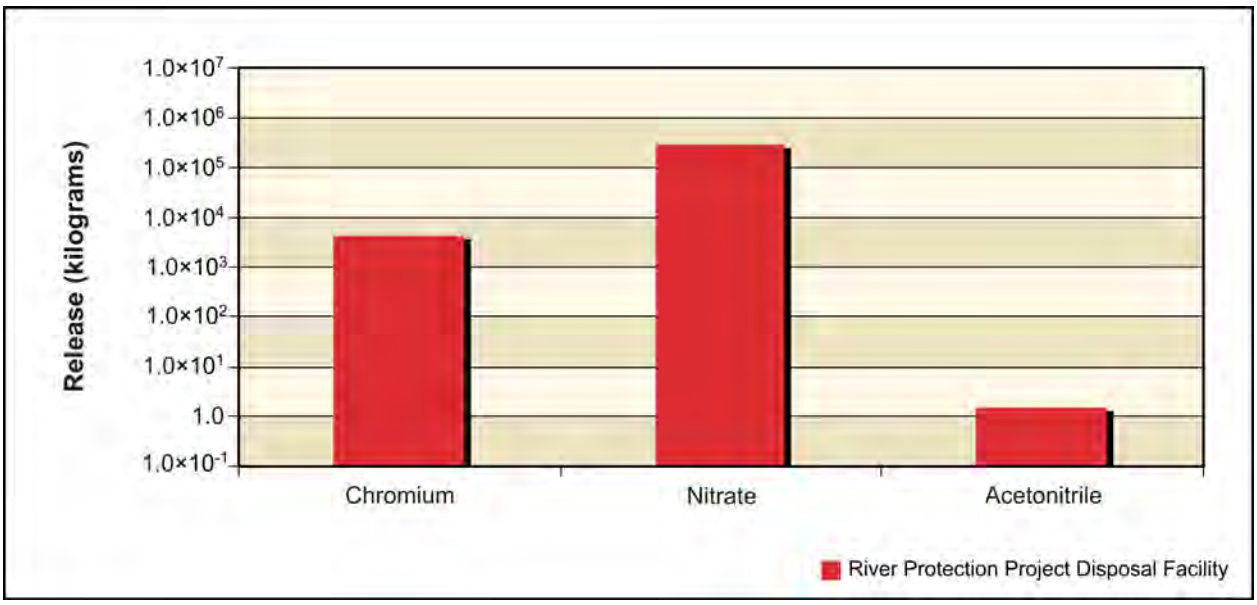


Figure 5–656. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

Figure 5–657 shows the release to the vadose zone for the Option Case at the RPPDF for the radiological risk drivers, and Figure 5–658, the chemical hazard drivers. For the RPPDF, the radiological risk drivers and the chemical hazard drivers for the Option Case have essentially identical releases to the vadose zone as in the Base Case.

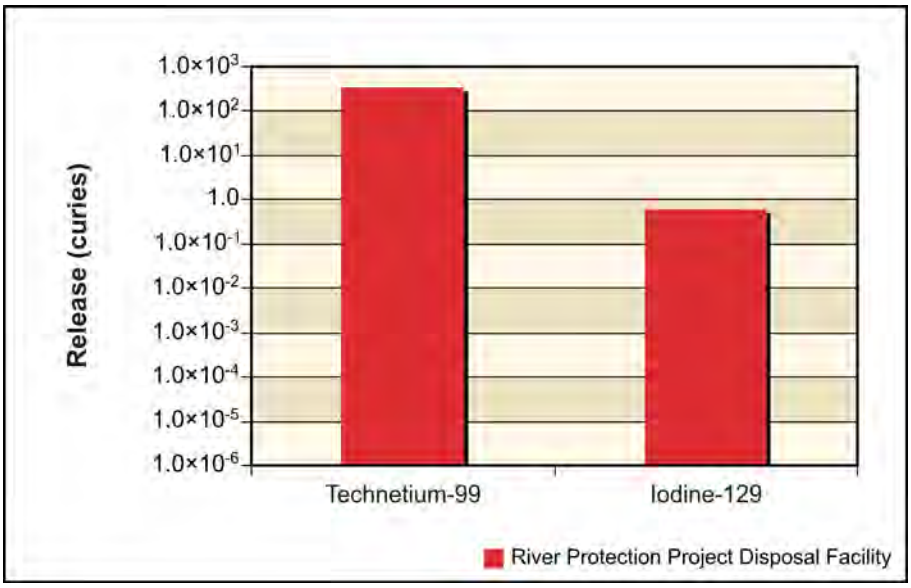


Figure 5–657. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at River Protection Project Disposal Facility to Vadose Zone

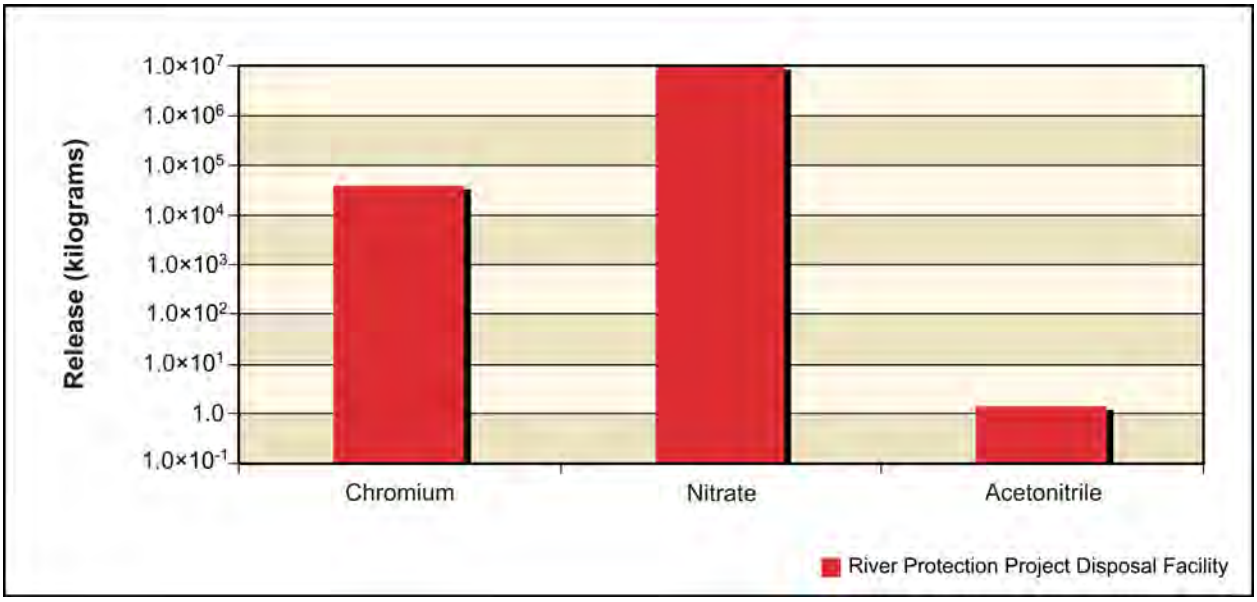


Figure 5–658. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at River Protection Project Disposal Facility to Vadose Zone

Figure 5–659 shows the release to groundwater for the Base Case at the RPPDF for the radiological risk drivers and Figure 5–660, the chemical hazard drivers. For the RPPDF, the amount released to groundwater was essentially equal to that released to the vadose zone for technetium-99, iodine-129, chromium, nitrate, and acetonitrile.

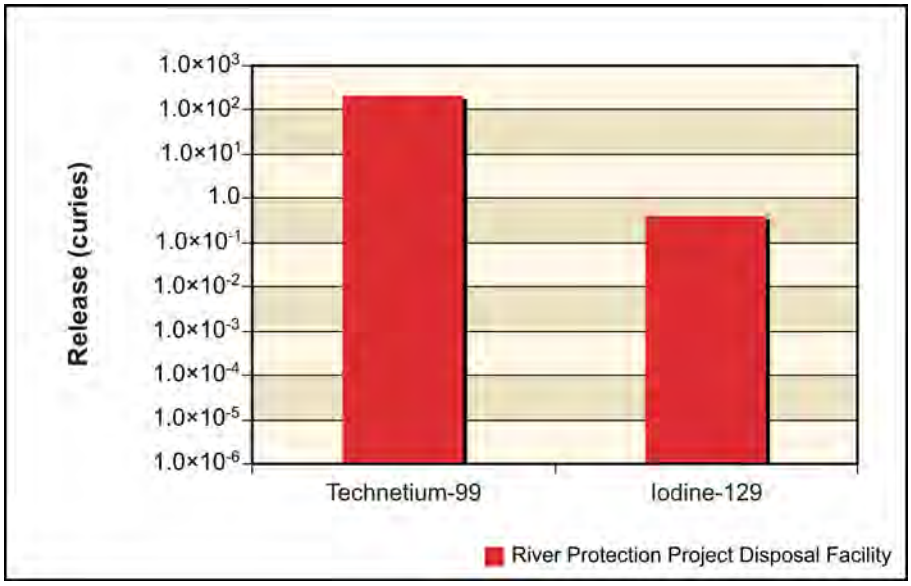


Figure 5–659. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at River Protection Project Disposal Facility to Groundwater

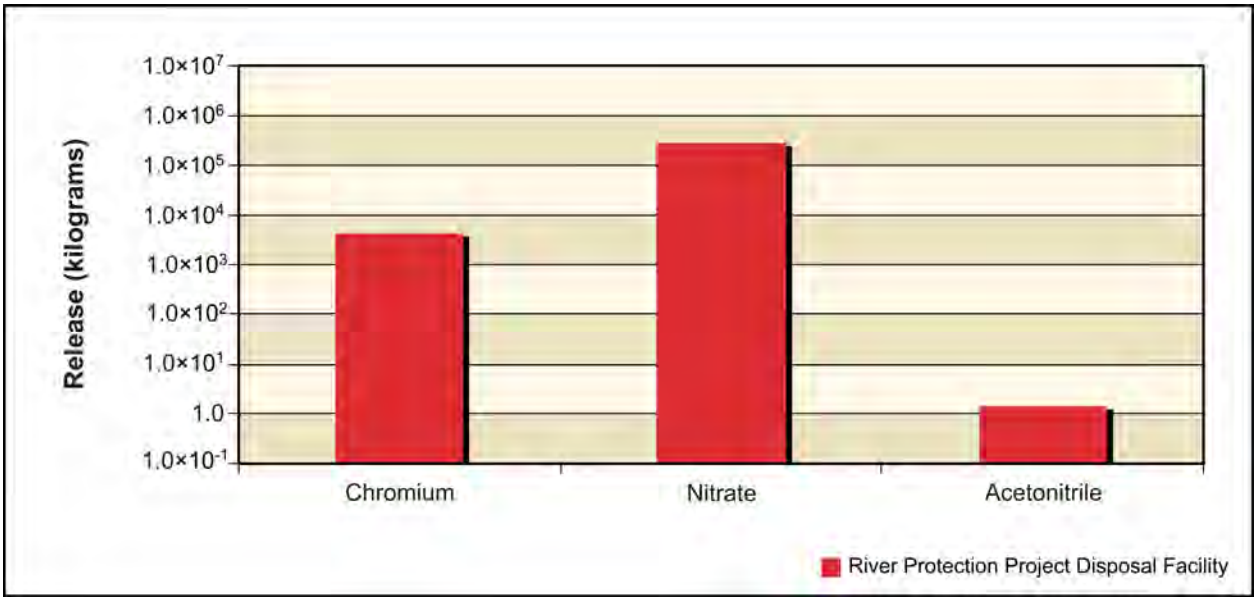


Figure 5–660. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at River Protection Project Disposal Facility to Groundwater

Figure 5–661 shows the release to groundwater for the Option Case at the RPPDF for the radiological risk drivers and Figure 5–662, the chemical hazard drivers. For the RPPDF, the radiological risk drivers and the chemical hazard drivers for the Option Case have essentially identical releases to the groundwater as in the Base Case.

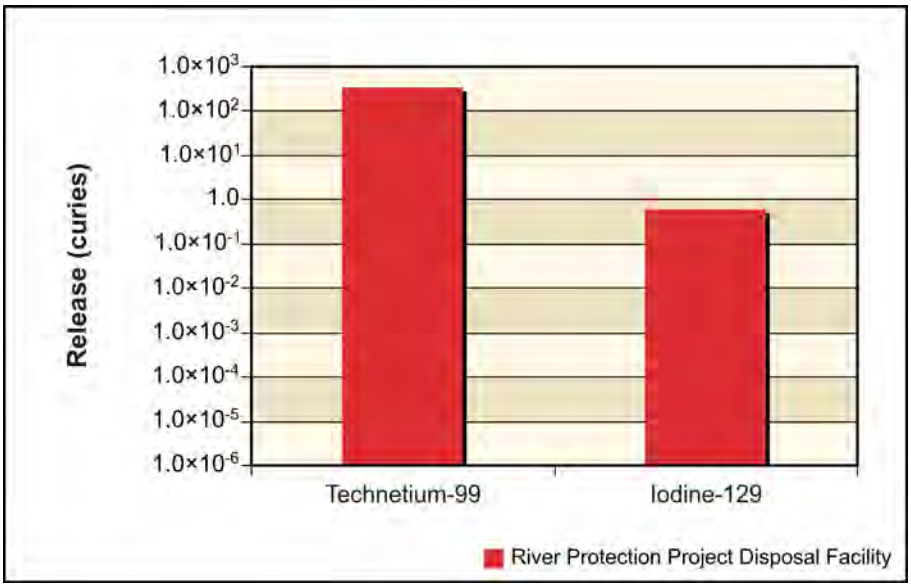


Figure 5–661. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at River Protection Project Disposal Facility to Groundwater

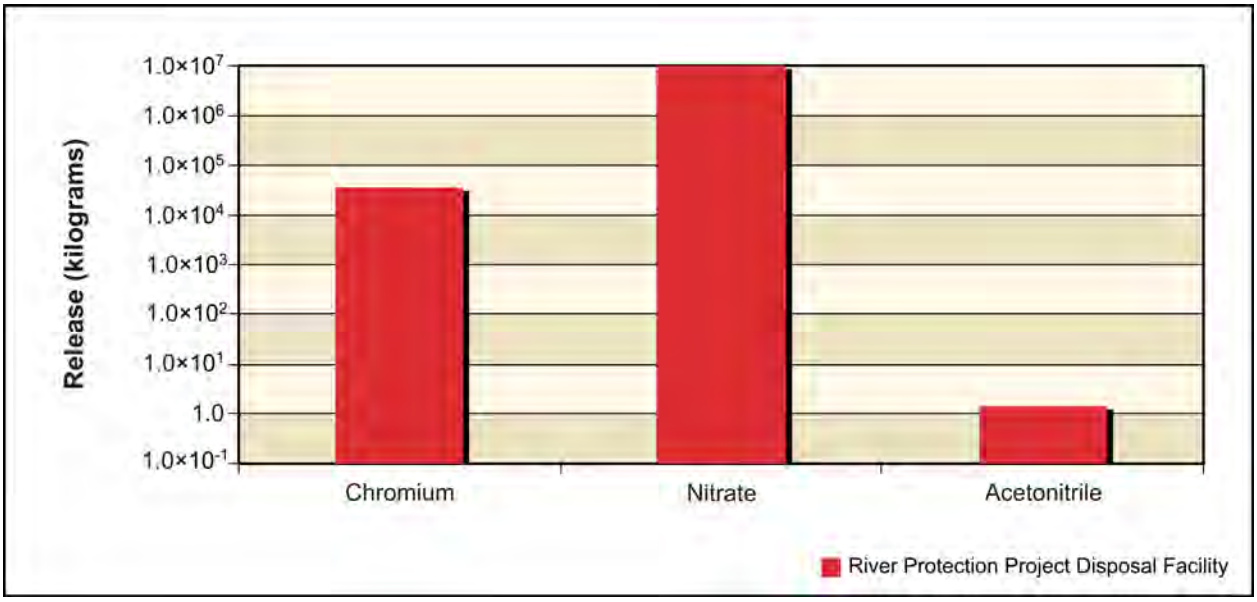


Figure 5–662. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at River Protection Project Disposal Facility to Groundwater

Figure 5–663 shows the release to the Columbia River for the Base Case at the RPPDF for the radiological risk drivers and Figure 5–664, the chemical hazard drivers. For the RPPDF, about 95 percent of the amount that was released from the groundwater reached the Columbia River for technetium-99, iodine-129, chromium, nitrate, and acetonitrile.

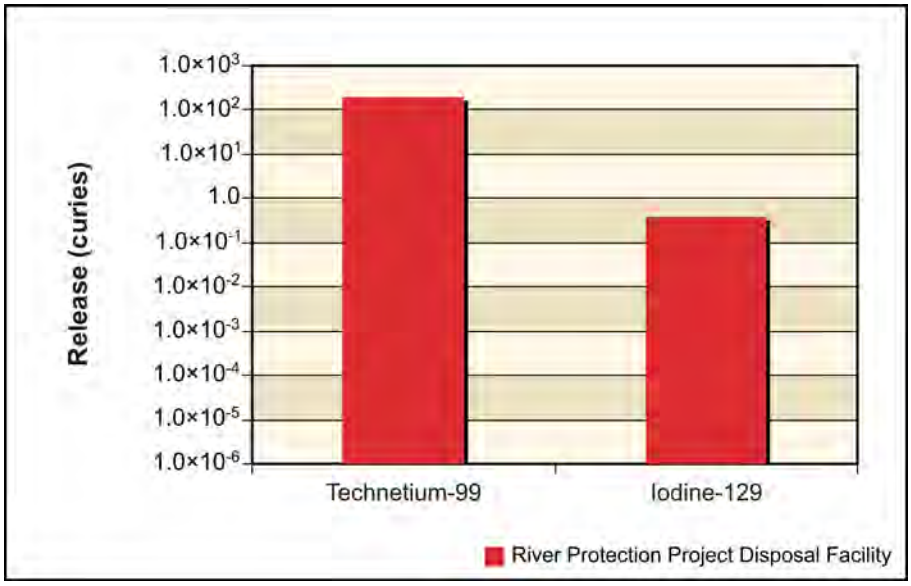


Figure 5–663. Waste Management Alternative 2, Disposal Group 3, Base Case, Radiological Releases at River Protection Project Disposal Facility to Columbia River

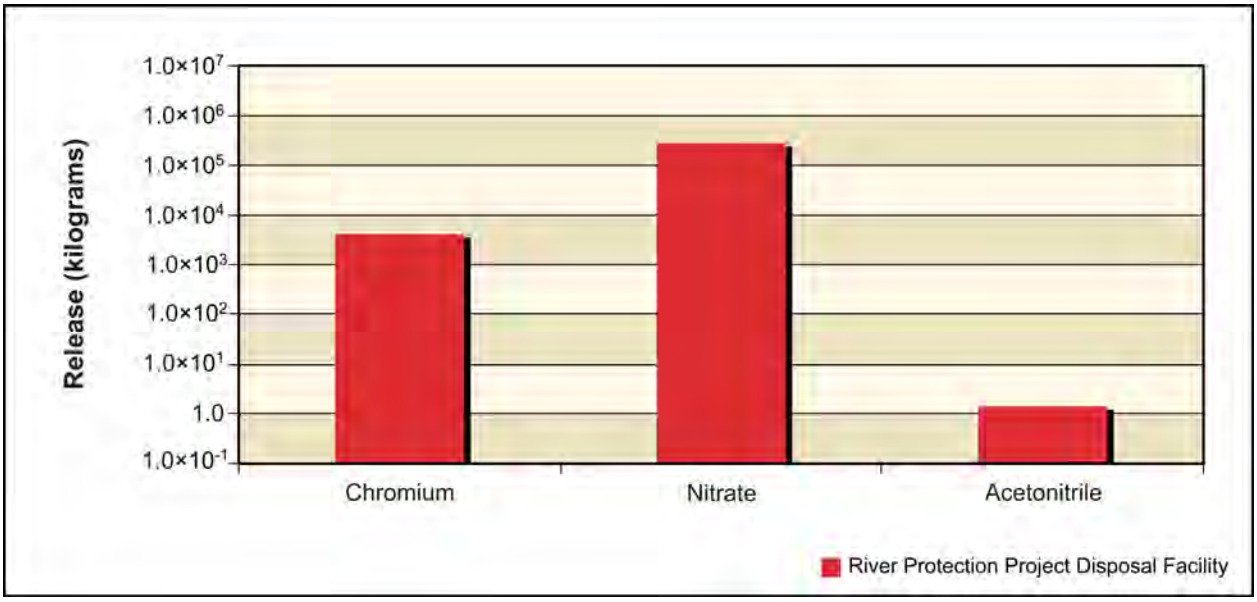


Figure 5–664. Waste Management Alternative 2, Disposal Group 3, Base Case, Chemical Releases at River Protection Project Disposal Facility to Columbia River

Figure 5–665 shows the release to the Columbia River for the Option Case at the RPPDF for the radiological risk drivers and Figure 5–666, the chemical hazard drivers. For the RPPDF, the radiological risk drivers and the chemical hazard drivers for the Option Case have essentially identical releases to the Columbia River as in the Base Case.

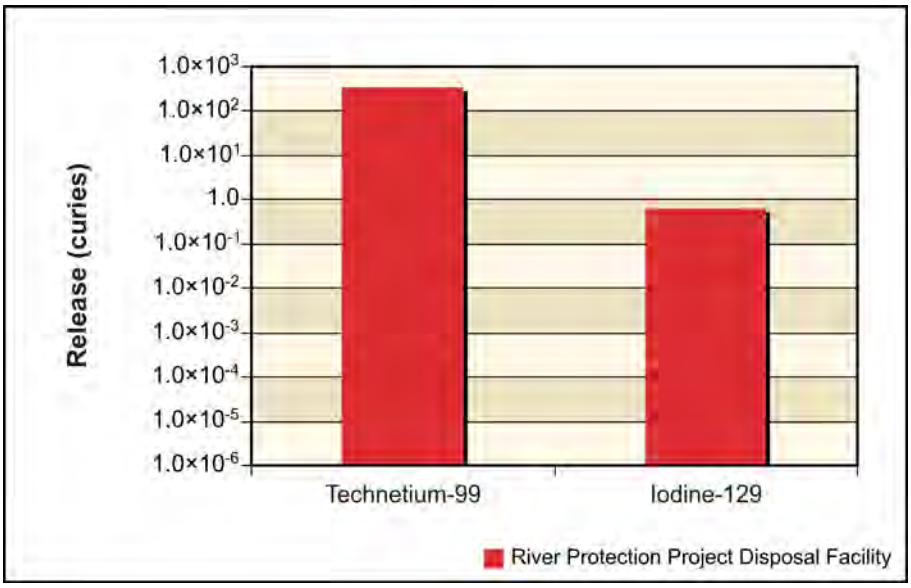


Figure 5–665. Waste Management Alternative 2, Disposal Group 3, Option Case, Radiological Releases at River Protection Project Disposal Facility to Columbia River

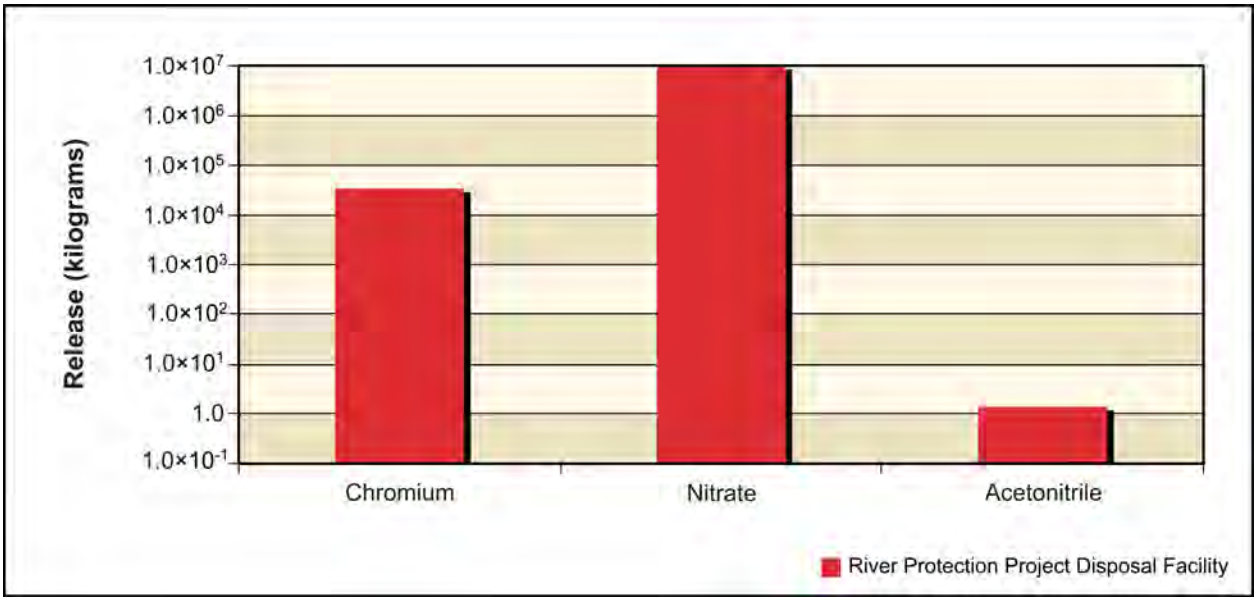


Figure 5–666. Waste Management Alternative 2, Disposal Group 3, Option Case, Chemical Releases at River Protection Project Disposal Facility to Columbia River

ANALYSIS OF CONCENTRATION VERSUS TIME

This section presents the impacts of Waste Management Alternative 2, Disposal Group 3, Base and Option Cases, in terms of groundwater concentration versus time at the Core Zone Boundary and the Columbia River. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per

liter. The benchmark concentration for each radionuclide and chemical is also shown. Because of the discrete nature of the concentration carried across a barrier or the river, a line denoting the 95th percentile upper confidence limit of the concentration is included on a few graphs. This confidence interval was calculated to show when the actual concentration over a certain time interval (95 percent of the time) is likely to be at or below this value. The confidence interval is basically a statistical aid to interpreting data with a significant amount of random fluctuation (noise). The confidence interval was calculated when: the concentration had a reasonable degree of noise, the concentration's trend was level, and the concentrations were near the benchmark. Note that the concentrations are plotted on a logarithmic scale to facilitate visual comparison of concentrations that vary over five orders of magnitude. Tables 5–87 and 5–88 list the maximum concentrations of the COPCs in the peak year at IDF-East and the RPPDF, Core Zone Boundary and Columbia River nearshore.

Table 5–87. Waste Management Alternative 2, Disposal Group 3, Base Case, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**3,040** (8646)	303 (3987)	**1,180** (8173)	848 (9284)	900
Iodine-129	**22** (8850)	0.5 (4073)	**11** (11300)	**6** (8985)	1
Chemical in micrograms per liter					
Chromium	3 (8561)	6 (4109)	11 (6384)	3 (4877)	100
Nitrate	16,600 (7367)	404 (4001)	6,550 (6859)	3,310 (7741)	45,000

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

Table 5–88. Waste Management Alternative 2, Disposal Group 3, Option Case, Maximum COPC Concentrations in the Peak Year at IDF-East and the RPPDF, Core Zone Boundary, and Columbia River Nearshore

Contaminant	IDF-East	RPPDF	Core Zone Boundary	Columbia River Nearshore	Benchmark Concentration
Radionuclide in picocuries per liter					
Technetium-99	**3,040** (8646)	386 (4013)	**1,180** (8173)	861 (9284)	900
Iodine-129	**22** (8850)	0.6 (4172)	**11** (11300)	**6** (8985)	1
Chemical in micrograms per liter					
Chromium	3 (8561)	36 (3878)	125 (6610)	20 (6701)	100
Nitrate	16,600 (7367)	10,300 (4544)	30,200 (4627)	5,620 (6522)	45,000

Note: Corresponding calendar years shown in parentheses. Concentrations that would exceed the benchmark value are indicated in **bold** text.

Key: COPC=constituent of potential concern; IDF-East=200-East Area Integrated Disposal Facility; RPPDF=River Protection Project Disposal Facility.

Figure 5–667 shows the concentration versus time plot in the Base Case for technetium-99. Releases cause the groundwater concentrations at the Core Zone Boundary and the Columbia River nearshore to approach the benchmark concentration around CY 7000 to CY 10,000. The concentrations at the Core Zone Boundary and at the Columbia River nearshore never constantly remain above the benchmark concentration throughout the period of analysis.

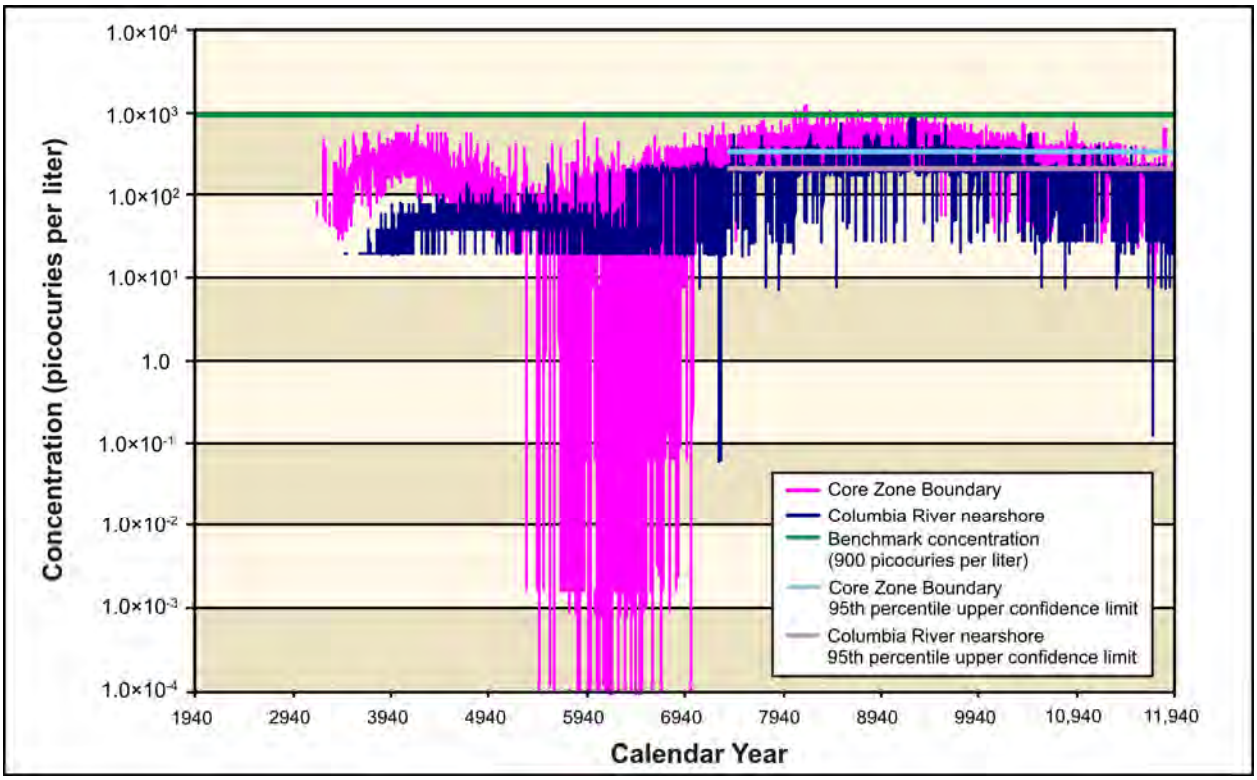


Figure 5–667. Waste Management Alternative 2, Disposal Group 3, Base Case, Technetium-99 Concentration Versus Time

Figure 5–668 shows the concentration versus time plot in the Option Case for technetium-99. The plot for technetium-99 in the Option Case is similar that in the Base Case.

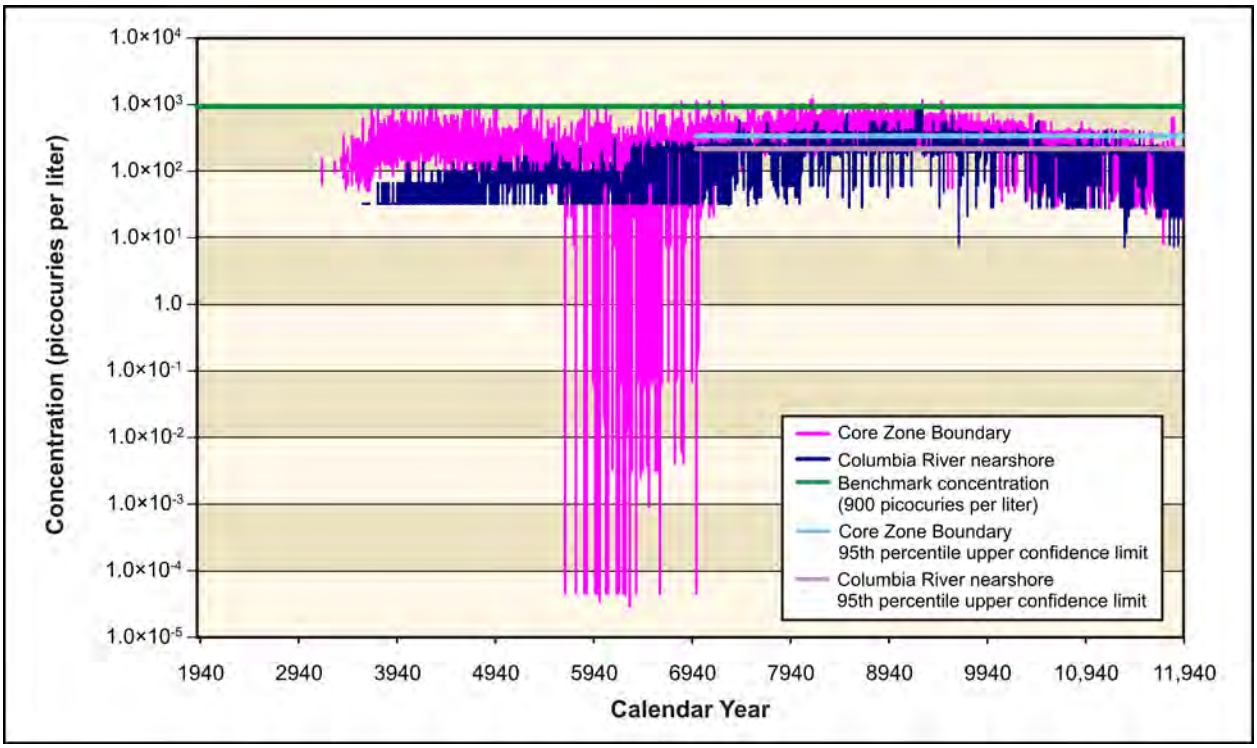


Figure 5–668. Waste Management Alternative 2, Disposal Group 3, Option Case, Technetium-99 Concentration Versus Time

The concentration versus time plot for iodine-129 in the Base Case shows a pattern similar to that of technetium-99, except that iodine-129 concentrations at the Core Zone Boundary and at the Columbia River nearshore exceed the benchmark from about CY 6000 until the end of the period of analysis. Exceedances peaked at around one order of magnitude above the benchmark concentration (see Figure 5–669).

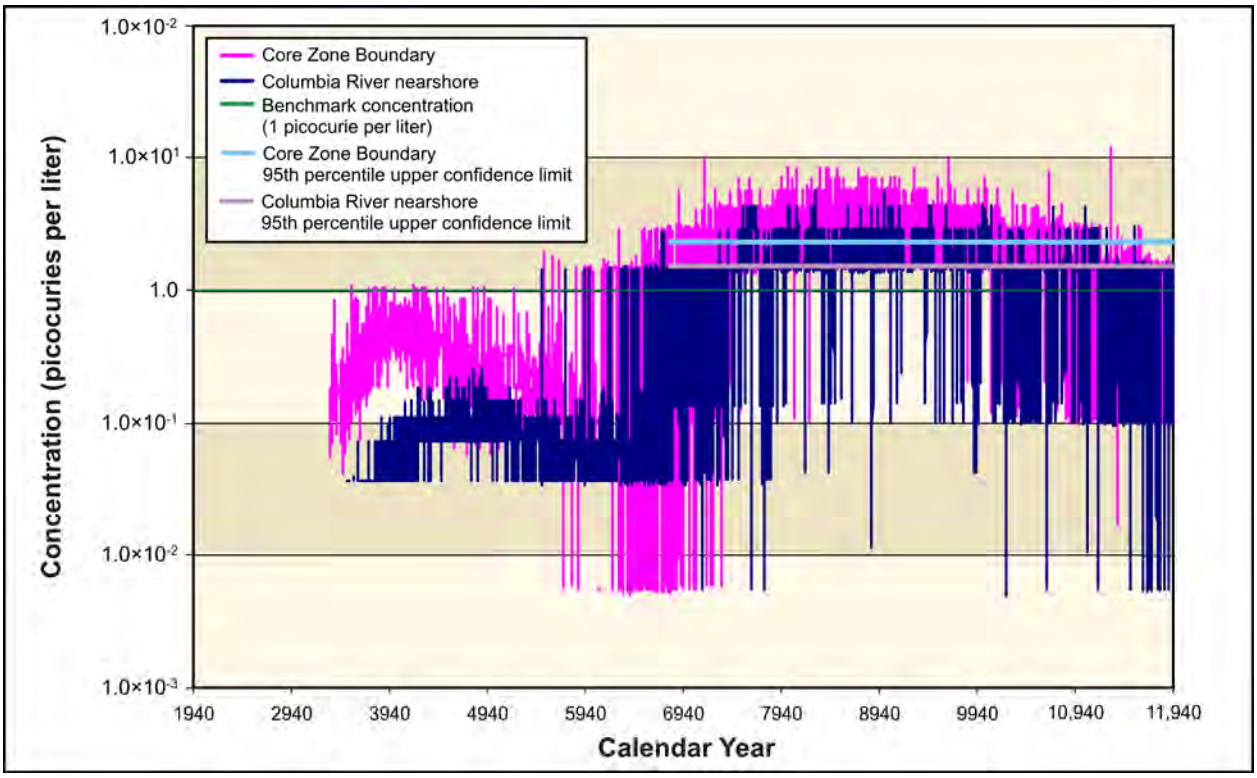


Figure 5–669. Waste Management Alternative 2, Disposal Group 3, Base Case, Iodine-129 Concentration Versus Time

The plot of iodine-129 concentration versus time in the Option Case is similar to that in the Base Case (see Figure 5–670).

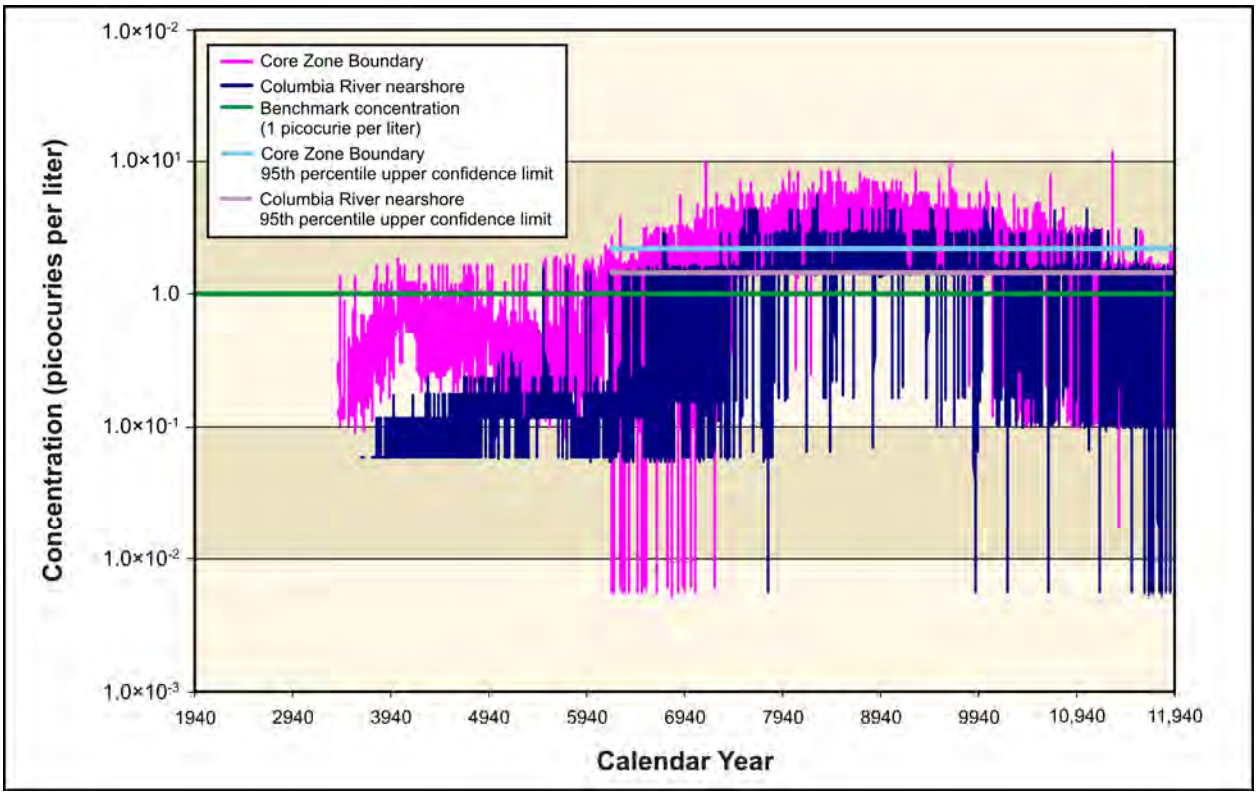


Figure 5–670. Waste Management Alternative 2, Disposal Group 3, Option Case, Iodine-129 Concentration Versus Time

Figure 5–671 shows the plot of concentration versus time for chromium in the Base Case. The concentrations at the Core Zone Boundary approach but do not exceed the benchmark from about CY 3800 to CY 5800. The concentrations at the Columbia River nearshore remained about two orders of magnitude below the benchmark.

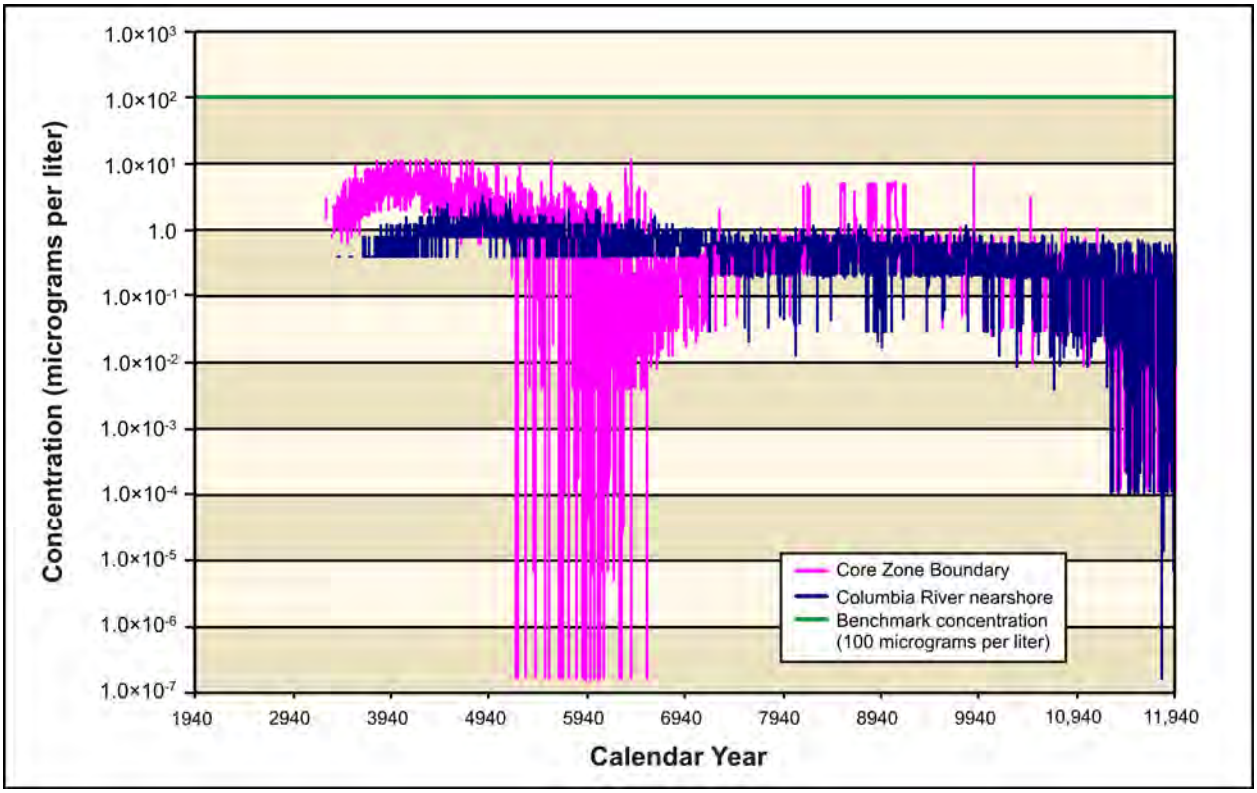


Figure 5–671. Waste Management Alternative 2, Disposal Group 3, Base Case, Chromium Concentration Versus Time

Figure 5–672 shows the plot of concentration versus time plot for chromium in the Option Case. The concentrations at the Core Zone Boundary and the Columbia River nearshore remain about one to two orders of magnitude below the benchmark.

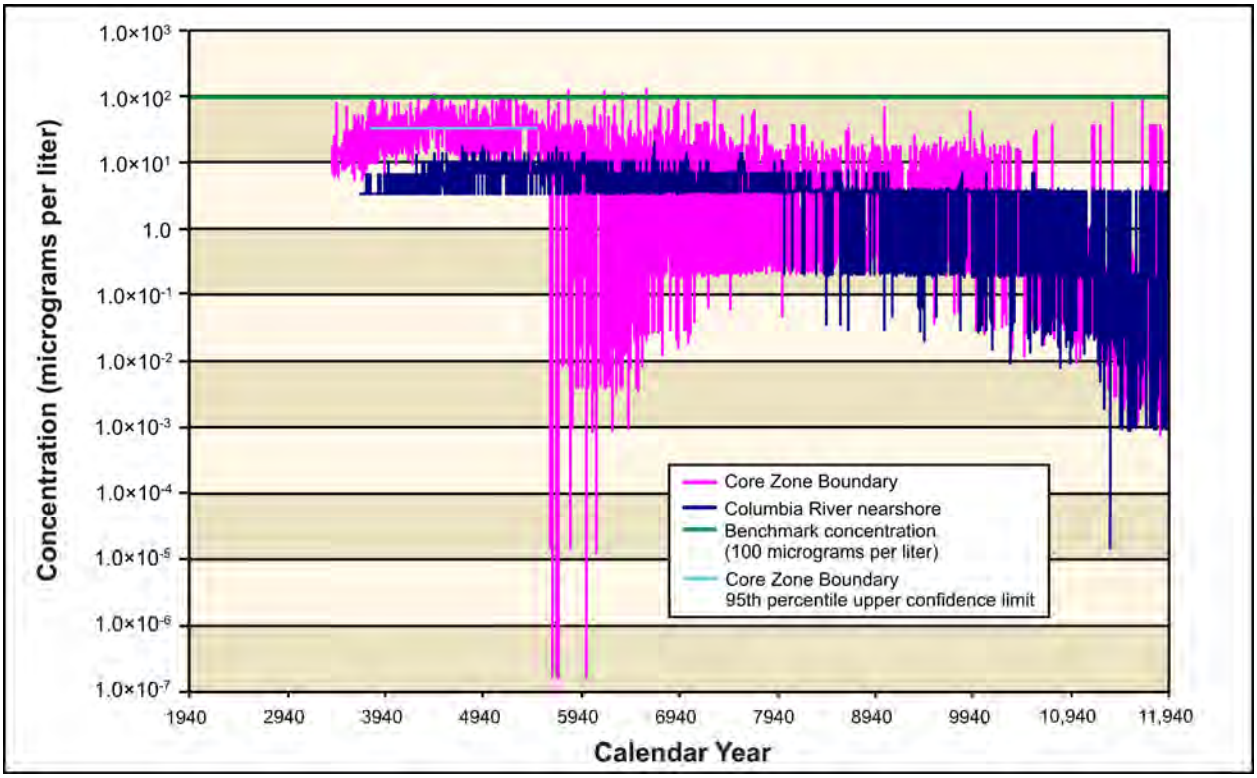


Figure 5–672. Waste Management Alternative 2, Disposal Group 3, Option Case, Chromium Concentration Versus Time

Figure 5–673 shows the plot of concentration versus time for nitrate in the Base Case. The concentrations at the Core Zone Boundary and the Columbia River nearshore both peak at around CY 8000. Even at the peak concentration levels, nitrate concentrations still remain about one order of magnitude below the benchmark.

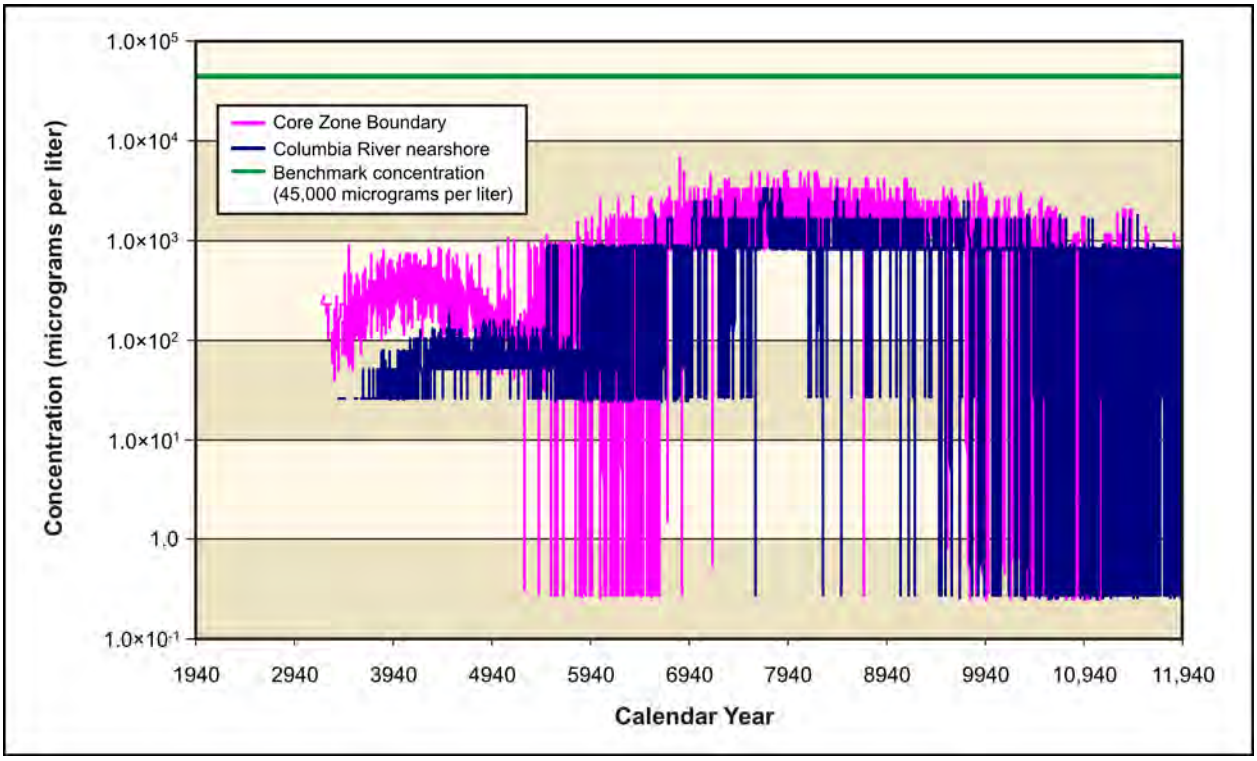


Figure 5–673. Waste Management Alternative 2, Disposal Group 3, Base Case, Nitrate Concentration Versus Time

Figure 5–674 shows the concentration versus time plot in the Option Case for nitrate. The concentrations at the Core Zone Boundary peak at around CY 4800 but remain about one-half order of magnitude below the benchmark concentration. Concentrations from the Columbia River nearshore remain fairly steady at around one order of magnitude below the benchmark.

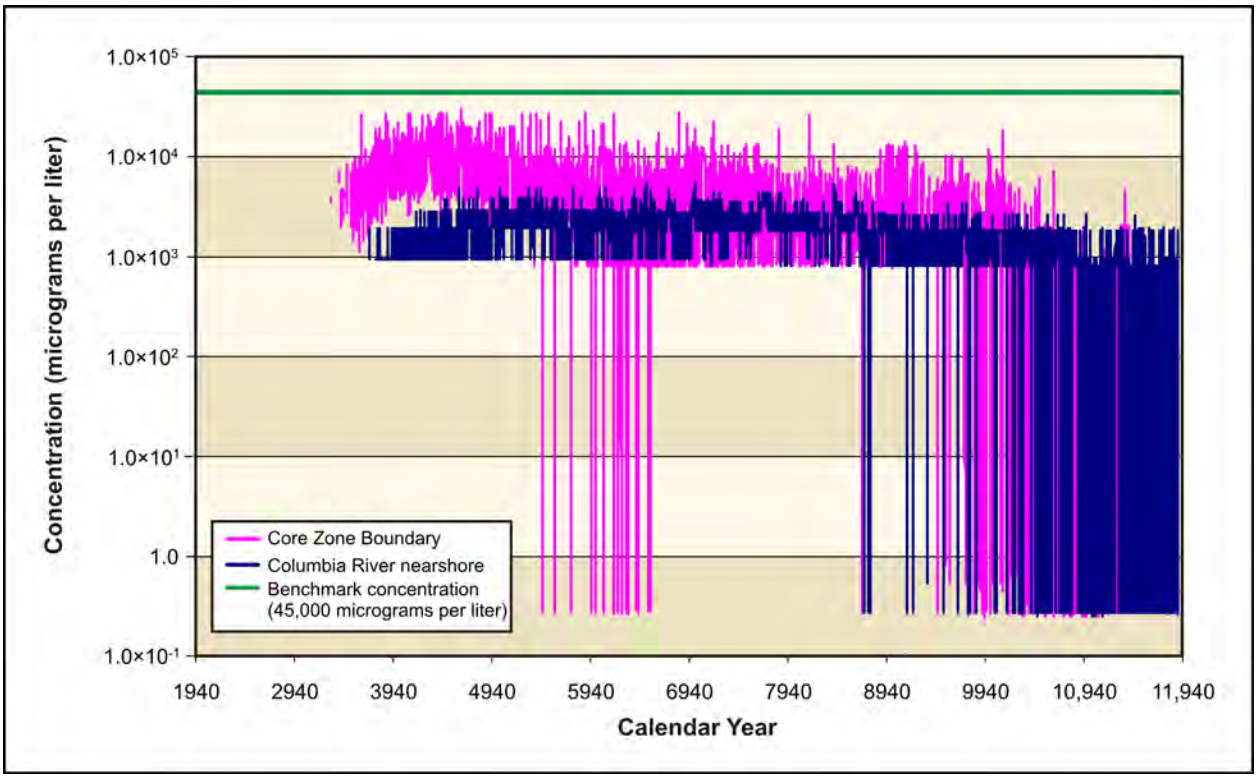


Figure 5–674. Waste Management Alternative 2, Disposal Group 3, Option Case, Nitrate Concentration Versus Time

Figure 5–675 shows the plot of concentration versus time for total uranium in the Base Case. It is not until around CY 9500 that concentrations begin to appear on the graph. The concentrations at the Core Zone Boundary and the Columbia River nearshore both remain about seven to nine orders of magnitude below the benchmark.

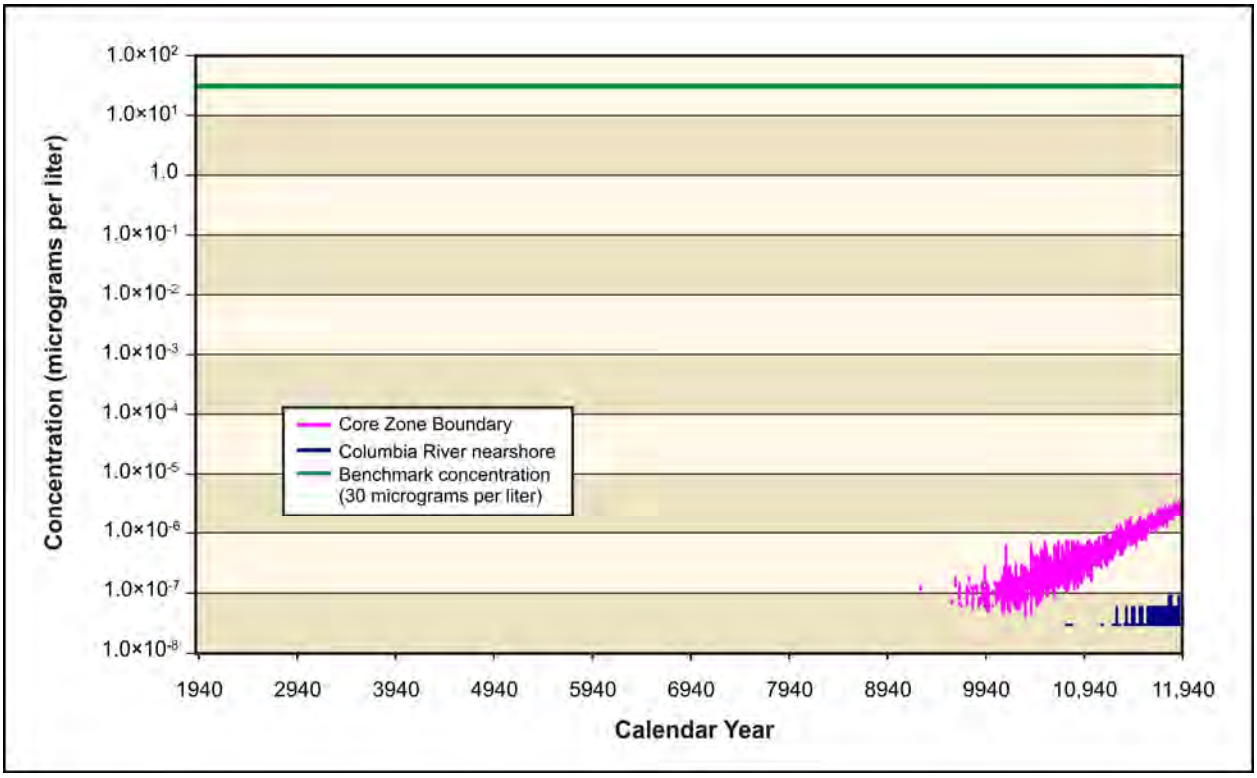


Figure 5–675. Waste Management Alternative 2, Disposal Group 3, Base Case, Total Uranium Concentration Versus Time

The plot of total uranium's concentration versus time in the Option Case is similar to that in the Base Case (see Figure 5–676).

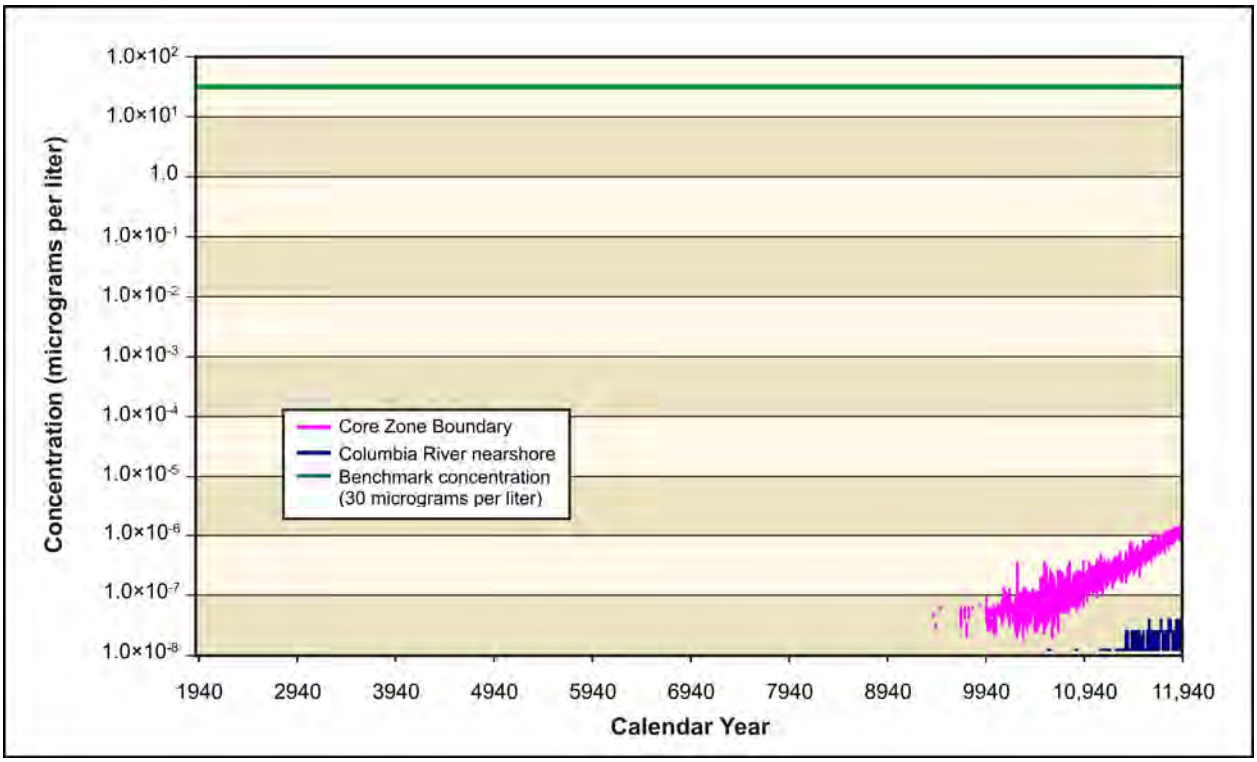


Figure 5–676. Waste Management Alternative 2, Disposal Group 3, Option Case, Total Uranium Concentration Versus Time

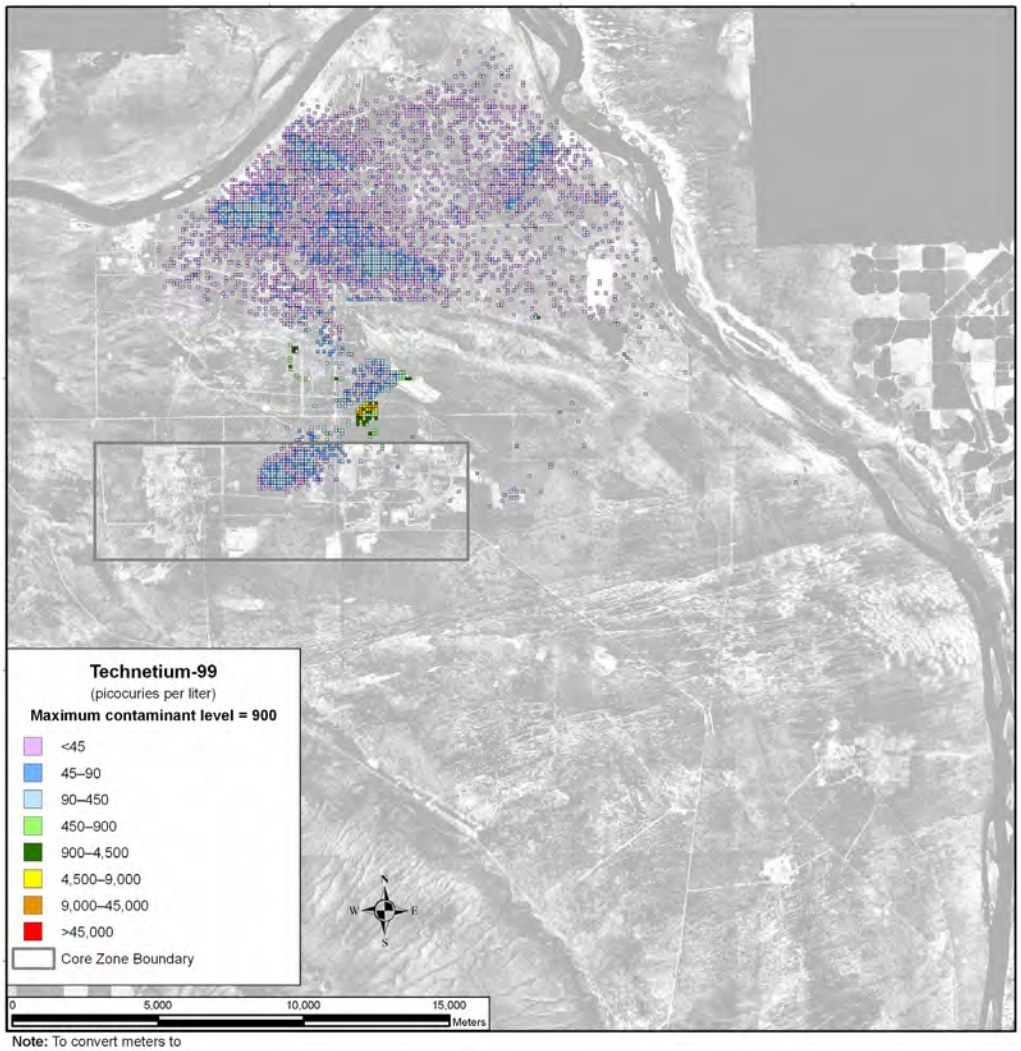
ANALYSIS OF SPATIAL DISTRIBUTION OF CONCENTRATION

This section presents the impacts of Waste Management Alternative 2, Disposal Group 3, in terms of the spatial distribution of groundwater concentration at selected times. Concentrations of radionuclides are in picocuries per liter; chemicals, in micrograms per liter. Concentrations of each radionuclide and chemical are indicated by a color scale relative to the benchmark concentration. Concentrations greater than the benchmark concentration are indicated by the fully saturated colors green, yellow, orange, and red in order of increasing concentration; concentrations lower than the benchmark concentration, by the faded colors green, blue, indigo, and violet in order of decreasing concentration. Note that the concentration ranges are on a logarithmic scale to facilitate visual comparison of concentrations that vary over three orders of magnitude.

Figure 5–677 shows the spatial distribution of groundwater concentration for technetium-99 in the Base Case during CY 3890. Releases from the RPPDF create a plume extending northerly through Gable Gap toward the Columbia River. Peak concentrations in this plume exceed the benchmark by about 10 to 50 times, although most of the plume is below the benchmark. By CY 7140, releases from the IDF create a new plume extending easterly toward the Columbia River (see Figure 5–678). Peak concentrations in this plume exceed the benchmark by five times. By the end of the period of analysis (CY 11,885), the plume created by the RPPDF has mostly dissipated, while the IDF plume persists, most of it below the benchmark (see Figure 5–679). Iodine-129 shows a similar spatial distribution over time but with slightly more intense peak concentrations (see Figures 5–680 through 5–682). Chromium and nitrate also show a similar spatial distribution over time, but with less intense areas of peak concentration (see Figures 5–683 through 5–685 and Figures 5–686 through 5–688).

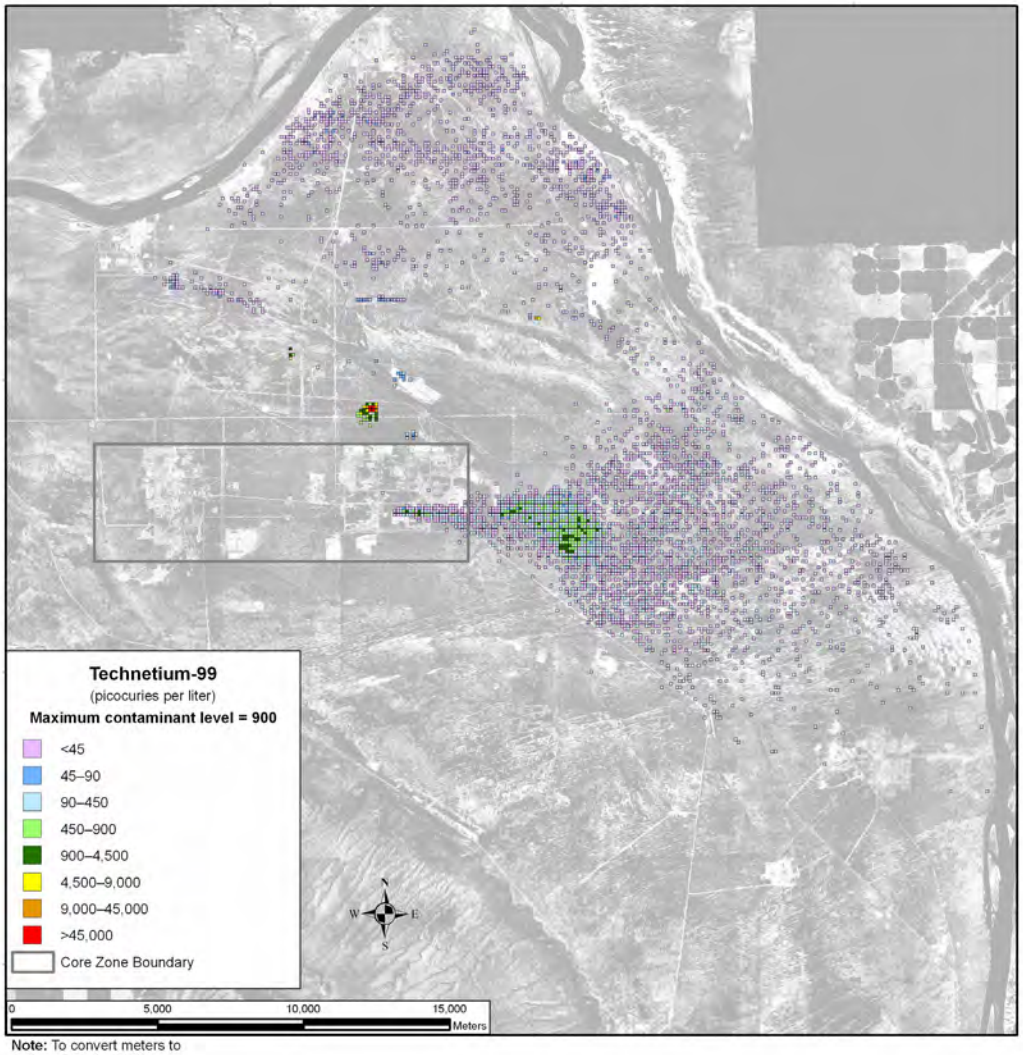
The spatial distributions of the conservative tracers in the Option Case are essentially identical to those in the Base Case (see Figures 5–689 through 5–700).

Total uranium is not as mobile as those radionuclides discussed above, moving about seven times slower than the pore water velocity. As a result, travel times through the vadose zone are longer, release to the aquifer is delayed, and travel times through the aquifer to the Columbia River are longer. Figure 5–701 shows the distribution of total uranium during CY 11,885 for the Base Case. A plume that is less than one-twentieth of the benchmark has been released from the RPPDF and is extending northerly through Gable Gap toward the Columbia River. Because of the slow nature of uranium's pore water velocity, most of the uranium releases are expected after the period of analysis. The spatial distribution of total uranium in the Option Case is essentially identical to that of the Base Case (see Figure 5-702).



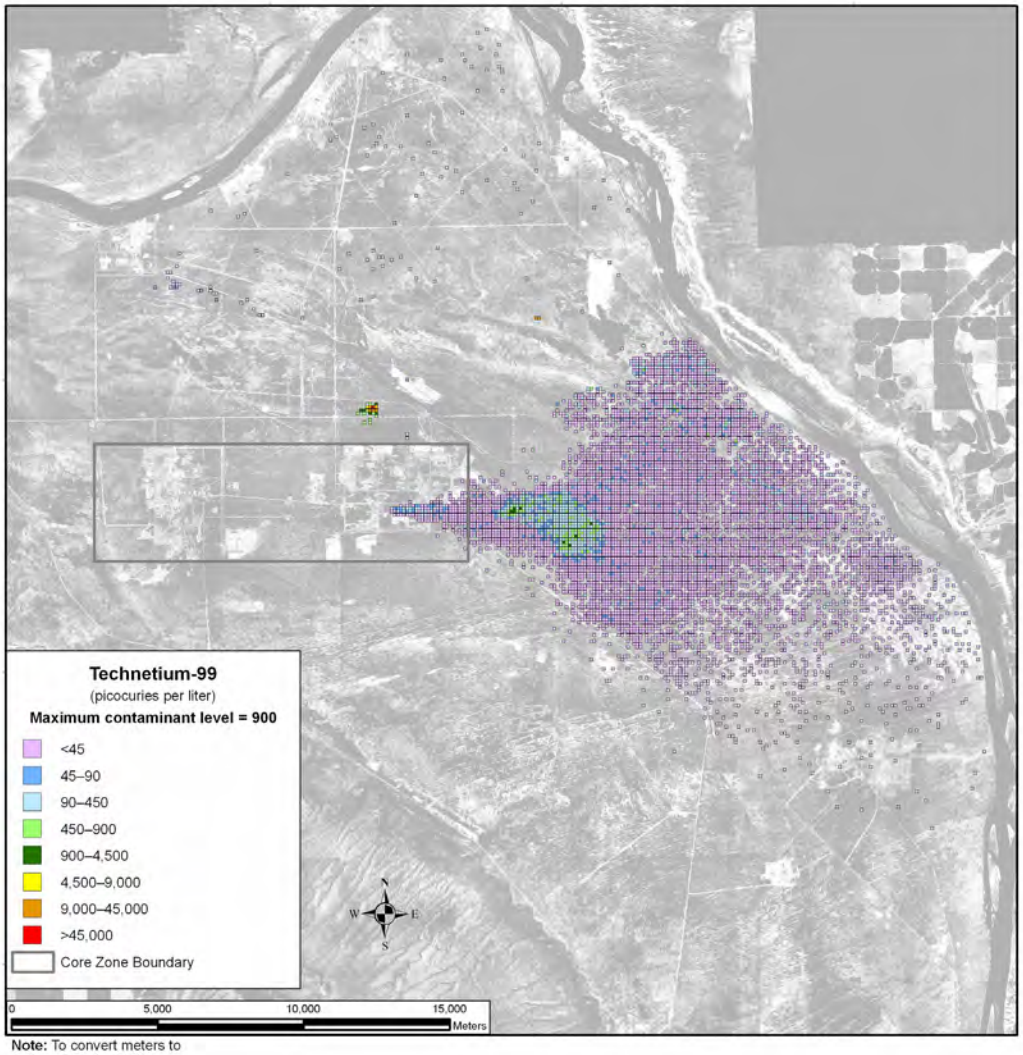
Note: To convert meters to feet, multiply by 3.281

Figure 5–677. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



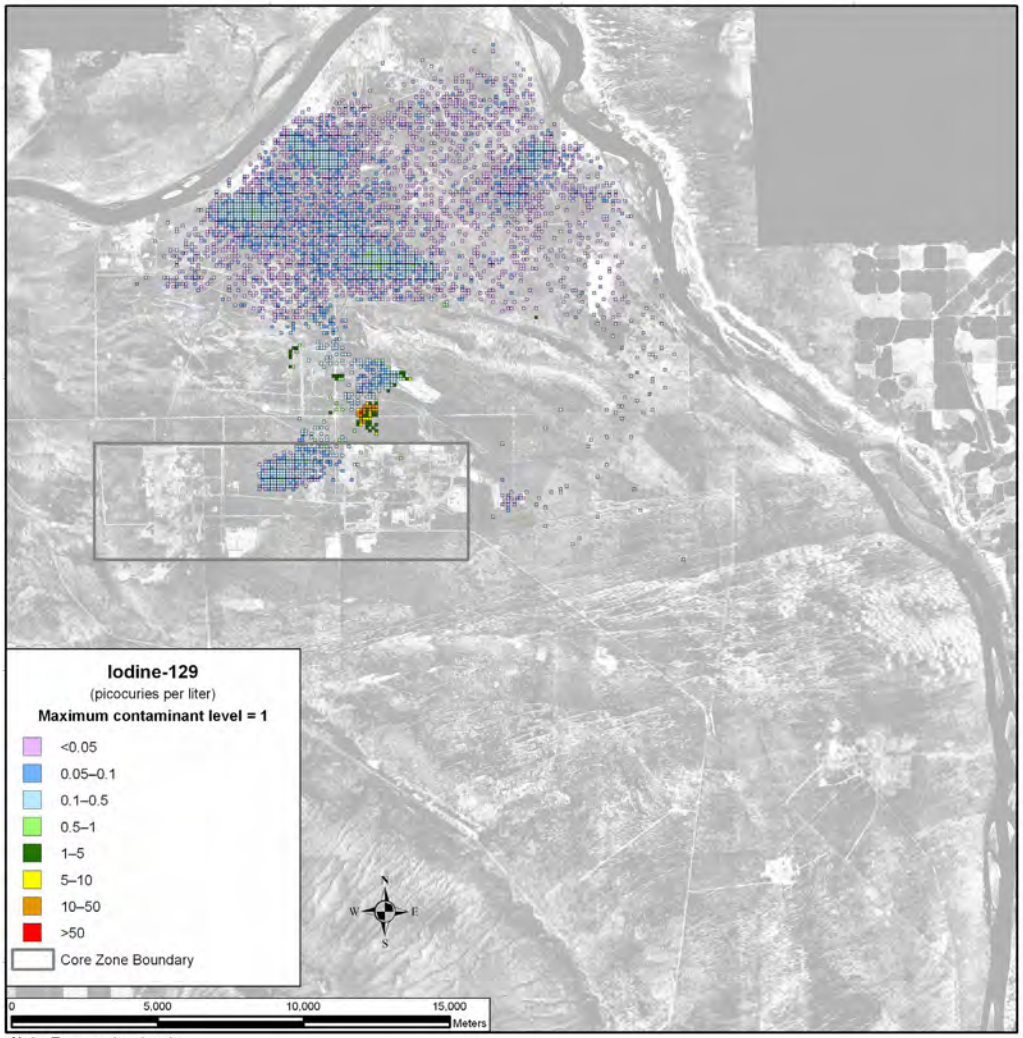
Note: To convert meters to feet, multiply by 3.281

Figure 5–678. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



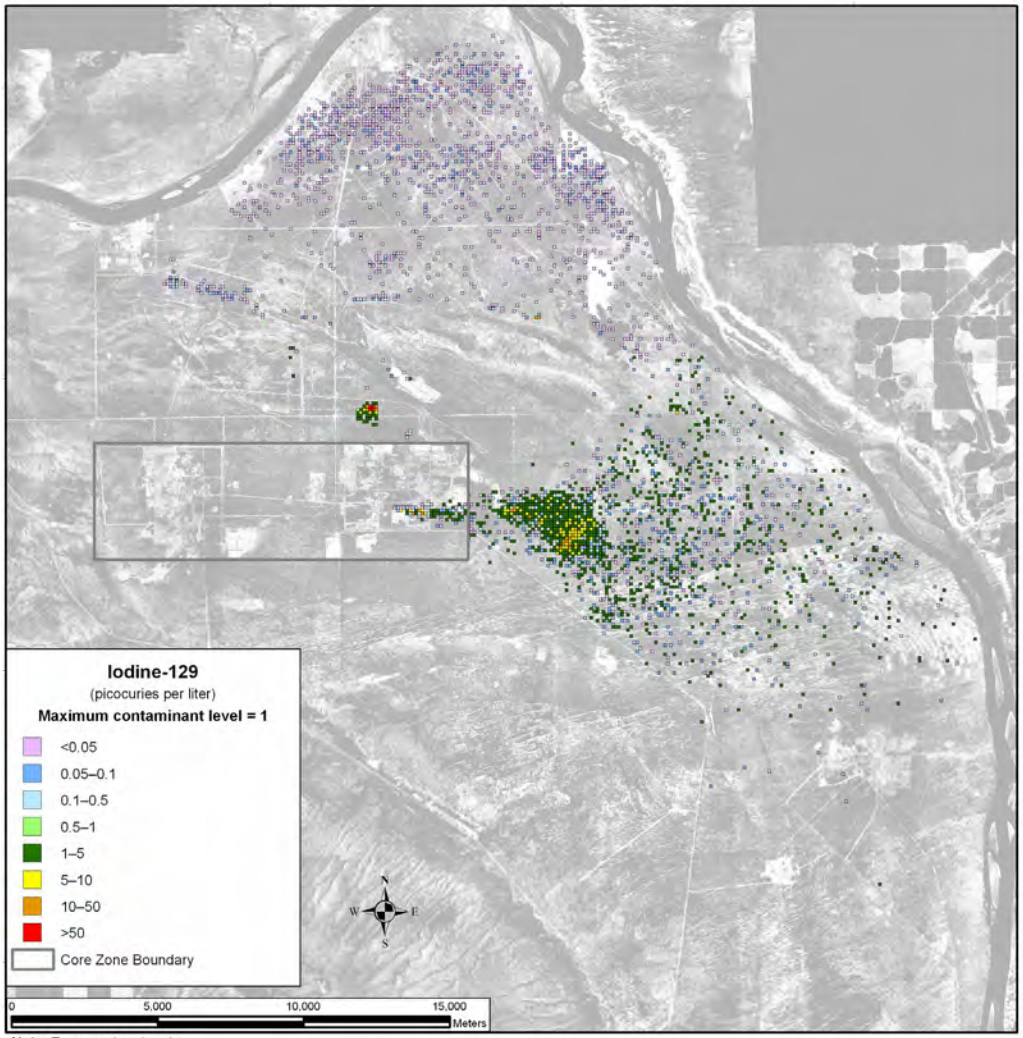
Note: To convert meters to feet, multiply by 3.281

Figure 5–679. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



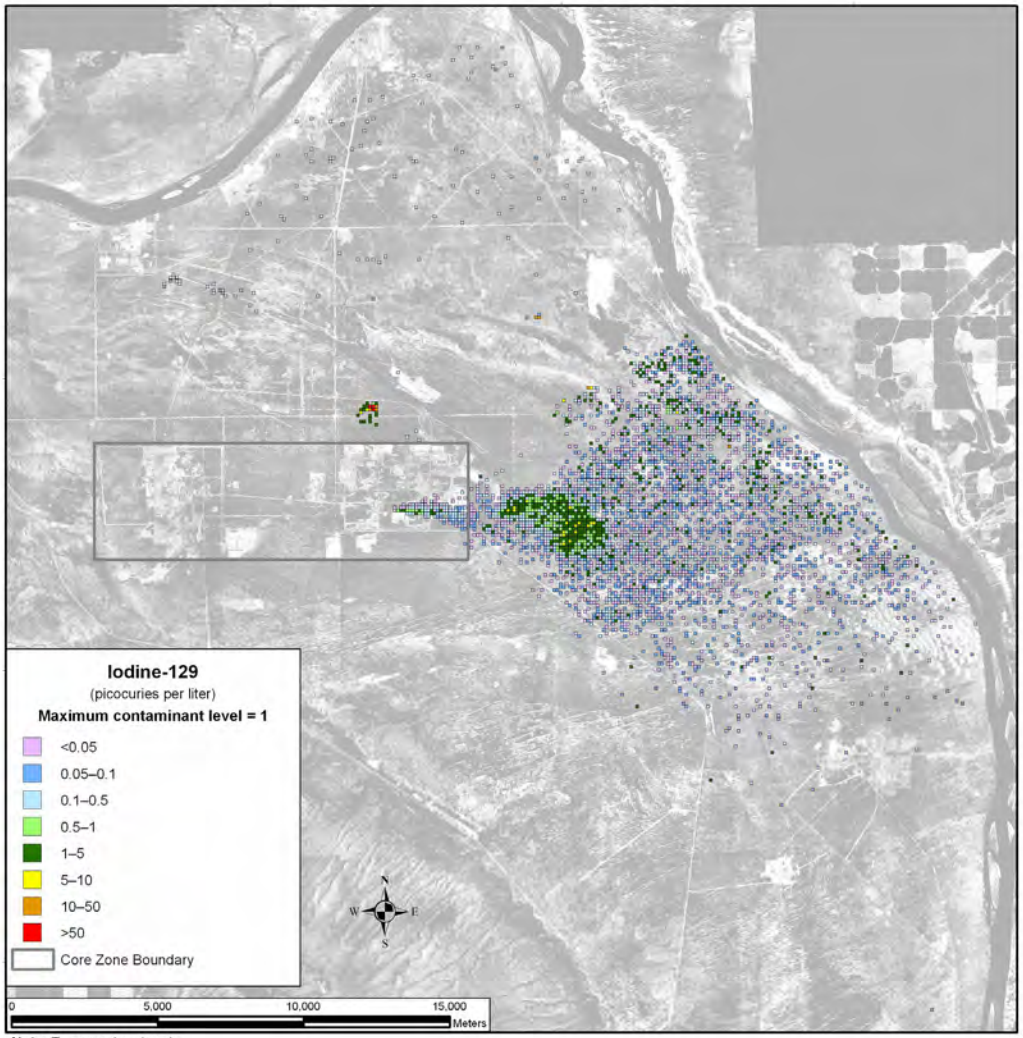
Note: To convert meters to feet, multiply by 3.281

Figure 5–680. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



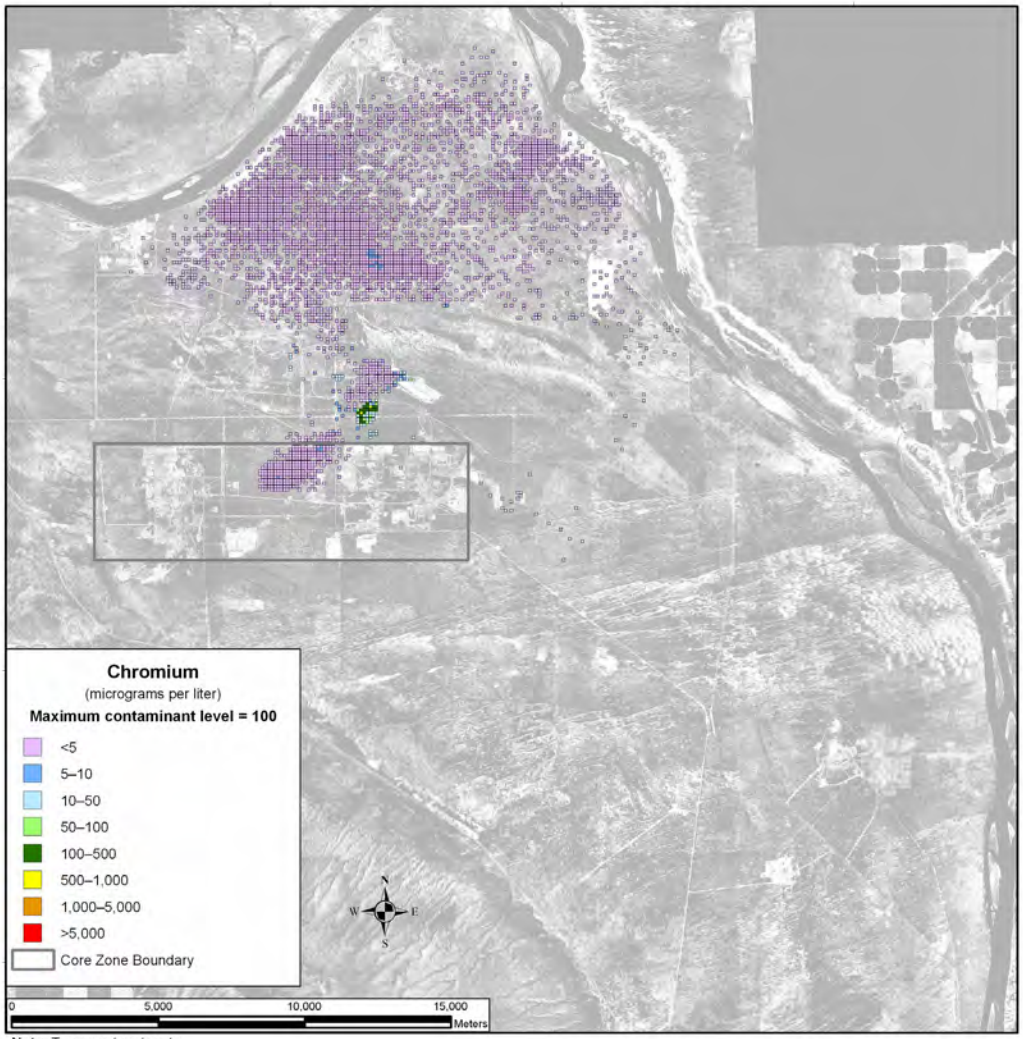
Note: To convert meters to feet, multiply by 3.281

Figure 5–681. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



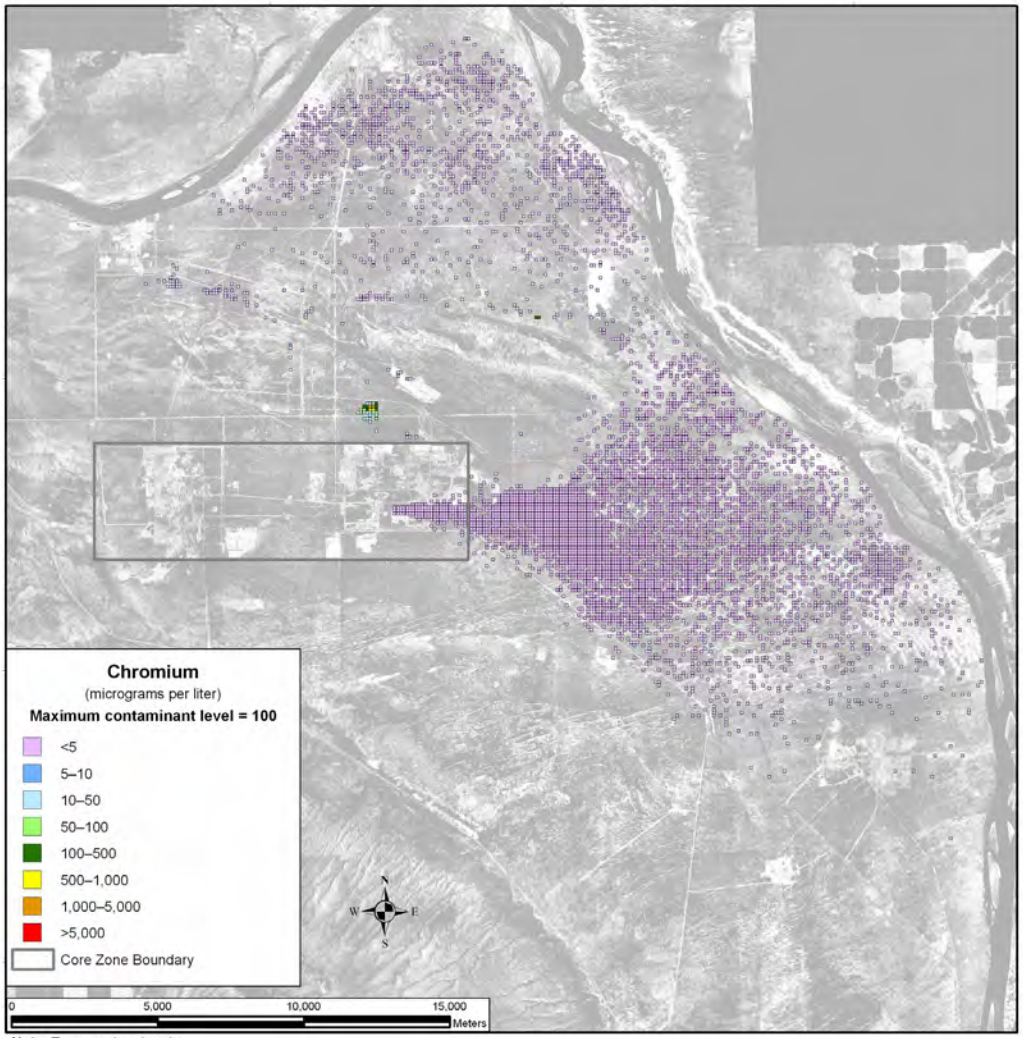
Note: To convert meters to feet, multiply by 3.281

Figure 5–682. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



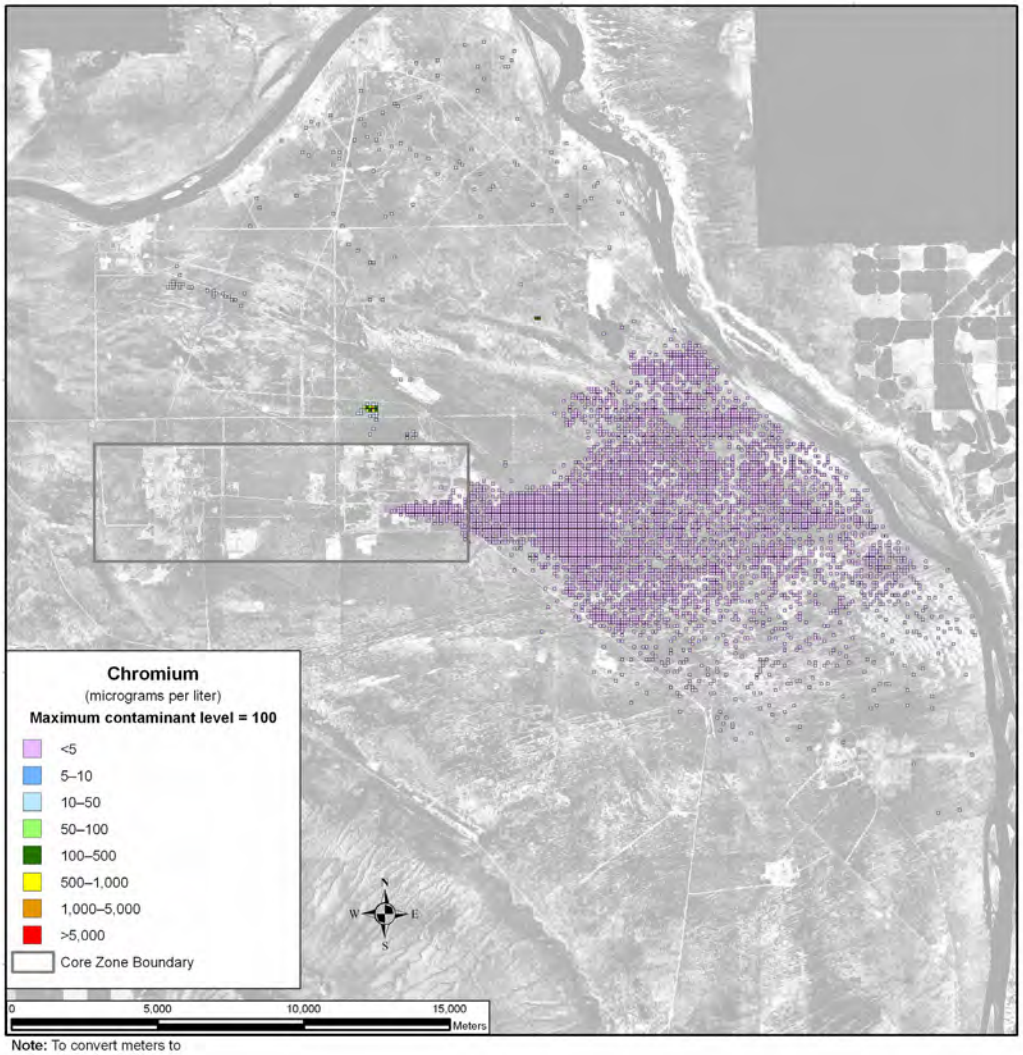
Note: To convert meters to feet, multiply by 3.281

Figure 5–683. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



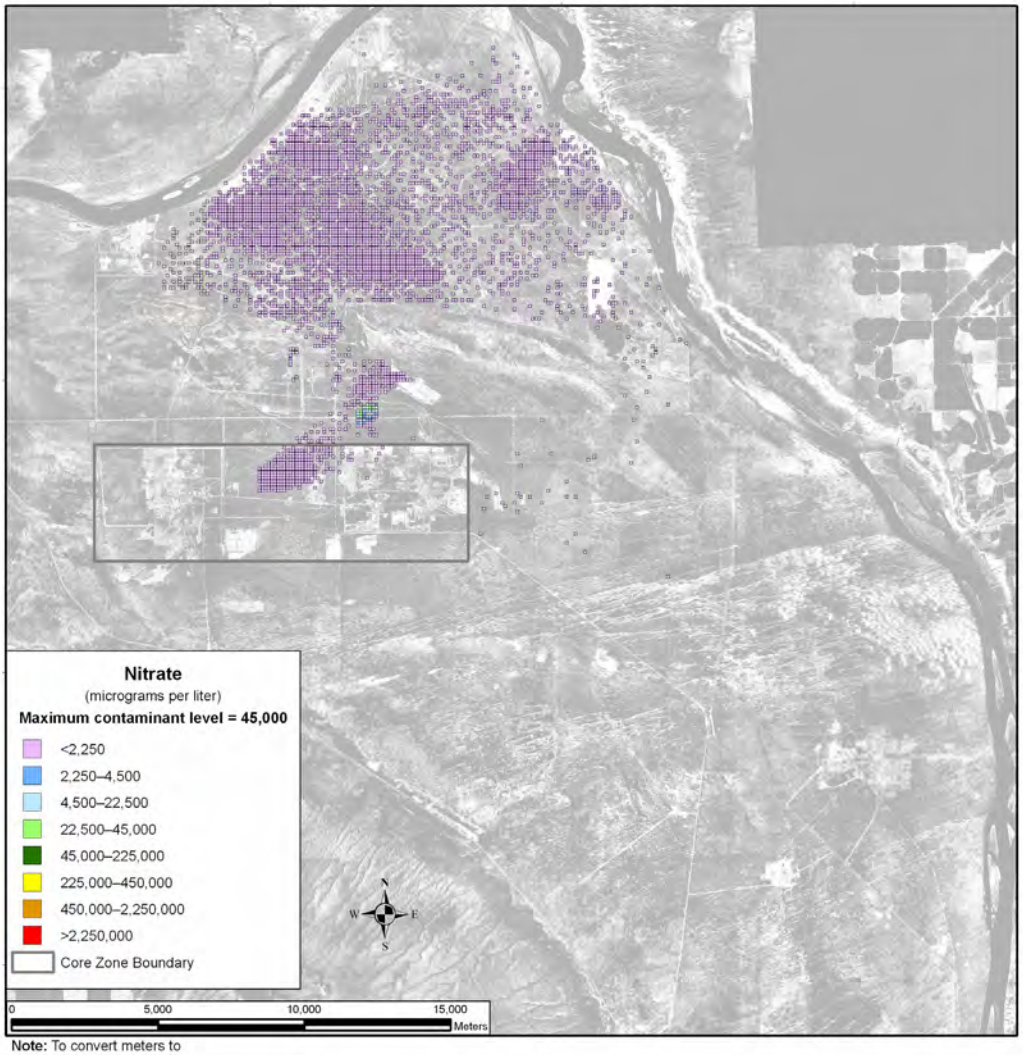
Note: To convert meters to feet, multiply by 3.281

Figure 5–684. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



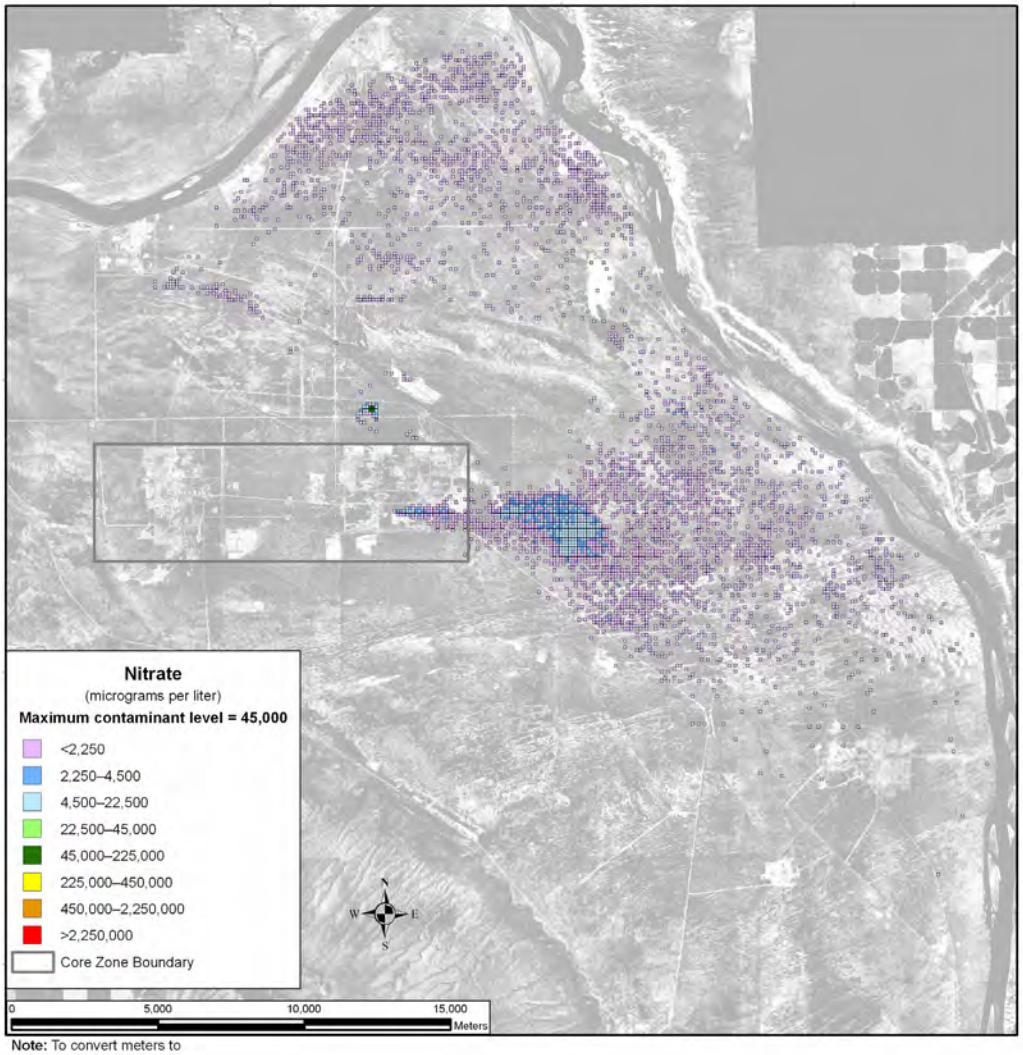
Note: To convert meters to feet, multiply by 3.281

Figure 5–685. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



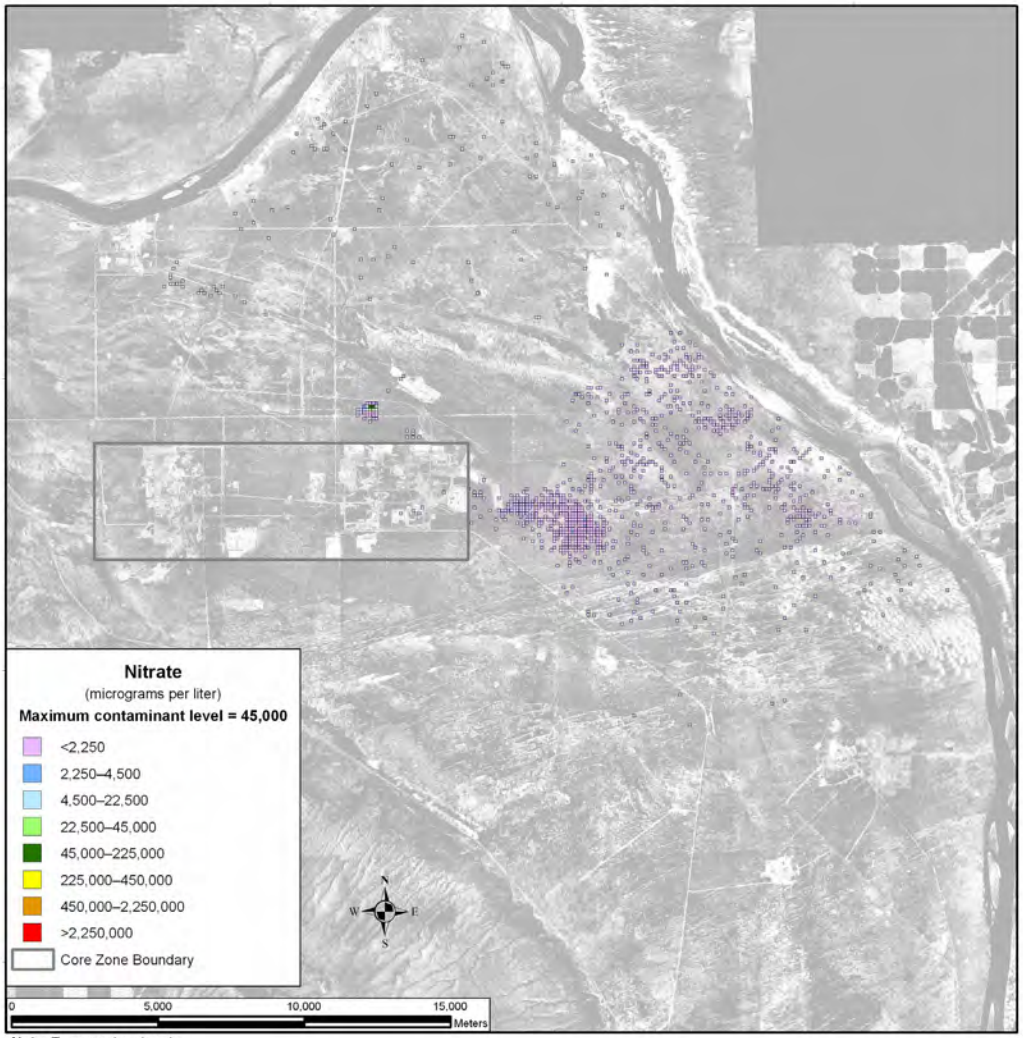
Note: To convert meters to feet, multiply by 3.281

Figure 5–686. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



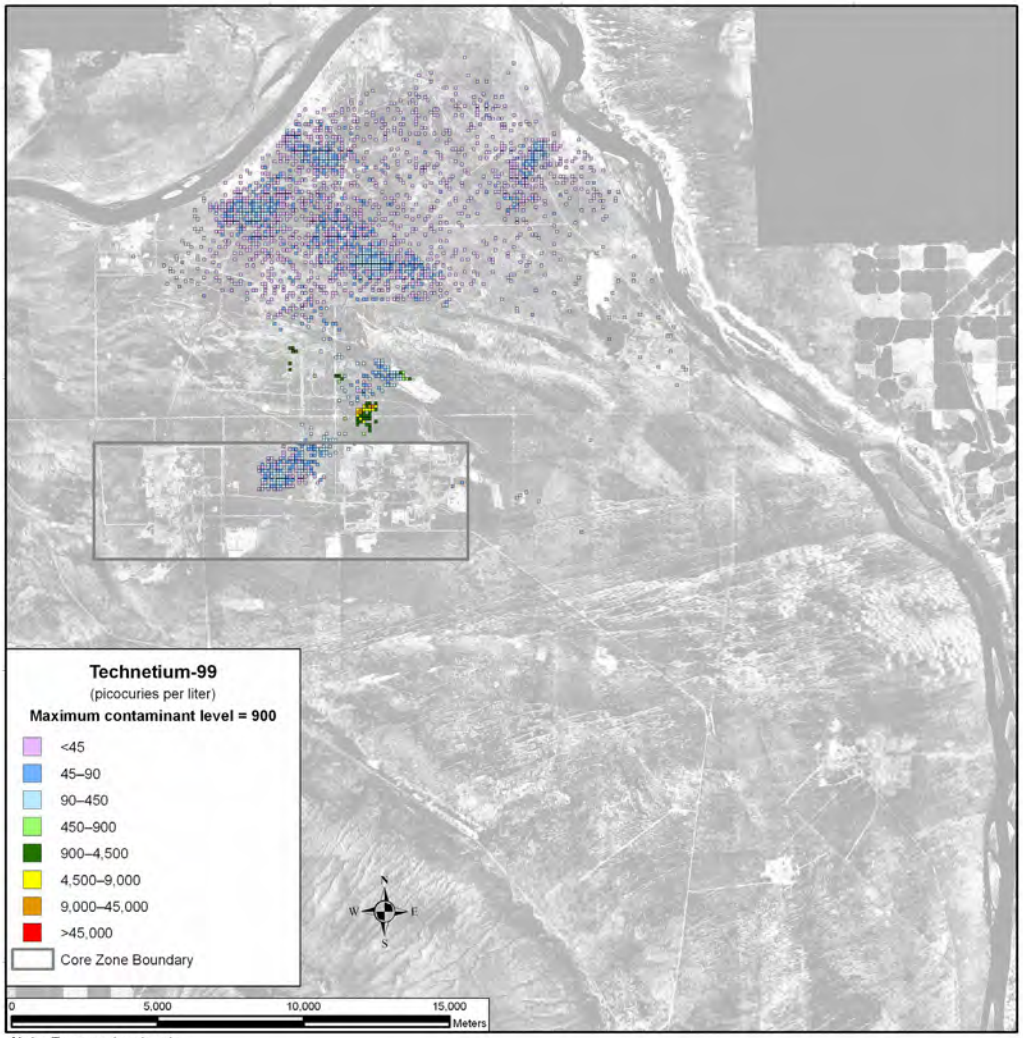
Note: To convert meters to feet, multiply by 3.281

Figure 5–687. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



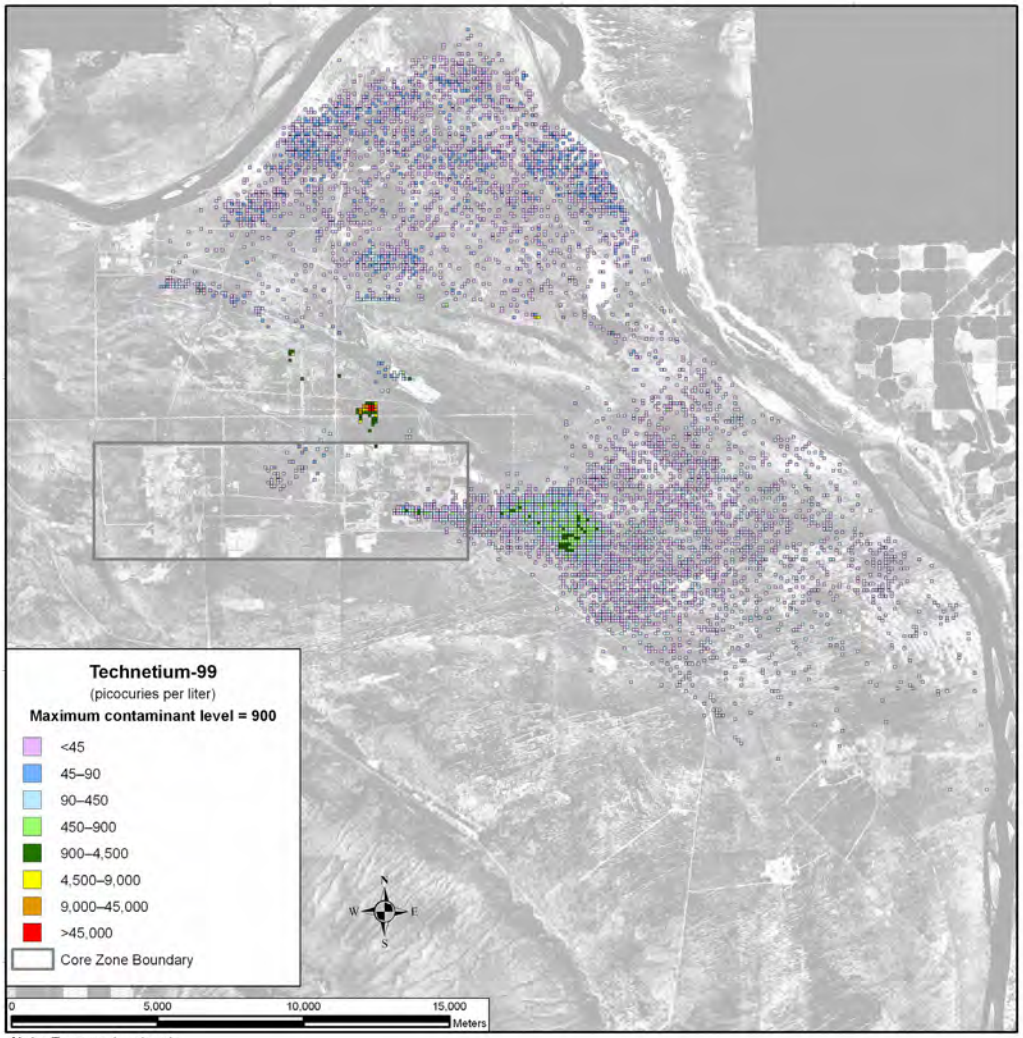
Note: To convert meters to feet, multiply by 3.281

Figure 5–688. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



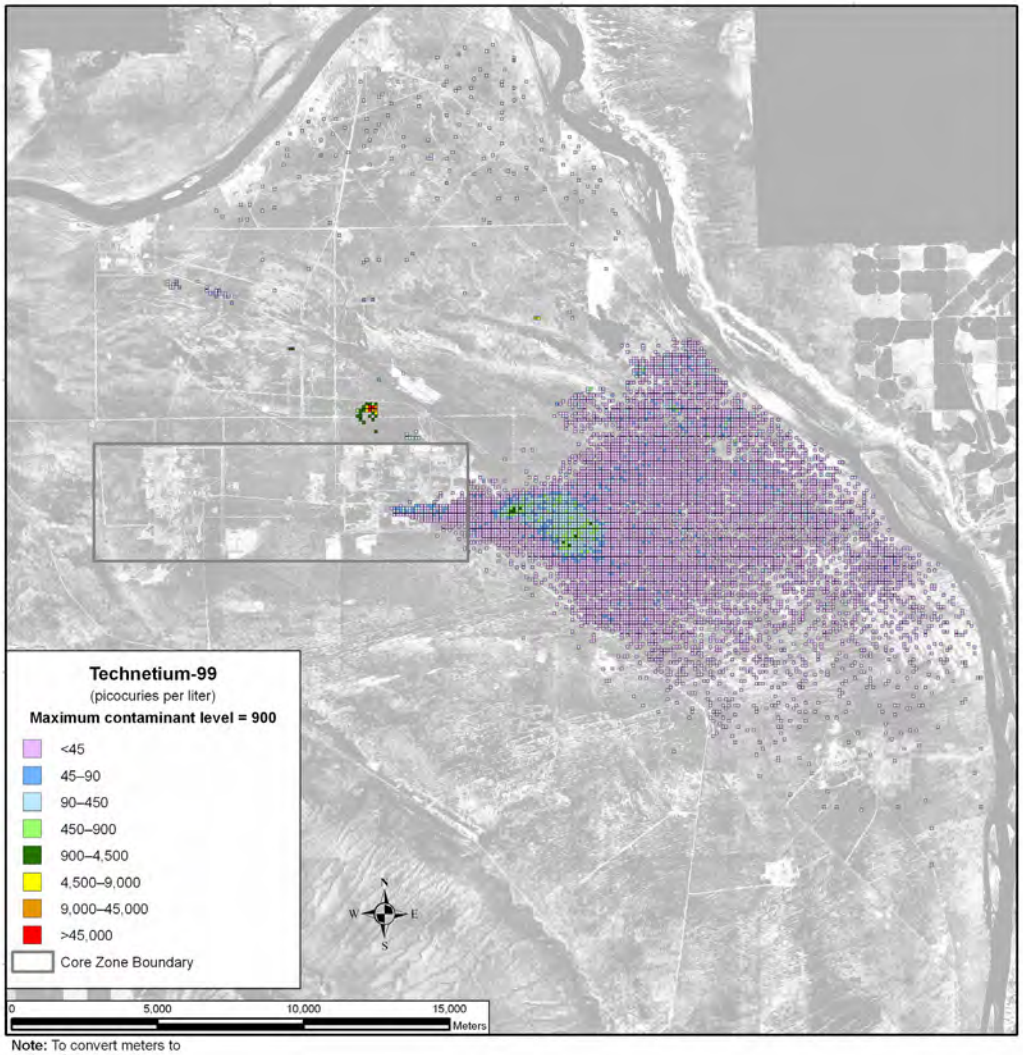
Note: To convert meters to feet, multiply by 3.281

Figure 5–689. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 3890



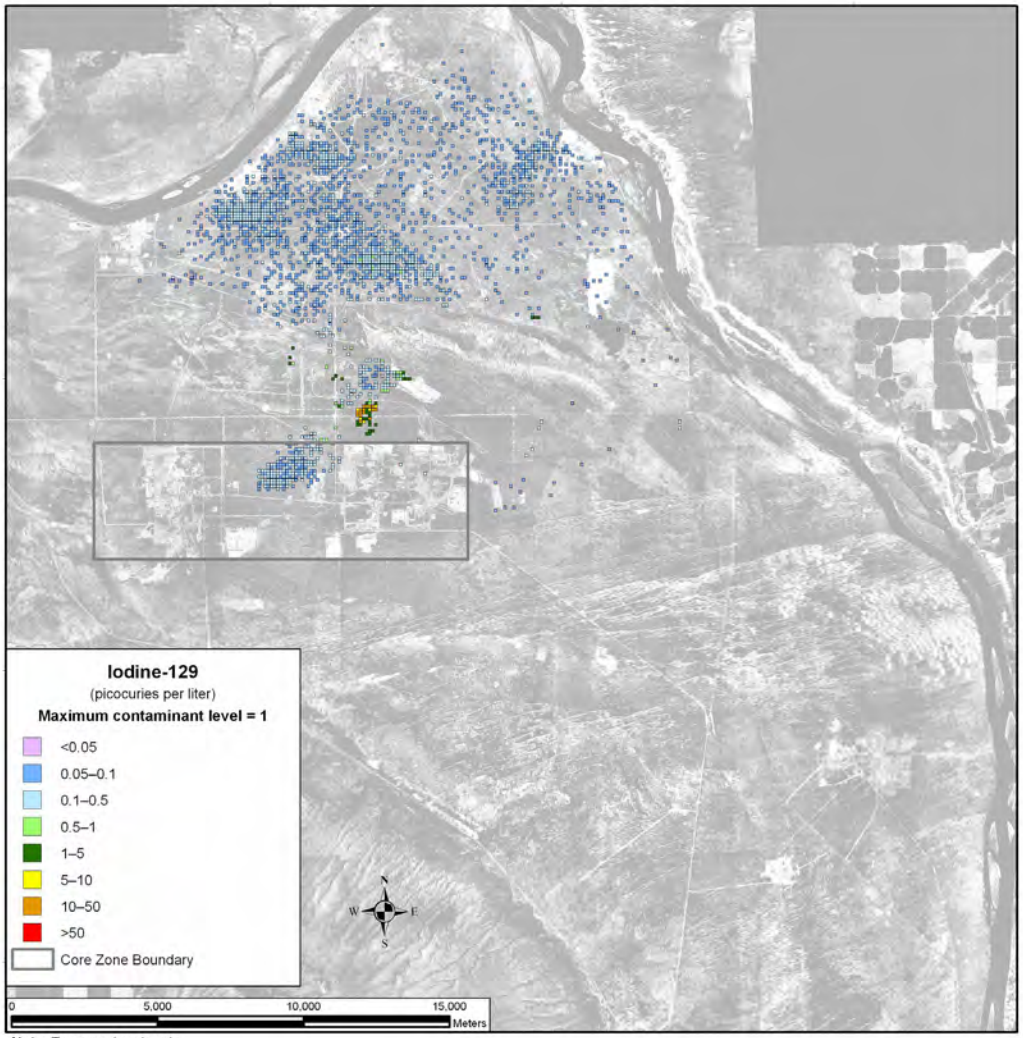
Note: To convert meters to feet, multiply by 3.281

Figure 5–690. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 7140



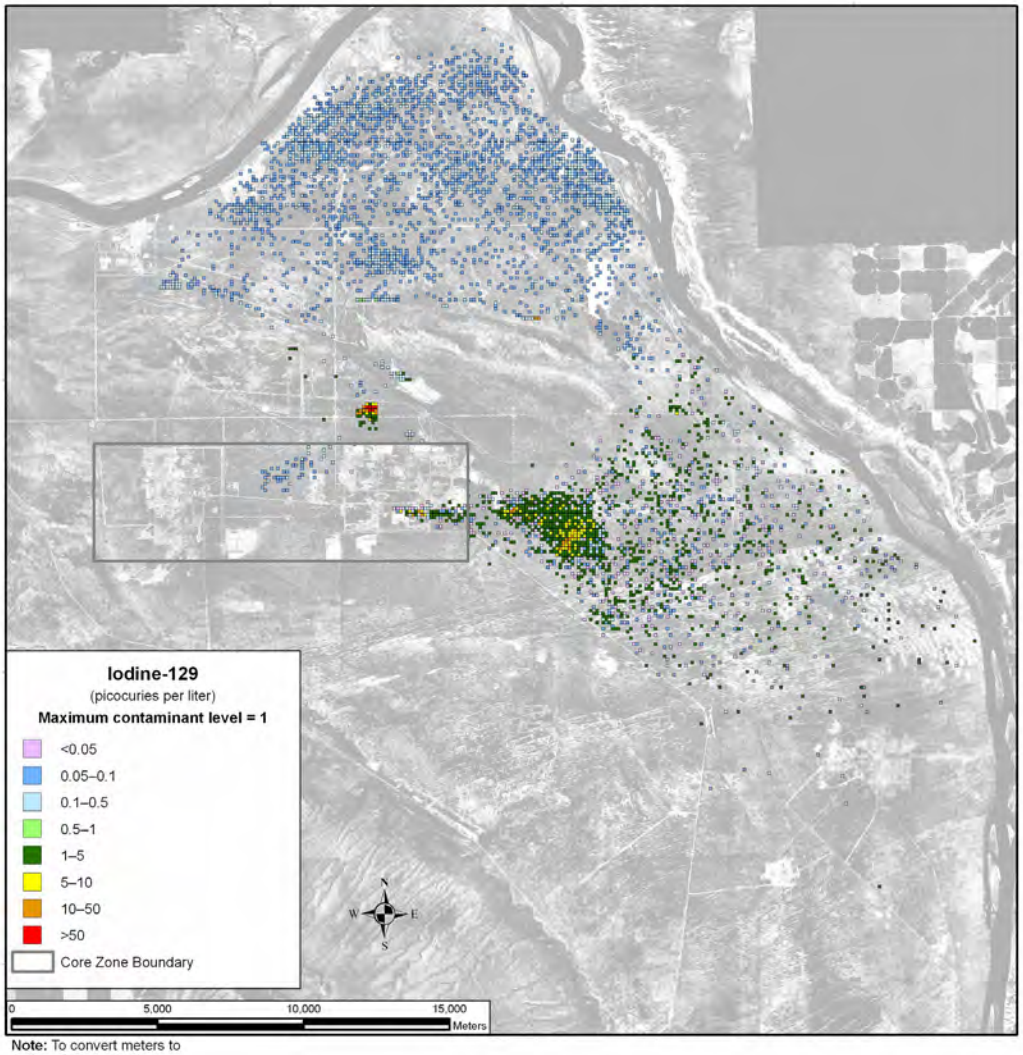
Note: To convert meters to feet, multiply by 3.281

Figure 5–691. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Technetium-99 Concentration During Calendar Year 11,885



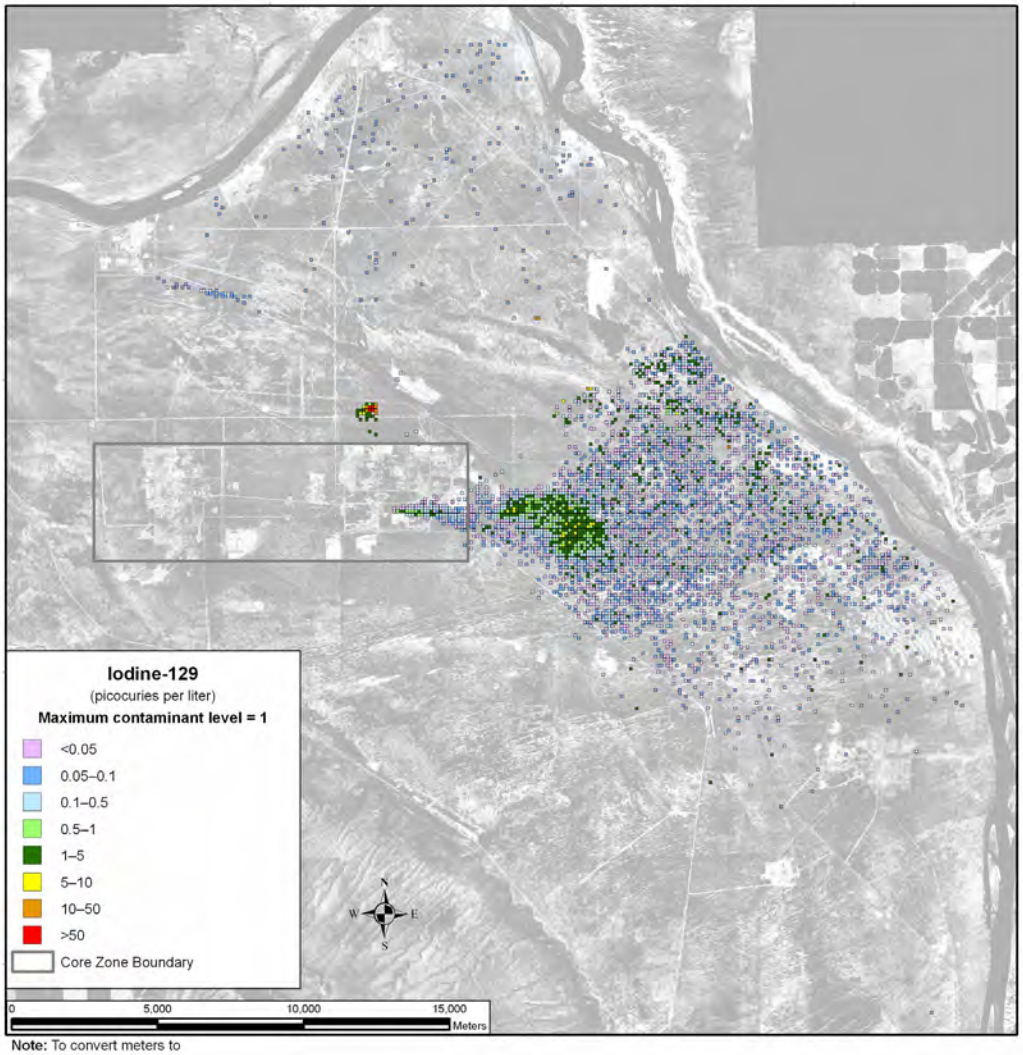
Note: To convert meters to feet, multiply by 3.281

Figure 5–692. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 3890



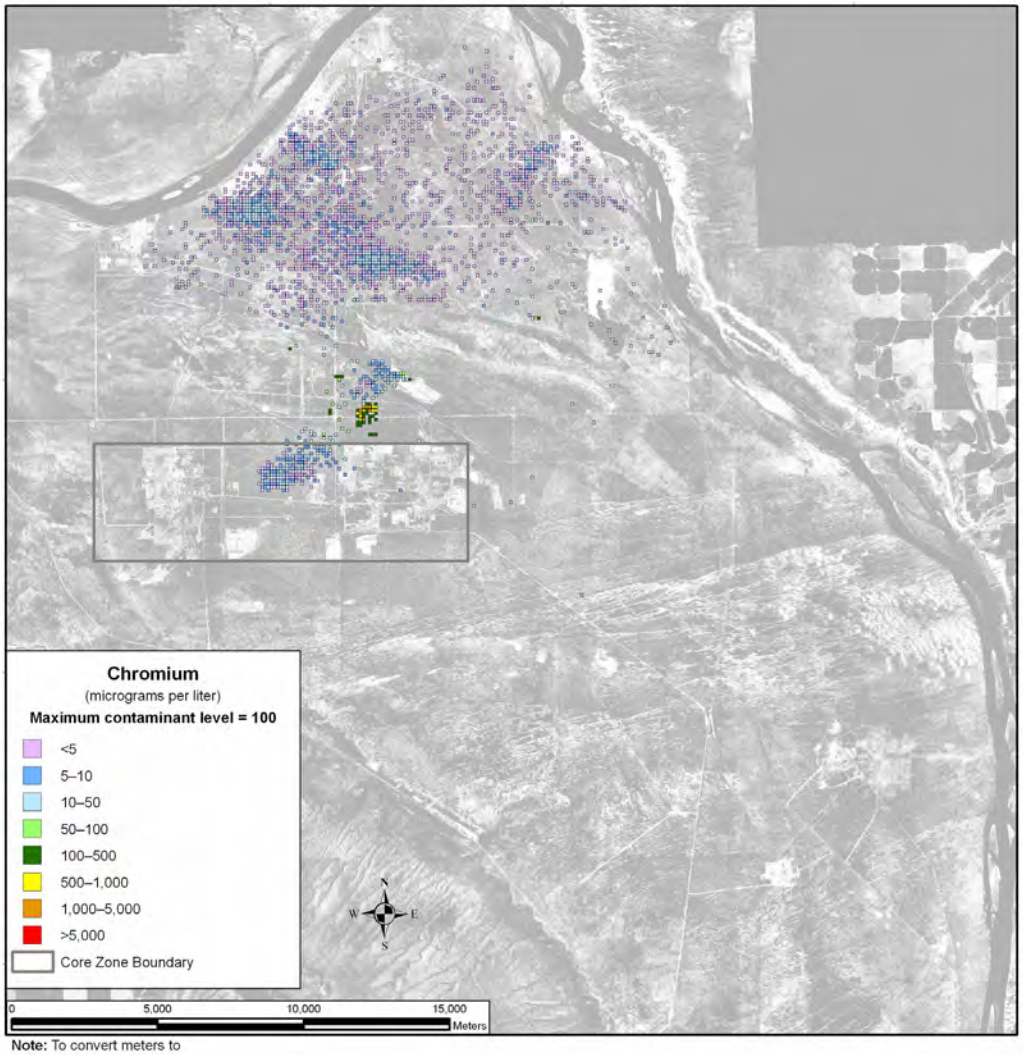
Note: To convert meters to feet, multiply by 3.281

Figure 5–693. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 7140



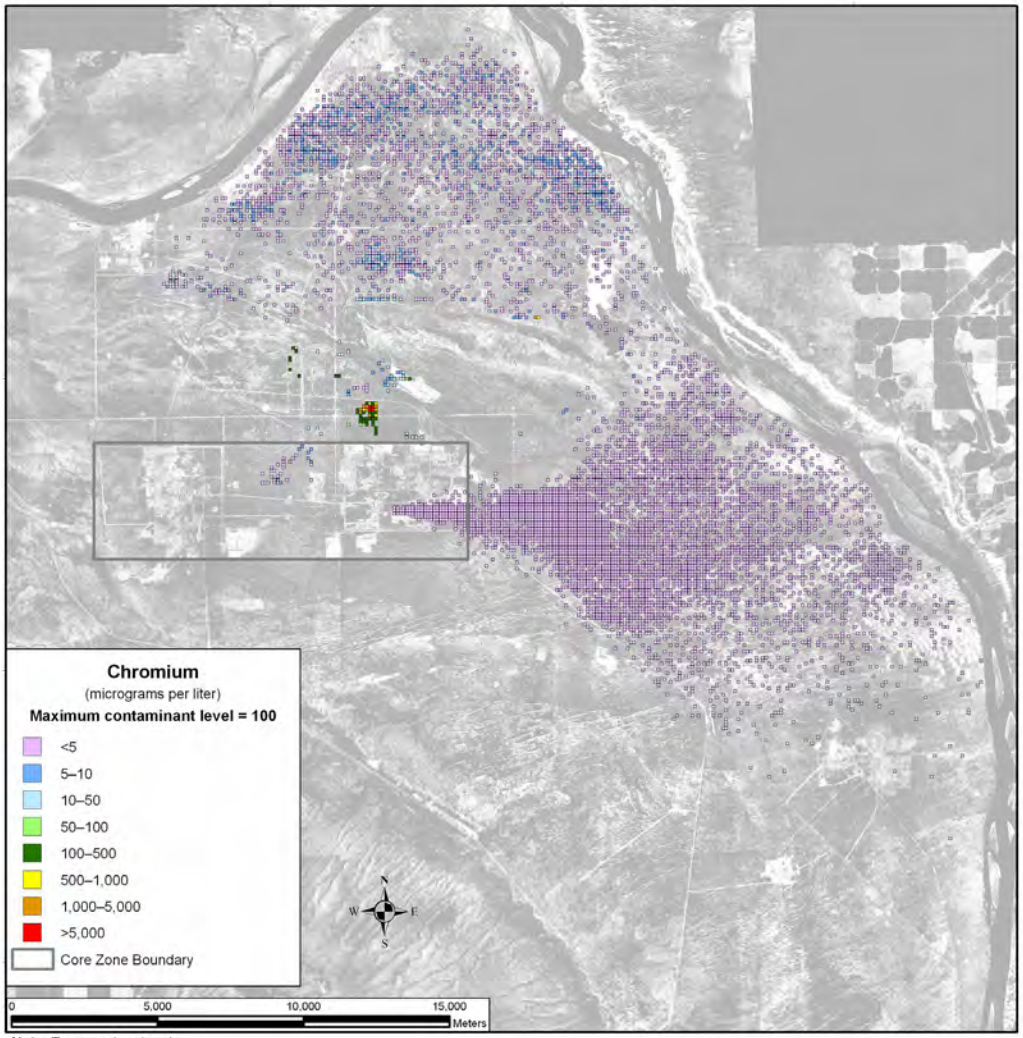
Note: To convert meters to feet, multiply by 3.281

Figure 5–694. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Iodine-129 Concentration During Calendar Year 11,885



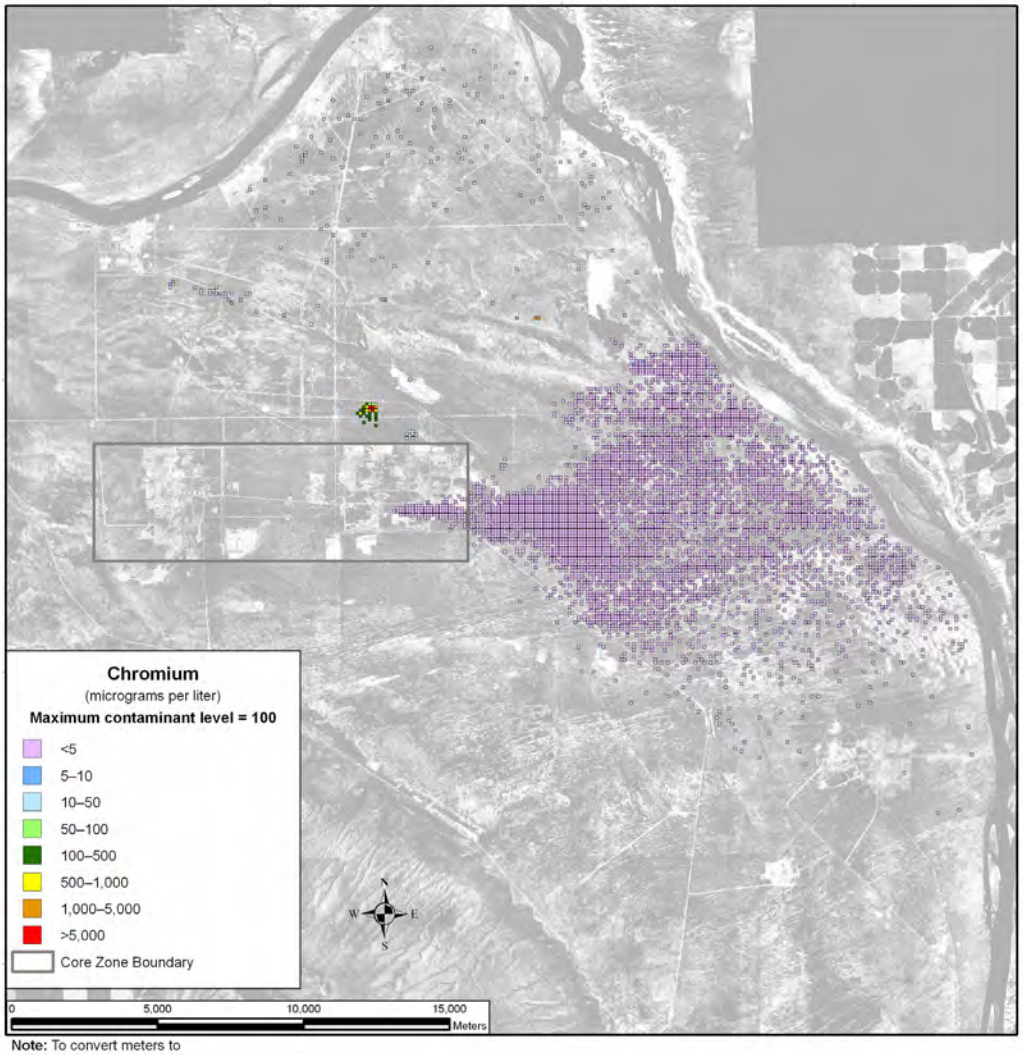
Note: To convert meters to feet, multiply by 3.281

Figure 5–695. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 3890



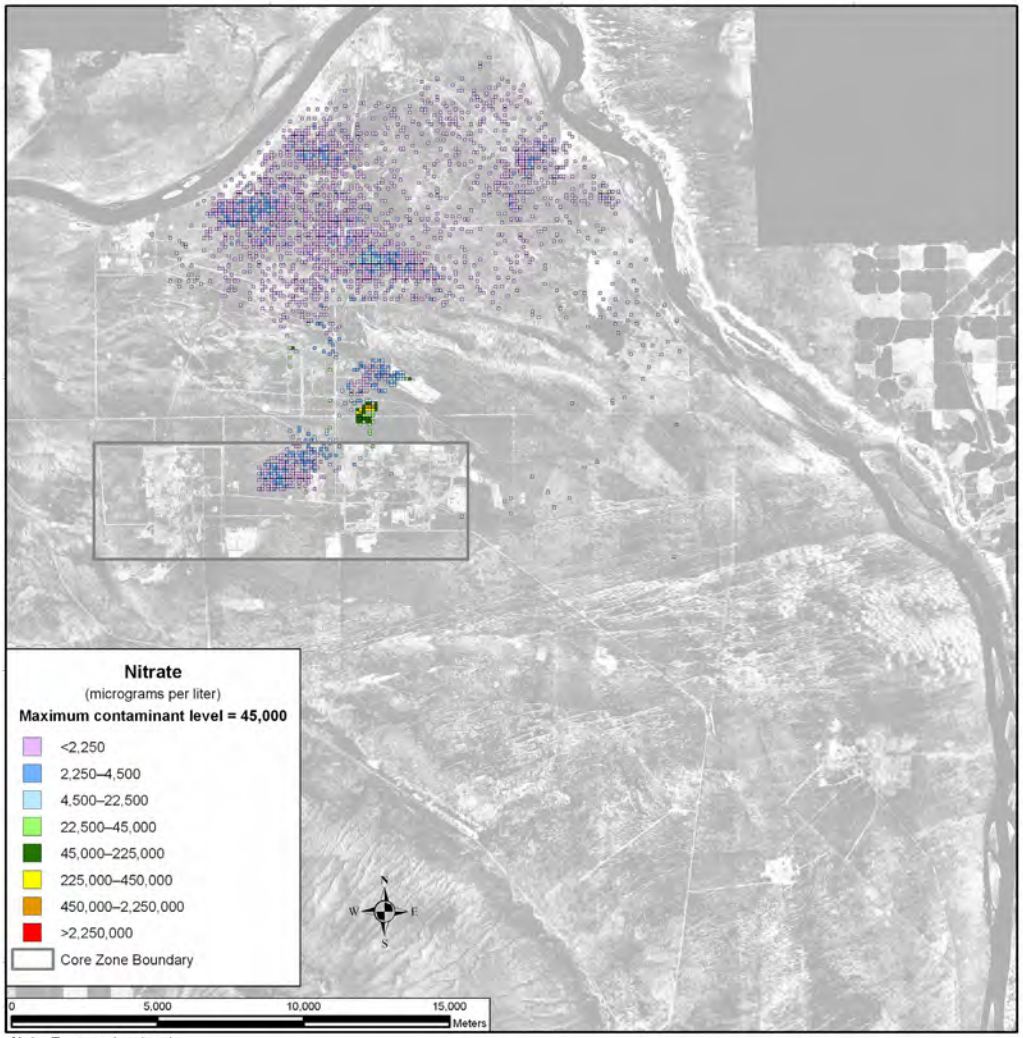
Note: To convert meters to feet, multiply by 3.281

Figure 5–696. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 7140



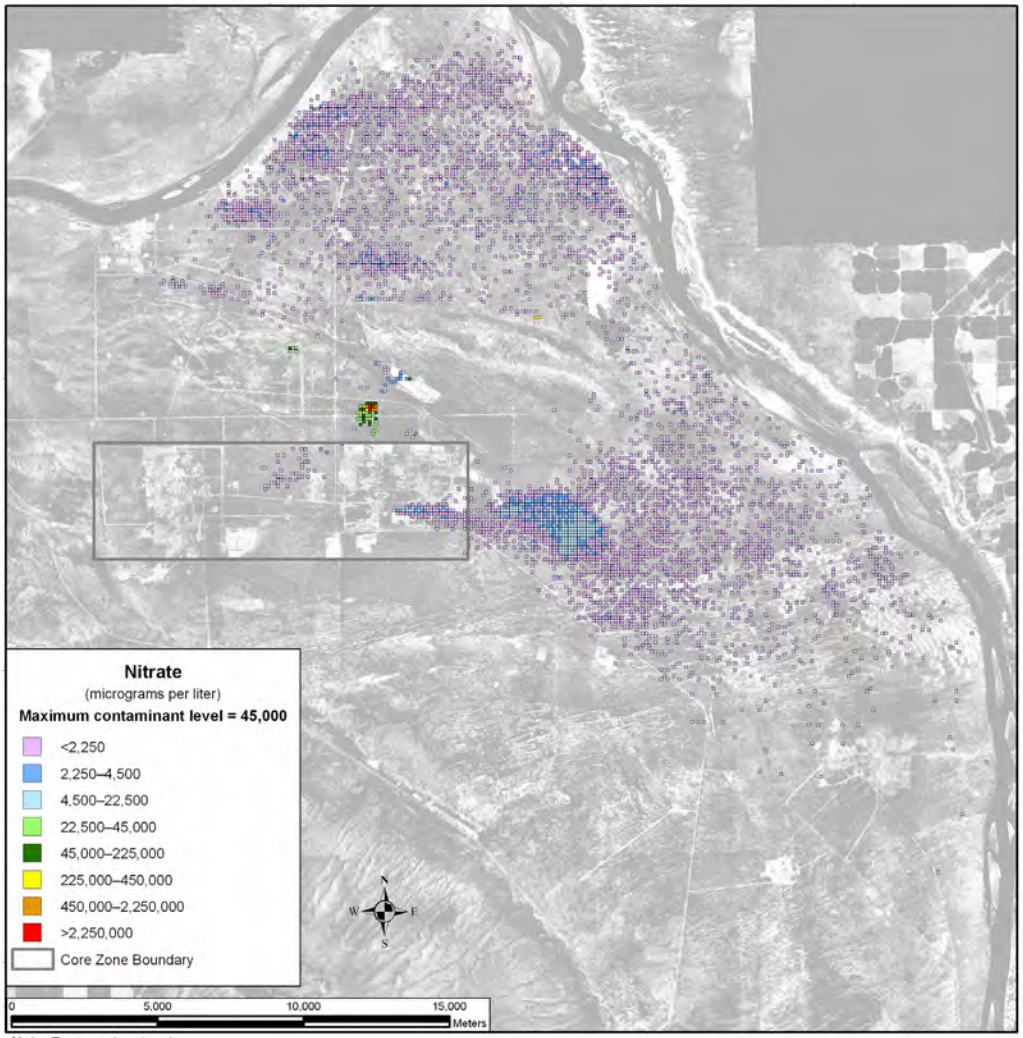
Note: To convert meters to feet, multiply by 3.281

Figure 5–697. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Chromium Concentration During Calendar Year 11,885



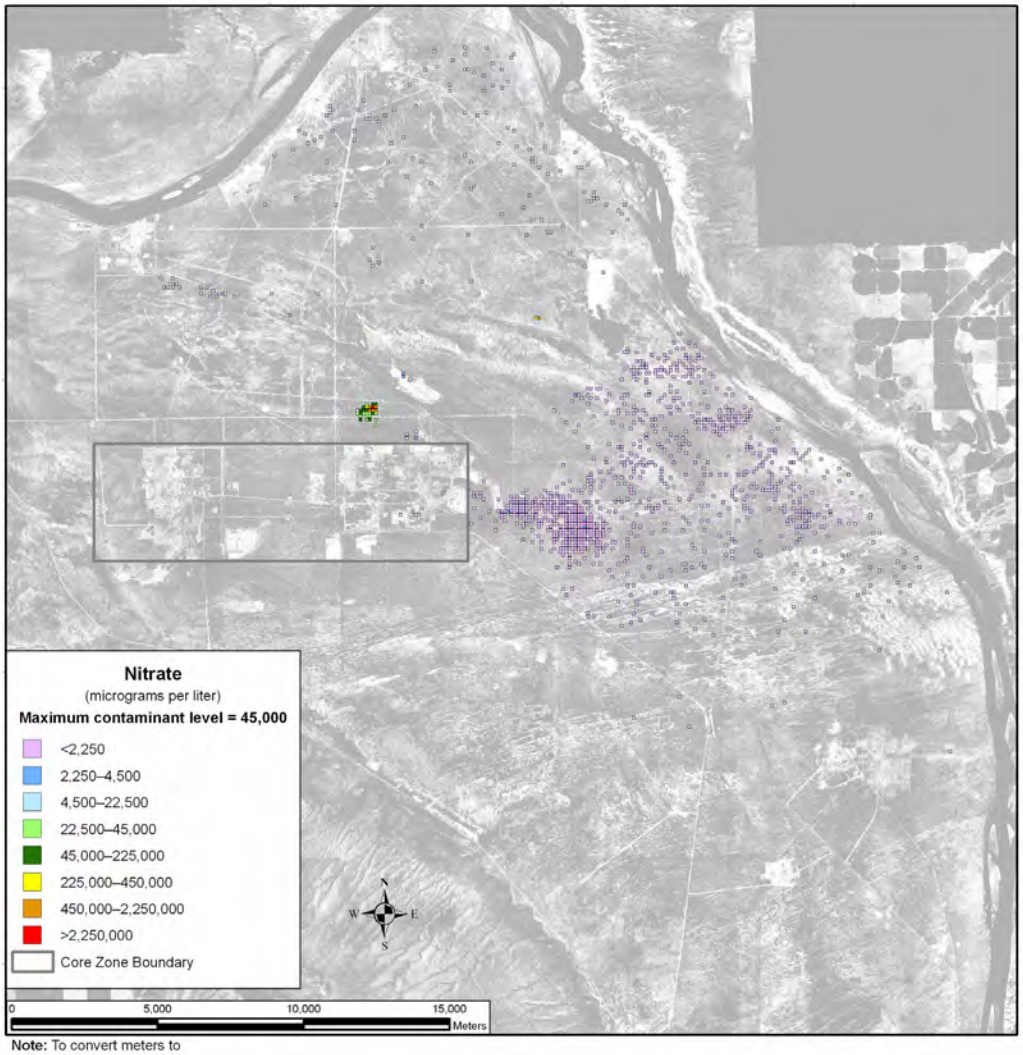
Note: To convert meters to feet, multiply by 3.281

Figure 5–698. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 3890



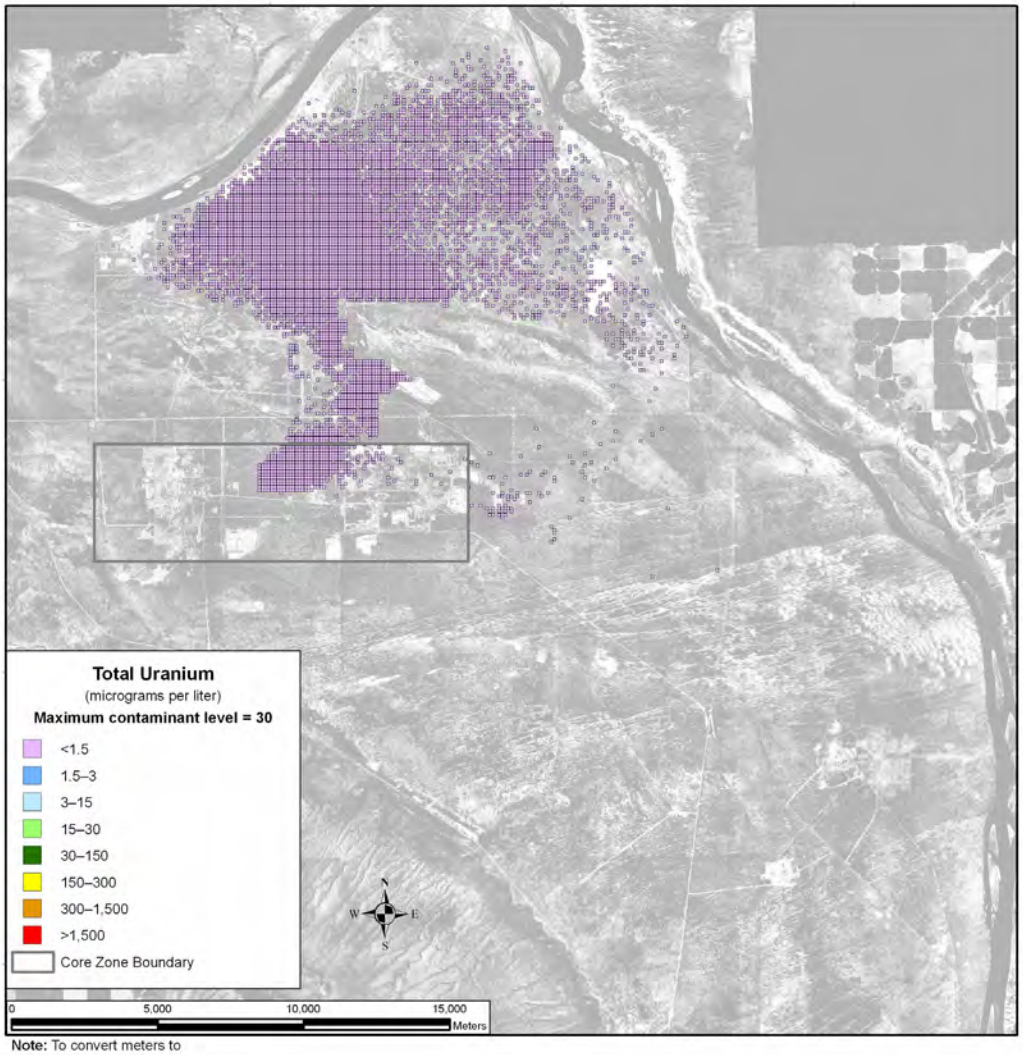
Note: To convert meters to feet, multiply by 3.281

Figure 5–699. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 7140



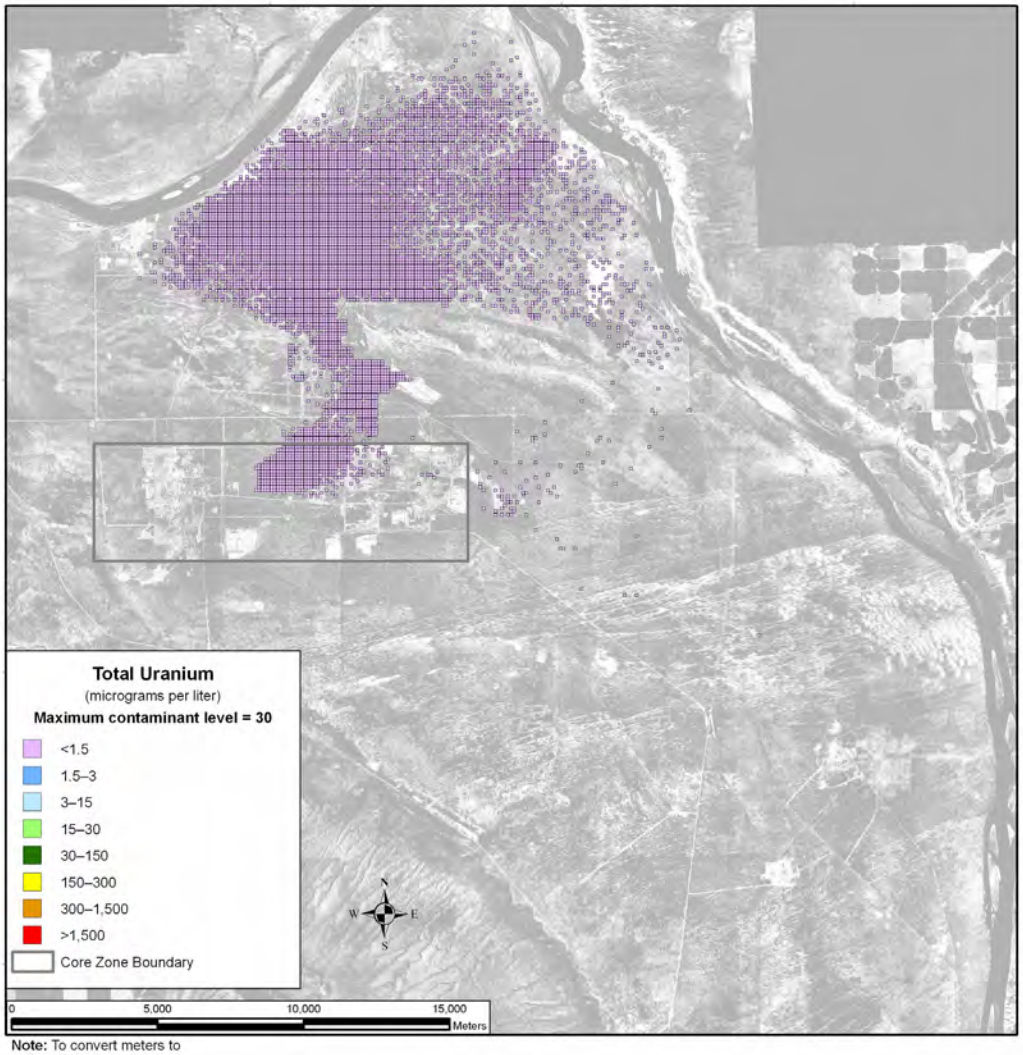
Note: To convert meters to feet, multiply by 3.281

Figure 5–700. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Nitrate Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–701. Waste Management Alternative 2, Disposal Group 3, Base Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885



Note: To convert meters to feet, multiply by 3.281

Figure 5–702. Waste Management Alternative 2, Disposal Group 3, Option Case, Spatial Distribution of Groundwater Total Uranium Concentration During Calendar Year 11,885

SUMMARY OF IMPACTS

For technetium-99 in the Base Case, releases cause the groundwater concentrations at the Core Zone Boundary and at the Columbia River nearshore to approach the benchmark concentration around CY 7000 to CY 10,000. The concentrations at the Core Zone Boundary and the Columbia River nearshore never consistently remain above the benchmark throughout the period of analysis.

The behavior of technetium-99 in the Option Case is similar to that in the Base Case.

Iodine-129 concentrations in the Base Case at the Core Zone Boundary and the Columbia River nearshore exceed the benchmark from about CY 6000 until the end of the period of analysis. Peak exceedances were approximately one order of magnitude above the benchmark concentration.

Iodine-129 concentrations in the Option Case show a pattern similar to that in the Base Case.

Concentrations of chromium at the Core Zone Boundary in the Base Case approach the benchmark from about CY 3800 to CY 5800. During that time, there are no significant benchmark exceedances. The concentrations from the Columbia River nearshore remained about one order of magnitude below the benchmark.

The concentrations over time in the Option Case for chromium at the Core Zone Boundary and from the Columbia River nearshore remain just below the benchmark.

For the Base Case, nitrate concentrations at the Core Zone Boundary and from the Columbia River nearshore peak at around CY 8000. Even at the concentrations peak, nitrate levels still remain about one order of magnitude below the benchmark level.

In the Option Case, the concentrations over time for nitrate at the Core Zone Boundary peaked around CY 4800 but remain about one order of magnitude below the benchmark. Concentrations from the Columbia River nearshore remained fairly steady at around one order of magnitude below the benchmark.

For the Base Case, total uranium concentrations begin to register on the graph at CY 9500. The concentrations at the Core Zone Boundary and from the Columbia River nearshore both remain about seven to eight orders of magnitude below the benchmark level.

Total uranium concentrations in the Option Case behave similarly.