DOE/NV/25946--736

NEVADA TEST SITE

2008 WASTE MANAGEMENT MONITORING REPORT

AREA 3 AND AREA 5 RADIOACTIVE WASTE MANAGEMENT SITES

June 2009

Prepared for:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by:

National Security Technologies, LLC
Las Vegas, Nevada

DISCLAIMER

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161-002
Phone: 800.553.6847
Fax: 703.605.6900
E-mail: orders@ntis.gov
Online Ordering: http://www.ntis.gov/help/ordermethods.aspx

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to the U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
Phone: 865.576.8401
Fax: 865.576.5728

.

DOE/NV/25946--736

NEVADA TEST SITE

2008 WASTE MANAGEMENT MONITORING REPORT

AREA 3 AND AREA 5 RADIOACTIVE WASTE MANAGEMENT SITES

June 2009

Prepared for:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by:

National Security Technologies, LLC
Las Vegas, Nevada

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Environmental monitoring data were collected at and around the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) at the Nevada Test Site. These data are associated with radiation exposure, air, groundwater, meteorology, vadose zone, subsidence, and biota. This report summarizes the 2008 environmental data to provide an overall evaluation of RWMS performance and to support environmental compliance and performance assessment (PA) activities. Some of these data (e.g., radiation exposure, air, and groundwater) are presented in other reports (National Security Technologies, LLC, 2008a; 2009; Warren and Grossman, 2008).

Direct radiation monitoring data indicate exposure levels at the RWMSs are at background levels. Air monitoring data at the Area 3 and Area 5 RWMSs indicate that tritium concentrations are slightly above background levels. All gamma spectroscopy results for air particulates collected at the Area 3 and Area 5 RWMS were below the minimum detectable concentrations, and concentrations of americium and plutonium are only slightly above detection limits. The measured levels of radionuclides in air particulates and moisture are below derived concentration guides for these radionuclides. Radon flux from waste covers is well below regulatory limits. Groundwater monitoring data indicate that the groundwater in the uppermost aquifer beneath the Area 5 RWMS is not impacted by facility operations. The 136.5 millimeters (mm) (5.37 inches [in.]) of precipitation at the Area 3 RWMS during 2008 is 13 percent below the average of 157.3 mm (6.19 in.), and the 75.4 mm (2.97 in.) of precipitation at the Area 5 RWMS during 2008 is 41 percent below the average of 126.8 mm (4.99 in.). Soil-gas tritium monitoring at borehole GCD-05U continues to show slow subsurface migration consistent with previous results. Water balance measurements indicate that evapotranspiration from the vegetated weighing lysimeter dries the soil and prevents downward percolation of precipitation more effectively than evaporation from the bare-soil weighing lysimeter. Data from the automated vadose zone monitoring system for the operational waste pit covers show that evaporation continues to slowly remove soil moisture that came from the heavy precipitation in the fall of 2004 and the spring of 2005. The vegetated final mono-layer cover on the U-3ax/bl disposal unit at the Area 3 RWMS effectively removes moisture from the cover by evapotranspiration. During 2008, there was no drainage through 2.4 meters (8 feet) of soil from the Area 3 drainage lysimeters that received only natural precipitation or were vegetated, but water drained from the bare-soil Area 3 drainage lysimeter that received 3 times natural precipitation.

All 2008 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility PAs.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AGL	above ground level
Am	Americium
AMSL	above mean sea level
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
BJY	Buster-Jangle Y
BN	Bechtel Nevada
°C	degrees Celsius
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter(s)
DCG	Derived Concentration Guide
DOE	U.S. Department of Energy
E	evaporation
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
ET_{ref}	reference evapotranspiration
°F	degrees Fahrenheit
ft	foot; feet
ft^3	cubic feet
GCD	greater confinement disposal
IL	investigation level
in.	inch(es)
km	kilometer(s)
kPa	kilopascal
LLW	low-level waste
$\mu Ci/m^3$	microcurie(s) per cubic meter
µg/L	microgram(s) per liter
m	meter(s)
m^3	cubic meter(s)
m/s	meter(s) per second(s)
MDC	minimum detectable concentration
MEDA	Meteorological Data Acquisition
mg/L	milligram(s) per liter
mi	mile(s)
mm	millimeter(s)
mmhos/cm	millimho(s) per centimeter
mph	mile(s) per hour

mR	milliroentgen(s)
mR/day	milliroentgen(s) per day
mR/yr	milliroentgen(s) per year
mrem	millirem(s)
mrem/yr	millirem(s) per year
NTS	Nevada Test Site
NSTec	National Security Technologies, LLC
PA	Performance Assessment
pCi/L	picocuries per liter
pCi/m^3	picocuries per cubic meter
pCi/m^2s	picocuries per square meter per second
PSI	pounds per square inch
Pu	Plutonium
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
SC	specific conductance
TDR	time-domain reflectometry
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides
VWC	volumetric water content

1.0 INTRODUCTION

This document summarizes the calendar year 2008 waste management environmental monitoring data for the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs). Characterization reports for the Area 3 RWMS (National Security Technologies, LLC [NSTec], 2007) and the Area 5 RWMS (Bechtel Nevada [BN], 2006) provide descriptions of each RWMS including location, setting, waste disposal operations, and monitoring programs. These reports also provide brief summaries of characterization and monitoring data. The *Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site* (BN, 2005c) and the *Closure Plan for the Area 5 Radioactive Waste Management Site at the Nevada Test Site* (NSTec, 2008b) identify the regulatory requirements and describe the intended approach for closing and monitoring the RWMSs after waste disposal is finished. This report summarizes environmental data, as briefly defined below.

- Direct radiation monitoring conducted to confirm that RWMS activities do not result in significant exposure above background levels.
- Air monitoring conducted to confirm that RWMS activities do not result in significant radionuclide concentrations above background levels and confirm compliance with National Emission Standards for Hazardous Air Pollutants.
- Groundwater monitoring conducted, as required by U.S. Environmental Protection Agency (EPA) regulations and U.S. Department of Energy (DOE) orders, to assess the water quality of the aquifer beneath the Area 5 RWMS and to confirm that Area 5 RWMS activities are not affecting the aquifer.
- Vadose zone monitoring conducted to assess the water balance at the RWMSs, confirm the assumptions made in the PAs (including no downward pathway), and evaluate the performance of operational monolayer-evapotranspirative waste covers.
- Soil-gas monitoring for tritium conducted to evaluate tritium movement at waste containment cell GCD-05U.
- Biota monitoring for tritium and other radionuclides conducted to evaluate the upward pathway through the waste covers.
- Subsidence monitoring conducted to ensure that subsidence features are repaired to prevent the development of preferential pathways through the covers.

These data are collected by NSTec, as required by various DOE orders and regulations from the Code of Federal Regulations (CFR). For a detailed description of these regulatory drivers, refer to the Integrated Closure and Monitoring Plan (BN, 2005c) and the Area 5 RWMS Closure Plan (NSTec, 2008b). These regulatory drivers exist to mitigate risk to the public and environment and include the following:

- DOE O 435.1, “Radioactive Waste Management”
- DOE O 450.1A, “Environmental Protection Program”

- DOE O 5400.5, "Radiation Protection of the Public and the Environment"
- 40 CFR 61, "EPA: National Emission Standards for Hazardous Air Pollutants"
- 40 CFR 264, "EPA: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"
- 40 CFR 265, "EPA: Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"

Environmental monitoring data are collected and analyzed as described in Quality Assurance, Analysis, and Sampling Plans, which can be found in the Nevada Test Site Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 2003). The RREMP was written with a Data Quality Objectives–driven process to identify what and how technically defensible environmental monitoring data are collected.

2.0 SITE DESCRIPTIONS

2.1 AREA 3 RWMS

The Area 3 RWMS is located on Yucca Flat within the Nevada Test Site (NTS). Yucca Flat is an elongated, sediment-filled basin that trends roughly north-south; the long axis extends approximately 27 kilometers (km) (17 miles [mi]), and the short axis extends approximately 16 km (10 mi). Yucca Flat is bound by Quartzite Ridge and Rainier Mesa on the north, the Halfpint Range on the east, the Massachusetts Mountains and CP Hills on the south, and Mine Mountain and the Eleana Range on the west (Figure 2-1). The Yucca Flat basin slopes from the north at an elevation of approximately 1,402 meters (m) (4,600 feet [ft]) above mean sea level (AMSL) to the south toward Yucca playa, with the lowest part of the basin at an elevation of approximately 1,189 m (3,900 ft) AMSL. The Area 3 RWMS elevation is 1,223 m (4,012 ft). Yucca Flat was one of several primary underground nuclear test areas, and much of the length of the valley is marked with subsidence craters (NSTec, 2007).

The unsaturated zone at the Area 3 RWMS is estimated to be approximately 488 m (1,600 ft) thick (BN, 1998), and the water table is assumed to occur in Tertiary tuff. The alluvium thickness is estimated between 370 and 460 m (1,200 and 1,500 ft) (BN, 2005b).

Typical daily air temperatures vary from -5 degrees Celsius (°C) (23 degrees Fahrenheit [°F]) to 11°C (52°F) in winter and from 15°C (59°F) to 37°C (98°F) in summer. Based on a 28-year record (1981–2008) from location Buster-Jangle Y (BJY) (4.5 km [2.8 mi] northwest of the Area 3 RWMS), the maximum observed temperature is 44°C (112°F) and the minimum is -20°C (-4°F). Based on a 47-year record (1961 to 2008) from location BJY, the average annual precipitation is 162.9 mm (6.41 in.) (Air Resources Laboratory, Special Operations and Research Division [ARL/SORD], 2009). During 2008, the temperature at 3 m ranged from -16.0°C (3.2°F) to 40.2°C (104.4°F), and precipitation was measured at 136.5 mm (5.37 in.) at the Area 3 RWMS. Precipitation is highly variable at the Area 3 RWMS. The standard deviation of the 11-year record of annual precipitation is 87.1 mm (3.43 in.); the maximum annual precipitation was 374.1 mm (14.73 in.) in 1998 and the minimum was 26.2 mm (1.03 in.) in 2002. Annual reference evapotranspiration (ET_{ref}) at the Area 3 RWMS, calculated using local meteorology data, is approximately 10 times annual average precipitation (Desotell et al., 2007).

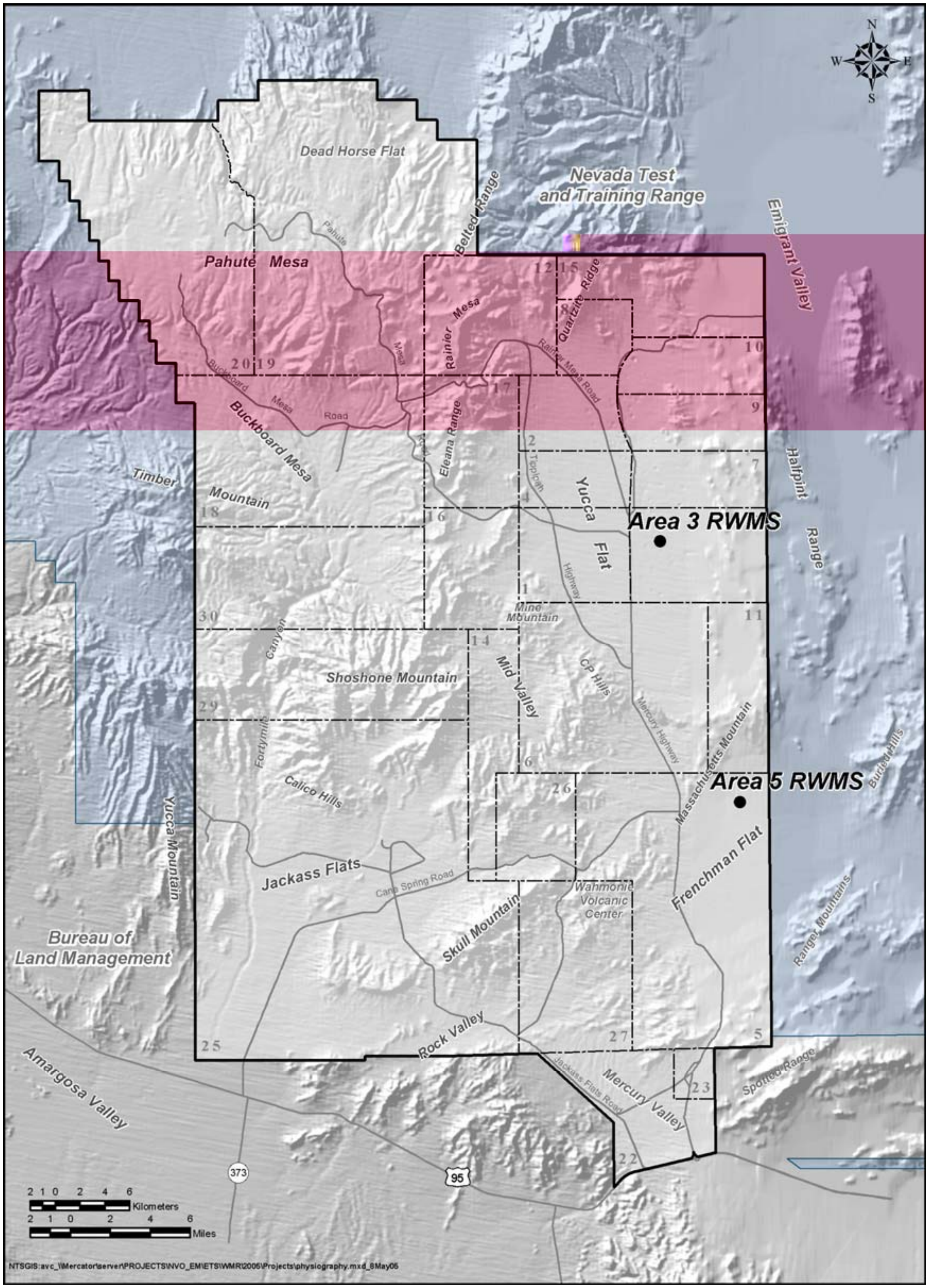


Figure 2-1 Locations of the Area 3 and Area RWMSs at the NTS

2.2 AREA 5 RWMS

The Area 5 RWMS is located on northern Frenchman Flat at the juncture of three coalescing alluvial fan piedmonts (Snyder et al., 1995). Frenchman Flat is a closed intermontane basin located in the southeastern portion of the NTS. Frenchman Flat is bound by the Massachusetts Mountains and the Halfpint Range on the north, the Buried Hills on the east, the Spotted Range on the south, and the Wahmonie Volcanic Center on the west (see Figure 2-1). The valley floor slopes gently toward a central playa (BN, 2006). Ground surface elevations range from 938 m (3,077 ft) AMSL at the playa to over 1,220 m (4,003 ft) AMSL in the nearby surrounding mountains. The Area 5 RWMS elevation is 962 m (3,156 ft).

The thickness of the unsaturated zone at the Area 5 RWMS is 235.8 m (774 ft) at the southeast corner of the RWMS (Well UE5PW-1), 256.6 m (842 ft) at the northeast corner (Well UE5PW-2), and 271.5 m (891 ft) to the northwest of the RWMS (Well UE5PW-3). Wells UE5PW-1 and UE5PW-2 penetrate only alluvium, while Well UE5PW-3 encounters tertiary tuff at a depth of approximately 189 m (620 ft) (BN, 2005a). The water table beneath the Area 5 RWMS is extremely flat. The average groundwater elevation measured at these wells is 733.7 m (2,407 ft) AMSL.

Typical daily air temperatures vary from about 5°C (23°F) to 11°C (52°F) in winter and from 17°C (62°F) to 39°C (103°F) in summer. Based on a 28-year record (1981–2008) from location Well 5B (6.4 km [4 mi] south of the Area 5 RWMS), the maximum observed temperature is 46°C (115°F) and the minimum is -21°C (-6°F). Based on a 46-year record (1963–2008) from location Well 5B, the average annual precipitation is 123.5 mm (4.86 in.) (ARL/SORD, 2009). During 2008, the temperature at 3 m ranged from -12.1°C (9.5°F) to 43.0°C (109.4°F), and precipitation measured 75.4 mm (2.97 in.) at the Area 5 RWMS. Precipitation is highly variable at the Area 5 RWMS. The standard deviation of the 14-year record of annual precipitation is 60.7 mm (2.39 in.); the maximum annual precipitation was 258.9 mm (10.19 in.) in 1998 and the minimum was 37.7 mm (1.48 in.) in 2002. Annual ET_{ref} at the Area 5 RWMS, calculated using local meteorology data, is approximately 13 times the annual average precipitation (Desotell et al., 2006).

Areas 3 and 5 are similar, except for slight differences in air temperature, precipitation, and soil texture. Area 3 receives approximately 30 percent more rainfall than Area 5, and the annual average temperature at Area 3 is about 2°C (4°F) cooler than at Area 5.

2.3 HYDROLOGIC CONCEPTUAL MODEL OF THE AREA 3 AND AREA 5 RWMS

Climate and vegetation strongly control the water movement in the upper few meters of alluvium at both RWMSs. The magnitude and direction of both liquid and vapor fluxes vary seasonally and often daily. Except for periods following precipitation events, water content values in the near-surface are quite low. Below the dynamic near-surface is a region where relatively steady upward water movement is occurring. In this region of slow upward flow, stable isotope compositions of soil pore water confirm that evaporation (E) is the dominant process (Tyler et al., 1996). The upward flow region extends to depths from approximately 3 to 49 m (10 to 160 ft) in Area 3, and from approximately 3 to 40 m (10 to 131 ft) in Area 5. Below the upward flow region, water potential measurements indicate the existence of a static region. The static region is between approximately 49 and 119 m (160 to 390 ft) deep in Area 3, and between approximately 40 and 90 m (131 to 295 ft) deep in Area 5 (Shott et al., 1997; 1998). In the static region, essentially no vertical liquid flow is currently occurring. Below the static region, flow is steady and downward due to gravity (Figure 2-2). Stable isotope compositions of pore water from these depths indicate that infiltration into this zone occurred under cooler past climatic conditions (Tyler et al., 1996). If water were to migrate below the current static zones, movement to the groundwater would be extremely slow due to the low water content of the alluvium. Estimates of travel time to the groundwater (assuming zero upward flux), based on hydraulic characteristics of the alluvium, and assuming that current conditions would still apply, are in excess of 500,000 years in Area 3 (Levitt and Yucel, 2002) and 50,000 years in Area 5 (Shott et al., 1998).

Based on the results of extensive research, field studies, modeling efforts, and monitoring data, which are summarized in the Area 3 and Area 5 PAs (Shott et al., 1997; 1998; Levitt et al., 1999; Levitt and Yucel, 2002; Desotell et al., 2006), groundwater recharge is not occurring under current climatic conditions at the RWMSs. Studies indicate that under bare-soil conditions, such as those found at the operational waste cell covers, some drainage may eventually occur through the waste covers into the waste zone. This drainage is estimated to be about 8 percent of the annual rainfall at Area 5, based on one-dimensional modeling results (Desotell et al., 2006).

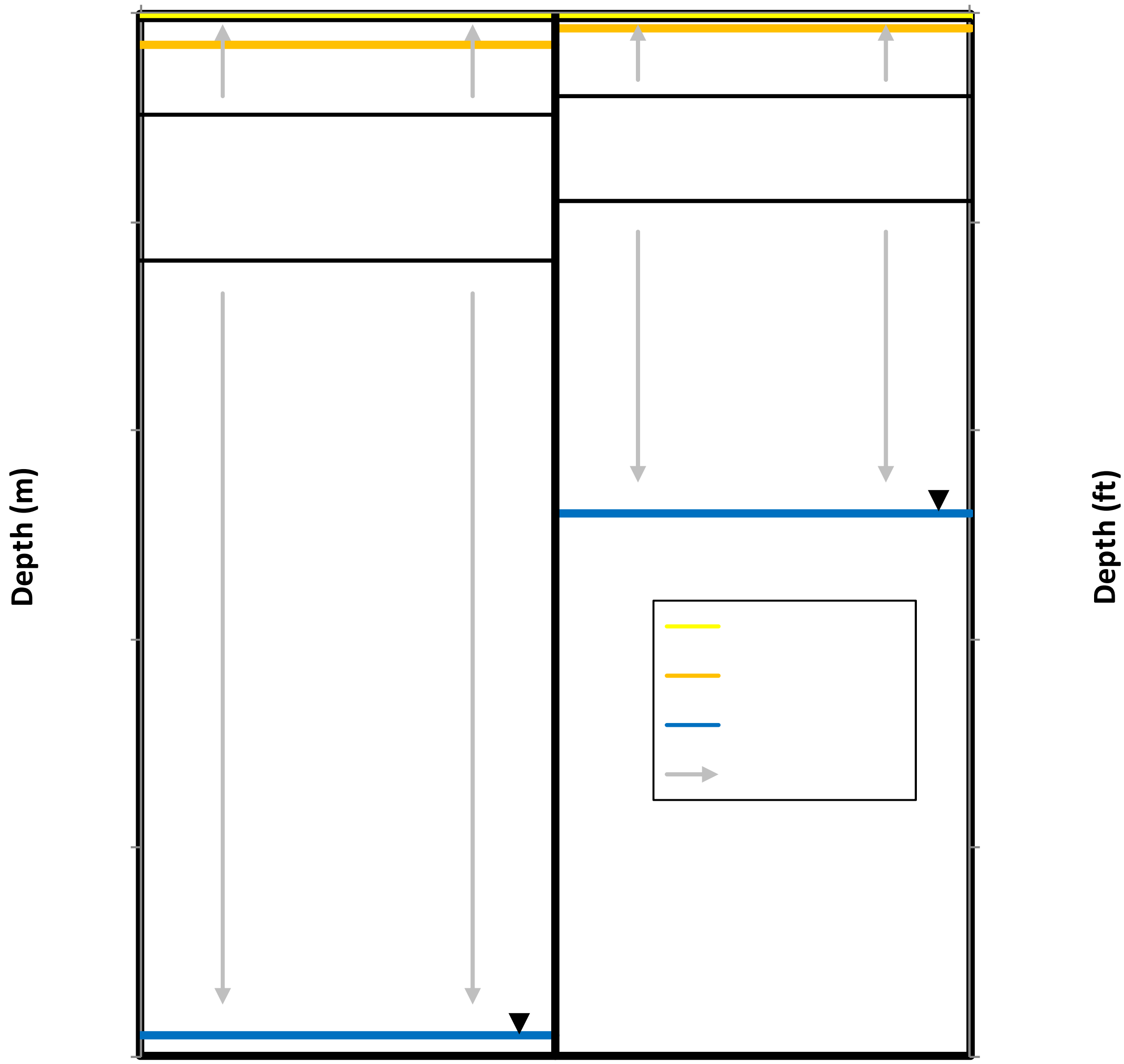


Figure 2-2 Vadose Zone Conceptual Models of the Area 3 and Area 5 RWMSs

THIS PAGE INTENTIONALLY LEFT BLANK

3.0 PROJECT DESCRIPTION

The Area 3 and Area 5 RWMSs are designed and operated for the disposal of radioactive low-level waste (LLW) and mixed waste that is generated on site (at the NTS), from DOE offsite locations, and from other approved offsite generators.

3.1 AREA 3 RWMS

Waste disposal cells within the Area 3 RWMS are subsidence craters resulting from underground nuclear testing. The seven craters within the Area 3 RWMS ranged from 122 to 177 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth at the time of formation (Plannerer, 1996). Five of these craters have been used for waste disposal. Disposal in the U-3ax crater began in the late 1960s and disposal in U-3bl began in 1984. Waste forms consisted primarily of contaminated soil and scrap metal, with some construction debris, equipment, and containerized waste. Craters U-3ax and U-3bl were combined to form the U-3ax/bl disposal unit (Corrective Action Unit [CAU] 110), which is now covered with a vegetated, native alluvium, evapotranspiration (ET) cover that is at least 2.4 m (8 ft) thick. The cover was constructed in 2000. For details of the final closure plan of CAU 110, refer to BN (2001). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at has been used for disposal of bulk LLW from the NTS and approved offsite generators. Crater U-3bh was originally used for disposal of contaminated soils from the Tonopah Test Range in 1997 and has been used since for waste disposal from other approved generators. The remaining two craters are not in use (Figure 3-1). For a detailed description of the facilities at the Area 3 RWMS, refer to Shott et al. (1997) and NSTec (2007). No waste has been disposed at the Area 3 RWMS since 2006.

3.2 AREA 5 RWMS

Waste disposal has occurred at the Area 5 RWMS since the early 1960s. The Area 5 RWMS consists of 32 landfill cells (pits and trenches) and 13 greater confinement disposal (GCD) boreholes (Figure 3-2 and Figure 3-3). Some previous documents list fewer landfill cells, but new cells continue to be constructed, and Trench 4 was separated into T04A and T04A1 (BN, 2005c). Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). The unlined disposal units receive sealed waste containers. Containers are stacked to approximately 1.2 m (4 ft) below original grade, and soil backfill is pushed over the containers in a single layer to a thickness of approximately 2.4 m (8 ft) thick. For a detailed description of the facilities at the Area 5 RWMS, refer to Shott et al. (1998). For further descriptions of pits, trenches, and GCD boreholes, refer to BN (2005c; 2006) and Cochran et al. (2001).

There are currently eight pits receiving waste at the Area 5 RWMS. The open pits include P03, P06, P10, P12, P13, P14, P15, and P16. The only active mixed waste disposal cell is P03. All other active units contain LLW except P06, which contains asbestiform LLW. C0012 Tc-.00

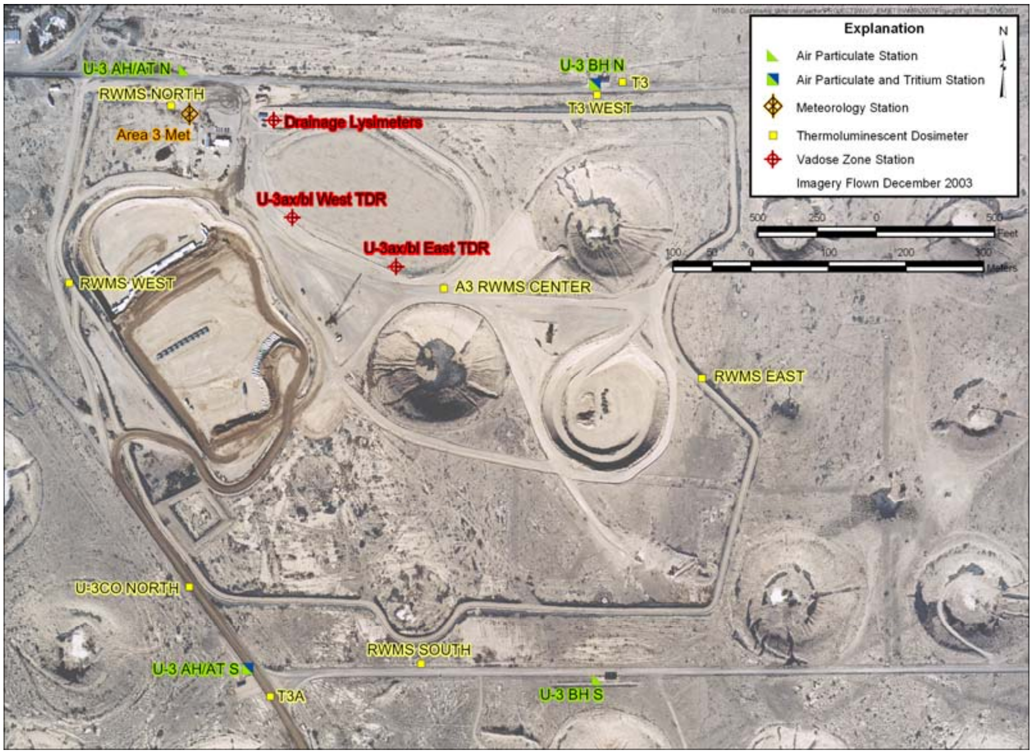


Figure 3-1 Monitoring Locations at the Area 3 RWMS

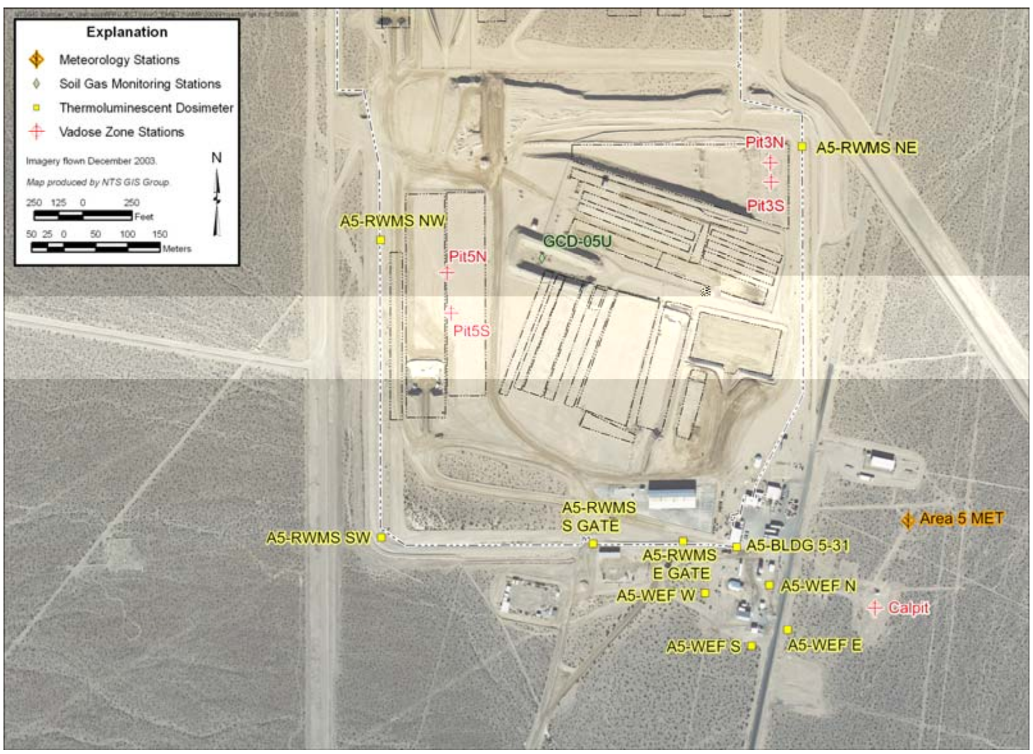


Figure 3-2 Monitoring Locations at the Area 5 RWMS

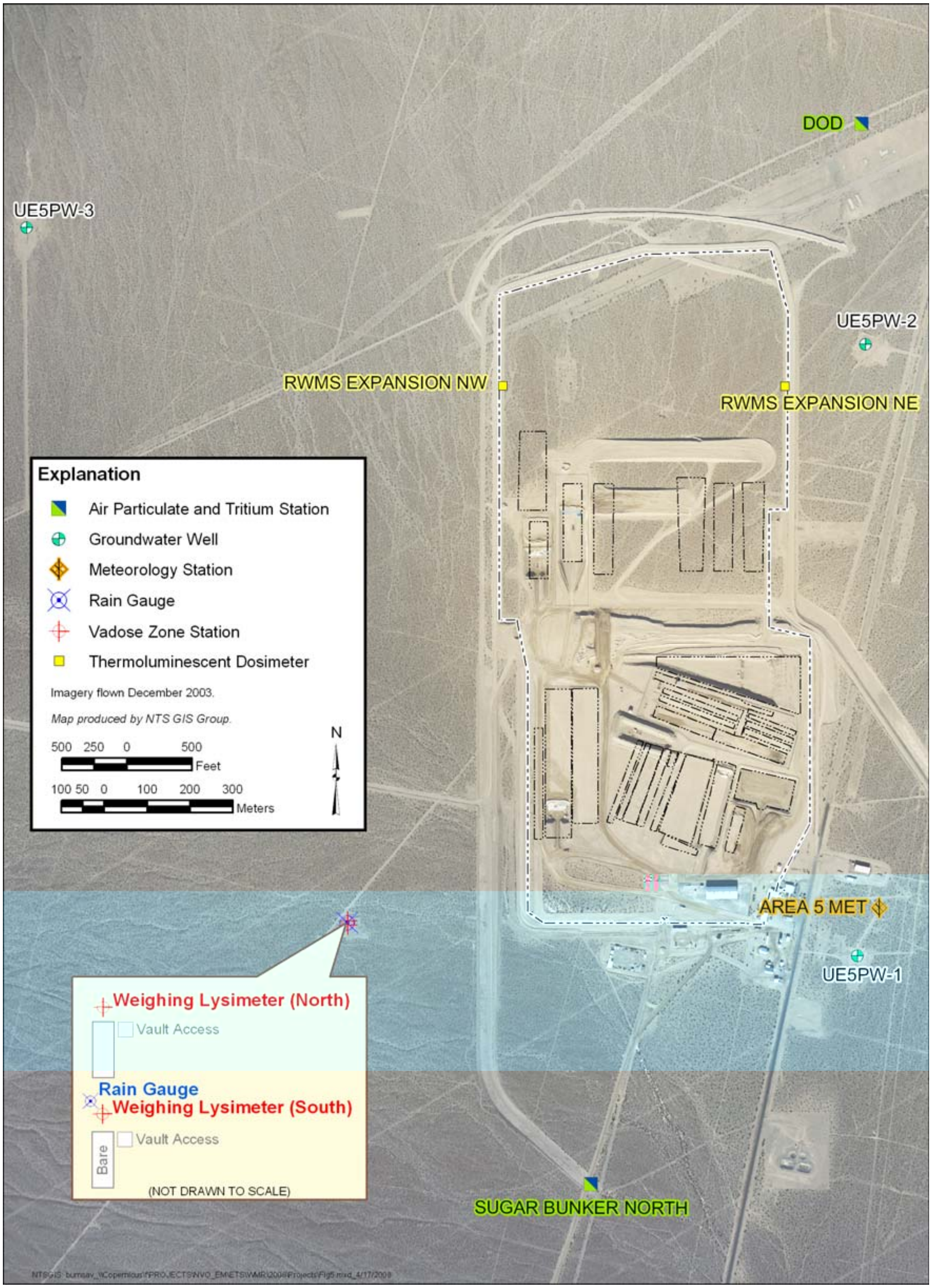


Figure 3-3 Pilot Wells, Weighing Lysimeters, and Air Monitoring at the Area 5 RWMS

THIS PAGE INTENTIONALLY LEFT BLANK

4.0 ENVIRONMENTAL MONITORING DATA

4.1 TYPES OF ENVIRONMENTAL MONITORING DATA

Area 3 RWMS monitoring locations are shown in Figure 3-1, and Area 5 RWMS monitoring locations are shown in Figure 3-2 and Figure 3-3. This report provides a general description and graphical representations of some of these data. Monitoring data currently being collected include:

- Radiation Exposure Data
    - Quarterly thermoluminescent dosimeter (TLD) measurements

- Air Monitoring Data
    - Weekly Data
        - Alpha concentrations
        - Beta concentrations
    - Biweekly Data
        - Tritium concentrations
    - Monthly Data
        - Gamma concentrations
        - Americium (Am) concentrations
        - Plutonium (Pu) concentrations
    - Periodic radon flux measurements from waste covers

- Groundwater Monitoring Data
    - Quarterly Water-Level Measurements
    - Semiannual Indicators of Contamination
        - pH (field measurement)
        - Specific conductance (SC) (field measurement)
        - Total organic carbon (TOC)
        - Total organic halides (TOX)
        - Tritium
    - Semiannual General Water Chemistry Parameters
        - Total calcium, iron, magnesium, manganese, potassium, sodium, silicon
        - Total sulfate, chloride, fluoride
        - Alkalinity
    - Biennial RREMP Analyses
        - Gross alpha
        - Gross beta
        - Gamma spectroscopy
        - Plutonium (^{238}Pu and $^{239+240}$Pu)
    - Triennial RREMP Analyses for Specific Radionuclides
        - Strontium (^{90}Sr)
        - Technetium (^{99}Tc)
        - Carbon (^{14}C)

- Meteorology Monitoring Data
  - Daily Meteorology Data
    - Average air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) above ground level (AGL)
    - Maximum air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Minimum air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Maximum relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Minimum relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Maximum wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average barometric pressure
    - Maximum barometric pressure
    - Minimum barometric pressure
    - Total precipitation
  - Hourly Meteorology Data
    - Average air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average wind direction 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
    - Average barometric pressure
    - Average solar radiation
    - Total precipitation

- Vadose Zone Monitoring Data
  - Annual Soil Gas Monitoring Data (soil gas tritium concentrations measured at GCD-05U gas sampling ports [nine depths])
  - Weighing Lysimeter Data (Area 5)
    - Daily and hourly E from the bare-soil weighing lysimeter
    - Daily and hourly ET from the vegetated weighing lysimeter
    - Daily and hourly precipitation and 5 minute precipitation rates
    - Daily soil volumetric water content (VWC) and soil water potential
    - Hourly soil temperature with depth
  - Drainage Lysimeter Data (Area 3)
    - Daily Soil VWC, soil water potential, and water storage with depth
    - Hourly temperature with depth
    - Daily and hourly drainage from each lysimeter
  - Daily Automated Vadose Zone Monitoring System Data
    - Soil VWC with depth in waste covers
    - Soil VWC beneath waste cells
    - Soil water potential with depth in waste covers
    - Soil temperature with depth in waste covers

- Periodic Subsidence Monitoring Data: locations and description of subsidence features on waste covers

- Biota Monitoring Data: periodic analysis of plant and animal samples for tritium and other radionuclide concentrations

4.2 RADIATION EXPOSURE DATA

The goals of direct radiation monitoring are to assess the external radiation environment, to detect changes in that environment, and to measure gamma radiation levels near potential exposure sites. Performance objectives in DOE O 435.1 require that LLW disposal facilities be sited, designed, operated, maintained, and closed, so it is reasonable to expect a less than 25 millirem per year (mrem/yr) total effective dose equivalent to representative members of the public from the facility. The effective dose equivalent is from all exposure pathways associated with the facility, but does not include the dose from radon and the background dose. Because the RWMSs are located well within the NTS boundaries, the public does not have access to these areas for significant periods of time. However, exposure rates measured by TLDs located at the RWMSs show the potential dose to a hypothetical person residing year-round at the RWMS.

TLDs (Panasonic UD 814AS) are used to measure ionizing radiation exposure from all sources, including natural and man-made radioactivity. These TLDs have three calcium sulfate elements housed in an air-tight, water-tight, ultraviolet-light–protected case. These elements are used to measure the total exposure rate from penetrating gamma radiation including background. The penetrating gamma radiation makes up the deep dose, which is compared to the 25 mrem/yr limit when background exposure is subtracted.

Figure 3-1, Figure 3-2, and Figure 3-3 show TLD monitoring locations near the Area 3 and Area 5 RWMSs. At each location, a pair of TLDs is placed at 1 ± 0.3 m (28 to 51 in.) AGL and are exchanged for analysis on a quarterly basis. TLDs are analyzed using automated TLD readers that are calibrated and maintained by the NSTec Radiological Control Department. Reference TLDs exposed to 100 milliroentgen (mR) from a ^{137}Cs radiation source under controlled conditions are used to scale the response of the measurement TLDs. Direct radiation exposure is usually reported in the unit mR, which is a measure of exposure in terms of numbers of ionizations in air. Generally, the dose in human tissue resulting from an exposure from the most common external radionuclides can be approximated by equating a 1 mR exposure with a 1 millirem (mrem) dose.

Between 1952 and 1972, 60 nuclear weapons tests were conducted within 400 m (1,312 ft) of the Area 3 RWMS boundary. Fourteen of these tests were atmospheric tests, which left radionuclide-contaminated surface soil with elevated radiation exposures across the area. Waste pits in the Area 3 RWMS are subsidence craters from seven subsurface tests that are being filled with LLW. During disposal operations, the waste is covered with clean soil resulting in lower exposures inside the Area 3 RWMS when compared with the average exposures at the Area 3 RWMS fence line or in Area 3 outside the fence line.

Annual radiation exposures in milliroentgen per year (mR/yr) during 2008 at locations inside and near the Area 3 RWMS are shown in Figure 4-1. The Area 3 monitoring locations are (1) inside the Area 3 RWMS (RWMS Center), (2) on the RWMS boundary (RWMS North, RWMS East, RWMS South, RWMS West), and (3) outside the RWMS boundary (T3, T3 West, T3A, and U3CO North) (Figure 3-1). The exposures measured inside the Area 3 RWMS and three of four measurements at the boundary are within the range of background exposures. The four TLD locations outside the Area 3 RWMS boundary and RWMS South (boundary location) have higher exposures due to historic aboveground nuclear weapons test locations in close proximity to these locations. Given this, radionuclides in the Area 3 RWMS contributed negligible external exposure to a hypothetical person residing at the Area 3 RWMS. Estimated daily exposure rates in milliroentgen per day (mR/day) from the quarterly exposure rate data at the Area 3 RWMS are presented in Figure 4-2.

Twenty-five nuclear weapons tests were conducted within 6.3 km (3.9 mi) of the Area 5 RWMS between 1951 and 1971. Fifteen of these were atmospheric tests and nine of the remaining ten tests released radioactivity to the surface. There were no nuclear weapons tests within the boundaries of the Area 5 RWMS. Estimated daily exposure rates from the quarterly exposure data at the Area 5 RWMS are within the range of exposures measured at NTS background locations (Figure 4-3).

Comparisons of 1998 to 2008 direct radiation exposure data using TLDs from the two RWMSs with direct radiation data from NTS background locations indicate that direct radiation exposure at the Area 3 and Area 5 RWMSs is generally low or declining (Figure 4-2 and Figure 4-3).

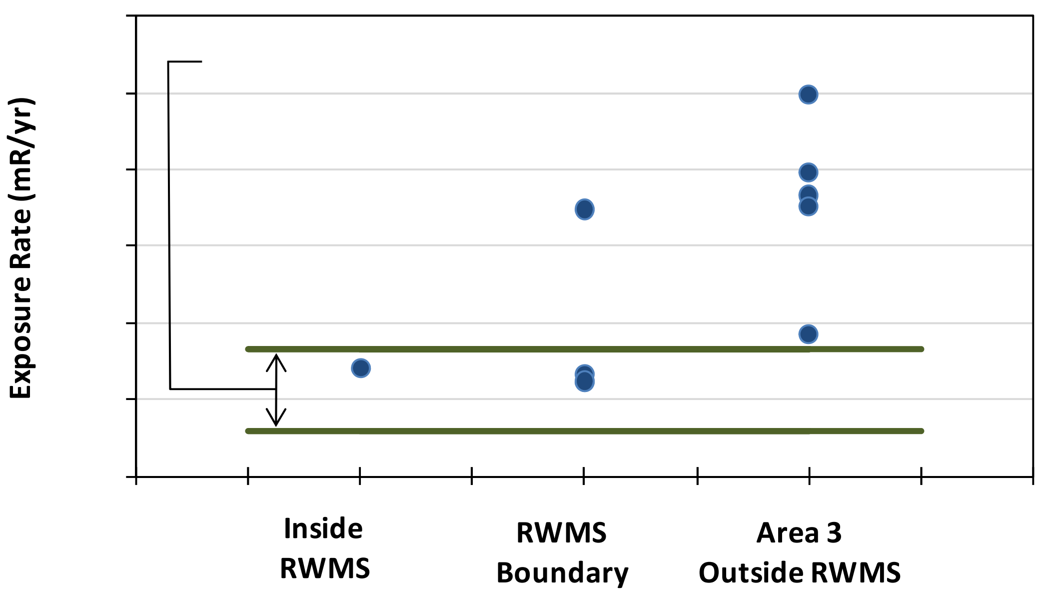


Figure 4-1 Annual Radiation Exposure Rates at the Area 3 RWMS

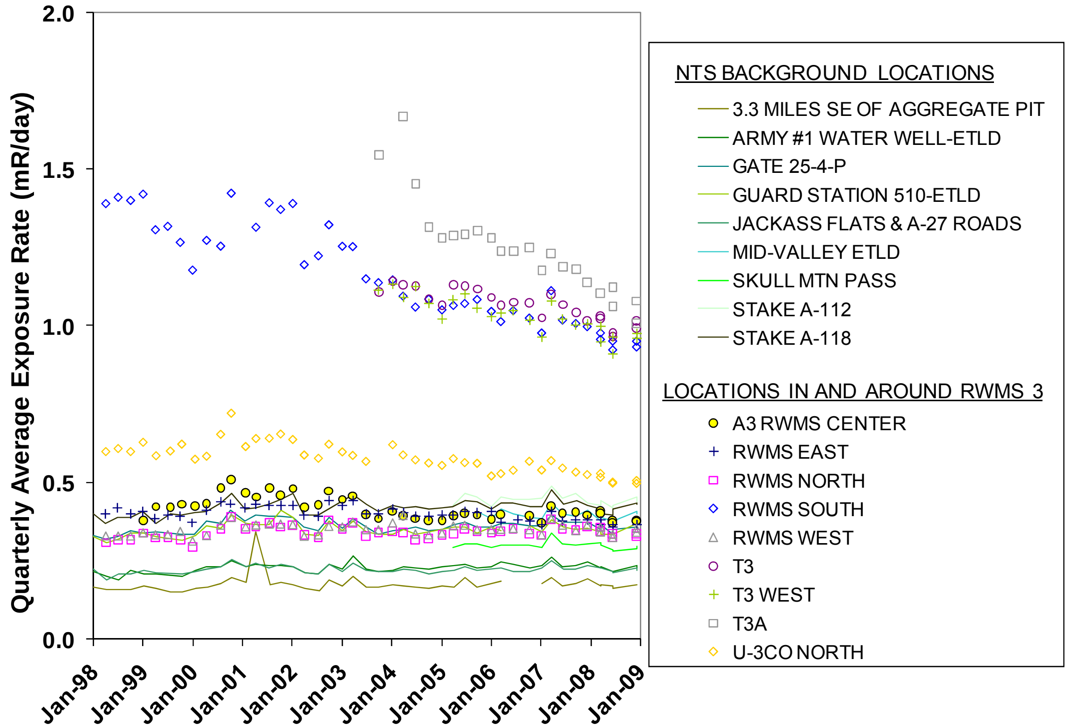


Figure 4-2 Quarterly Average Daily Exposure Rates at the Area 3 RWMS and NTS Background TLD Locations from 1998 to 2008

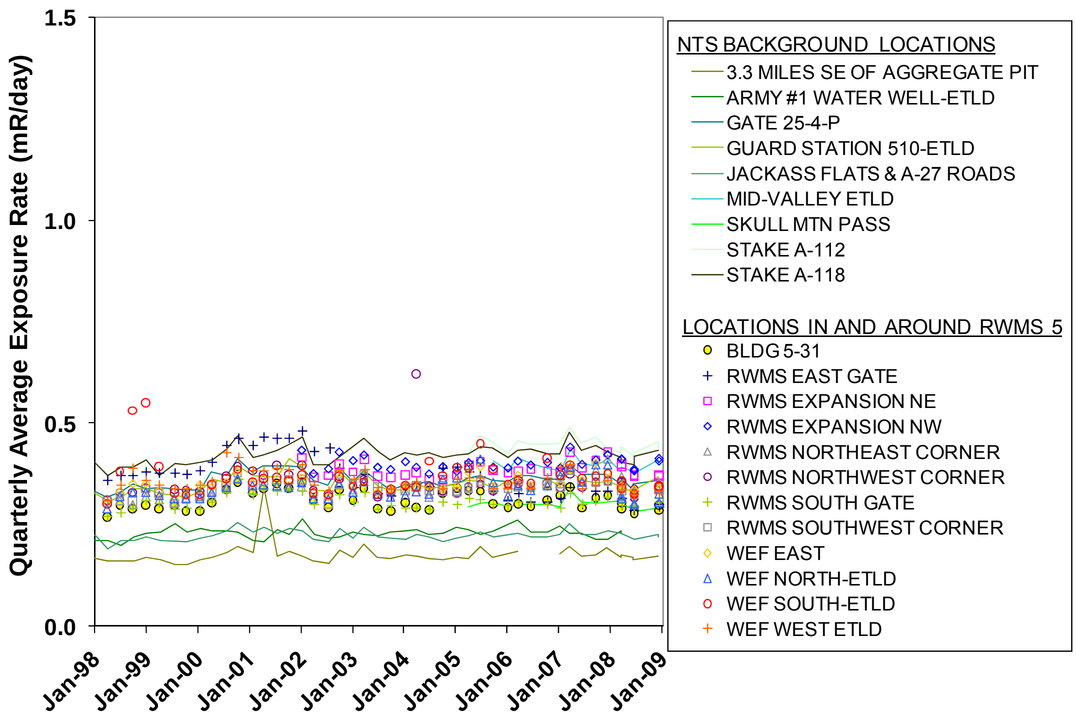


Figure 4-3 Quarterly Average Daily Exposure Rates at the Area 5 RWMS and NTS Background TLD Locations from 1998 to 2008

4.3 AIR MONITORING DATA

4.3.1 Tritium

Tritium is a highly mobile isotope of hydrogen that acts as a conservative tracer and is therefore an excellent performance indicator of volatile radionuclide migration from waste cells. Atmospheric moisture is continuously collected at the Area 3 and Area 5 RWMSs and analyzed for tritium. Approximately 11 cubic meters (m^3) (388 cubic feet [ft^3]) of air is drawn across a desiccant during each two-week sample period to collect atmospheric moisture. The moisture is distilled from the desiccant, and the tritium activity is measured by liquid scintillation.

The two tritium monitoring locations at the Area 3 RWMS are U-3bh N and U-3ah/at S (Figure 3-1). The two Area 5 RWMS monitoring locations are DoD, which is approximately 1.0 km (0.6 mi) north of the Area 5 RWMS, and Sugar Bunker, which is approximately 1.5 km (0.9 mi) south of the Area 5 RWMS (Figure 3-3). These monitoring locations are in the prevailing downwind directions to provide adequate environmental monitoring for each RWMS.

During 2008, tritium concentrations at the Area 3 and Area 5 RWMSs showed levels well below the DOE Derived Concentration Guide (DCG) (DOE O 5400.5) for tritium adjusted to the 25 mrem/yr exposure specified in DOE O 435.1. During 2008, measured tritium concentrations in air ranged from -0.37 to 4.97 picocuries per cubic meter (pCi/m^3) (Figure 4-4).

Tritium concentrations in air are typically highest from June through September (Figure 4-4). Also, slightly higher tritium concentrations were observed during January through mid-February 2008, at U-3bh N on the northeast edge of the Area 3 RWMS. The source of this tritium is not clear, but the time coincides with fractures and subsidence observed at the U-3ax/bl cover on December 18, 2007, and repair of those fractures and subsidence in January 2008.

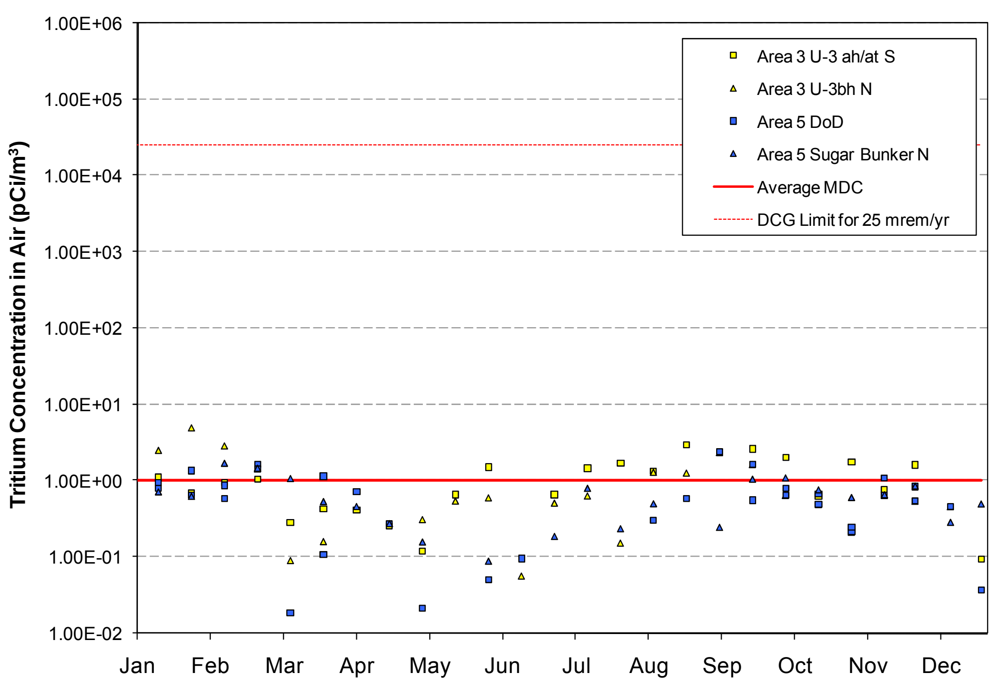


Figure 4-4 Tritium Concentrations in Air at the Area 3 and Area 5 RWMSs during 2008

4.3.2 Particulates

Air particulate samples are collected weekly on glass-fiber filters near each RWMS and are screened for gross alpha and gross beta radioactivity to provide early detection of any change in environmental concentrations of airborne radioactivity. Monthly composites of the filters from each sampling location are analyzed by gamma spectroscopy for gamma-emitting radioactivity and by radiochemical analyses for americium and plutonium.

The four air particulate monitoring locations at the Area 3 RWMS are U-3bh N, U-3bh S, U 3ah/at N, and U-3ah/at S (Figure 3-1). The two air particulate monitoring locations at the Area 5 RWMS are DoD and Sugar Bunker (Figure 3-3).

All gamma spectroscopy results from 2008 are below their associated sample-specific minimum detectable concentration (MDC). The alpha spectroscopy results from 2008 for each location are above the MDCs in 8 to 58 percent of the samples for ^{241}Am (Figure 4-5), above the MDCs in 0 to 17 percent of samples for ^{238}Pu (Figure 4-6), and above the MDCs in 33 to 83 percent of samples for $^{239+240}$Pu (Figure 4-7). The americium and plutonium concentrations at the Area 3 RWMS are slightly higher than at the Area 5 RWMS. There is no indication that RWMS operations contributed americium or plutonium activity above normal variability observed at all locations. All measured concentrations of americium and plutonium were below the DCG, adjusted to 25 mrem/yr, for each radionuclide.

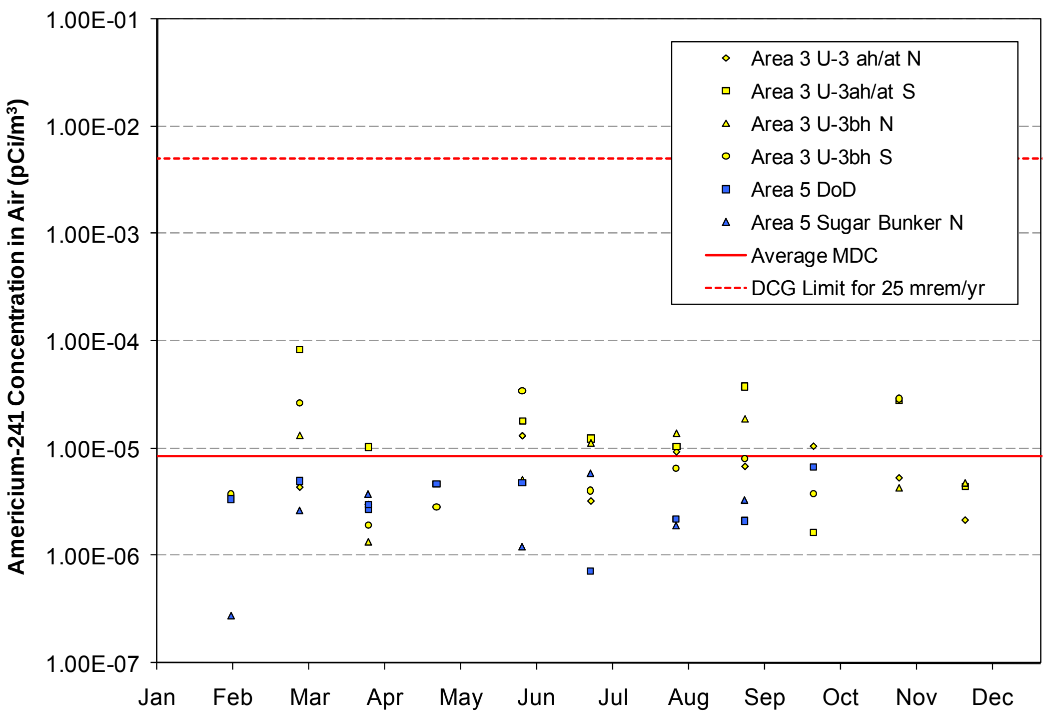


Figure 4-5 Concentration of ^{241}Am in Air at the Area 3 and Area 5 RWMSs during 2008

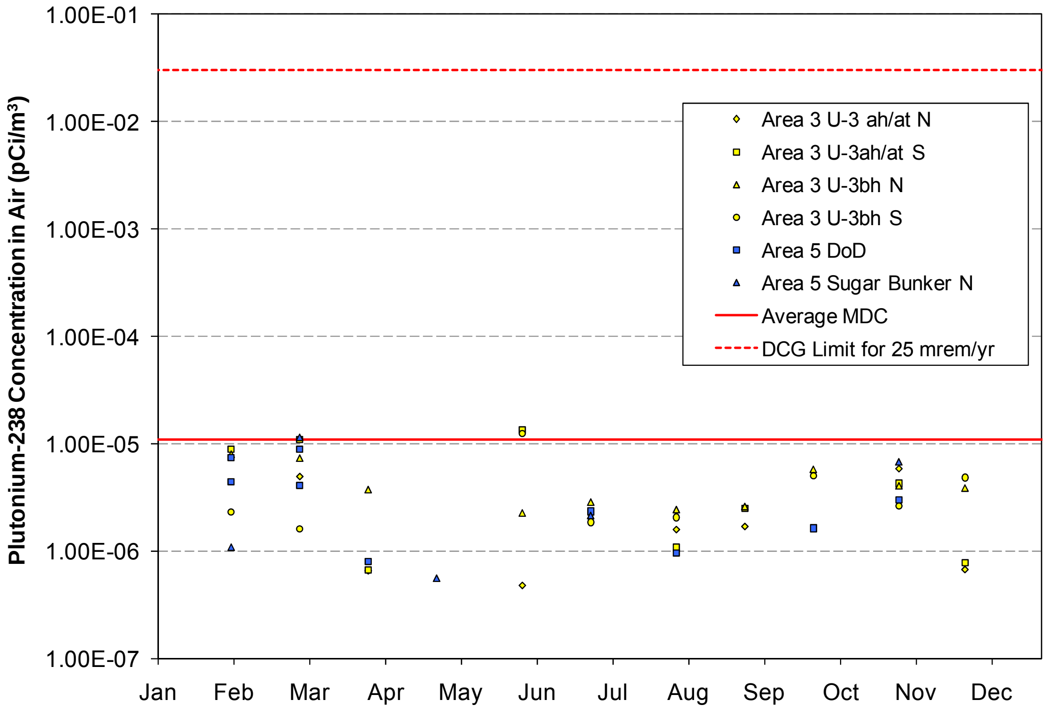


Figure 4-6 Concentration of ^{238}Pu in Air at the Area 3 and Area 5 RWMSs during 2008

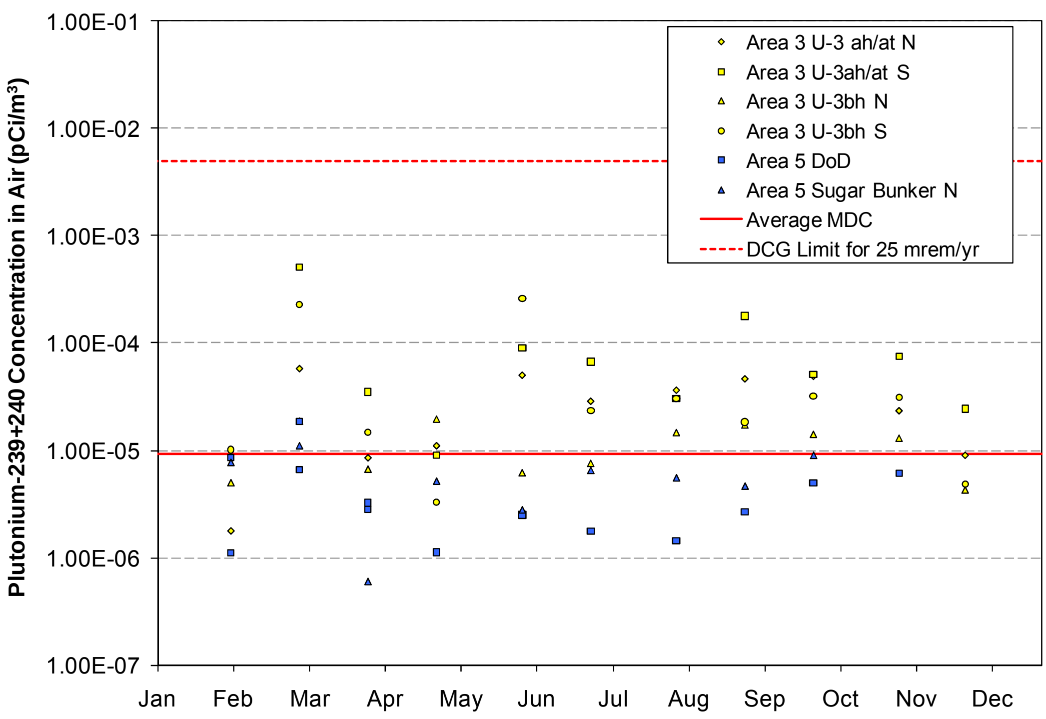


Figure 4-7 Concentration of $^{239+240}$Pu in Air at the Area 3 and Area 5 RWMSs during 2008

4.3.3 Radon

The performance objective (DOE M 435.1-1) for radon emissions from DOE radioactive waste facilities is 20 picocuries per square meter per second (pCi/m^{2}s). Radon flux measurements were made during 2008 at the Area 3 and Area 5 RWMSs for comparison with the regulatory limit. Radon flux was measured on the U-3ax/bl cover in Area 3 and on the P06 and P13 covers in Area 5. These covers were selected because they contain radon and thorium-bearing waste. Radon flux was also measured at an undisturbed site outside both the Area 3 and Area 5 RWMSs. Figure 4-8 shows the measurement locations in Area 3, and Figure 4-9 shows the measurement locations in Area 5. Radon flux on the U-3ax/bl cover was measured from July 30 to August 6, 2008, and from December 8 to December 9, 2008. Radon flux on P06 and P13 was measured from December 9 to December 11, 2008. These measurements were made using radon flux domes (Rad Elec, Inc.) placed on the ground surface. Electrets inserted in the domes are electrically discharged by ionization of air from radon. The amount of discharge is correlated with radon flux from the ground.

Radon flux results from 2000 through 2008 are summarized in Figure 4-10. All radon flux measurements were at least five times lower than the regulatory limit. The July/August 2008 measurements made at the Area 3 RWMS were concentrated on the west side of the U 3ax/bl cover (Figure 4-8) in an attempt to repeat the slightly higher results from December 2006 and December 2007 on the west end of the cover. Overall, the July/August 2008 results were slightly higher than the December 2008 measurements, but neither of these 2008 average radon flux measurements was different from historical measurements or the Area 3 control location (CC Road) (P = 0.08). Average radon flux measurements at the Area 5 RWMS were also not different from their control location at the Weighing Lysimeter Facility (P = 0.6), although one measurement on P06 was relatively high at 3.9 pCi/m^2 s (Figure 4-9). This measurement is still less than 25 percent of the 20 pCi/m^{2}s limit.

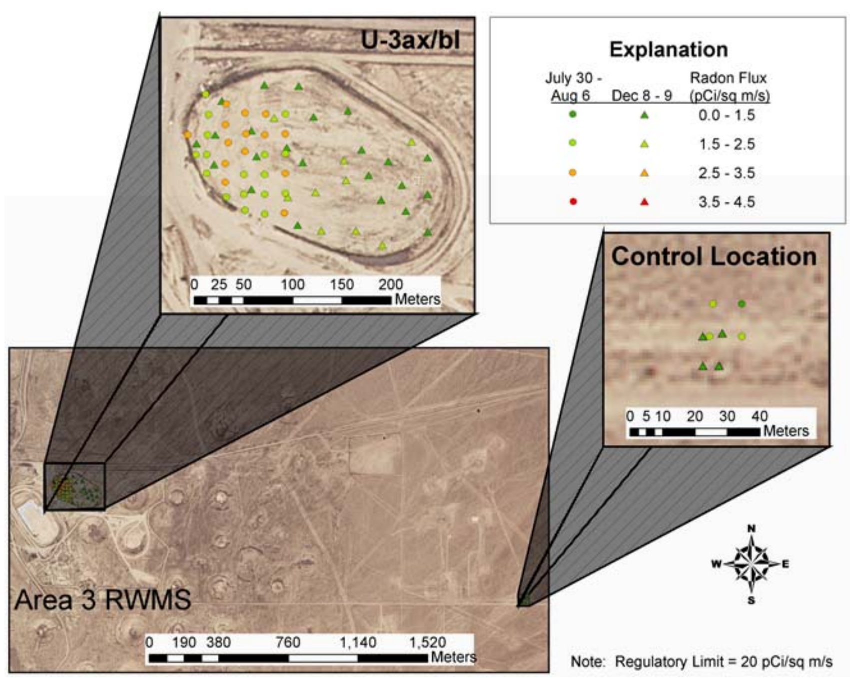


Figure 4-8 Radon Flux Measurement Locations in Area 3

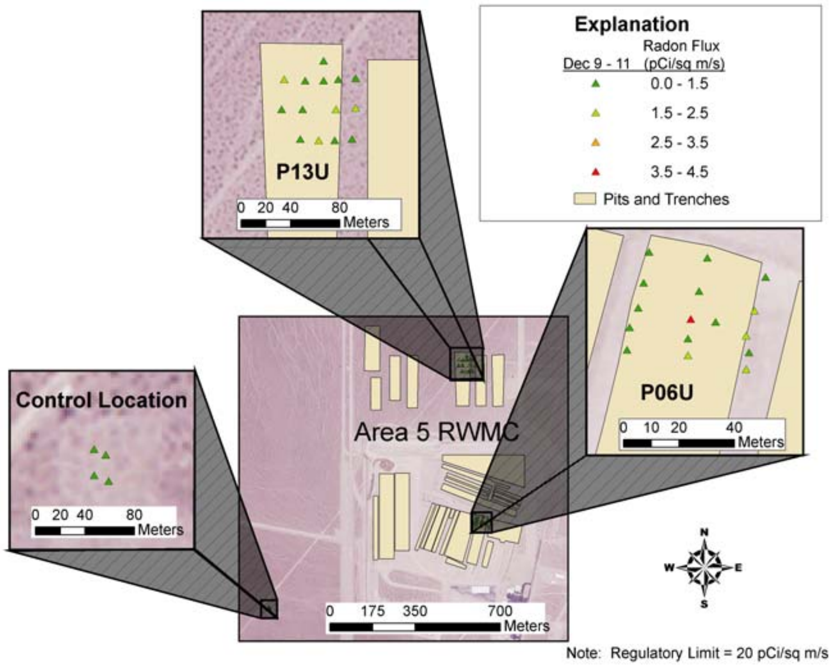


Figure 4-9 Radon Flux Measurement Locations in Area 5

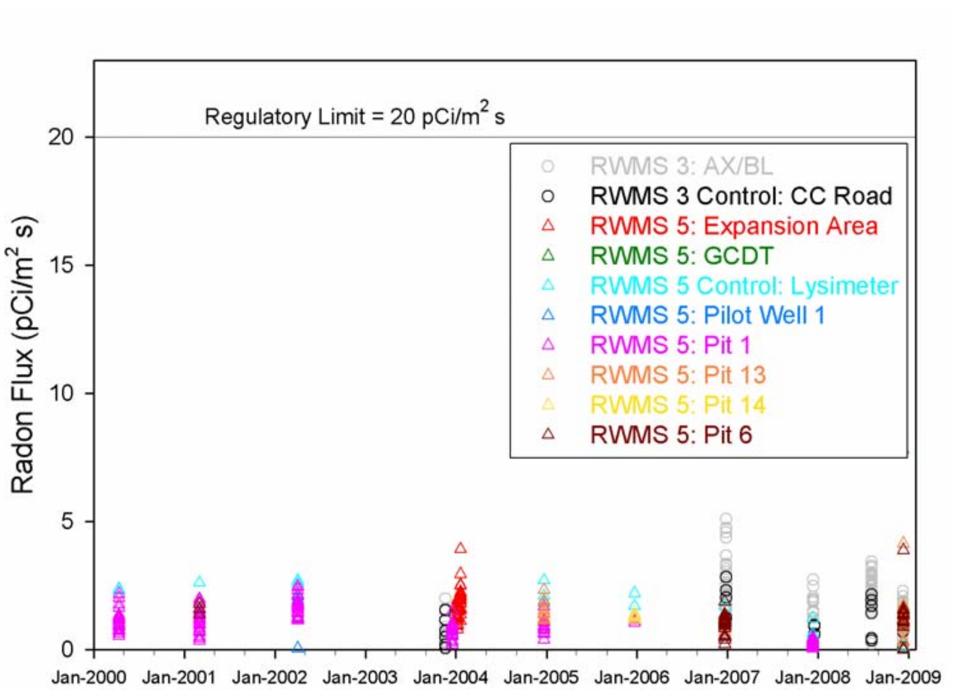


Figure 4-10 Radon Flux Results from 2000 through 2008

4.4 GROUNDWATER MONITORING DATA

Three wells (UE5PW-1, UE5PW-2, and UE5PW-3) were drilled around the perimeter of the Area 5 RWMS in 1993 (see Figure 3-3). These wells are sampled twice a year to monitor the groundwater below the Area 5 RWMS. Investigation levels (IL) have been established for five indicators of contamination migration. The measured indicators are SC, pH, TOC, TOX, and tritium. Further groundwater analyses are required if any analyte exceeds its IL. Results from 2008 are summarized in Table 4-1. General water chemistry parameters are also measured.

To date, all analytical data from groundwater sampling events from the wells indicate that the groundwater in the uppermost aquifer is unaffected by activities at the Area 5 RWMS. Detailed information and data on the groundwater monitoring program at the Area 5 RWMS are presented in the *Nevada Test Site 2008 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site* (NSTec, 2009).

Table 4-1. Investigation Levels and Results from 2008 Groundwater Monitoring

Indicator Parameter	Investigation Level	Results
pH	<7.6 or > 9.2	8.00 to 8.17
SC	0.440 mmhos/cm	0.360 to 0.386 mmhos/cm
TOX	1 mg/L	<0.5 to 0.65 mg/L
TOC	50 µg/L	<5.2 to 6.4 µg/L
Tritium	2,000 pCi/L	-10.7 to 12.1 pCi/L

Units are millimhos per centimeter (mmhos/cm), milligrams per liter (mg/L), micrograms per liter (µg/L), and picocuries per liter (pCi/L).

Groundwater elevation measurements are taken quarterly using an electronic tape. All groundwater elevation data from manual measurements taken since the wells were drilled in 1993 are shown in Figure 4-11. The 2008 average depths to groundwater from the top of casing are 235.77 m (773.51 ft) for UE5PW-1, 256.37 m (841.11 ft) for UE5PW-2, and 271.50 m (890.76 ft) for UE5PW-3. The average groundwater elevations are 733.61 m (2406.85 ft) AMSL at UE5PW-1, 733.75 m (2407.31 ft) AMSL at UE5PW-2, and 733.72 (2407.21 ft) AMSL at UE5PW-3. These data indicate that the water table beneath the Area 5 RWMS is flat, with little or no groundwater flow. Estimated groundwater flow is less than 0.15 m/year (0.49 ft/year) to the south.

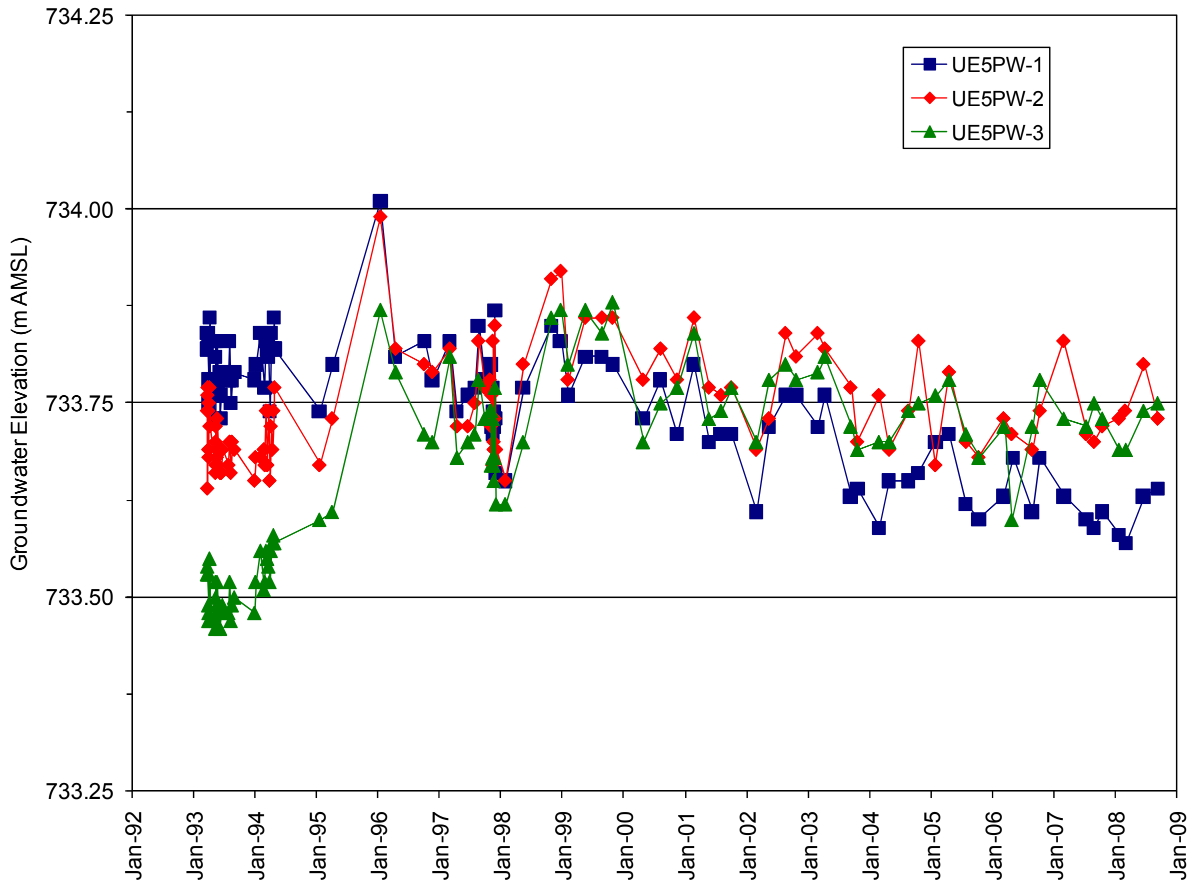


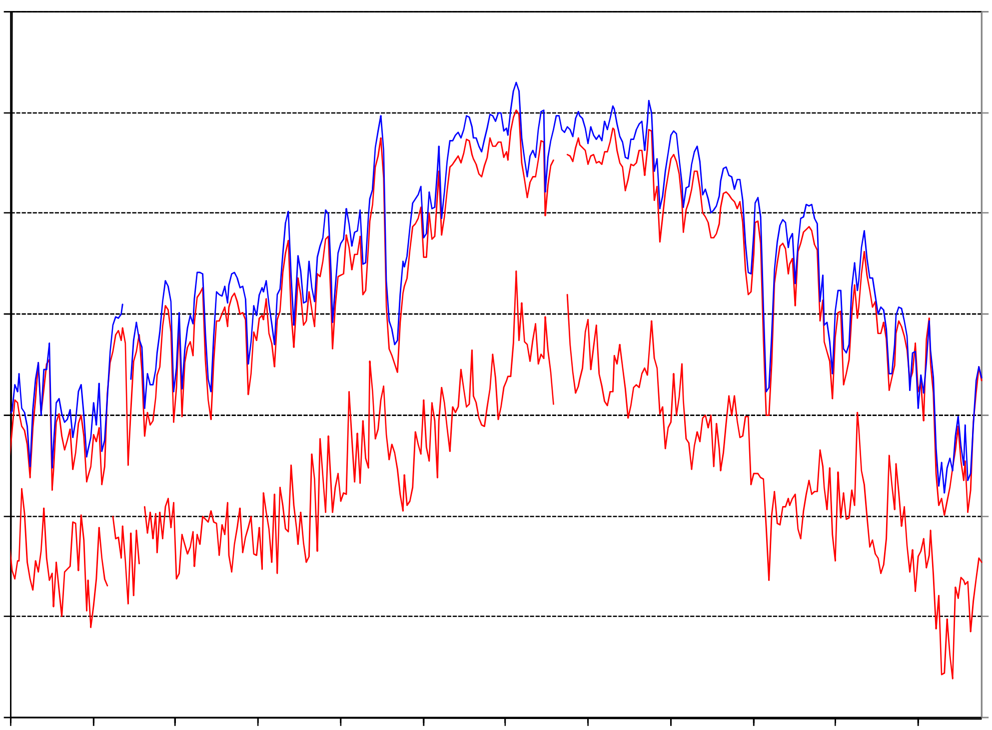
Figure 4-11 Groundwater Elevation at the Three Area 5 RWMS Pilot Wells

4.5 METEOROLOGY MONITORING DATA

Meteorology monitoring data collected in 2008 include precipitation, air temperature, humidity, wind speed and direction, barometric pressure, and incoming solar radiation. These are basic meteorological parameters required to quantify the exchange of water and heat between the soil and the atmosphere. These data were collected from two meteorology stations, one located approximately 30 m (100 ft) northwest of the Area 3 RWMS, and one near the Area 5 RWMS about 100 m (328 ft) north from Well UE5PW-1 (see Figure 3-1 and Figure 3-2).

4.5.1 Air Temperature

Air temperatures at the Area 3 RWMS are slightly cooler than air temperatures at the Area 5 RWMS. The 2008 average recorded temperatures at 3 m (10 ft) are 13.7ºC (56.7ºF) at the Area 3 RWMS and 16.2ºC (61.2ºF) at the Area 5 RWMS. The 2008 maximum and minimum temperatures at 3 m (10 ft) are 40.2ºC (104.4ºF) and -16.0ºC (3.2ºF) at the Area 3 RWMS and 43.0ºC (109.4ºF) and -12.1ºC (10.2ºF) at the Area 5 RWMS (Figure 4-12).



4.5.2 Relative Humidity

Measured relative humidity at the Area 3 RWMS and the Area 5 RWMS is similar. The daily average relative humidity during 2008 at these two sites is approximately 30 percent (Figure 4-13). Measured relative humidity ranged from 1 to 100 percent.

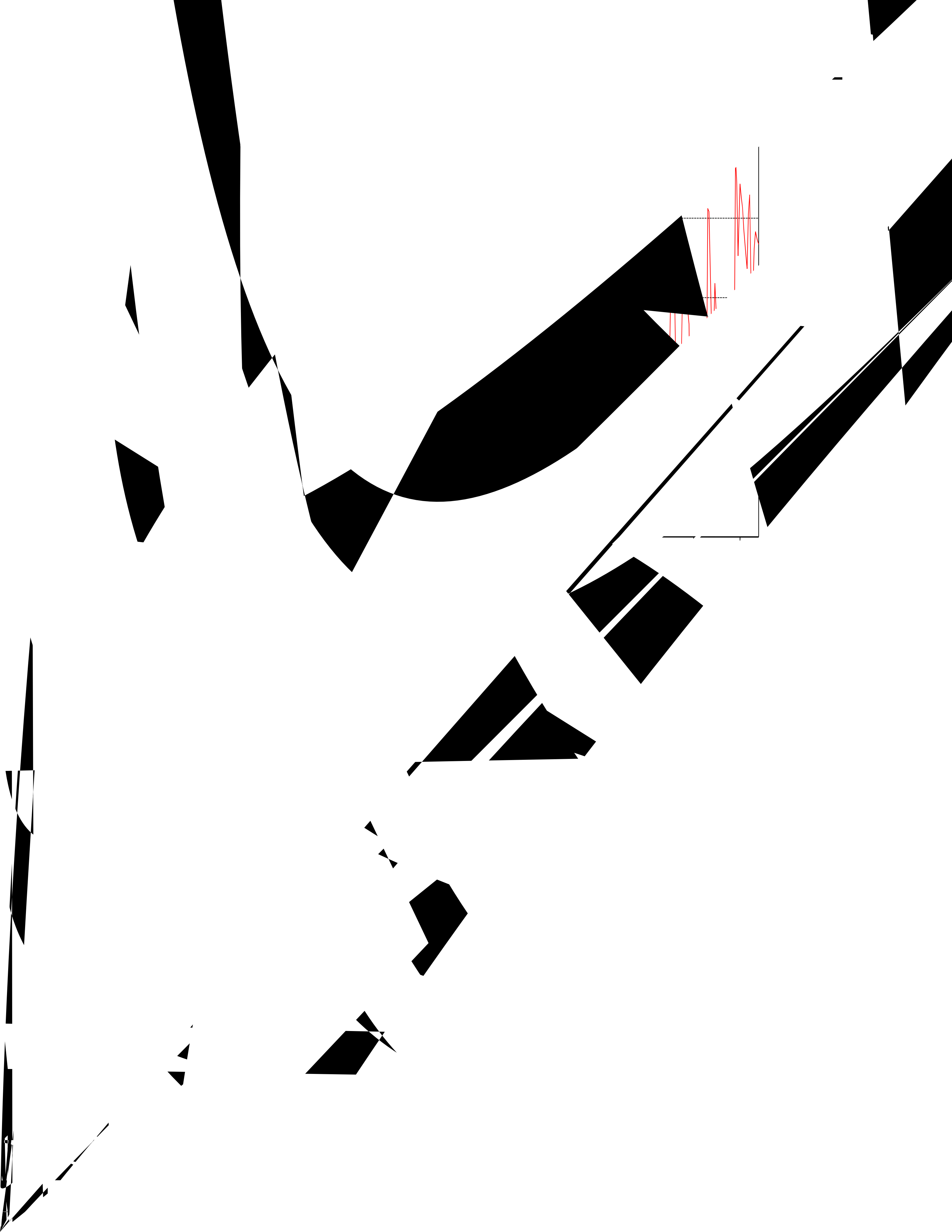
4.5.3 Barometric Pressure

Average daily barometric pressure measured at the Area 3 RWMS and the Area 5 RWMS show very similar patterns (Figure 4-14). The average barometric pressure at the Area 3 RWMS is 87.8 kilopascals (kPa) (12.73 pounds per square inch [PSI]), and the average barometric pressure at the Area 5 RWMS is 90.5 kPa (13.13 PSI). The difference in barometric pressure readings between the two locations is caused by the 261 m (856 ft) difference in elevation.

4.5.4 Wind Speed and Wind Direction

The average wind speed is slightly higher at the Area 3 RWMS than at the Area 5 RWMS. During 2008, the average wind speed at the Area 3 RWMS was 3.1 meters per second (m/s) (6.9 miles per hour [mph]), and the maximum gust was 23.6 m/s (52.8 mph). During 2008, the average wind speed at the Area 5 RWMS was 2.6 m/s (5.8 mph), and the maximum gust was 20.0 m/s (44.7 mph). Daily maximum and average wind speeds are in Figure 4-15 and Figure 4-16.

Wind rose diagrams illustrate wind direction and wind speed distribution in each direction using hourly wind data measured at a height of 3 m AGL. Generally, more wind comes from the north and higher wind speeds come from the south. Wind roses from the Area 3 and Area 5 RWMSs are presented in Figure 4-17 and Figure 4-18, respectively. The one-year wind roses presented here are very similar to the multiple-year wind roses.



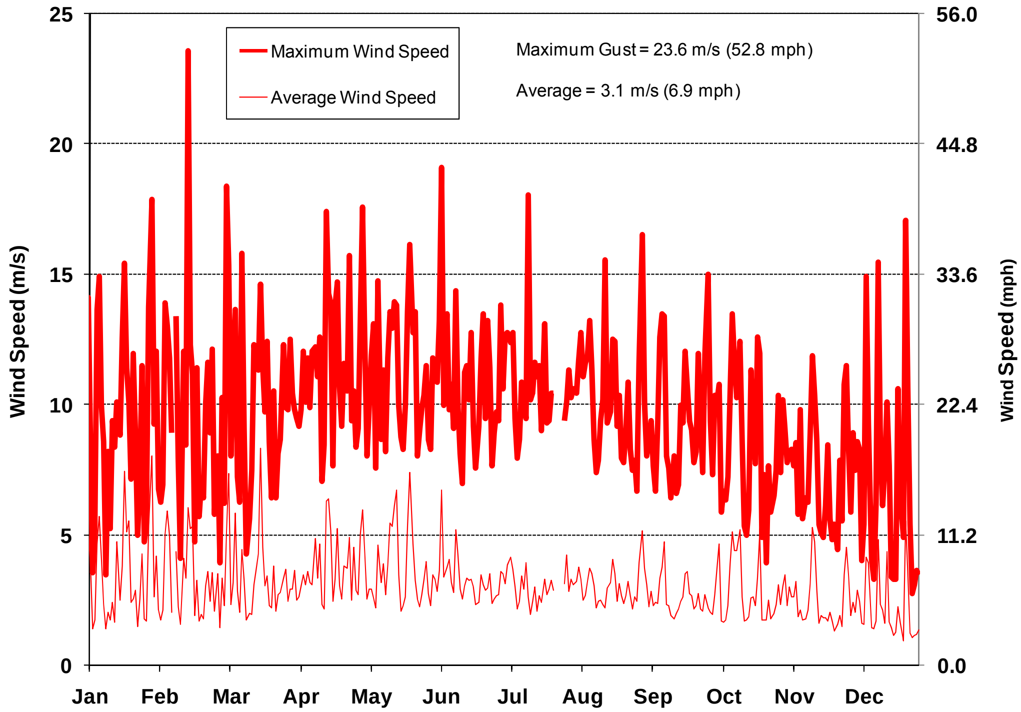
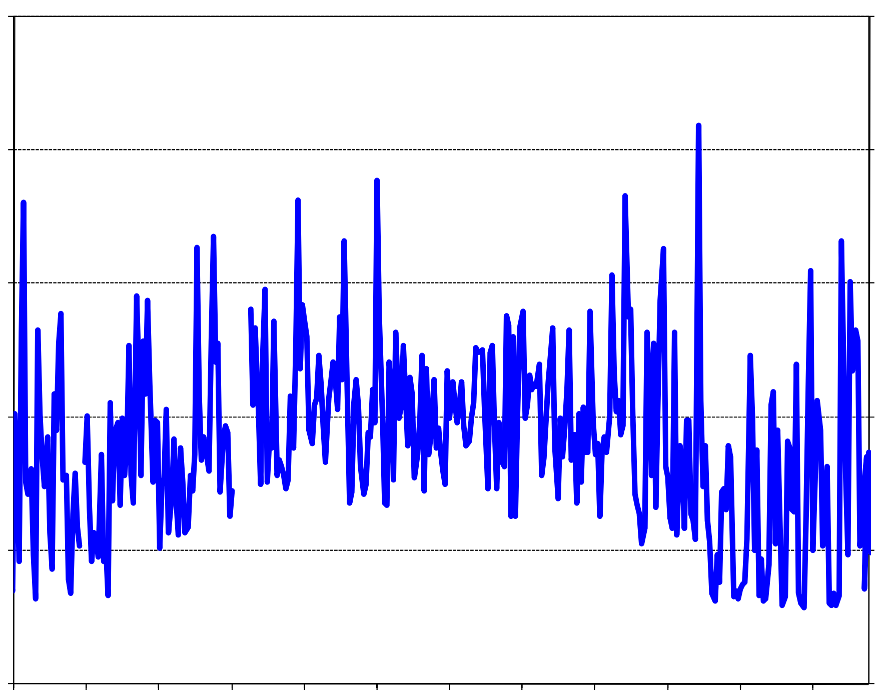


Figure 4-15 Daily 3 m Wind Speed at the Area 3 RWMS



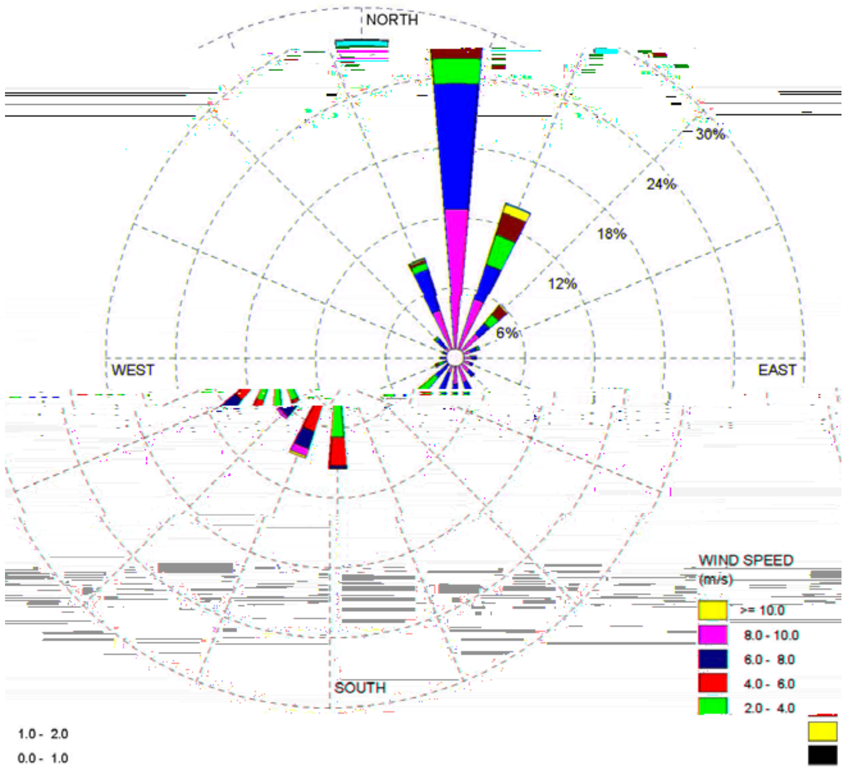


Figure 4-17 Wind Rose Diagram for the Area 3 RWMS

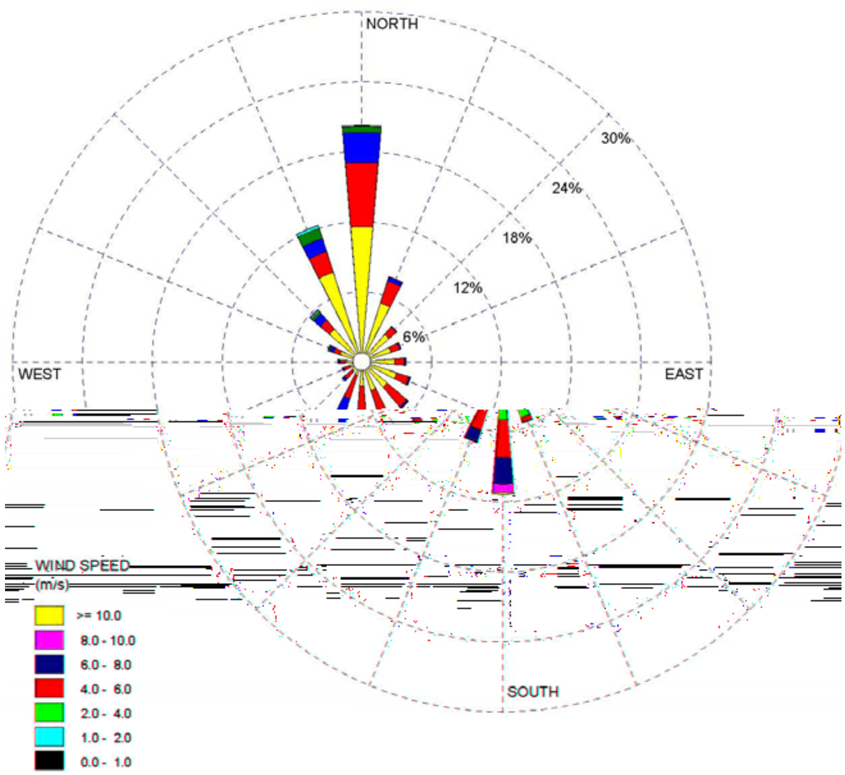


Figure 4-18 Wind Rose Diagram for the Area 5 RWMS

4.5.5 Precipitation

Rainfall at the Area 3 RWMS in 2008 was 13 percent below average, totaling 136.5 mm (5.37 in.). The average annual precipitation measured at the Area 3 RWMS for 1996 to 2008 is 157.3 mm (6.19 in.). The maximum daily rainfall at the Area 3 RWMS during 2008 was 16.2 mm (0.64 in.) on July 12, 2008. Precipitation was measured on 33 days during 2008 at the Area 3 RWMS (Figure 4-19).

Rainfall at the Area 5 RWMS in 2008 was 41 percent below average, totaling 75.4 mm (2.97 in.). This is the second driest year since measurements began at the Area 5 RWMS in 1995. The average annual precipitation measured at the Area 5 RWMS for 1995 to 2008 is 126.8 mm (4.99 in.). The maximum daily rainfall at the Area 5 RWMS during 2008 was 13.1 mm (0.52 in.) on January 27, 2008. Precipitation was measured on 30 days during 2008 at the Area 5 RWMS (Figure 4-20).

Historical precipitation data recorded at BJY (located about 3 km [2 mi] northwest of the Area 3 RWMS) and at the Area 3 RWMS are in Figure 4-21. The BJY station is a Meteorological Data Acquisition (MEDA) station operated by ARL/SORD. The 48-year average annual precipitation at BJY from 1961 to 2008 is 162.9 mm (6.41 in.). Historical precipitation data recorded at the Well 5B station (located about 5.5 km [3.4 mi] south of the Area 5 RWMS) and the Area 5 RWMS are provided in Figure 4-22. The Well 5B station is also an ARL/SORD MEDA station. The 46-year average annual precipitation at Well 5B from 1963 to 2008 is 123.5 mm (4.86 in.).

4.5.6 Reference Evapotranspiration

The calculated 2008 ET_{ref} at the Area 3 RWMS is 1,572 mm (61.9 in.) and at the Area 5 RWMS is 1,615 mm (63.6 in.). ET_{ref} is the rate that readily available soil water is vaporized from a uniform surface of dense, actively growing vegetation. Crop coefficients are used to convert ET_{ref} to potential evapotranspiration rates (Allen et al., 2005). ET_{ref} is calculated using a modified version of the radiation-based equation of Doorenbos and Pruitt (1977). The equation calculates ET_{ref} from hourly measurements of solar radiation, air temperature, relative humidity, wind speed, and barometric pressure. This method provides results similar to the Penman Equation that was previously used for the data reports through 2001 (Campbell, 1977). The Doorenbos and Pruitt equation reduces data input requirements because no net radiation data are used. The ratio of ET_{ref} to precipitation in 2008 at the Area 3 RWMS is 11.5, and the ratio ET_{ref} to precipitation in 2008 at the Area 5 RWMS is 21.4. The very high ratio of ET_{ref} to precipitation at the Area 5 RWMs during 2008 is caused by the very low precipitation.

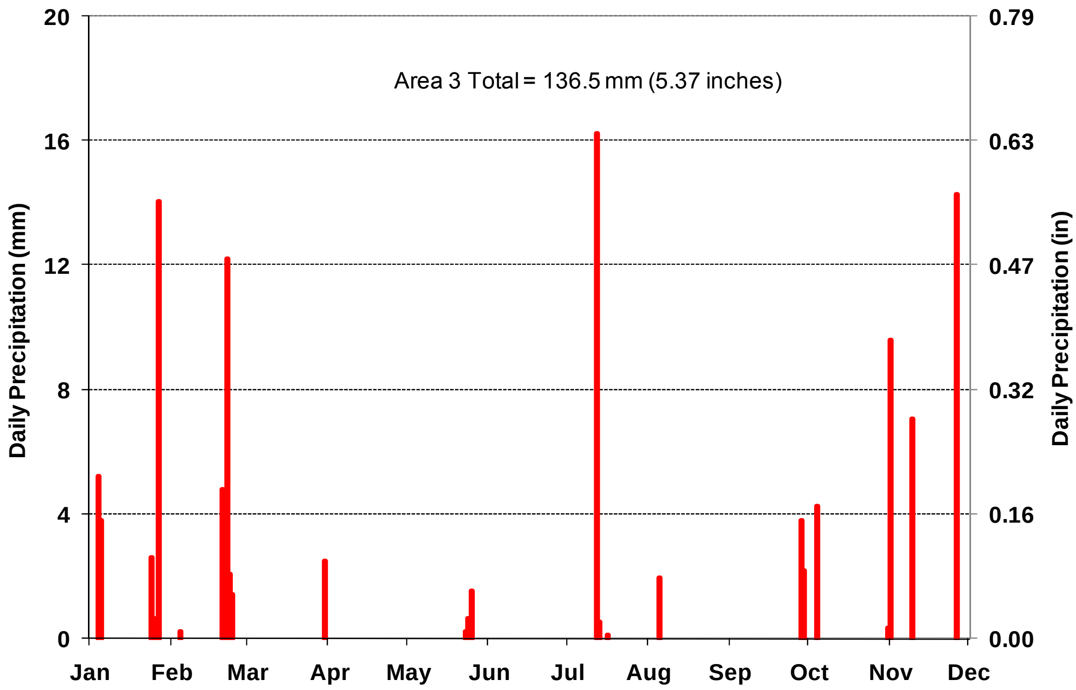


Figure 4-19 Daily Precipitation at the Area 3 RWMS

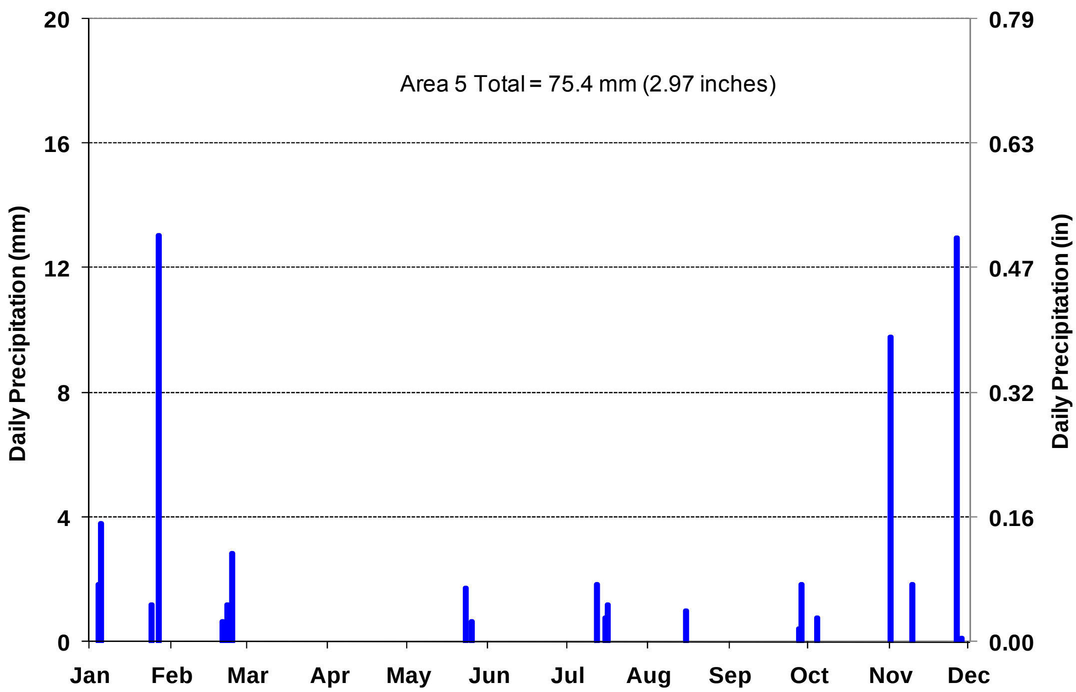


Figure 4-20 Daily Precipitation at the Area 5 RWMS

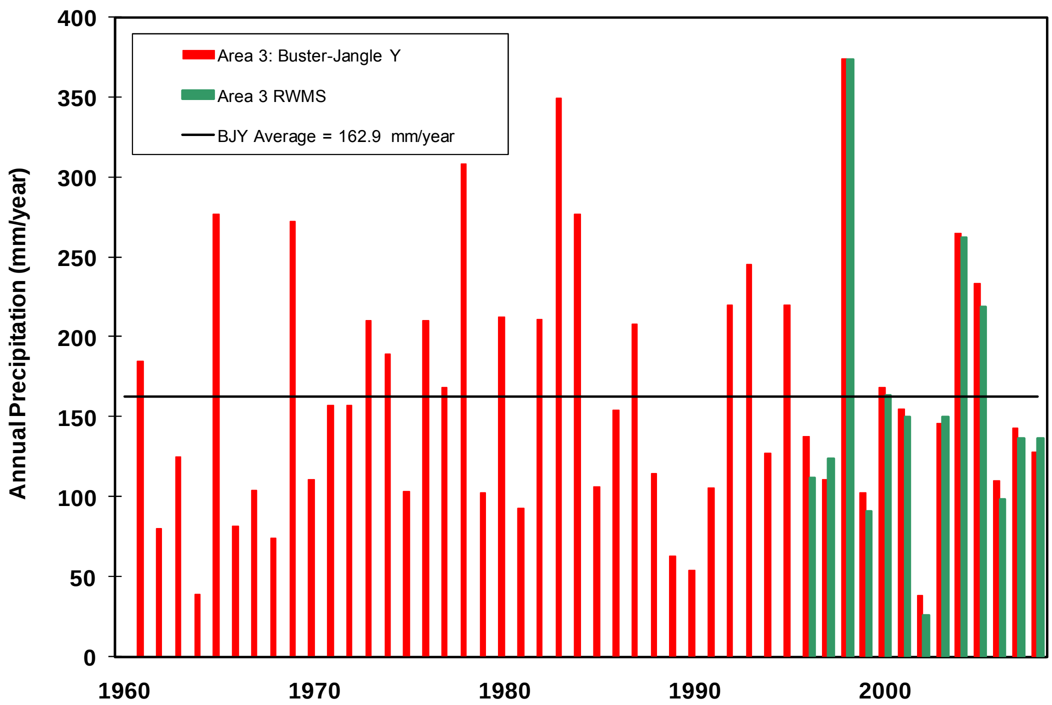


Figure 4-21 Historical Precipitation Record for Buster-Jangle Y and the Area 3 RWMS

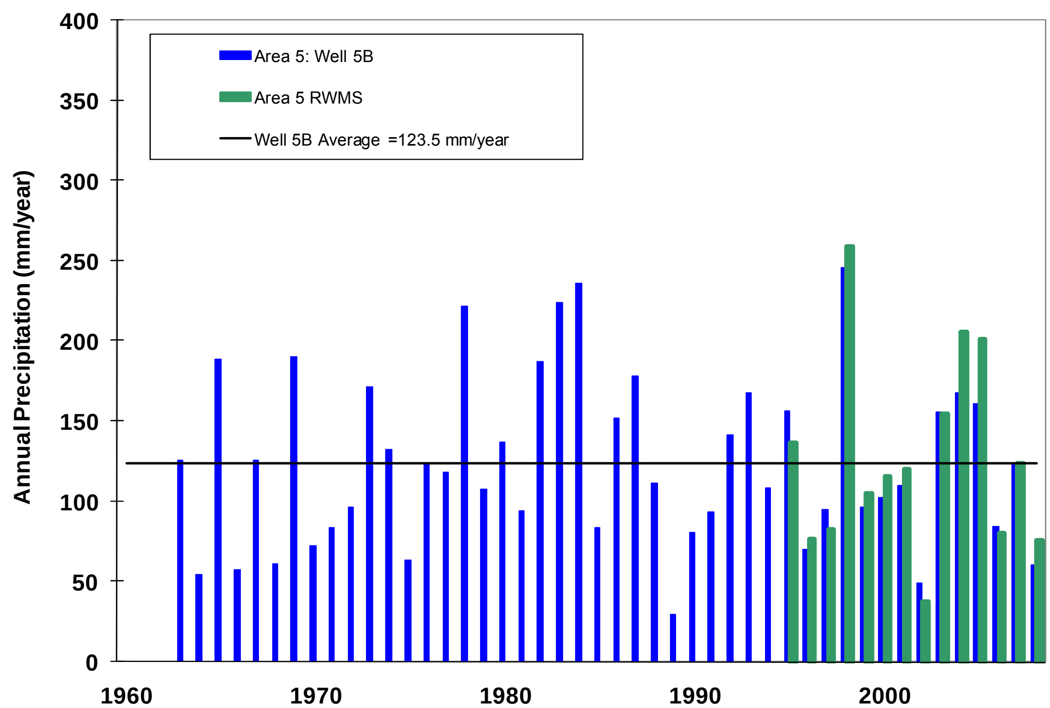


Figure 4-22 Historical Precipitation for Well 5B and the Area 5 RWMS

4.6 VADOSE ZONE MONITORING DATA

4.6.1 Monitoring Strategy

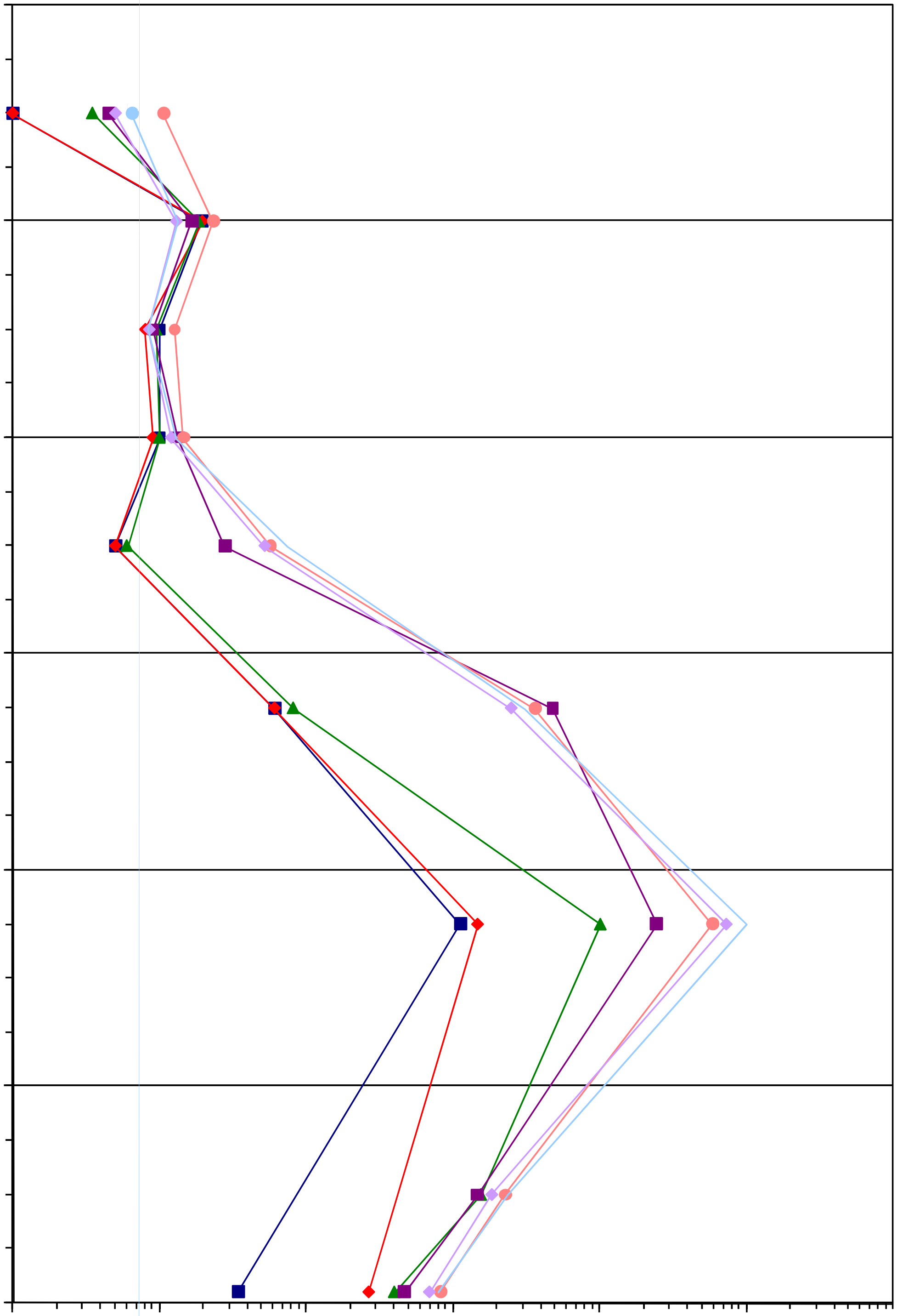
Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs to demonstrate compliance with DOE O 435.1 and confirm the assumptions in the PA for each RWMS (e.g., hydrologic conceptual models, including soil water contents, flux rates and directions, and volatile radionuclide releases). The vadose zone monitoring is also performed to detect changing trends in performance, provide added assurance to PA conclusions regarding facility performance, evaluate the performance of the operational monolayer waste covers, and confirm the PA performance objective of protecting groundwater resources.

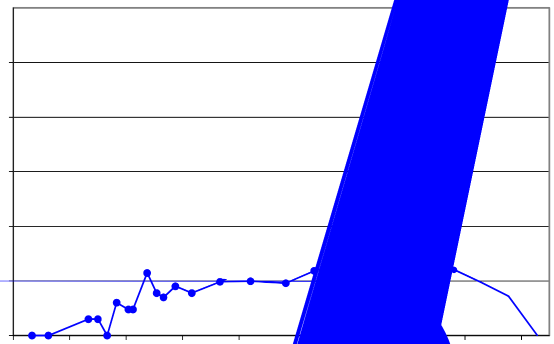
The design of the current vadose zone monitoring program at the RWMSs is based on an understanding of the vadose zone system acquired through extensive characterization studies (BN, 1998; 2005a; 2005b; Blout et al., 1995; Reynolds Electrical & Engineering Co., Inc., 1993a; 1993b; Shott et al., 1997; 1998; Tyler et al., 1996) and modeling studies (Levitt et al., 1999; Desotell et al., 2006; 2007). The objectives of the vadose zone monitoring program are accomplished, in part, by measuring water balances at each RWMS. Water balance studies involve using meteorology data to calculate ET_{ref} values (the driving force of upward flow), directly measuring ET and bare-soil E at the RWMS lysimeter facilities, and measuring soil water content and soil water potential in waste cell covers and floors using automated waste cover monitoring systems. The vadose zone monitoring strategy also evaluates the subsurface migration of tritium by sampling soil gas for the presence of tritium at borehole GCD-05U located near the center of Area 5 RWMS (see Figure 3-2).

4.6.2 Soil Gas Tritium

Soil gas tritium monitoring is conducted via soil gas sampling at borehole GCD-05U. This 3.0 m (10 ft) diameter borehole has a large tritium inventory (~2.2 million curies [Ci] at time of disposal) buried from 20 to 37 m (65 to 120 ft) below ground surface. Two separate strings of nine soil gas sampling ports are buried in the borehole. The sampling ports are at depths of 3.0 m (10 ft), 6.1 m (20 ft), 9.1 m (30 ft), 12.2 m (40 ft), 15.2 m (50 ft), 19.8 m (65 ft), 25.9 m (85 ft), 33.5 m (110 ft), and 36.3 m (119 ft) below ground surface. Soil gas is pumped from the sampling ports to the surface at a low flow rate (2 cubic centimeters per minute). A cold trap removes water vapor from the air stream, and the tritium activity of the water is measured by liquid scintillation. Typically 25 liters of soil gas sample provide approximately 0.35 grams of water. Tritium sampling at borehole GCD-05U provides a direct measure of changes in tritium activity with depth due to degradation of waste containers, transport by advection, and diffusion. Sampling started in 1990 and has continued at least annually through 2008.

Soil gas tritium was sampled from the nine GCD-05U sampling depths in July 2008. The 17-year trend in results indicates that upward migration of tritium through soil from the waste level is extremely slow. Tritium concentrations have remained constant and low from the surface down to 12.2 m (40 ft). Tritium concentrations at 15.2 m (50 ft) slowly increased through 1997 but then leveled off. The sample ports at depths of 19.8, 25.9, 33.5, and 36.3 m (65, 85, 110, and 119 ft) are adjacent to the tritium source. Tritium concentrations at these depths have increased since 1990. The highest measured soil gas tritium concentration of 363.9 microcuries per cubic meter ($\mu Ci/m^3$) indicates that most of the 2.2 million Ci originally buried at the site remains contained. Soil gas tritium concentrations with depth and time are illustrated in Figure 4-23 and Figure 4-24.





4.6.3 Area 5 Weighing Lysimeter Facility

The Area 5 Weighing Lysimeter Facility consists of two precision weighing lysimeters located about 400 m (1,312 ft) southwest of the Area 5 RWMS (see Figure 3-3). Each lysimeter is a 2 m wide by 4 m long (6.6 ft wide by 13 ft long) by 2 m (6.6 ft) deep, open-top steel box filled with soil and mounted on a sensitive scale. Weight changes of each lysimeter are continuously monitored using an electronic load cell. Each load cell can measure approximately 0.1 mm (0.004 in.) of precipitation or ET. One lysimeter is vegetated with the native plant species *Larrea tridentate* (Creosote bush) and *Lycium andersonii* (Anderson's wolfberry) at the approximate density of the surrounding desert. The other lysimeter is kept bare to simulate the bare operational waste covers at the Area 5 RWMS. The load cells have provided an accurate data set of the surface water balance at the Area 5 RWMS since March 1994.

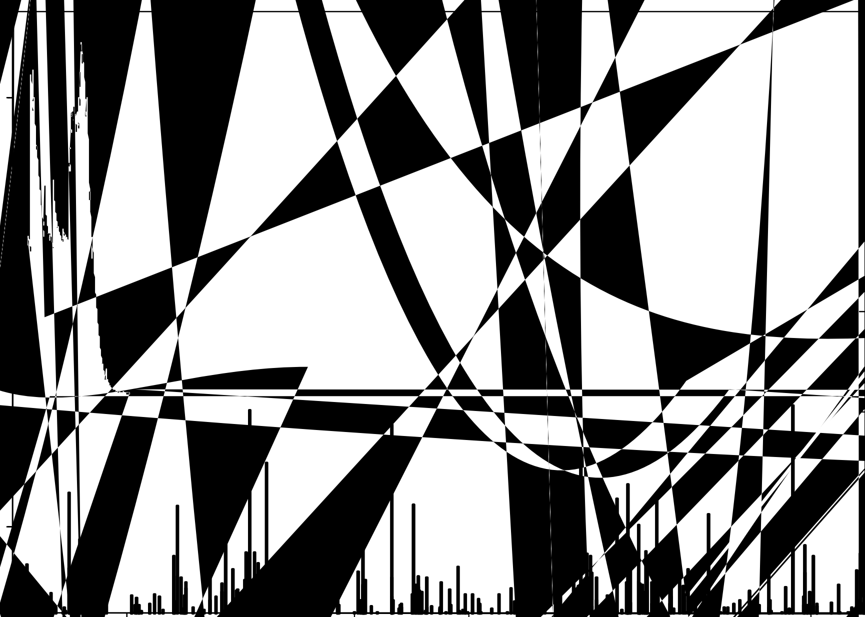
The weighing lysimeter data represent a simplified water balance: the change in soil water storage is equal to precipitation minus E (on bare lysimeters) or ET (on vegetated lysimeters). The water balance is simplified because no drainage can occur through the solid bottoms of the lysimeters and because a 2.5 centimeter (cm) (1 in.) lip around the edge of the lysimeters prevents run-on and runoff. Total soil water storage for the period of March 30, 1994, through December 31, 2008, is illustrated in Figure 4-25.

The vegetated lysimeter is considerably drier than the bare-soil lysimeter, despite the small number of plants on the vegetated lysimeter (about 15 percent plant cover). The average soil water storage depth in the vegetated lysimeter from January 1, 1996, to December 31, 2008, is 115 mm (4.5 in.). This is equivalent to an average volumetric water content of 5.8 percent. For the same period, the average soil water storage depth in the bare lysimeter is 207 mm (8.1 in.), which is equivalent to an average volumetric water content of 10.4 percent. During 2008 the average soil water storage depth in the vegetated lysimeter is 118 mm (4.6 in.), and the average water storage depth in the bare lysimeter is 211 mm (8.3 in.).

Soil water storage decreases rapidly in the vegetated lysimeter following high rainfall periods due to ET. Typically, soil water decreases more slowly in the bare lysimeter due to E. Increases in soil water storage observed early in the data record in the vegetated lysimeter are a result of irrigation conducted to ensure survival of transplanted vegetation.

No water has ever accumulated at the bottom of the vegetated lysimeter. Heavy precipitation during the late fall and winter combined with low E rates and higher initial water contents may result in water accumulation at the bottom of the bare lysimeter. A suction of -8.0 kPa (-1.2 PSI) was applied to the suction candles on the bottom of the bare lysimeter from May 5, 2008, to June 19, 2008. No water effluent was collected from the suction candles during this period. Long-term numerical simulations (30 years) using a unit gradient bottom boundary were used to determine the amount of drainage that would have occurred if water could drain from the lysimeters. These simulations indicate an average of 1.0 cm/yr of water reaches the bottom of the bare lysimeter and essentially no water reaches the bottom of the vegetated lysimeter (Desotell et al., 2006).

During 2008, E from the bare lysimeter was 87.5 mm (3.4 in.) and ET from the vegetated lysimeter was 76.7 mm (3.0 in.). Because both E and ET were greater than the 70.6 mm (2.8 in.) of precipitation at the Weighing Lysimeter Facility during 2008, water storage decreased in both lysimeters during 2008 (Figure 4-26). Precipitation exceeded both E and ET in January, November, and December 2008, and ET exceeded E in March and April 2008 (Figure 4-27).



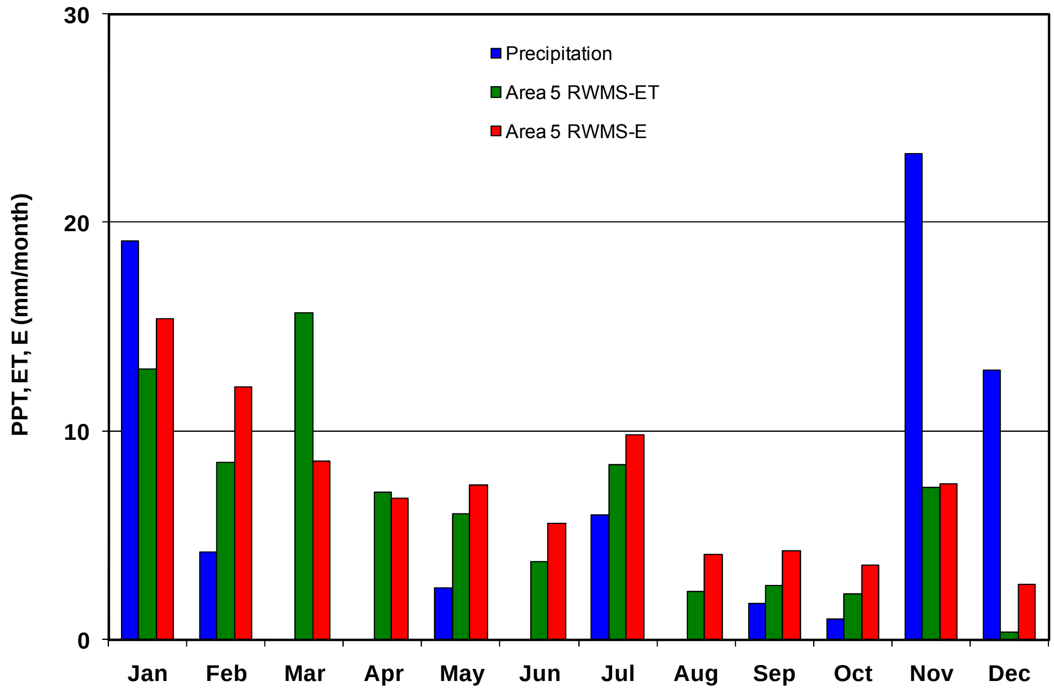


Figure 4-27 Monthly Precipitation, E, and ET Measured in the Weighing Lysimeters during 2008

4.6.4 Automated Waste Cover Monitoring System

In 1998, time-domain reflectometry (TDR) probes were buried 1.2 m (4 ft) beneath the floor of open Pit 5 at the Area 5 RWMS. The four probes are adjacent to the Pit 5N and Pit5S monitoring locations with one probe buried near the Pit 5 center line and one probe near the eastern edge of Pit 5 at the two monitoring locations (Figure 3-2). Approximately 4.4 m (14 ft) of waste and then approximately 2.3 m (8 ft) of operational cover were placed above these probes during disposal operations. The total depth of these probes is now approximately 7.9 m (26 ft). Measured volumetric water content in the floor of Pit 5 has remained constant at approximately 10 percent (Figure 4-28). The constant measured water content indicates that no moisture has percolated to 1.2 m (4 ft) below the waste.

In 1999, TDR probes were also installed in the operational cover of Pit 3 at monitoring locations Pit 3N and Pit 3S (Figure 3-2). At each location probes were buried at depths ranging from 10 to 180 cm (0.3 to 5.9 ft). Precipitation events, beginning in October 2004, infiltrated into the operational cover and percolated below the deepest probe at 180 cm (5.9 ft) at both the north location (Figure 4-29) and the south location (Figure 4-30) in early March 2005. This moisture is below the range of substantial surface E. By September 2007, the volumetric water content at 180 cm (5.9 ft) at both sites had returned to approximately 12 percent. A 58.1 mm (2.29 in.) precipitation event occurred on September 21 and September 22, 2007. Water contents increased to 90 cm depth at Pit 3N and to 120 cm depth at Pit 3S after this storm. By May 2008, this moisture was removed from the Pit 3 operational cover by E without any percolation below 120 cm (Figure 4-29 and Figure 4-30).

In 2000, TDR probes were installed in the Pit 4 operational cover at location Pit 5S and in the Pit 5 operational cover at Pit 5N (Figure 3-2). At each location the probes are buried at depths ranging from 20 to 180 cm (0.7 to 5.9 ft). Precipitation events beginning in October 2004 infiltrated into the operational cover of Pit 4 and Pit 5, and percolated deeper than the deepest probe at 180 cm (5.9 ft) at Pit 4 in March 2005 (Figure 4-31) and at Pit 5 in April 2005 (Figure 4-32). The gradual drying of the soil profile continued in 2008. Because this moisture is below the range of substantial surface E, the gradual drying is most likely due to downward percolation. The 58.1 mm (2.29 in.) precipitation event on September 21 and September 22, 2007 increased water contents to 60 cm depth in both the Pit 4 operational cover (Figure 4-31) and the Pit 5 operational cover (Figure 4-32).

In December 2000, TDR probes were installed in the final vegetated cover of the U-3ax/bl waste disposal unit at the Area 3 RWMS. Eight vertically arranged TDR probes were installed at four locations at depths ranging from 30 to 244 cm (1 to 8 ft). Measured soil water content values for one location (East Nest A) in the U-3ax/bl waste cover are shown in Figure 4-33. The TDR data indicate that the soil water content in the cover generally decreased over time as the vegetation on the cover grew. The precipitation events beginning in October 2004 infiltrated into the final cover of U-3ax/bl, but the moisture has been removed without percolating below the 244 cm (8 ft) deep sensor. Unlike the bare-soil operational covers on Pit 3, Pit 4, and Pit 5, the moisture at U-3ax/bl was removed by ET before reaching 244 cm (8 ft). The wetting front from 6.6 cm (2.6 in.) precipitation event on September 21 and September 22, 2007, only reached 30 cm (1 ft) deep as compared to 90 to 120 cm (3 to 4 ft) deep in the bare operational covers. The initial water content values are lower in the vegetated U-3ax/bl cover, so more precipitation water is stored per unit depth as the wetting front moves down. Vegetation is critical to the effectiveness of the U-3ax/bl cover. In the native environment, the area covered by plant material is about 12 percent. Obtaining 12 percent vegetative cover on the soil caps is dependent upon the seed germination success and seedling survival of native plants seeded or transplanted onto the soil cap. A quantitative analysis of the vegetative cover on the U-3ax/bl soil cap is conducted annually in the spring. The percent cover for the established U-3ax/bl cover has ranged from 20.2 percent in 2005, to 19.6 percent in 2006, to 10.6 percent in 2007, to 26.8 percent in 2008. *Atriplex confertifolia* (Shadscale) was the dominant perennial plant on the U-3ax/bl cover (12.2 percent cover) and annual plants accounted for 14 percent cover (U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2008).

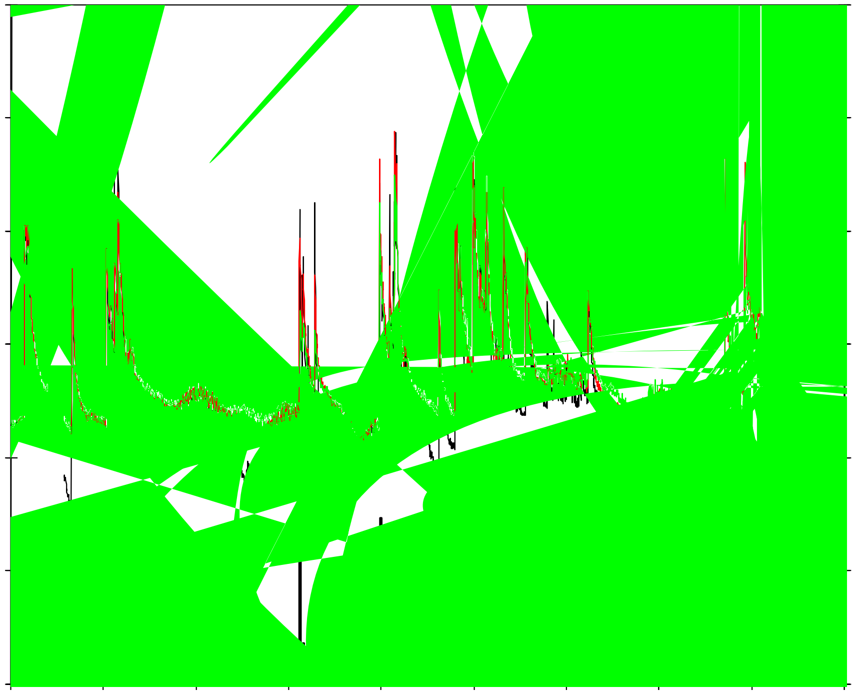
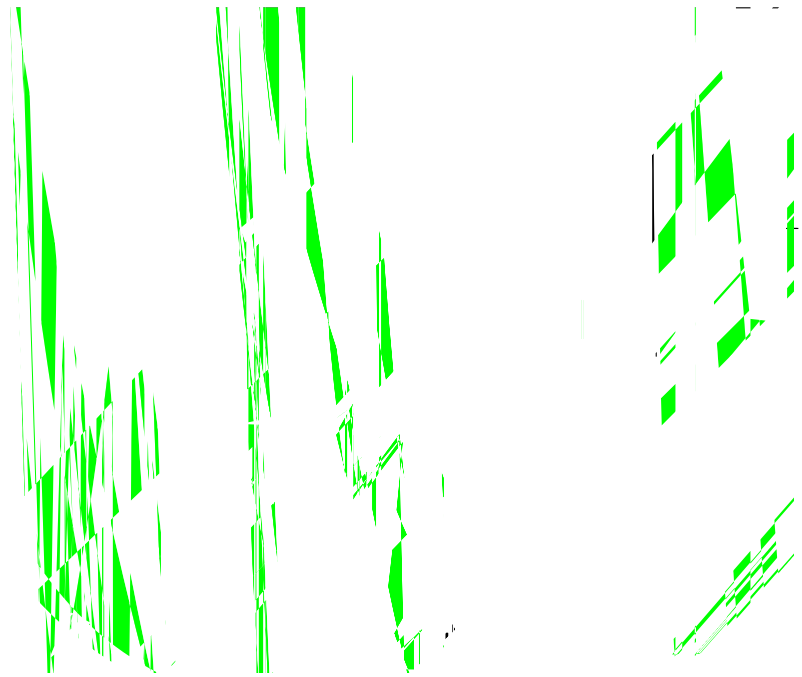


Figure 4-31 Water Content in the Pit 4 Waste Cover at Pit 5S



4.6.5 Area 3 Drainage Lysimeter Facility

The Area 3 Drainage Lysimeter Facility is immediately northwest of the U-3ax/bl waste disposal unit at the Area 3 RWMS (Figure 3-1). This facility is designed to collect saturated gravity drainage from eight 3.05 m (10 ft) diameter by 2.44 m (8 ft) deep lysimeters. Each lysimeter is filled with native soil and packed to mimic the U-3ax/bl soil cover. Each lysimeter has eight TDR probes to measure moisture content depth profiles, paired with eight heat dissipation probes to measure soil water potential depth profiles. The probes are installed at 7.6 cm (0.25 ft), 15 cm (0.5 ft), 30 cm (1 ft), 61 cm (2 ft), 91 cm (3 ft), 122 cm (4 ft), 183 cm (6 ft), and 244 cm (8 ft) deep. Measured water content values at the bottom of the lysimeters and drainage from the lysimeters provide an indirect measure of potential drainage from the U-3ax/bl soil cover. The lysimeter facility was constructed to fulfill data needs including reducing uncertainty in the expected performance of monolayer-ET closure covers under various surface vegetation treatments and climatic change scenarios such as increased rainfall.

There are three surface vegetation treatments subject to two climate treatments on the lysimeters. The three surface vegetation treatments are bare-soil, invader species (primarily *Salsola iberica* [Russian thistle], *Halogeton glomerata* [halogeton], and *Descurania pinnata* [tumble mustard]), and native species (primarily *Atriplex confertifolia* [shadscale], *Krascheninnikovia lanata* [winterfat], *Ephedra nevadensis* [ephedra], and *Achnatherum hymenoides* [Indian rice grass]). The climate treatments are natural precipitation and 3 times natural precipitation. The 3 times natural precipitation lysimeters receive natural precipitation and are irrigated with an amount equal to 2 times natural precipitation.

The eight lysimeters are identified as Lysimeter A through Lysimeter H. Lysimeter A is bare soil with natural precipitation, Lysimeter B is bare soil with 3 times natural precipitation, Lysimeter C is invader species with natural precipitation, Lysimeter D is invader species with 3 times natural precipitation, Lysimeters E and G are native species with natural precipitation, and Lysimeters F and H are native species with 3 times natural precipitation. The 2008 precipitation at the Drainage Lysimeters was 124 mm (4.9 in.). The 2008 irrigation applied to Lysimeters B, D, F, and H is 249 mm (9.8 in.). The 2008 lysimeter treatments are summarized in Table 1.

There were 916 liters (242 gallons) of drainage from Lysimeter B during 2008. The equivalent depth of this drainage is 12.6 cm (5.0 in.). This drainage occurred from January 1, 2008, to September 10, 2008, and from December 24, 2008, to December 31, 2008, and is 34 percent of total precipitation and applied irrigation. There was no drainage from any other lysimeter during 2008. Drainage has only occurred from the irrigated lysimeters. Total cumulative drainage from each irrigated lysimeter is 80.5 cm (31.7 in.) from Lysimeter B, 5.8 cm (2.3 in.) from Lysimeter D, 29.3 cm (11.5 in.) from Lysimeter F, and 12.3 cm (4.8 in.) from Lysimeter H (Figure 4-34).

Table 4-2. Area 3 Drainage Lysimeter Treatments in 2008

Lysimeter	Climate	Precipitation (mm)	Irrigation (mm)	Surface Vegetation
A	Natural precipitation	124	0	Bare-soil
B	3 times natural precipitation	124	249	Bare-soil
C	Natural precipitation	124	0	Invader species
D	3 times natural precipitation	124	249	Invader species
E	Natural precipitation	124	0	Native species
F	3 times natural precipitation	124	249	Native species
G	Natural precipitation	124	0	Native species
H	3 times natural precipitation	124	249	Native species

Figure 4-35 shows the total water storage for all eight lysimeters during the last 5 years. Water storage is calculated using TDR data. The two bare-soil lysimeters (Lysimeters A and B) have the highest water storage. Water storage in the vegetated lysimeters (Lysimeters C, D, E, F, G, and H) was elevated in the beginning of 2008, but most of this moisture was removed by ET by the early summer. Water storage in the irrigated lysimeters increased in late 2008.

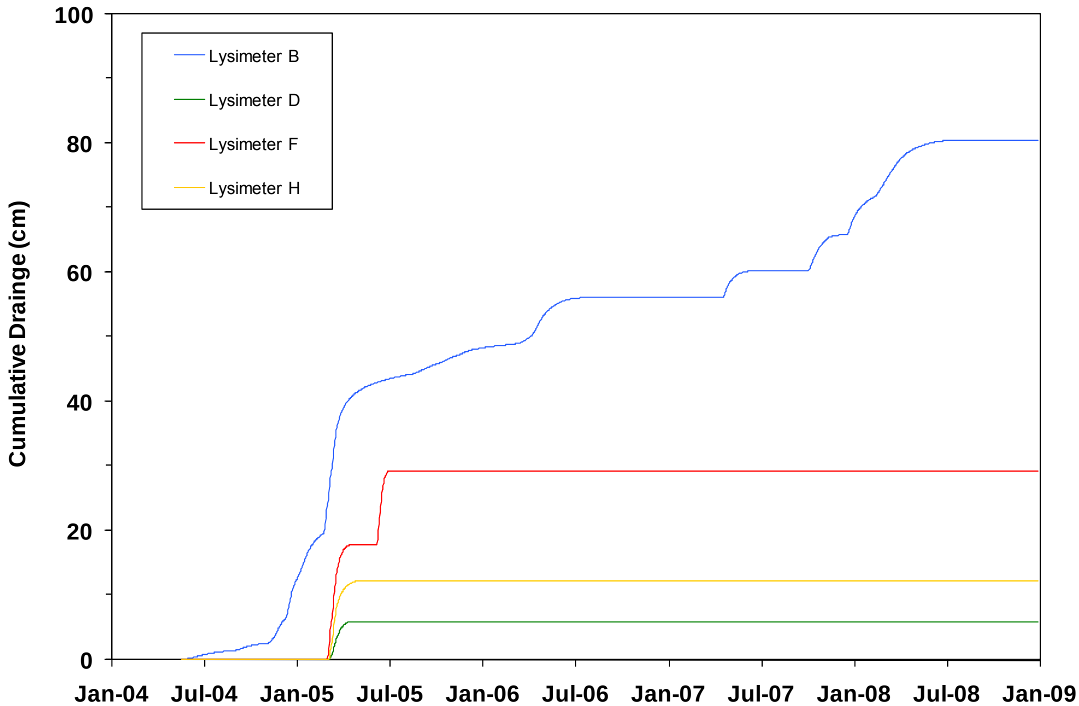
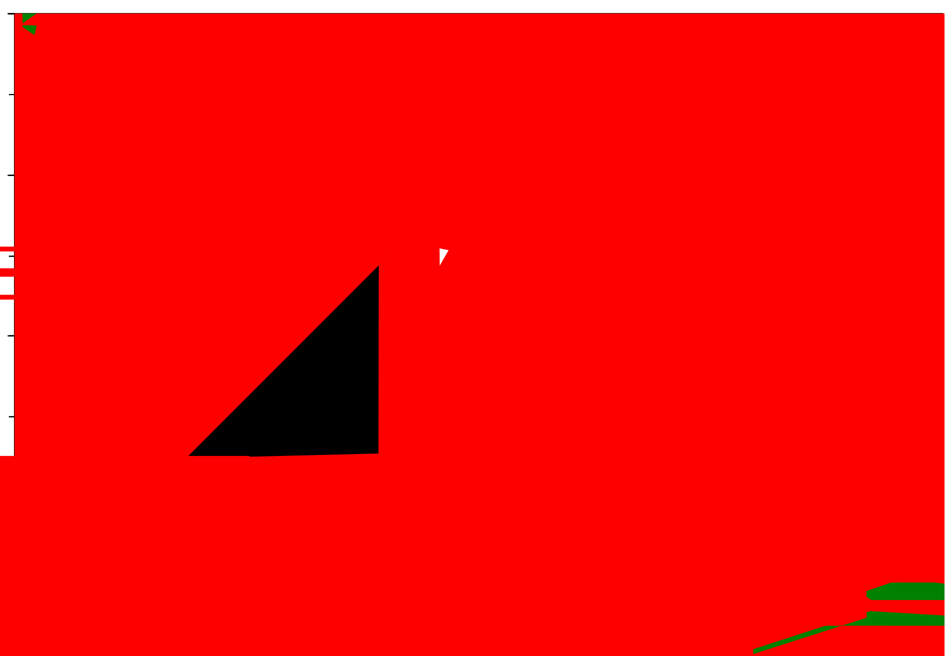


Figure 4-34 Cumulative Drainage from the Drainage Lysimeters



4.6.6 Waste Cover Subsidence

Subsidence monitoring is conducted to ensure that subsidence features are repaired to prevent the development of preferential water migration pathways through the waste covers. Subsidence monitoring also helps ensure that vadose zone monitoring data are representative of the entire RWMS. Typically as small depressions or cracks are observed in the covers, they are filled before large subsidence features develop. No large subsidence features were observed during 2008.

4.6.7 Biota Monitoring Data

There was not any biota monitoring at either the Area 3 or Area 5 RWMS in 2008.

5.0 CONCLUSIONS

The 2008 environmental and operational monitoring data from the Area 3 and Area 5 RWMSs indicate that these facilities are performing as expected for the long-term isolation of buried waste. Direct radiation exposure data indicate a rate that is well below any dose of concern, and air monitoring data indicate that concentrations of radioactive materials in air remain below any concentrations of concern. Groundwater and vadose zone monitoring data indicate that the groundwater beneath the Area 5 RWMS is unaffected by the waste disposal operations. Soil gas monitoring data at GCD-05U indicate little natural migration of tritium away from the waste at this disposal borehole. Vadose zone monitoring data indicate that vegetation prevents infiltrating precipitation from percolating deep into the soil by returning the moisture to the atmosphere by ET. Long-term vadose zone monitoring data from the weighing lysimeters indicate no drainage through the bottoms of the vegetated lysimeters. All 2008 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility PAs.

THIS PAGE INTENTIONALLY LEFT BLANK

6.0 REFERENCES

Air Resources Laboratory, Special Operations and Research Division, 2009. *Special Operations and Research Web Site*. http://www.sord.nv.doe.gov. [Accessed May 14, 2009].

Allen, R. G., I. A. Walter, R.L. Elliot, T. A. Howell, D. Itenfisu, M. E. Jensen, and R. L. Snyder, 2005. *The ASCE Standardized Reference Evapotranspiration Equation.* American Society of Civil Engineers.

ARL/SORD, see Air Resources Laboratory, Special Operations and Research Division.

Bechtel Nevada, 2006. *Characterization Report for the 92-Acre Area of the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nevada.* DOE/NV/11718--1154. June 2006.

———, 2005a. *Site Characterization and Monitoring Data from Area 5 Pilot Wells*. DOE/NV/11718--1067. September 2005.

———, 2005b. *Site Characterization Data from the U-3ax/bl Exploratory Boreholes.* DOE/NV/11718--003-Rev1. Bechtel Nevada. August 2005.

———, 2005c. *Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site.* DOE/NV/11718--449 REV2. June 2005.

———, 2003. *Nevada Test Site Routine Radiological Environmental Monitoring Plan.* DOE/NV/11718--804. Bechtel Nevada. June 2003.

———, 2001. *Closure Report for Corrective Action Unit 110: Area 3 RWMS U-3ax/bl Disposal Unit, Nevada Test Site, Nevada.* DOE/NV/11718--743. June 2001.

———, 1998. *Hydrogeologic Characterization of the Unsaturated Zone at the Area 3 Radioactive Waste Management Site.* Volume 1: “Data Interpretations.” Volume 2: “Data.” DOE/NV/11718--210. February 1998.

Blout, D. O., W. S. Birchfiel, D. P. Hammermeister, K. A. Zukosky, and K. D. Donnelson, 1995. *Site Characterization Data from Area 5 Science Boreholes, NTS, Nye County, Nevada.* DOE/NV/11432--170. Reynolds Electrical & Engineering Co., Inc. February 1995.

BN, see Bechtel Nevada.

Campbell, G. S., 1977. *An Introduction to Environmental Biophysics.* Heidelberg Science Library. Springer-Verlag, New York.

Cochran, J. R., W. E. Beyeler, D. A. Brosseau, L. H. Brush, T. J. Brown, B. Crowe, S. H. Conrad, P. A. Davis, T. Ehrhorn, T. Feeney, B. Fogleman, D. P. Gallegos, R. Haaker, D. Kalinina, L. L. Price, D. P. Thomas, and S. Wirth, 2001. *Compliance Assessment Document for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site.* Sandia Report SAND2001-2977. Sandia National Laboratories. September 2001.

Desotell, L. T., D. B. Hudson, D. Anderson, V. Yucel, G. Shott, G. L. Pyles, and J. T. Carilli, 2007. "Performance of Evapotranspirative Covers Under enhanced Precipitation: Preliminary Data." In: *Proceedings of the Waste Management '07 Conference*. February 26–March 1, 2007. Tucson, Arizona.

Desotell, L. T., D. B. Hudson, V. Yucel, and J. T. Carilli, 2006. "Use of Long-Term Lysimeter Data in Support of Shallow Land Waste Disposal Cover Design." In: *Proceedings of the Waste Management '06 Conference*. February 26 to March 2, 2006. Tucson, Arizona.

Doorenbos, J., and W. O. Pruitt, 1977. *Guidelines for Predicting Crop Water Requirements.* FAO Irrigation and Drainage Paper No. 24, 2d ed. U.N. Food and Agricultural Organization. Rome, Italy.

Levitt, D. G., and V. Yucel. 2002. "Potential Groundwater Recharge and the Effects of Soil Heterogeneity on Flow at Two Radioactive Waste Management Sites at the Nevada Test Site." In: *Proceedings of the 2002 International Groundwater Symposium*. March 25–28, 2002. Berkeley, California.

Levitt, D. G., M. J. Sully, B. L. Dozier, and C. F. Lohrstorfer, 1999. "Determining the Performance of an Arid Zone Radioactive Waste Site Through Site Characterization, Modeling, and Monitoring." In: *Proceedings of the Waste Management '99 Conference*. February 28–March 4, 1999. Tucson, Arizona.

National Security Technologies, LLC, 2009. *Nevada Test Site 2008 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site.* DOE/NV/25946--619. January 2009.

———, 2008a. *Nevada Test Site Environmental Report 2007.* DOE/NV/25946--543. September 2008.

———, 2008b. *Closure Plan for the Area 5 Radioactive Waste Management Site at the Nevada Test Site.* DOE/NV/25946--553. September 2008.

———, 2007. *Characterization Report Area 3 Radioactive Waste Management Site Nevada Test Site, Nevada.* DOE/NV/25946--080. March 2007.

NSTec, see National Security Technologies, LLC.

Plannerer, H. N., 1996. *Siting Criteria for Angle Drilling Under the U-3ah/at Disposal Unit*. Los Alamos National Laboratory Report LA-UR-96-1679. May 13, 1996.

Reynolds Electrical & Engineering Co., Inc., 1993a. *Hydrogeologic Data for Existing Excavations at the Area 5 RWMS, Nevada Test Site, Nye County, Nevada*. DOE/NV/11432--40. December 1993.

———, 1993b. *Hydrogeologic Data for Science Trench Boreholes at the Area 5 RWMS, Nevada Test Site, Nye County, Nevada.* December 1993.

Shott, G. J., L. E. Barker, S. E. Rawlinson, M. J. Sully, and B. A. Moore, 1998. *Performance Assessment for the Area 5 RWMS at the NTS, Nye County, Nevada.* Revision 2.1. DOE/NV/11718--176. Bechtel Nevada. January 1998.

Shott, G. J., V. Yucel, M. J. Sully, L. E. Barker, S. E. Rawlinson, and B. A. Moore, 1997. *Performance Assessment/Composite Analysis for the Area 3 RWMS at the NTS, Nye County, Nevada.* Revision 2.1. DOE/NV--491-REV 2.1. Bechtel Nevada. September 1997.

Snyder, K. E., R. D. Van Remortel, D. L. Gustafson, H. E. Huckins-Gang, J. J. Miller, S. E. Rawlinson, and S. M. Parsons, 1995. *Surficial Geology and Landscape Development in Northern Frenchman Flat, Area 5 RWMS, DOE NTS. Interim Summary and Soil Data Report.* DOE/NV/25946--466. Raytheon Services Nevada. September 1995.

Tyler, S. W., J. B. Chapman, S. H. Conrad, D. P. Hammermeister, D. O. Blout, J. J. Miller, M. J. Sully, and J. M Ginanni, 1996. "Soil-Water Flux in the Southern Great Basin, United States: Temporal and Spatial Variations Over the Last 120,000 Years." *Water Resources Research.* Vol. 32, No. 6, pp. 1481–1499.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2008. *Post-Closure Inspection and Monitoring Report for Corrective Action Unit 110: Area 3 WMD U-3ax/bl Crater, Nevada Test Site, Nevada, For the Period July 2007–June 2008.* DOE/NV--1284. August 2008.

Warren, R. W., and R. F. Grossman, 2008. *National Emission Standards for Hazardous Air Pollutants, Calendar Year 2007.* DOE/NV/ 25946--483. National Security Technologies, LLC. June 2008.

THIS PAGE INTENTIONALLY LEFT BLANK

DISTRIBUTION LIST

U. S. Department of Energy	Copies
Jhon T. Carilli LLW Federal Sub-Project Director, Waste Management Project U.S. Department of Energy National Nuclear Security Administration Nevada Site Office P.O. Box 98518 M/S 505 Las Vegas, NV 89193-8518	4
E. Frank Di Sanza Federal Project Director, Waste Management Project U.S. Department of Energy National Nuclear Security Administration Nevada Site Office P.O. Box 98518 M/S 505 Las Vegas, NV 89193-8518	1
Kenneth M. Small RCRA Program Manager, Waste Management Project U.S. Department of Energy National Nuclear Security Administration Nevada Site Office P.O. Box 98518 M/S 505 Las Vegas, NV 89193-8518	1
U.S. Department of Energy National Nuclear Security Administration Nevada Site Office Public Reading Facility c/o Nuclear Testing Archive P.O. Box 98521, M/S 400 Las Vegas, NV 89193-8521	2 (CD)
U.S. Department of Energy National Nuclear Security Administration Nevada Site Office Technical Library P.O. Box 98518, M/S 505 Las Vegas, NV 89193-8518	1 (CD)
U.S Department of Energy Office of Scientific and Technical Information P.O. Box 62 Oak Ridge, TN 37831-0062	1 digital file

National Security Technologies, LLC

Environmental Management Library National Security Technologies, LLC P.O. Box 98518, M/S NLV094 Las Vegas, NV 89193-8521	1 digital file
David B. Hudson National Security Technologies, LLC P.O. Box 98521, M/S NLV083 Las Vegas, NV 89193-8521	1
Theodore J. Redding National Security Technologies, LLC P.O. Box 98521, M/S NTS273 Las Vegas, NV 89193-8521	1
Gregory J. Shott National Security Technologies, LLC P.O. Box 98521, M/S NLV083 Las Vegas, NV 89193-8521	1
Alissa J. Silvas National Security Technologies, LLC P.O. Box 98521, M/S NLV022 Las Vegas, NV 89193-8521	1
Ronald W. Warren National Security Technologies, LLC P.O. Box 98521, M/S NTS273 Las Vegas, NV 89193-8521	1
Vefa Yucel National Security Technologies, LLC P.O. Box 98521, M/S NLV083 Las Vegas, NV 89193-8521	1