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NEVADA NATIONAL SECURITY SITE
2013 WASTE MANAGEMENT MONITORING REPORT
AREA 3 AND AREA 5 RADIOACTIVE WASTE MANAGEMENT SITES

August 2014

Prepared for:

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

Prepared by:

National Security Technologies, LLC
Las Vegas, Nevada

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EXECUTIVE SUMMARY

Environmental monitoring data are collected at and around the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) within the Nevada National Security Site (NNSS). These data are associated with radiation exposure, air, groundwater, meteorology, and vadose zone. This report summarizes the 2013 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, 2013; 2014a; 2014b).

Direct radiation monitoring data indicate exposure levels at the RWMSs are within the range of background levels measured at the NNSS. Slightly elevated exposure levels outside the Area 3 RWMS are attributed to nearby historical aboveground nuclear weapons tests. Air monitoring data show tritium concentrations in water vapor and americium and plutonium concentrations in air particles are close to detection limits and background levels. The measured levels of radionuclides in air particulates and moisture are below Derived Concentration Standards for these radionuclides. Groundwater monitoring data indicate the groundwater in the uppermost aquifer beneath the Area 5 RWMS is not impacted by RWMS operations. Results of groundwater analysis from wells around the Area 5 RWMS were all below established investigation levels. Leachate samples collected from the leachate collection system at the mixed low-level waste cell were below established contaminant regulatory limits.

The 105.8 millimeters (mm) (4.17 inches [in.]) of precipitation at the Area 3 RWMS during 2013 is 30% below the average of 150.3 mm (5.92 in.), and the 117.5 mm (4.63 in.) of precipitation at the Area 5 RWMS during 2013 is 5% below the average of 123.6 mm (4.86 in.). 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. Automated vadose zone monitoring on Area 5 and Area 3 RWMS cell covers show no evidence of precipitation percolating through the cover to the waste. Moisture from precipitation did not percolate below 60 centimeters (cm) (2 feet [ft]) in the vegetated final cover on the U-3ax/bl disposal unit at the Area 3 RWMS, and moisture from precipitation and irrigation did not percolate below 45 cm (1.5 ft) on the 92-Acre Area final cover. Irrigation was applied to this cover for seed germination and plant growth. During 2013, there was no drainage through 2.4 meters (8 ft) of soil from the Area 3 drainage lysimeters that received only natural precipitation. Twenty percent of the applied precipitation and irrigation drained from the bare-soil drainage lysimeter that received 3-times natural precipitation.

All 2013 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.

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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
cm	centimeter(s)
Cs	cesium
DCS	Derived Concentration Standard
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
g/m^3	gram(s) per cubic meter
HDPE	high-density polyethylene
IL	investigation level
in.	inch(es)
kg/ha	kilogram(s) per hectare
km	kilometer(s)
kPa	kilopascal(s)
L	liter(s)
lb/A	pound(s) per acre
LLW	low-level waste
µg/L	microgram(s) per liter
m	meter(s)
m^3	cubic meter(s)
m/s	meter(s) per second
MDC	minimum detectable concentration
MEDA	Meteorological Data Acquisition

mg/L	milligram(s) per liter
mi	mile(s)
MLLW	mixed low-level waste
mm	millimeter(s)
mmhos/cm	millimho(s) per centimeter
mph	mile(s) per hour
mR	milliroentgen(s)
mR/yr	milliroentgen(s) per year
mrem	millirem(s)
mrem/yr	millirem(s) per year
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSA/NSO	U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
PA	performance assessment
PCB	polychlorinated biphenyls
pCi/L	picocurie(s) per liter
pCi/m^3	picocurie(s) per cubic meter
pCi/m^2/s	picocurie(s) per square meter per second
PSI	pound(s) per square inch
PST	Pacific Standard Time
Pu	plutonium
RCRA	Resource Conservation and Recovery Act
RREMP	Routine Radiological Environmental Monitoring Plan
RTD	resistance temperature detector(s)
RTG	radioisotope thermoelectric generator(s)
RWMS	Radioactive Waste Management Site
SC	specific conductance
Sr	strontium
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 2013 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], 2007a) 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 *Closure Plan for the Area 3 Radioactive Waste Management Site at the Nevada Test Site* (NSTec, 2007b) and the *Closure Plan for the Area 5 Radioactive Waste Management Site at the Nevada Test Site* (NSTec, 2008) 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 to 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 performance assessments (PAs) (including no downward pathway), and evaluate the performance of monolayer-evapotranspirative waste covers
- Subsidence monitoring conducted to assess the stability of waste cover
- Biota monitoring to assess the engineered, planted, vegetated, final cover on closed waste cells and to evaluate the upward biological pathway for radionuclides

These data are collected by NSTec, as required by various DOE orders and requirements from the Code of Federal Regulations (CFR). For a detailed description of these regulatory drivers, refer to the closure plans for the Area 3 RWMS and the Area 5 RWMS (NSTec, 2007b; 2008). 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 436.1, “Departmental Sustainability”
- DOE O 458.1, “Radiation Protection of the Public and the Environment”
- 40 CFR 61, “National Emission Standards for Hazardous Air Pollutants”
- 40 CFR 264, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities”
- 40 CFR 265, “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 National Security Site (NNSS). Yucca Flat is an elongated, sediment-filled basin that trends roughly north-south; the north-south long axis extends approximately 27 kilometers (km) (17 miles [mi]), and the west-east 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, 2007a).

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 (1,214 and 1,509 ft) (BN, 2005a).

Based on a 21-year record from 1981 to 2001 at location Buster-Jangle Y (BJY) (4.5 km [2.8 mi] northwest of the Area 3 RWMS), typical daily air temperatures vary from −3 degrees Celsius (°C) (26 degrees Fahrenheit [°F]) to 12°C (54°F) during the winter months of December, January, and February and from 14°C (57°F) to 34°C (94°F) during the summer months of June, July, and August. The average winter temperature is 4°C (40°F), and the average summer temperature is 24°C (75°F). During this 21-year period, the maximum observed temperature was 43.3°C (110°F) and the minimum observed temperature was −20°C (−4°F). Average relative humidity is 53% at 4:00 Pacific Standard Time (PST), 28% at 10:00 PST, 26% at 16:00 PST, and 45% at 22:00 PST. January has the highest relative humidity of 67% at 4:00 PST, 42% at 10:00 PST, 43% at 16:00 PST, and 62% at 22:00 PST. July has the lowest relative humidity of 40% at 4:00 PST, 19% at 10:00 PST, 17% at 16:00 PST, and 30% at 22:00 PST. The maximum wind gust observed at BJY during this 21-year period was 29.3 meters per second (m/s) (65.6 miles per hour [mph]) in 1987 (Soule, 2006). The average annual precipitation at BJY during the 53-year period from 1961 through 2013 is 159.8 millimeters (mm) (6.29 inches [in.]). Typically low intensity, longer duration storms occur during the winter, and thunderstorms occur during the late summer. February has the most precipitation, and June has the least precipitation (Air Resources Laboratory, Special Operations and Research Division [ARL/SORD], 2014). Annual reference evapotranspiration (ET_{ref}) at the Area 3 RWMS, calculated using local meteorology data, is approximately 10 times the annual average precipitation (Desotell et al., 2007).

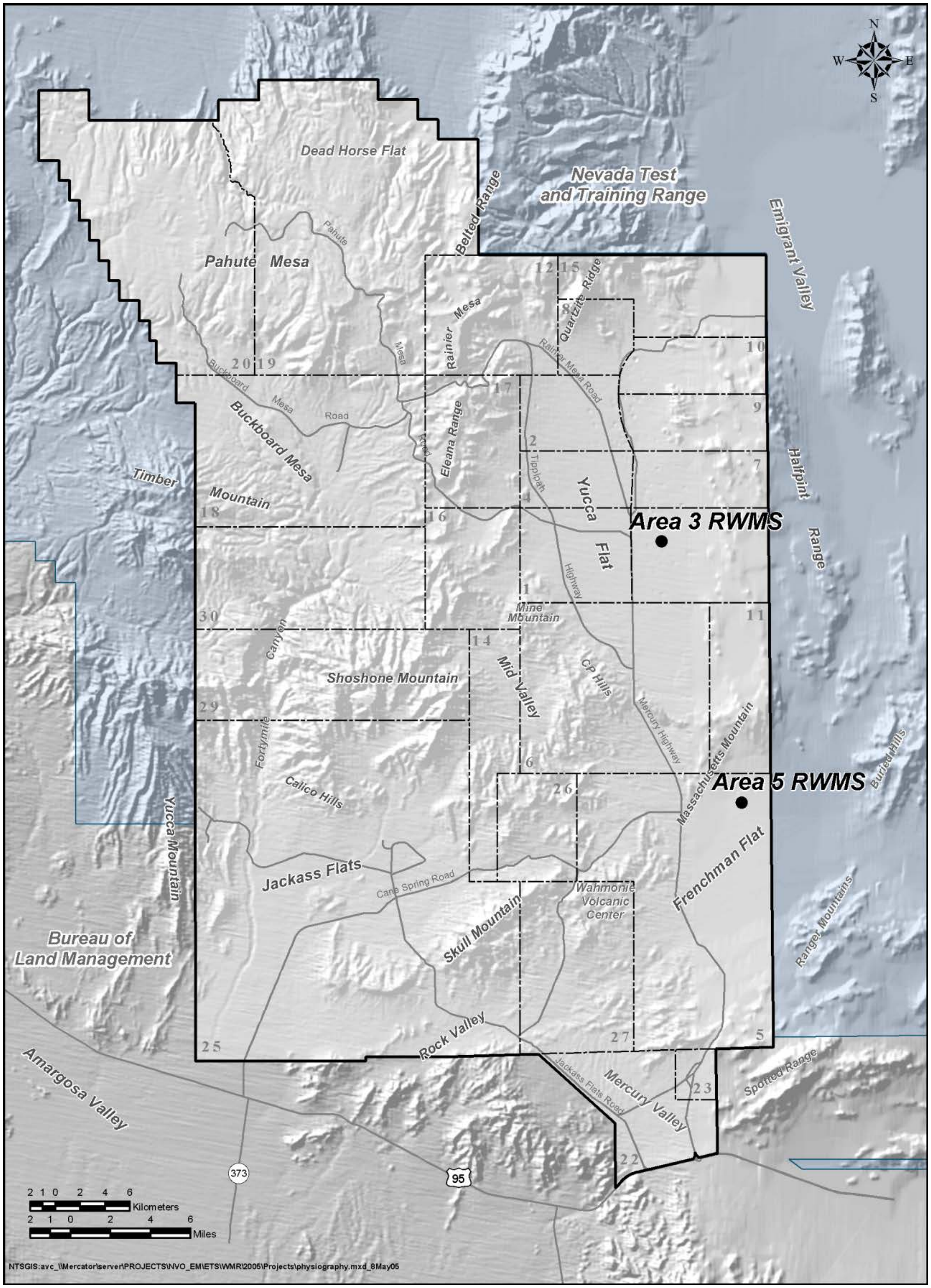

Figure 2-1 Location of the Area 3 and Area 5 RWMSs

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 NNSS. 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 (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 235.9 m (774.0 ft) at the southeast corner of the RWMS (Well UE5PW-1), 256.5 m (841.5 ft) at the northeast corner (Well UE5PW-2), and 271.6 m (891.1 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, 2005b). The water table beneath the Area 5 RWMS is extremely flat with flow velocities of less than 0.1 m/year (0.33 ft/year). The average groundwater elevation measured at these wells in 2013 is 733.6 m (2,407 ft) AMSL.

Based on a 21-year record from 1981 to 2001 at location Well 5B (6.4 km [4 mi] south of the Area 5 RWMS), typical daily air temperatures vary from −4°C (25°F) to 14°C (57°F) during the winter months of December, January, and February and from 15°C (59°F) to 37°C (99°F) during the summer months of June, July, and August. The average winter temperature is 5°C (41°F), and the average summer temperature is 26°C (79°F). During this 21-year period, the maximum observed temperature was 46°C (115°F) and the minimum observed temperature was −21°C (−6°F). Average relative humidity is 46% at 4:00 PST, 25% at 10:00 PST, 20% at 16:00 PST, and 37% at 22:00 PST. January has the highest relative humidity of 65% at 4:00 PST, 46% at 10:00 PST, 34% at 16:00 PST, and 58% at 22:00 PST. June has the lowest relative humidity of 32% at 4:00 PST, 14% at 10:00 PST, 12% at 16:00 PST, and 21% at 22:00 PST. The maximum wind gust observed at Well 5B during this 21-year period was 29.8 m/s (66.7 mph) in 1988 (Soule, 2006). The average annual precipitation at Well 5B during the 50-year period from 1964 through 2013 is 122.4 mm (4.82 in.). Typically low intensity, longer duration storms occur during the winter, and thunderstorms occur during the late summer. February has the most precipitation, and June has the least precipitation (ARL/SORD, 2014). Annual ET_{ref} at the Area 5 RWMS, calculated using local meteorology data, is approximately 12 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% 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 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 161 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 hydraulic gradient in the static region is zero. The static region is between approximately 49 and 119 m (161 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 soil 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% of the annual rainfall at Area 5, based on one-dimensional modeling results (Desotell et al., 2006).

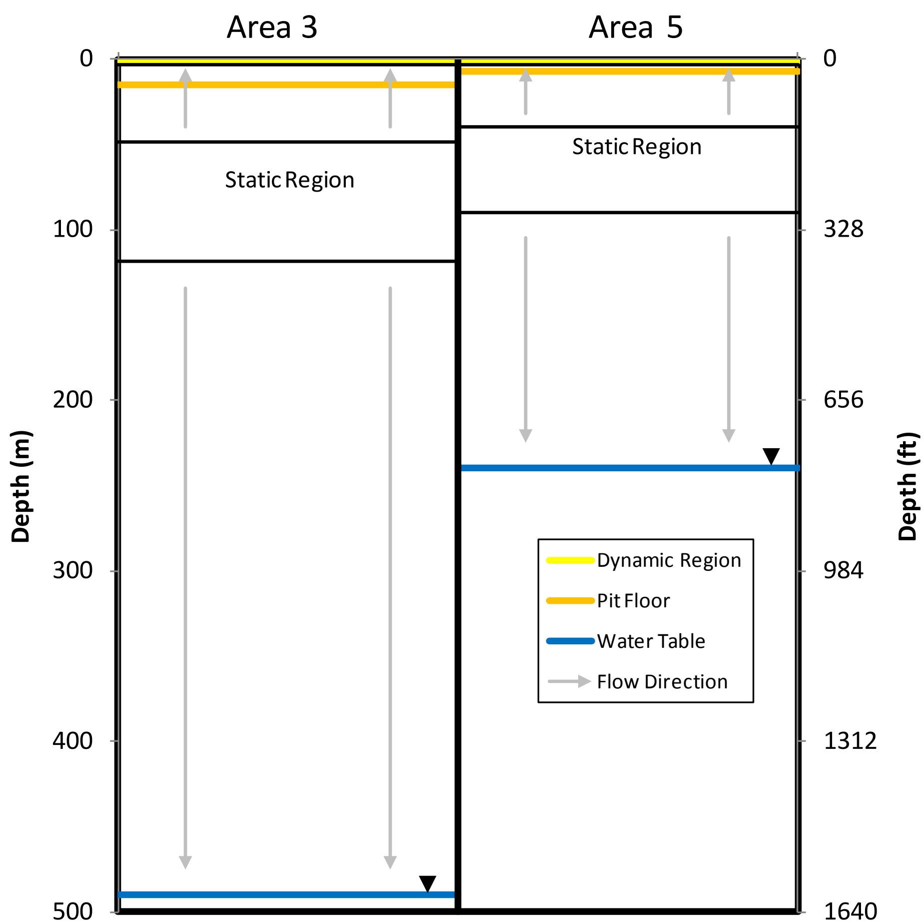

Figure 2-2 Vadose Zone Conceptual Models of the Area 3 and Area 5 RWMSs

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 low-level waste (MLLW) that is generated at the NNSS, from DOE offsite locations, and from other approved offsite generators.

3.1 AREA 3 RWMS

The Area 3 RWMS covers approximately 51 hectares (126 acres). The area enclosed by a fence is used for waste disposal operations and covers approximately 49 hectares (121 acres). The Area 3 RWMS includes seven subsidence craters from underground nuclear testing: U-3ax, U-3bl, U-3ah, U-3at, U-3bh, U-3az, and U-3bg. At the time of formation, these seven craters ranged from 122 to 177 m (400 to 581 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth (Plannerer, 1996). Five of these subsidence craters were developed into three waste disposal units. Alluvium between craters U-3ax and U-3bl and between craters U-3ah and U-3at was excavated to form two large disposal units (U-3ax/bl and U-3ah/at). Crater U-3bh is also used for waste disposal. Craters U-3az and U-3bg are not used for waste disposal (Figure 3-1).

U-3bh and U-3ah/at are operational and can accept unclassified LLW but have not received any waste since 2006. U-3bh was originally used for disposal of contaminated soils from the Tonopah Test Range during 1997 and was later used for waste disposal from other approved generators. Disposal in U-3ah/at began in 1988 and has been used for disposal of bulk LLW from the NNSS and approved offsite generators.

U-3ax/bl received unclassified LLW and potential MLLW from 1968 to 1987. 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. U-3ax/bl was closed in 2000 by constructing an engineered, monolayer, vegetated, evapotranspiration (ET) cover under the Federal Facility Agreement and Consent Order between the Nevada Division of Environmental Protection and DOE. U-3ax/bl is identified as Corrective Action Unit [CAU] 110 and is permanently closed under the Resource Conservation and Recovery Act (RCRA) as a hazardous waste landfill. The RCRA equivalent cover is constructed of native alluvium at least 2.4 m (8 ft) thick planted with native plants. For details of the closure of CAU 110, refer to U.S. Department of Energy, Nevada Operations Office (2000; 2001) and BN (2001).

For a detailed description of the facilities at the Area 3 RWMS, refer to Shott et al. (1997) and NSTec (2007a).

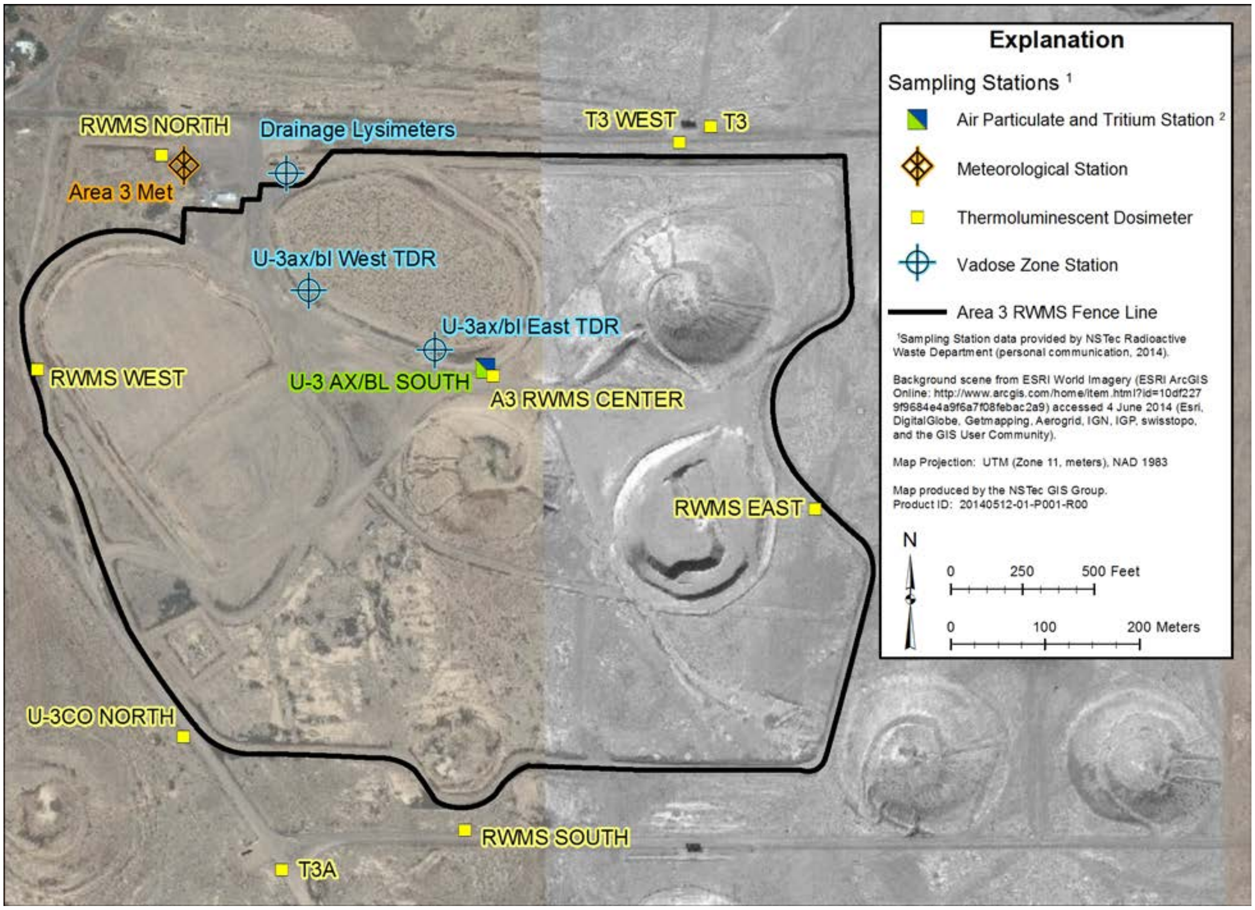

Figure 3-1 Monitoring Locations at the Area 3 RWMS

3.2 AREA 5 RWMS

The Area 5 RWMS (NNSS Area 5A) covers approximately 300 hectares (741 acres) with approximately 100 hectares (247 acres) enclosed by a fence and used for waste disposal operations. This area consists of 38 disposal cells (pits and trenches) and 13 greater confinement disposal (GCD) boreholes (Figure 3-2). The excavated disposal cells range in depth from 4.6 to 15 m (15 to 49 ft). Cell 18 (P18) was built with a RCRA-compliant double liner and leachate collection system over a geosynthetic clay liner. All other cells are unlined. GCD boreholes are 36 m (118 ft) deep, 3 to 3.7 m (10 to 12 ft) diameter uncased boreholes.

Waste disposal has occurred at the Area 5 RWMS since the early 1960s. Initially LLW and MLLW from the demolition of nuclear test sites and facilities at the NNSS were buried at the Area 5 RWMS. In 1978, DOE formally established the Area 5 RWMS, and it became a disposal site for other DOE complex facilities. During the 1980s the GCD boreholes were constructed and received high specific activity LLW and transuranic waste.

Currently, the 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 (2005b; 2006) and Cochran et al. (2001).

The approximately 92-Acre Area in the southern portion of the Area 5 RWMS was permanently closed by constructing an engineered, monolayer, vegetated evapotranspiration (ET) cover with a minimum 2.5 m (8.2 ft) thickness over the waste cells. After grading and soil preparation was completed, the cover surface was disked and seeded with a mixture of native species during October through December 2011. Construction was completed in January 2012. A solid set irrigation system was installed on the cover, and irrigation was applied during seed germination in the spring and fall of 2012 (Goodrich, 2010; U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office [NNSA/NSO], 2010; 2012; The Delphi Group and J. A. Cesare and Associates, 2012). On May 7, 2013, an initial vegetation survey was completed on the 92-Acre Area cover by sampling forty 100 m (328 ft) transects. Successful establishment of the seeded species was very low, and there were very high concentrations of invasive weed species (primarily *Halogeton glomeratus* (halogeton) and *Salsola tragus* (Russian thistle). Based on the interpretation of this survey, remedial revegetation was required to establish a viable plant community on the cover.

In October 2013, four plots were established on the north cover above P03 to investigate alternative, remedial seeding and mulching techniques. Half of this area was broadcast seeded and the other half was hydroseeded. The seed mix included native shrubs and grasses, including *Achnatherum hymenoides* (Indian ricegrass), *Ambrosia dumosa* (white bursage), *Atriplex canescens* (fourwing saltbush), *Atriplex confertifolia* (shadscale), *Baileya multiradiata* (desert marigold), *Elymus elymoides* (squirreltail), *Encelia farionosa* (brittlebush), *Ephedra nevadensis* (Nevada ephedra), *Larrea tridentata* (creosote), and *Sphaeralcea ambigua* (desert globemallow). Each seeded area was split and hydromulched at either 2,242 kilogram per hectare (kg/ha) (2,000 pounds per acre [lb/A]) or 1,681 kg/ha (1,500 lb/A). Precipitation was supplemented with irrigation on the four plots during November 2013. The remaining cover will be re-seeded later using the most effective technique. The engineered ET cover within the 92-Acre Area is approximately 18.2 hectares (45 acres). This area is identified as CAU 111. The 92-Acre Area ET cover closed 25 cells (P01, P02, P03, P04, P05, P06, P07, P09, P11,T01B, T02B, T03B, T04B, T06B, T07B, T01A, T02A, T03A, T04A, T04A-1, T05, T06A, T07A, T08, and T09),12 GCD boreholes (GCD-01, GCD-02, GCD-03, CGD-04, GCD-05, GCD-06, GCD-07, GCD-08, GCD-09, GCD-10, GCD-11, and GCD-12), and the CWI Trenches. P26 was also closed by the ET cover, but it is completely within P03. Four cells outside the 92-Acre Area (P08, P10, P12, and P15) are operationally inactive.

During 2013, waste was disposed in eight cells at the Area 5 RWMS: P12, P16, P17, P18, P19, P20, P21, and T13. All active cells contain LLW, and P18 also contains MLLW.

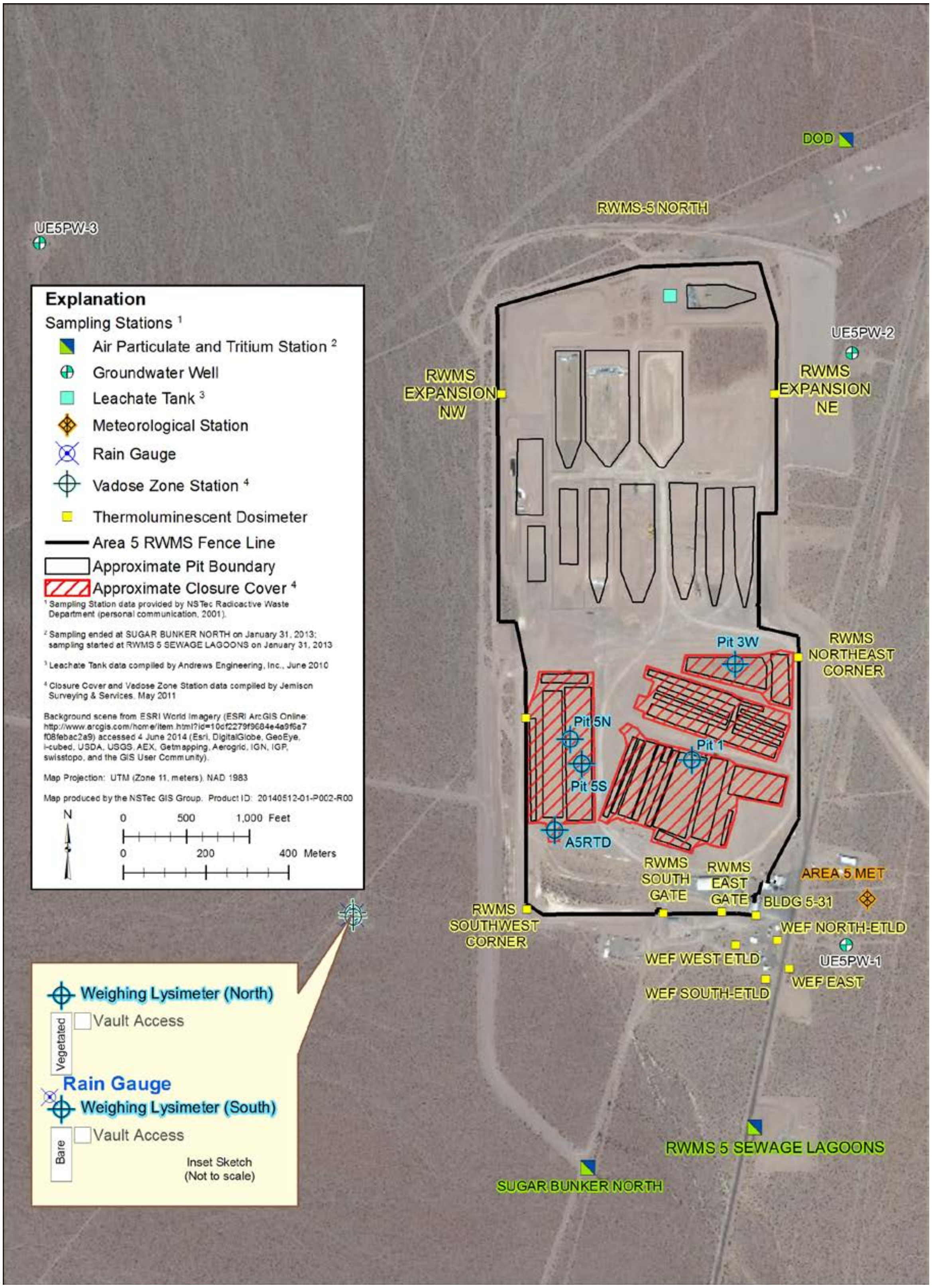

Figure 3-2 Monitoring Locations at the Area 5 RWMS

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. A summary of the types of environmental monitoring data at the Area 3 RWMS is provided in Table 4-1, and a summary of the types of environmental monitoring at the Area 5 RWMS is provided in Table 4-2. This report provides a general description and graphical representations of some of these data.

There were changes to the monitoring program during 2013. Air monitoring at Sugar Bunker North was discontinued on January 31, 2103, and air monitoring began at RWMS 5 Sewage Lagoons on January 31, 2013 (see Figure 3-2). This change was made to use line power available at RWMS 5 Sewage Lagoons.

Table 4-1 Environmental Monitoring at the Area 3 RWMS

Monitoring	Description
Radiation Exposure	• 3-month measurement interval at 9 locations • Thermoluminescent dosimeter (TLD) measurements of total radiation exposure
Air	• 2-week sample interval at 1 location inside Area 3 RWMS • Tritium concentration in atmospheric moisture • Gross alpha and beta concentration of particulates • Air particulate analysis on quarterly composites—gamma-emitting radionuclides, americium (Am), and plutonium (Pu) concentrations
Radon Flux	• Periodic radon flux measurements • Various locations on waste covers
Meteorology	• Daily and hourly measurements at 1 location • Air temperature at 3.0 m and 9.5 m • Relative humidity at 3.0 m and 9.5 m • Vapor pressure at 3.0 and 9.5 m • Wind speed and direction at 3.0 and 9.5 m • Barometric pressure • Precipitation—hourly, daily, and 5-minute rate • Solar radiation • Energy balance for ET calculation—net solar radiation, soil heat flux, soil temperature, soil water content
Vadose Zone	• Drainage lysimeters • 8 lysimeters at 1 location • 3 vegetation treatments (bare soil, invader species, and native species) with 2 irrigation treatments (precipitation and 3-times precipitation) • Daily and hourly measurements at each lysimeter—drainage, water content, water potential, and temperature • Daily water content profiles in final U-3ax/bl cover at 4 locations
Biota	• Periodic sampling of vegetation, small mammals, and animal burrow spoils for tritium and radionuclides • Annual plant density and plant cover measurements on each drainage lysimeter and the U-3ax/bl cover
Subsidence	• 8 surveyed subsidence monuments on U-3ax/bl cover with 2-year measurement interval • Cover inspections at 3-month interval

Table 4-2 Environmental Monitoring at the Area 5 RWMS

Monitoring	Description
Radiation Exposure	• 3-month measurement interval at 12 locations • TLD measurements of total radiation exposure
Air	• 2-week sample interval at 2 locations • Tritium concentration in atmospheric moisture • Gross alpha and beta concentration of particulates • Air particulate analysis on quarterly composites—gamma-emitting radionuclides, Am, and Pu concentrations
Radon Flux	• Periodic radon flux measurements • Various locations on waste covers
Groundwater	• 3 wells surrounding Area 5 RWMS • Water level measurement at 3-month interval • Groundwater samples at 6-month interval • Analysis for indicators of contamination—Field measurements of pH and specific conductance (SC), Total organic carbon (TOC), Total Organic halides (TOX), and tritium • Analysis of water chemistry—calcium, magnesium, potassium, sodium, iron, manganese, sulfate, chloride, fluoride, and silicate • Alkalinity
Meteorology	• Daily and hourly measurements at 1 location • Air temperature at 3.0 m and 9.5 m • Relative humidity at 3.0 m and 9.5 m • Vapor pressure at 3.0 and 9.5 m • Wind speed and direction at 3.0 and 9.5 m • Barometric pressure • Precipitation—hourly, daily, and 5-minute rate • Solar radiation • Energy balance measurements for ET calculation—net solar radiation, soil heat flux, soil temperature, soil water content
Vadose Zone	• 2 weighing lysimeters—bare soil and vegetated at 1 location • Direct measurement of ET • Daily water content, water potential, and temperature profiles at each lysimeter • Daily water content, water potential, and temperature profiles in 92-Acre Area cover at 4 locations • Daily water content below closed disposal cell at 4 locations • Soil temperature around radioisotope thermoelectric generators (RTGs)
Biota	• Periodic sampling of vegetation, small mammals, and animal burrow spoils for tritium, and particulate radionuclides • Annual plant density and plant cover measurements on each weighing lysimeter and the 92-Acre Area cover

Table 4-2 Environmental Monitoring at the Area 5 RWMS (continued)

Monitoring	Description
Subsidence	• 52 surveyed subsidence monuments on the 92-Acre Area cover at 1-year measurement interval • Quarterly subsidence inspections
Leachate	• Chemical analysis of P18 MLLW disposal cell leachate • Sampling and analysis when leachate collection tank is full

4.2 RADIATION EXPOSURE DATA

Direct radiation monitoring assesses and detects changes in the external radiation environment and measures gamma radiation levels near potential exposure sites. Performance objectives in DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual," require that LLW disposal facilities be sited, designed, operated, maintained, and closed, so a reasonable, expected, total effective dose equivalent from the facility to a representative member of the public is less than 25 millirem per year (mrem/yr). The effective dose equivalent is from all exposure pathways associated with the facility but does not include the dose from radon or background. The RWMSs are located well within the NNSS boundaries, so 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 continuously 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. The elements 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.

Figures 3-1 and 3-2 show TLD monitoring locations near the Area 3 and Area 5 RWMSs, respectively. A pair of TLDs is placed 1 ± 0.3 m (28 to 51 in.) above ground level (AGL) at each location and 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 cesium-137 (^{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 cells 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 measured in milliroentgens per year (mR/yr) during 2013 at nine locations inside and near the Area 3 RWMS range from 130 to 335 mR/yr (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 nearby historical aboveground nuclear weapons tests. This distribution of exposures indicates radionuclides in the Area 3 RWMS have a negligible contribution to total exposure for a hypothetical person residing at the Area 3 RWMS when compared to exposures resulting from historical aboveground nuclear weapons tests. Estimated daily exposure rates in mR/day from the quarterly exposure rate data at the Area 3 RWMS are within the range of exposure rates at NNSS background locations (Figure 4-2).

Between 1951 and 1971, 25 nuclear weapons tests were conducted within 6.3 km (3.9 mi) of the Area 5 RWMS. 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. One exposure rate from the quarterly exposure data at the Area 5 RWMS was above the range of exposures measured at NNSS background locations (Figure 4-3). This was at the RWMS Northwest Corner TLD location during the second quarter of 2004 and was due to a waste shipment being stored near the TLD prior to its disposal. All other measurements are within the range of background levels measured on the NNSS.

Comparisons of 2000 to 2013 direct radiation exposure data using TLDs from the two RWMSs with direct radiation data from NNSS background locations indicate that direct radiation exposure at the Area 3 and Area 5 RWMSs is generally low or declining (Figures 4-2 and 4-3).

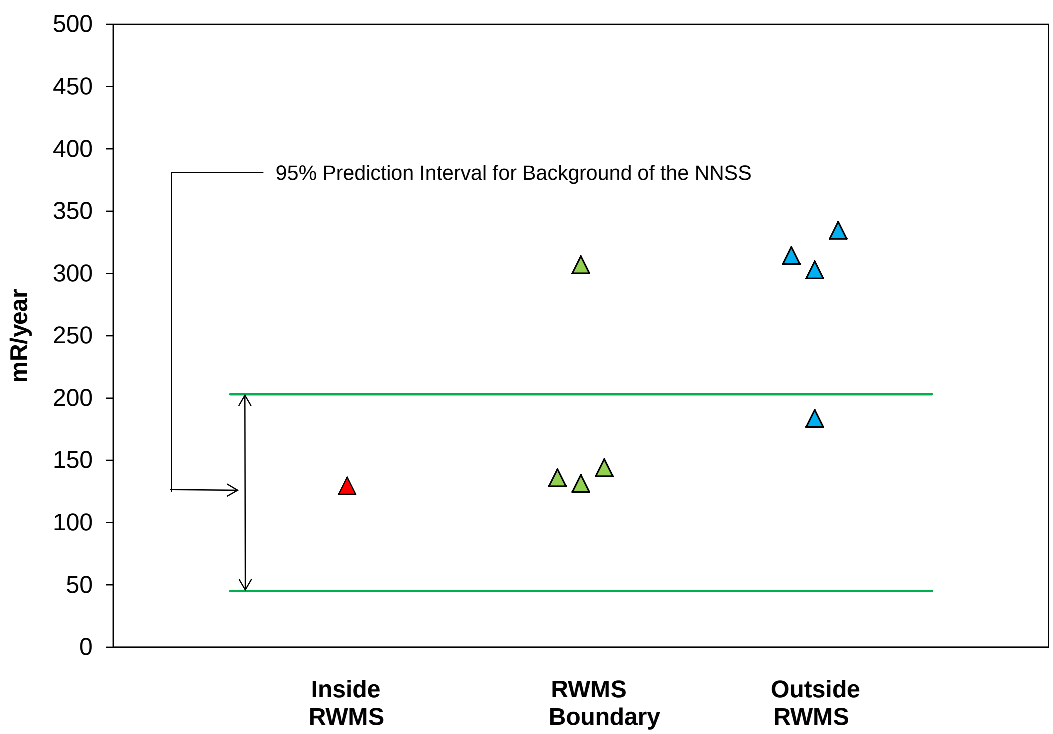

Figure 4-1 Annual Radiation Exposure Rates at the Area 3 RWMS during 2013

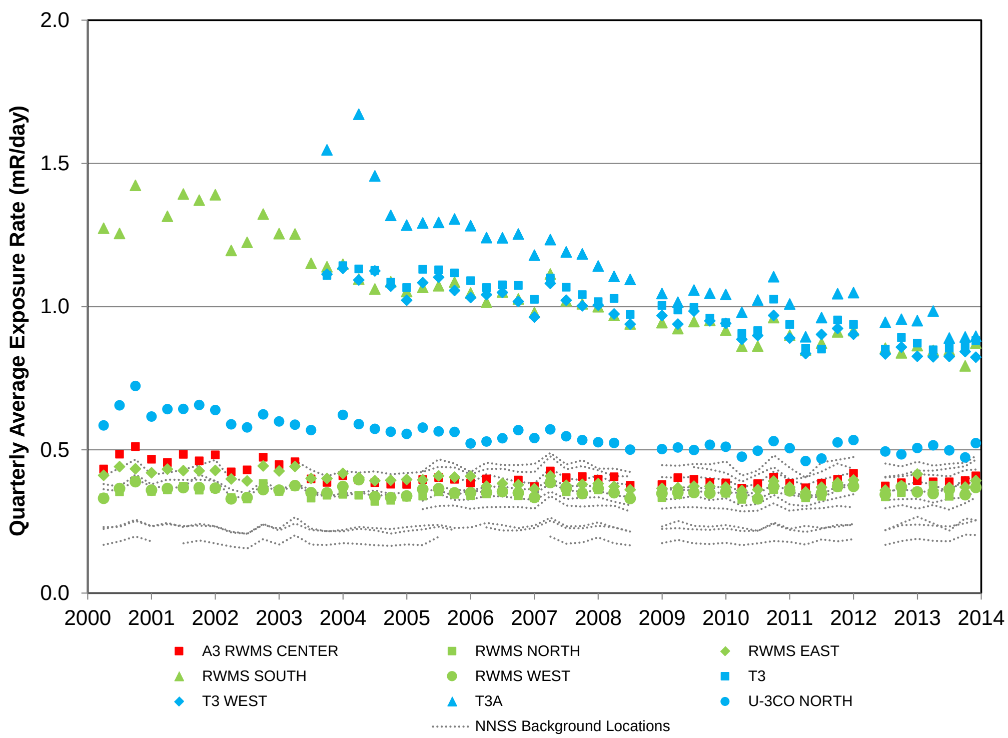

Figure 4-2 Quarterly Average Daily Exposure Rates at the Area 3 RWMS and NNSS Background TLD locations from 2000 through 2013

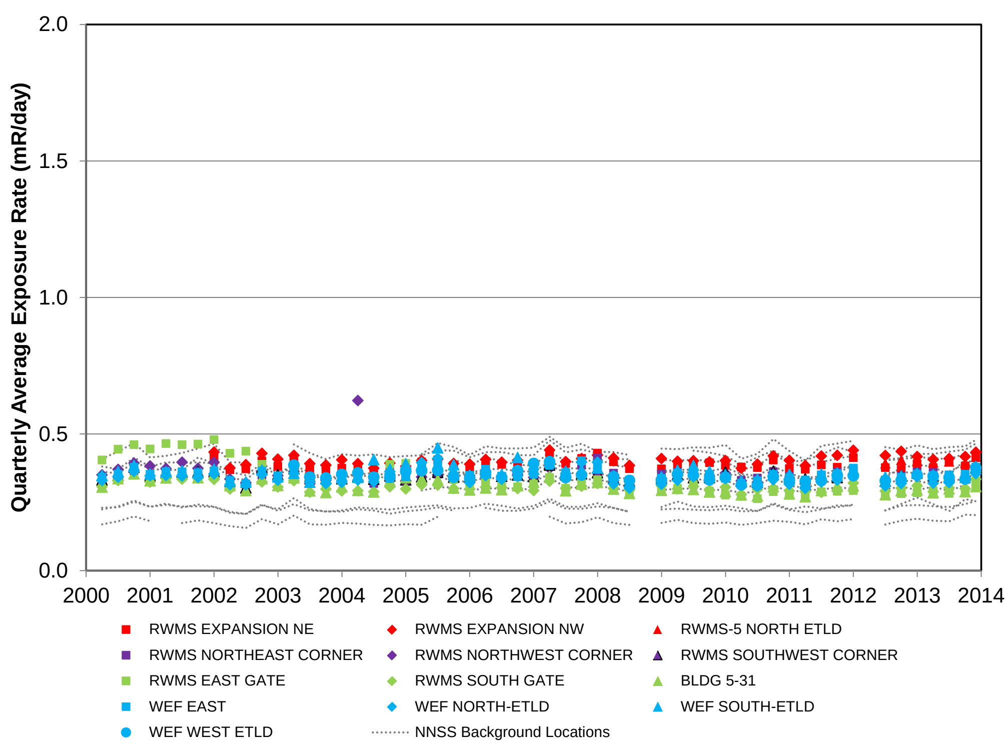

Figure 4-3 Quarterly Average Daily Exposure Rates at the Area 5 RWMS and NNSS Background TLD locations from 2000 through 2013

4.3 AIR MONITORING DATA

4.3.1 Tritium

Tritium is a highly mobile isotope of hydrogen that acts as a conservative tracer. It is 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 are drawn across a desiccant during each 2-week sample period to collect atmospheric moisture. Moisture is distilled from the desiccant, and tritium activity is measured by liquid scintillation.

Tritium was sampled at three air monitoring locations near the Area 3 RWMS during 2013 (Figure 3-1). These locations are U-3ax/bl South, Bilby Crater, and Kestrel Crater N. U-3ax/bl South measures radionuclide concentrations near the center of the Area 3 RWMS while Bilby Crater and Kestrel Crater N measure radionuclide concentrations in the prevailing wind directions at the Area 3 RWMS. Bilby Crater is approximately 1.2 km (0.75 mi) north of the Area 3 RWMS and Kestrel Crater N is approximately 1.5 km (0.9 mi) south of the Area 3 RWMS. Consistently higher radionuclide concentrations at U-3ax/bl South compared to Bilby Crater and Kestrel Crater N might indicate the Area 3 RWMS is the source of the elevated radionuclide concentrations while similar radionuclide concentrations would indicate the Area 3 RWMS is not a strong source of radionuclides.

Tritium was sampled at three air monitoring locations near the Area 5 RWMS during 2013 (Figure 3-2). These locations are DoD, Sugar Bunker N, and RWMS 5 Sewage Lagoons. Only two locations were sampled simultaneously. Monitoring ended at Sugar Bunker N and started at RWMS 5 Sewage Lagoons on January 31, 2013. This change was made to use line power instead of solar power and to move the sampler away from a heavily used dirt road that overloaded filters at the Sugar Bunker N location. The DoD station is approximately 1.0 km (0.6 mi) north-northeast of the center of the Area 5 RWMS, and the RWMS 5 Sewage Lagoons station is approximately 1.5 km (0.9 mi) south-southeast of the center of the Area 5 RWMS (Figure 3-2). These monitoring locations are generally in the prevailing wind directions and provide adequate environmental monitoring for the Area 5 RWMS.

During 2013, tritium concentrations at the Area 3 and Area 5 RWMSs ranged from −1.05 to 2.04 picocuries per cubic meter (pCi/m^3). Most results are below the minimum detectable concentration (MDC). All results are well below the DOE Derived Concentration Standard (DCS) (DOE-STD-1196-2011) for tritium adjusted to the 10 mrem/yr dose limit specified in DOE M 435.1 for the air pathway. This scaled DCS is the tritium concentration in air that results in a 10 mrem annual effective dose to a person breathing it for the entire year. In general, higher tritium concentrations occurred in June through October, but all concentrations were much lower than the DCS (Figure 4-4).

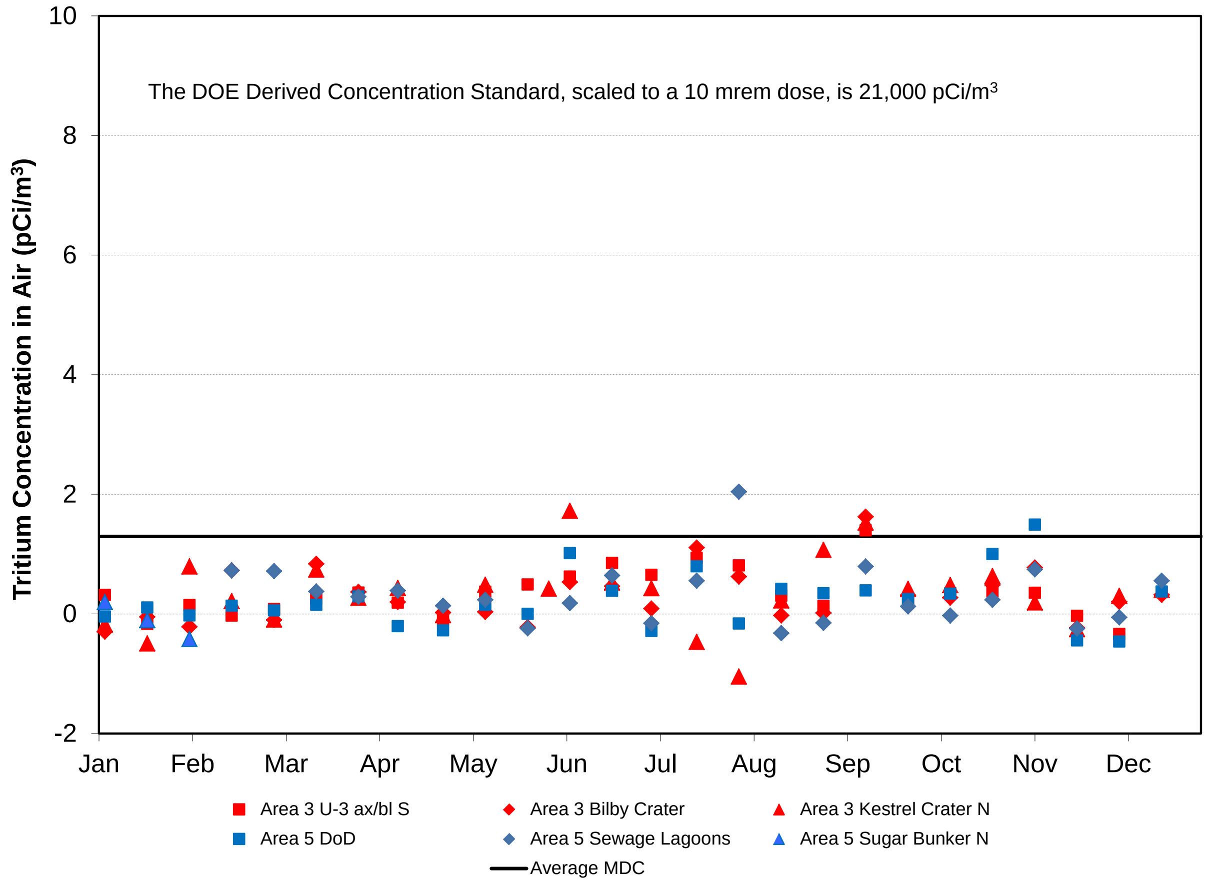

Figure 4-4 Tritium Concentration in Air at the Area 3 and Area 5 RWMSs during 2013

4.3.2 Particulates

Air particulate samples were collected every 2 weeks during 2013 at the same locations described above for tritium monitoring (Figures 3-1 and 3-2). Each sample was collected using a vacuum pump to draw approximately 1,700 m^3 (60,035 ft^3) of air through a glass-fiber filter with a collection efficiency of 99.99%. The air particulates are collected on the filter. Each filter was screened for gross alpha and gross beta radioactivity to provide early detection of any change in environmental concentrations of airborne radioactivity. Quarterly composites of the filters from each sampling location were analyzed by gamma spectroscopy for gamma-emitting radionuclides and by alpha spectroscopy for Am and Pu.

The results for ^{241}Am, ^{238}Pu, and $^{239+240}$Pu in air are provided in Figures 4-5, 4-6, and 4-7. Am and Pu concentrations tend to be slightly higher at the Area 3 RWMS compared with those at the Area 5 RWMS. The third quarter composite result from U-3ax/bl South had elevated Am and Pu, but this did not continue into the fourth quarter as expected if this elevated measurement was related to waste at the Area 3 RWMS. The single elevated value is probably related to a discrete, physical disturbance of the fallout from nearby, historical atmospheric tests. All results are well below the 10 mrem/year adjusted DCS for each radionuclide.

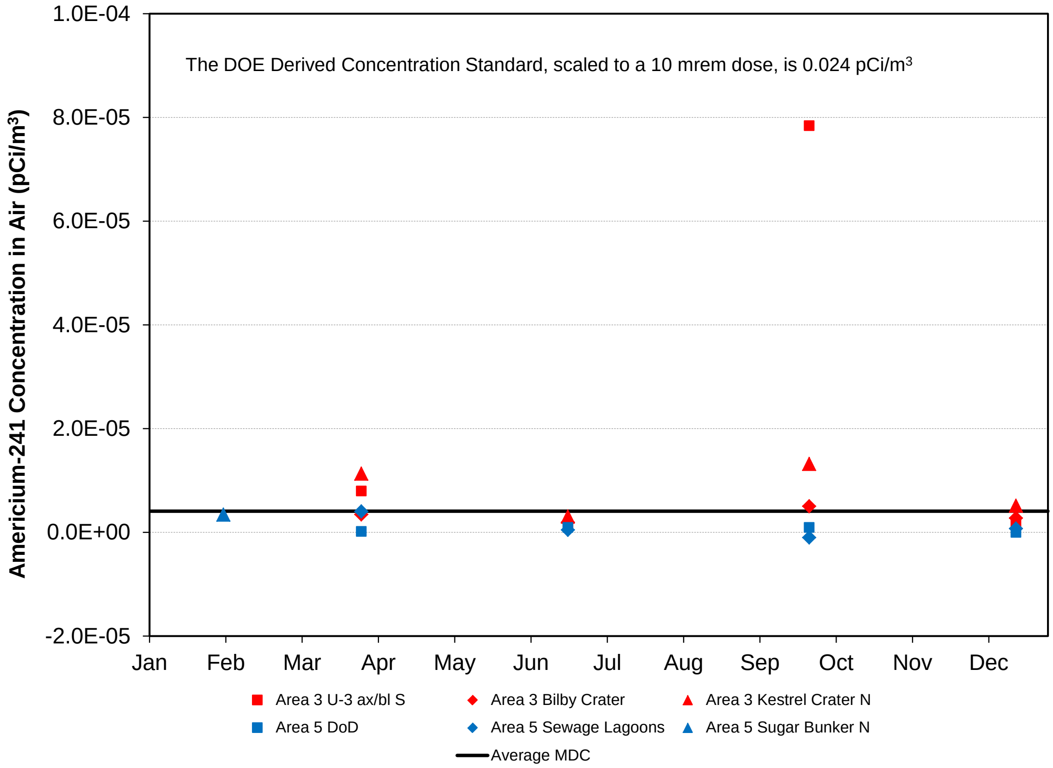

Figure 4-5 Concentration of ^{241}Am in Air at the Area 3 and Area 5 RWMSs during 2013

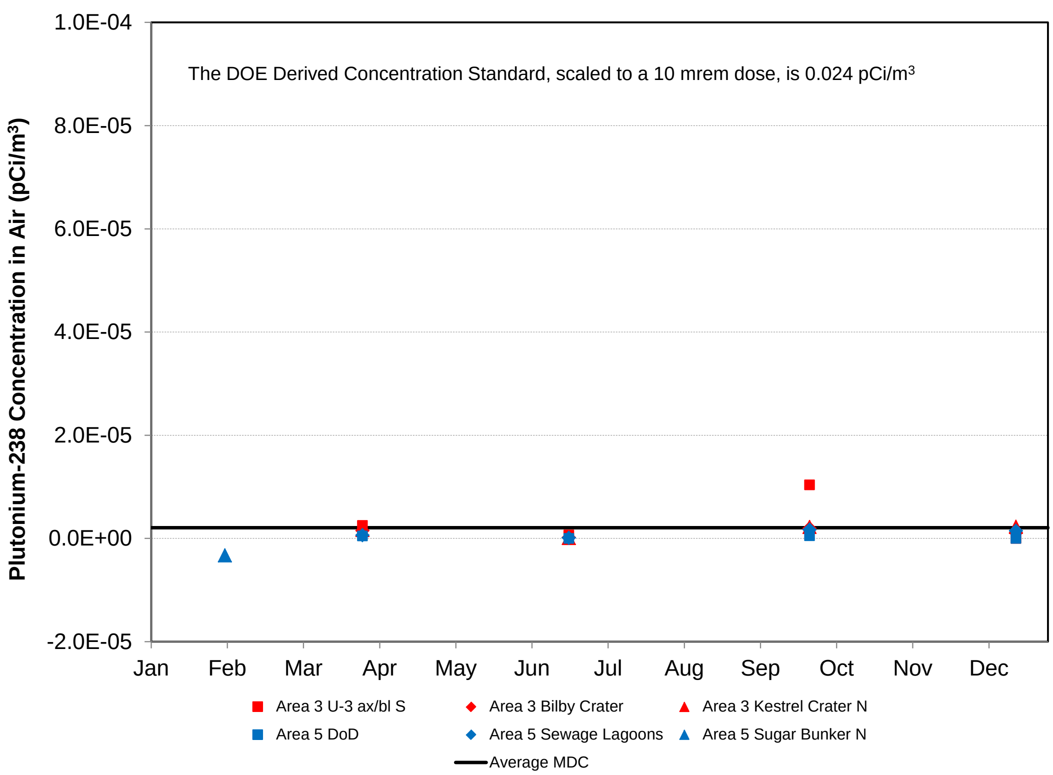

Figure 4-6 Concentration of ^{238}Pu in Air at the Area 3 and Area 5 RWMSs during 2013

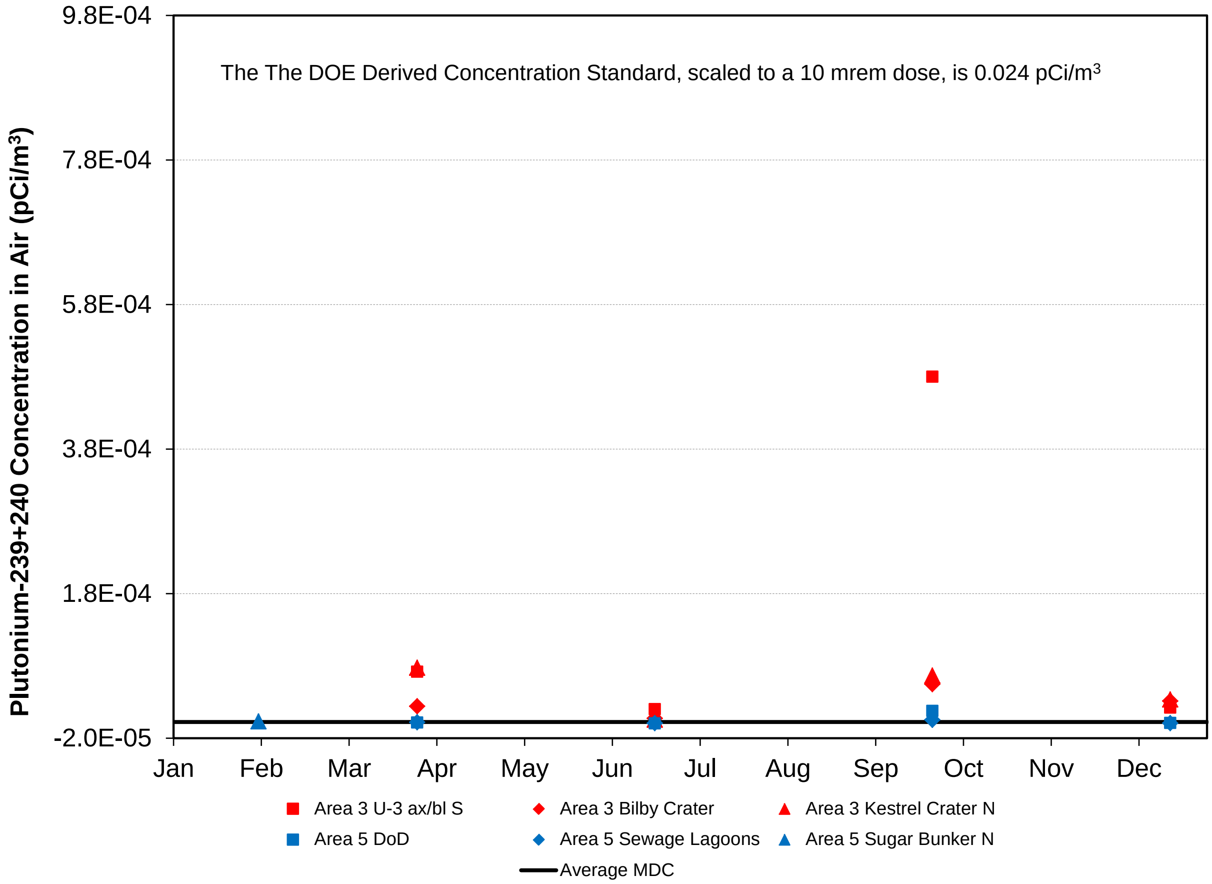

Figure 4-7 Concentration of $^{239+240}$Pu in Air at the Area 3 and Area 5 RWMSs during 2013

4.3.3 Radon

The performance objective from DOE M 435.1-1, "Radioactive Waste Management Manual," for radon emissions from DOE radioactive waste facilities is 20 picocuries per square meter per second (pCi/m^2/s). Radon flux was measured at multiple locations at the Area 5 RWMS and at an undisturbed, control site outside the Area 5 RWMS during 2013 (Figure 4-8). No measurements were collected at the Area 3 RWMS during 2013. Measurements were collected from December 31, 2013, to January 7, 2014, 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.

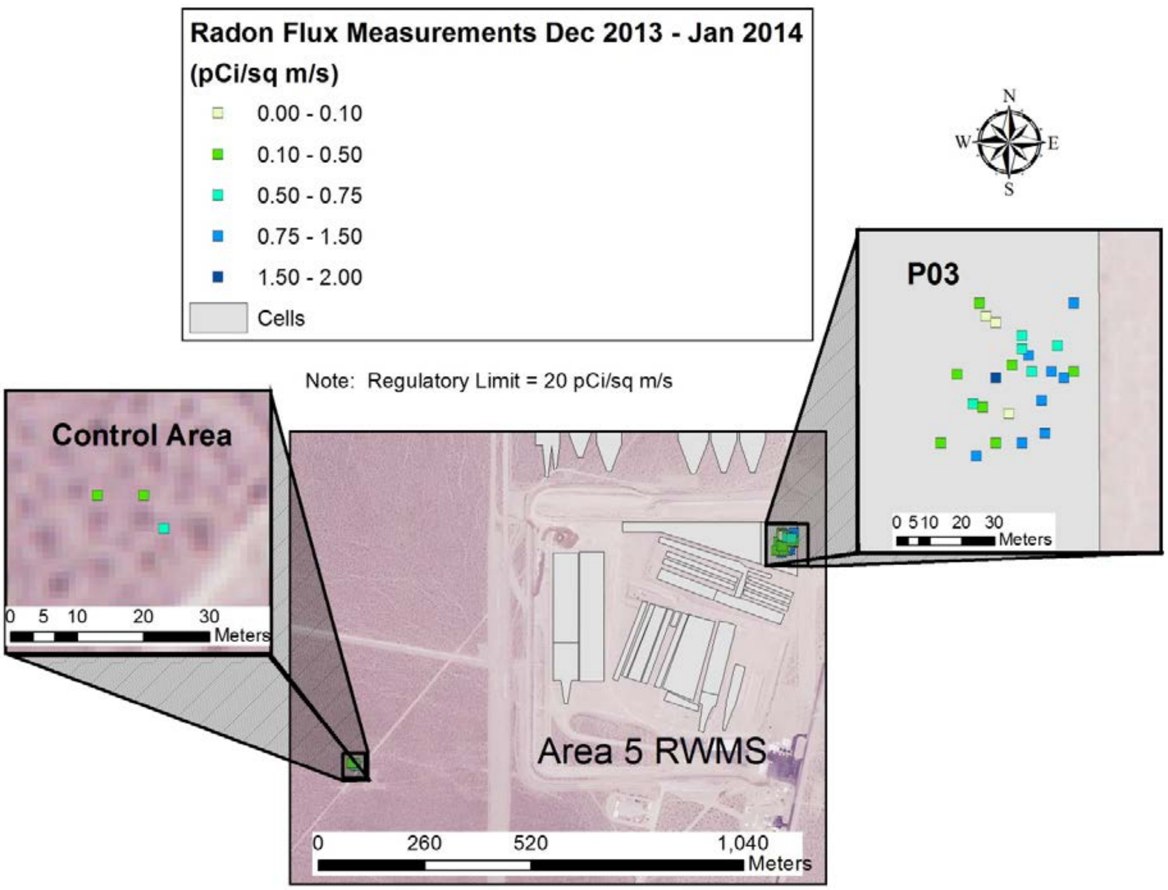

Figure 4-8 Radon Flux Measurement Locations at Area 5 RWMS

Radon flux results taken on both the Area 3 and Area 5 RWMSs over the past 11 years are summarized in Figure 4-9. Radon fluxes through the soil surface remained relatively low. All radon flux results were at least 5 times lower than the regulatory limit, and there are no apparent trends.

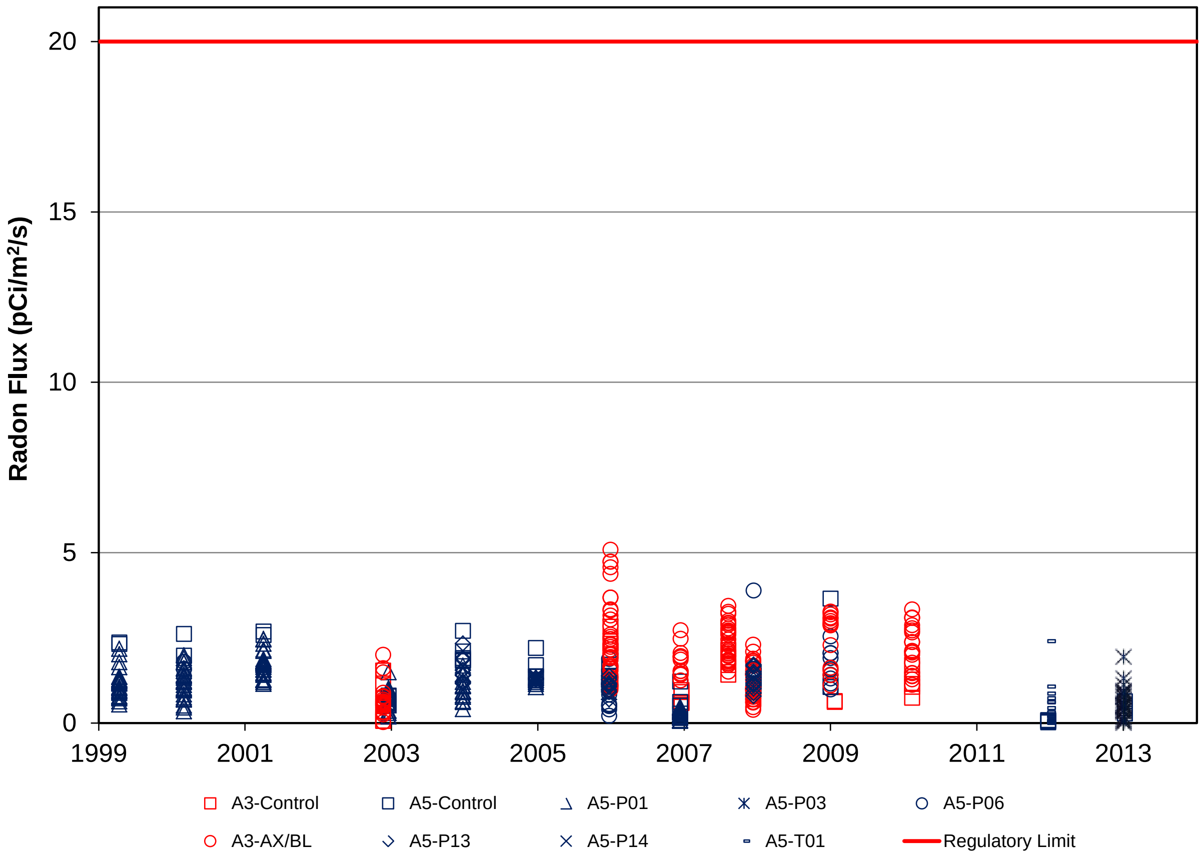

Figure 4-9 Radon Flux Measurements from 2003 through 2013

4.4 GROUNDWATER MONITORING DATA

4.4.1 Groundwater Monitoring at the Pilot Wells

Three wells (UE5PW-1, UE5PW-2, and UE5PW-3) were drilled around the perimeter of the Area 5 RWMS in 1993 (see Figure 3-2). These wells are sampled twice a year to monitor the groundwater below the Area 5 RWMS. Groundwater samples were collected on March 5 and August 13, 2013. Investigation levels (ILs) 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 2013 are summarized in Table 4-3. 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 National Security Site 2013 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site* (NSTec, 2014a).

Table 4-3 Investigation Levels and Results from 2013 Groundwater Monitoring

Indicator Parameter	Investigation Level	Results
pH	<7.6 or >9.2	7.80 to 8.30
SC	0.440 mmhos/cm	0.352 to 0.374 mmhos/cm
TOC	1 mg/L	0.41 to 0.57 mg/L
TOX	50 µg/L	<3.3 to 7.6 µg/L
Tritium	2,000 pCi/L	−22.95 to −7.54 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 elevations at the pilot wells are measured quarterly using an electronic tape. Groundwater elevations were measured on March 4, June 6, August 12, and October 15, 2013. All groundwater elevation data since the wells were drilled in 1993 are shown in Figure 4-10. The 2013 average depths to groundwater from the top of casing are 235.86 m (773.82 ft) at UE5PW-1, 256.46 m (841.40 ft) at UE5PW-2, and 271.56 m (890.94 ft) at UE5PW-3. The average groundwater elevations are 733.51 m (2,406.52 ft) AMSL at UE5PW-1, 733.66 m (2,407.01 ft) AMSL at UE5PW-2, and 733.66 m (2,407.01 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 velocity is less than 0.12 m/year (0.39 ft/year) to the south.

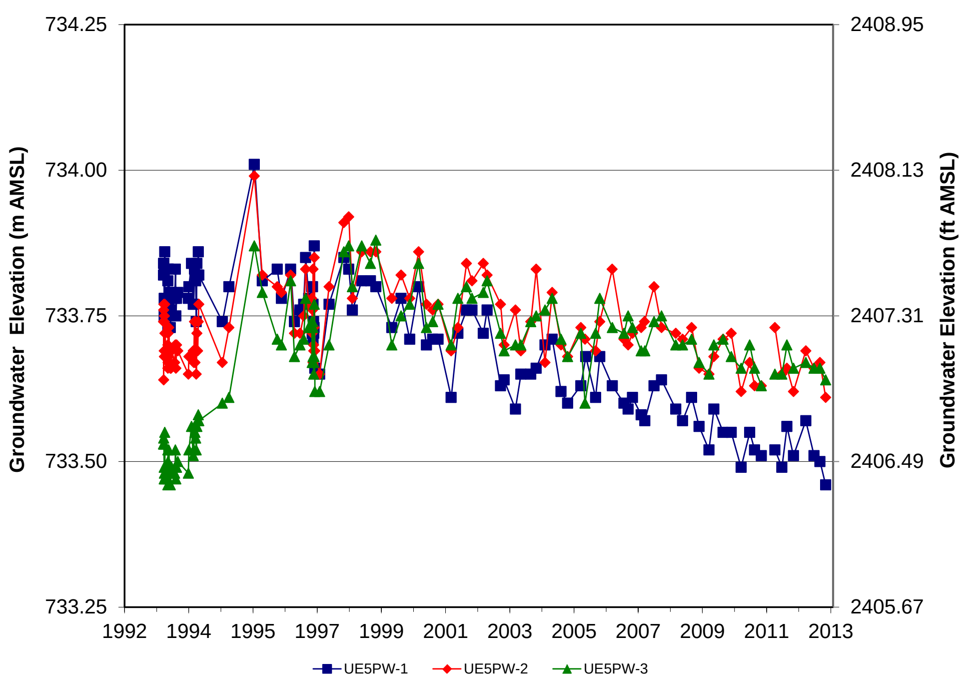

Figure 4-10 Groundwater Elevations at the Area 5 Pilot Wells

4.4.2 Leachate Monitoring at P18

Cell 18 is a lined, mixed waste disposal cell located in the northeastern corner of the Area 5 RWMS. It was constructed during 2010 and began receiving waste in January 2011. The Cell 18 liner is a RCRA-compliant double liner with a leachate collection and leak detection system placed over a geosynthetic clay liner. The double liner is covered by approximately 61 cm (24 in.) of compacted soil on the cell side slopes and approximately 76 cm (30 in.) of compacted soil on the cell floor. The primary liner is 80-mil textured high density polyethylene (HDPE) and the secondary liner is 60-mil textured HDPE. The primary liner is directly below a 160-mil double-sided geocomposite drainage layer, and a second 160-mil double-sided geocomposite drainage layer separates the primary liner from the underlying secondary liner.

Any precipitation or other water applied to the 1.35-hectare (3.33-acre) area covered by the liner that is not removed by ET eventually infiltrates into the soil above the liner, percolates through the soil to the primary liner, and eventually drains into the primary sump in the floor of Cell 18. Any water leaking through the primary liner would percolate to the secondary liner and eventually drain into the secondary sump in the floor of Cell 18. Water collected in the primary sump is pumped from the sump to a 3,000-gallon tank on the surface above the cell.

Approximatly 76,159 L (20,119 gal) of leachate have been pumped from the primary sump into the leachate tank since pumping began in 2011 (Figure 4-11). This leachate volume is equivalent to 6.4 mm of precipitation over the cell area, or 2% of total precipitation. Slightly more than half of the total leachate volume (46,708 L [12,339 gal]) was pumped during 2013. The 2013 leachate volume is equivalent to 3.4 mm of precipitation over the cell area, or 3% of total 2013 precipitation at the Area 5 RWMS.

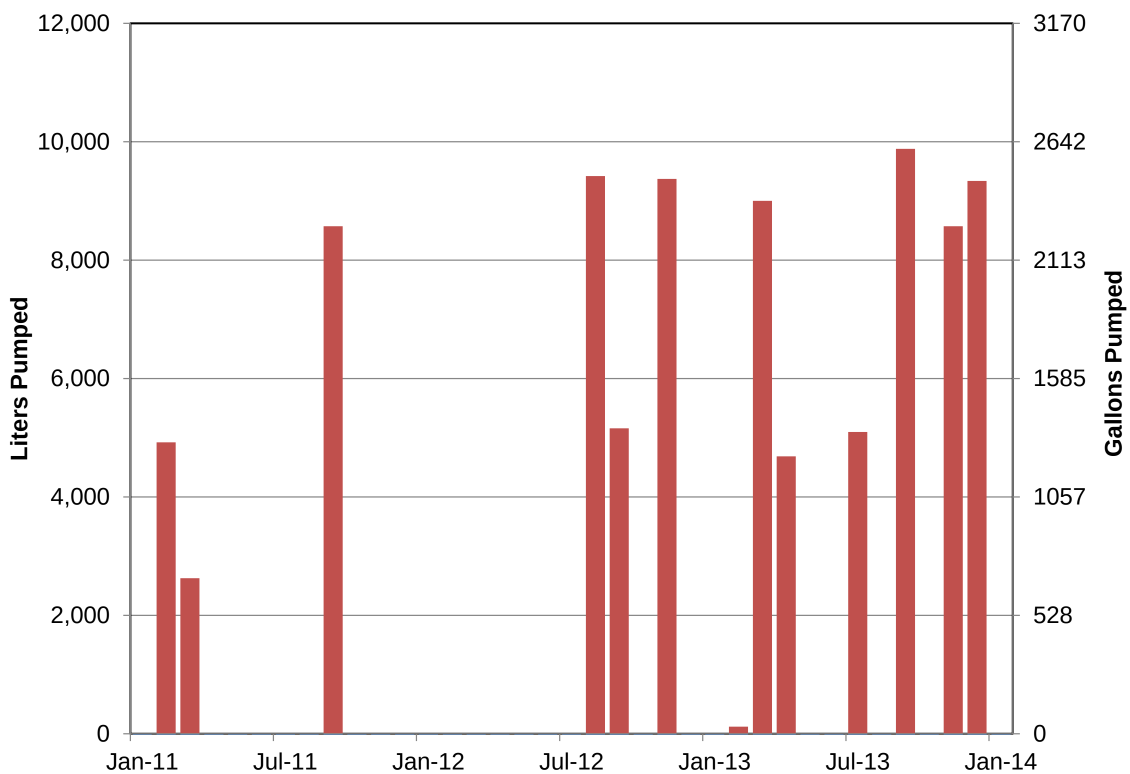

Figure 4-11 Leachate Volume Pumped from Cell 18 Primary Sump

When the tank approaches its 3,000-gallon capacity, leachate samples are collected from the tank and analyzed for the toxicity characteristic contaminants listed in Table 1 of 40 CFR 261.24 (2003), polychlorinated biphenyls (PCB), pH, and SC. Leachate samples have been collected ten times and the tank has been emptied nine times since Cell 18 opened in 2011 through 2013. During 2013, leachate samples were collected five times (March 27, July 31, October 3, November 6, and December 18, 2013) and the tank was emptied five times (February 11, April 24, September 5, November 4, and December 11, 2013). Typically there is approximately a 1-month delay between sampling and emptying the leachate tank. The tank was emptied on February 11, 2103, based on results from leachate samples collected during 2012. The results from the sample collected on December 11, 2013, were not available in 2013, so the leachate tank was not emptied until 2014. Detailed results for the leachate are presented in the *Nevada National Security Site 2013 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site* (NSTec, 2014a).

Indicators of contamination monitored for leachate:

- Toxicity characteristic contaminants
    - Metals – arsenic, barium, cadmium, chromium, lead, selenium, silver
    - Mercury
    - Semi-volatiles – o-cresol, m-cresol, p-cresol, 1,4-dichlorobenzene, 2,4-dinitrotoluene, hexachlorobenze, hexachlorobutadiene, hexachloroethane, nitrobenzene, pentrachlorophenol, pyridine, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol
    - Volatiles – benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichloroethane, 1,1-dichloroethylene, methyl ethyl ketone, tetrachloroethylene, trichloroethylene, vinyl chloride
    - Organochlorine pesticides – chlordane, endrin, heptachlor (and its epoxide), lindane, methoxychlor, toxaphene
    - Chlorinated herbicides – 2,4-dichlorophenoxyacetic acid, 2,4,5-Trichlorophenoxy propionic acid
- PCB
- pH
- SC

Through 2013, no regulatory limits for toxicity characteristic contaminants have been exceeded, and no PCBs have been detected in any leachate samples. During 2013, the leachate SC ranged from 2.480 and 2.811 mmhos/cm, and the leachate pH ranged from 7.59 to 7.95. After leachate analysis results are evaluated, the leachate is pumped from the collection tank and used for dust control in Cell 18.

4.5 METEOROLOGY MONITORING DATA

Meteorology monitoring data collected in 2013 include precipitation, air temperature, humidity, wind speed and direction, barometric pressure, and incoming solar radiation. Net solar radiation, soil heat flux, soil temperature, and soil water content are also measured for energy balance based calculations of ET. 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 (Figures 3-1 and 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 2013 average recorded temperatures at 9.5 m (31 ft) above ground level were 14.2°C (57.6°F) at the Area 3 RWMS and 16.3°C (61.3°F) at the Area 5 RWMS. The 2013 maximum and minimum temperatures at 9.5 m (31 ft) at the Area 3 RWMS were 42.7°C (108.9°F) on July 3, 2013, and −15.4°C (4.3°F) on January 13, 2013, and at the Area 5 RWMS were 44.7°C (112.5°F) on June 30, 2013, and −13.0°C (8.6°F) on January 13, 2013 (Figure 4-12).

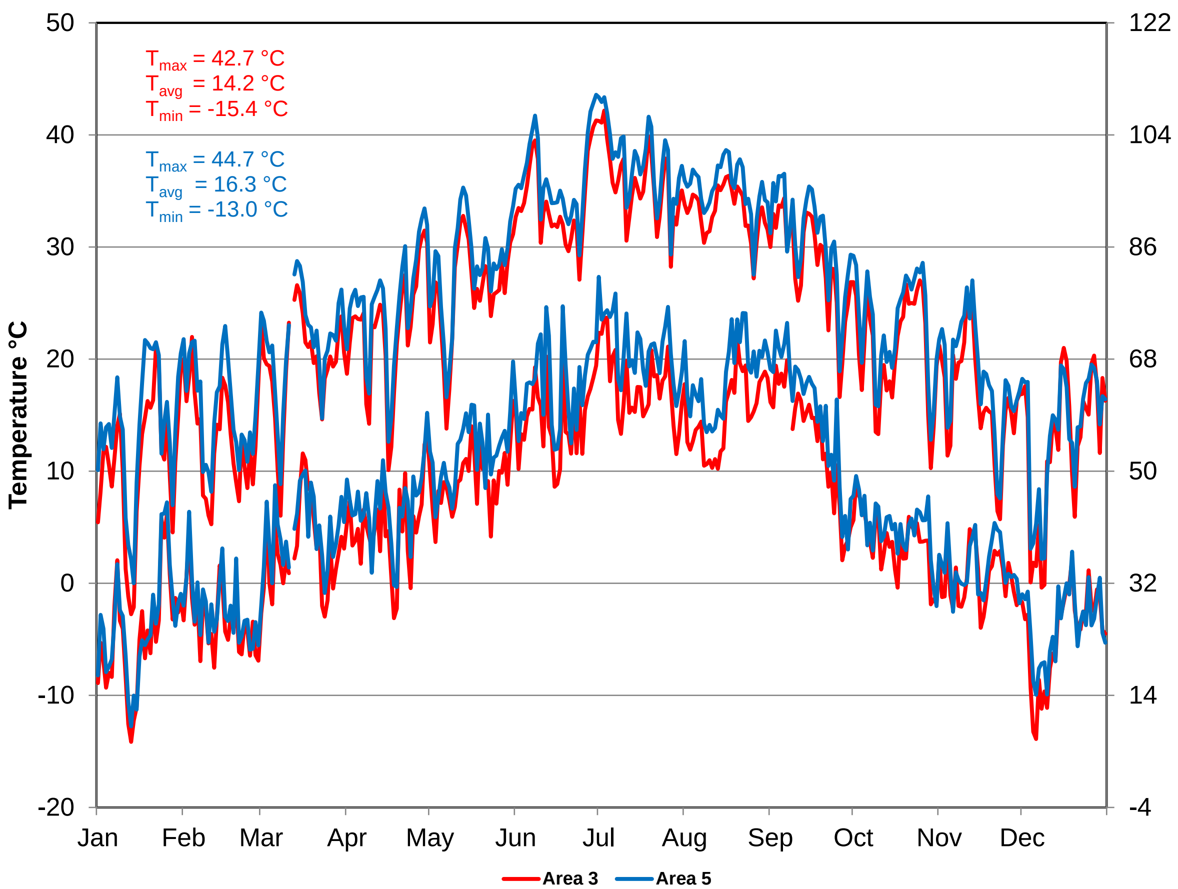

Figure 4-12 Daily Maximum and Minimum Air Temperatures at the Area 3 and Area 5 RWMSs

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 2013 at 9.5 m (31 ft) above ground level was 32.5% for Area 3 and 30.4% for Area 5 (Figure 4-13). Measured daily average relative humidity ranged from 4.84% to 88.7%.

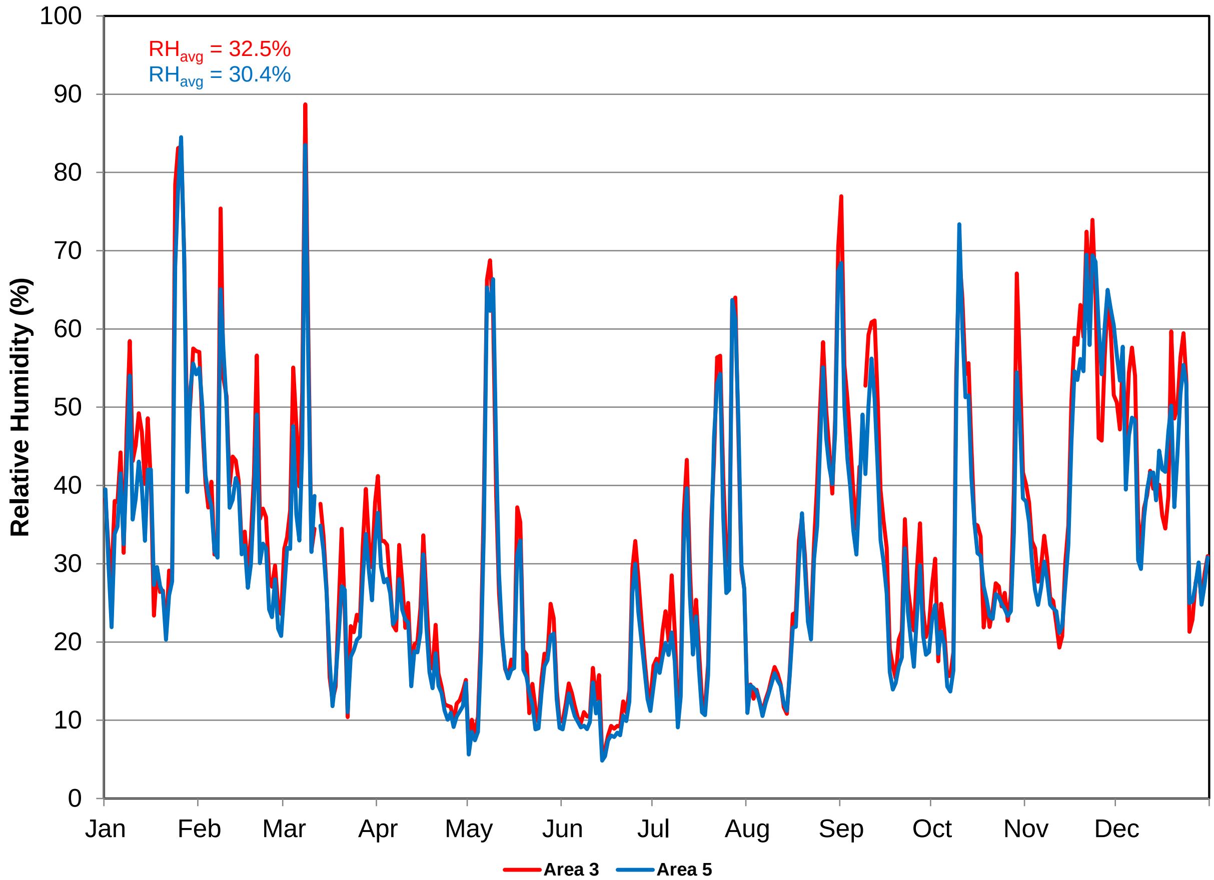

Figure 4-13 Daily Average Relative Humidity at the Area 3 and Area 5 RWMSs

Vapor density or absolute humidity measures the amount of water vapor in air as grams per cubic meter (g/m^3) and can be calculated from relative humidity and air temperature. It is directly related to the air vapor pressure and measures the absolute amount of water in the air. Unlike relative humidity, vapor density is not temperature dependent. The daily average water density during 2013 was 3.9 g/m^3 at Area 3 and 4.1 g/m^3 at Area 5 (Figure 4-14). The measured daily average water density ranged from 0.8 g/m^3 to 14.8 g/m^3.

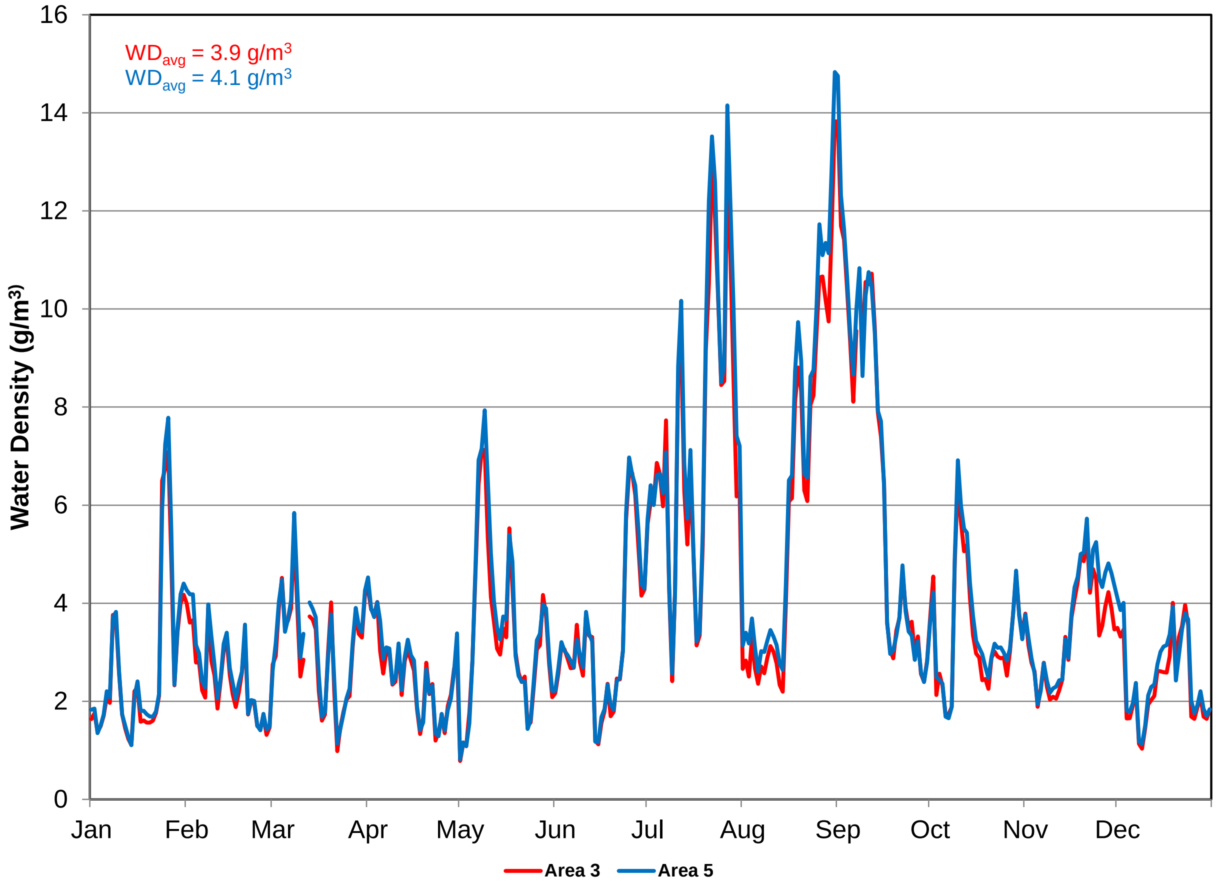

Figure 4-14 Daily Average Atmospheric Water Density at the Area 3 and Area 5 RWMSs

4.5.3 Barometric Pressure

Average daily barometric pressure measured at the Area 3 RWMS and the Area 5 RWMS typically show very similar patterns. The pressure transducer used to measure barometric pressure at Area 5 was replaced on March 12, 2013. The previous transducer did not function properly, so the Area 5 data begin on March 13, 2013 (Figure 4-15). The average barometric pressure at the Area 3 RWMS was 87.8 kilopascals (kPa) (12.7 pounds per square inch [PSI]). The average barometric pressure at the Area 5 RWMS was 91.1 kPa (13.2 PSI). The difference in barometric pressure readings between the two locations is caused by the 261 m (856 ft) difference in elevation.

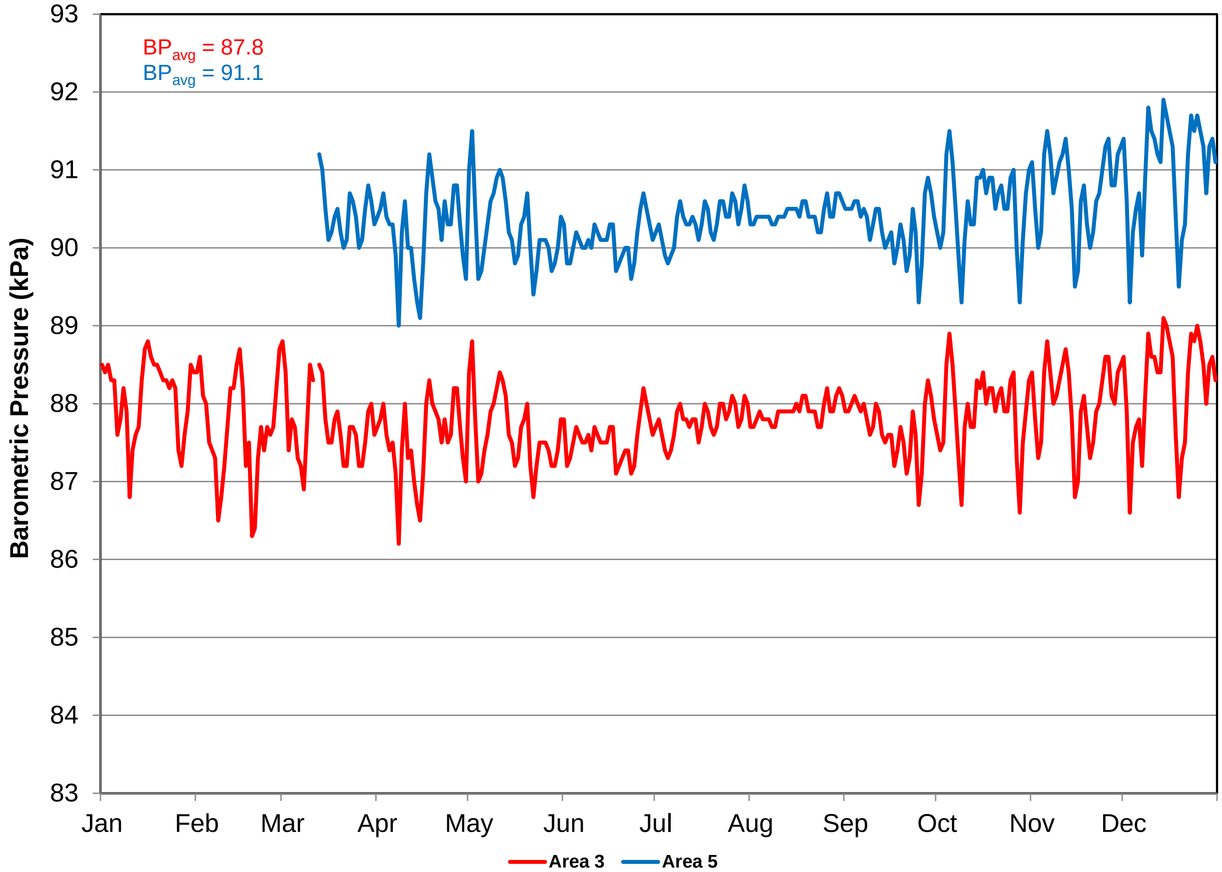

Figure 4-15 Average Barometric Pressure at the Area 3 and Area 5 RWMSs

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 2013, the average daily wind speed at the Area 3 RWMS at 9.5 m (31 ft) was 3.9 m/s (8.7 mph), and the maximum gust was 22.9 m/s (51.2 mph) on September 8. During 2013, the average daily wind speed at the Area 5 RWMS at 9.5 m (31 ft) was 3.2 m/s (7.2 mph), and the maximum gust was 21.1 m/s (47.2 mph) on July 20. Daily maximum and average wind speeds at the Area 3 and Area 5 RWMSs are in Figures 4-16 and 4-17, respectively.

Wind rose diagrams illustrate wind direction and wind speed distribution in each direction using hourly wind data measured at a height of 9.5 m (31 ft) 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 4-18 and Figure 4-19, respectively. The 1-year wind roses presented here are very similar to the multiple-year wind roses.

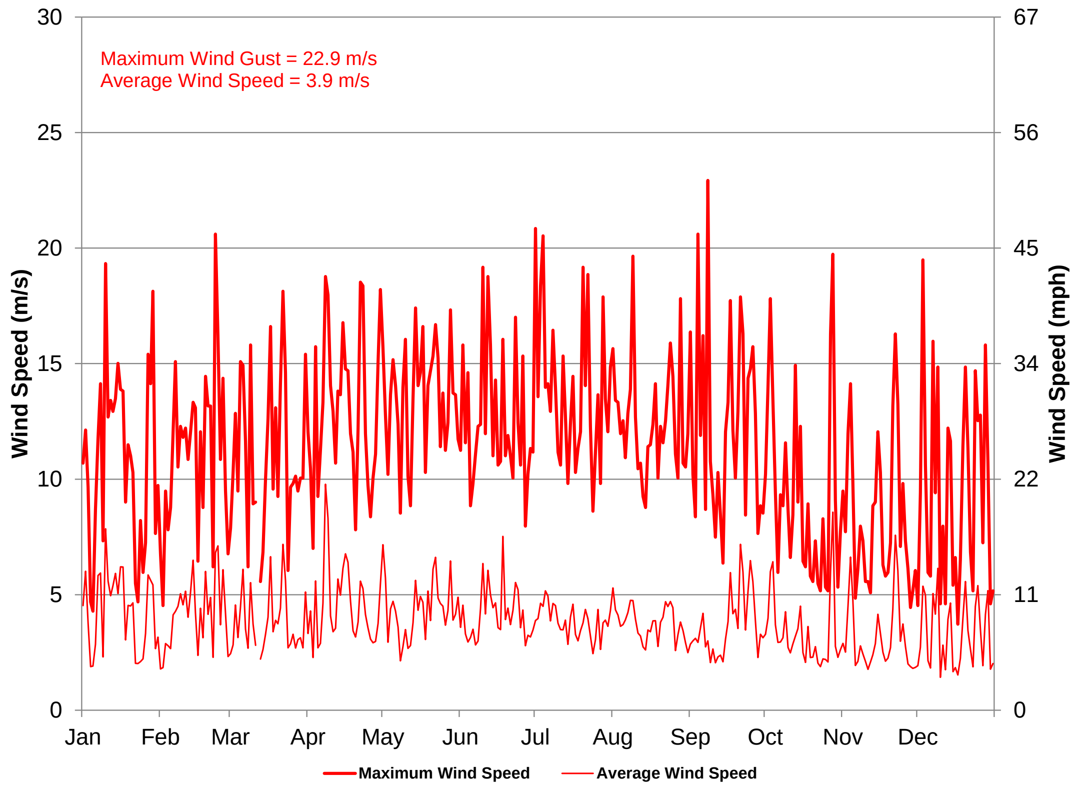

Figure 4-16 Daily Wind Speed at the Area 3 RWMS

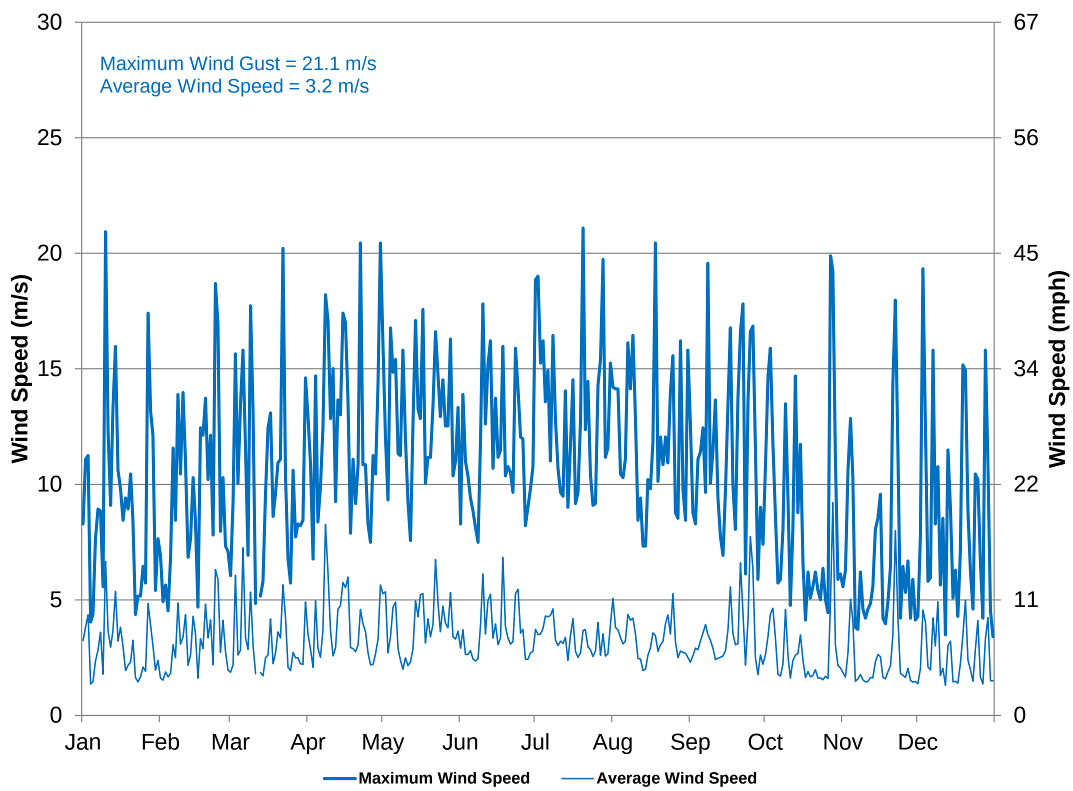

Figure 4-17 Daily Wind Speed at the Area 5 RWMS

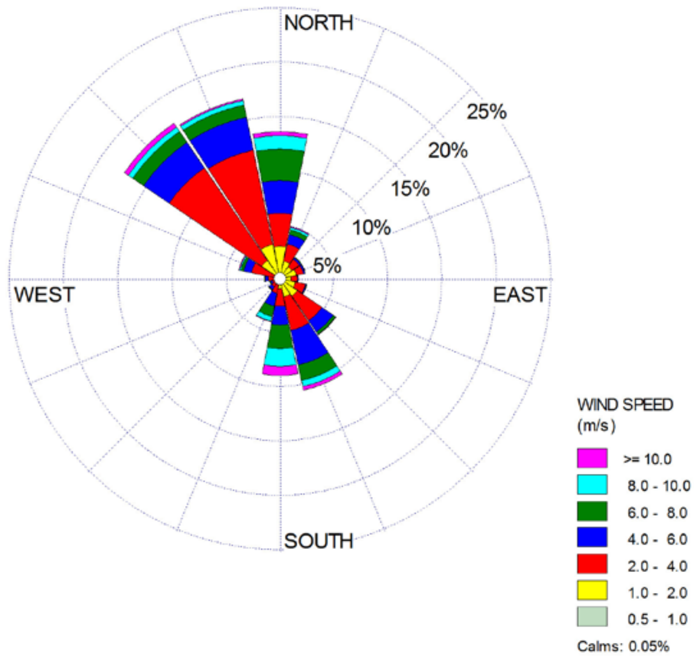

Figure 4-18 Wind Rose Diagram for the Area 3 RWMS

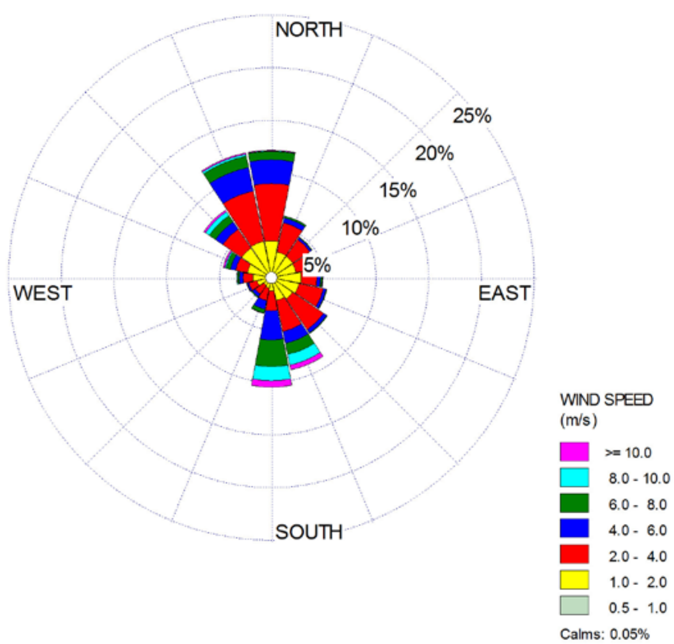

Figure 4-19 Wind Rose Diagram for the Area 5 RWMS

4.5.5 Precipitation

Rainfall at the Area 3 RWMS in 2013 was 30% below average, totaling 105.8 mm (4.17 in.). The average annual precipitation measured at the Area 3 RWMS from 1996 through 2013 is 150.3 mm (5.92 in.). The maximum daily rainfall at the Area 3 RWMS during 2013 was 39.5 mm (1.56 in.) on September 8. Precipitation was measured on 37 days during 2013 at the Area 3 RWMS (Figure 4-19).

Rainfall at the Area 5 RWMS in 2013 was 5% below average, totaling 117.5 mm (4.63 in.). The average annual precipitation measured at the Area 5 RWMS from 1995 through 2013 is 123.6 mm (4.86 in.). The maximum daily rainfall at the Area 5 RWMS during 2013 was 18.9 mm (0.74 in.) on November 21. Precipitation was measured on 32 days during 2013 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 4-22. The BJY station is a Meteorological Data Acquisition (MEDA) station operated by ARL/SORD. The 53-year average annual precipitation at BJY from 1961 to 2013 is 159.8 mm (6.29 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 at the Area 5 RWMS are provided in Figure 4-23. The Well 5B station is also an ARL/SORD MEDA station. The 50-year average annual precipitation at Well 5B from 1964 to 2013 is 122.4 mm (4.82 in.).

4.5.6 Reference Evapotranspiration

The calculated 2013 ET_{ref} at the Area 3 RWMS is 1,612 mm (63.5 in.) and at the Area 5 RWMS is 1,553 mm (61.1 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 2013 at the Area 3 RWMS is 15.2, and the ratio of ET_{ref} to precipitation in 2013 at the Area 5 RWMS is 13.2.

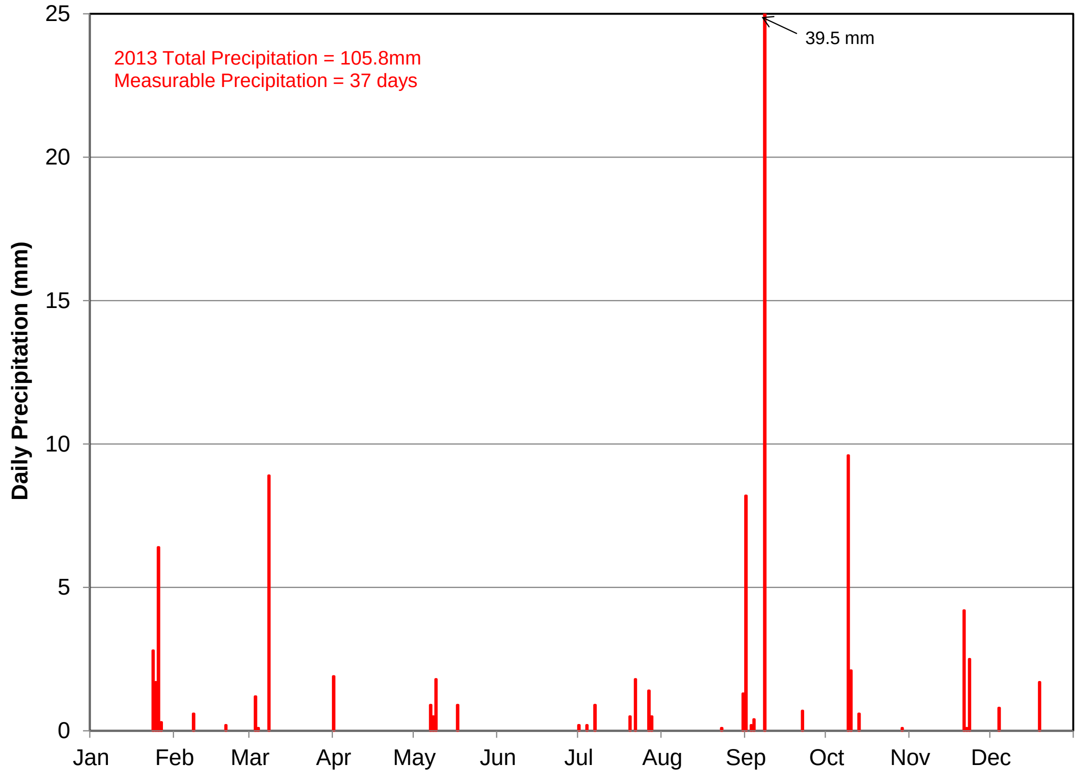

Figure 4-20 Daily Precipitation at the Area 3 RWMS

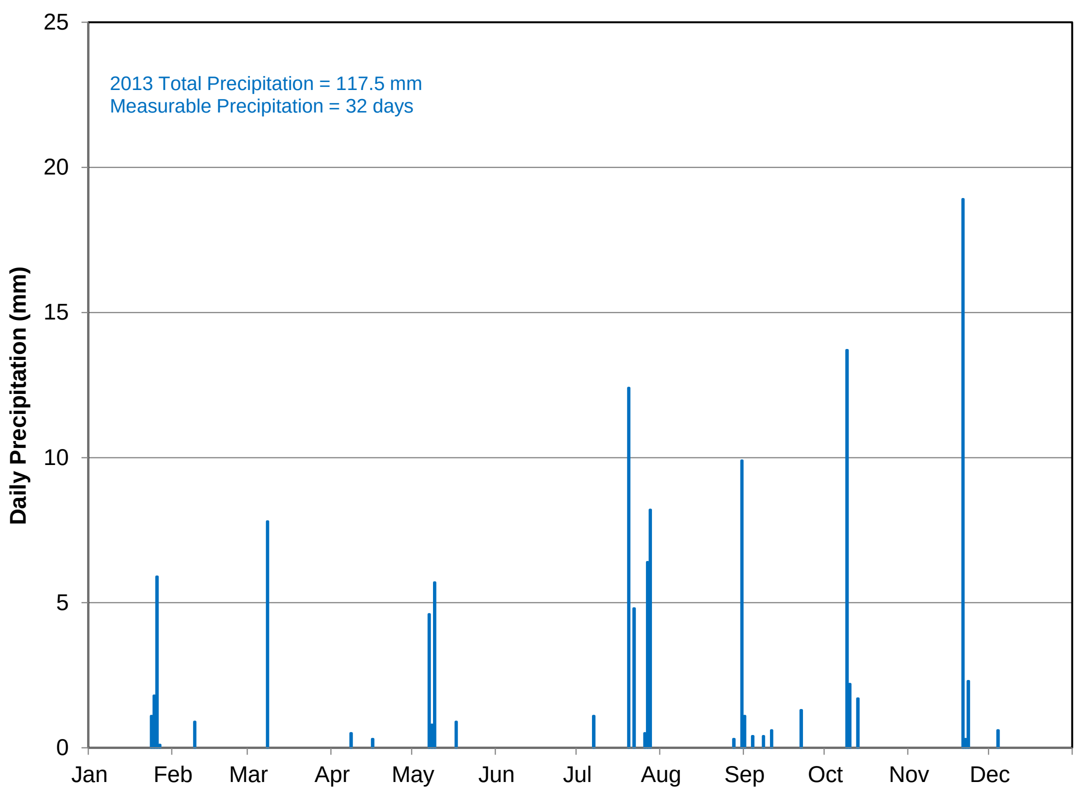

Figure 4-21 Daily Precipitation at the Area 5 RWMS

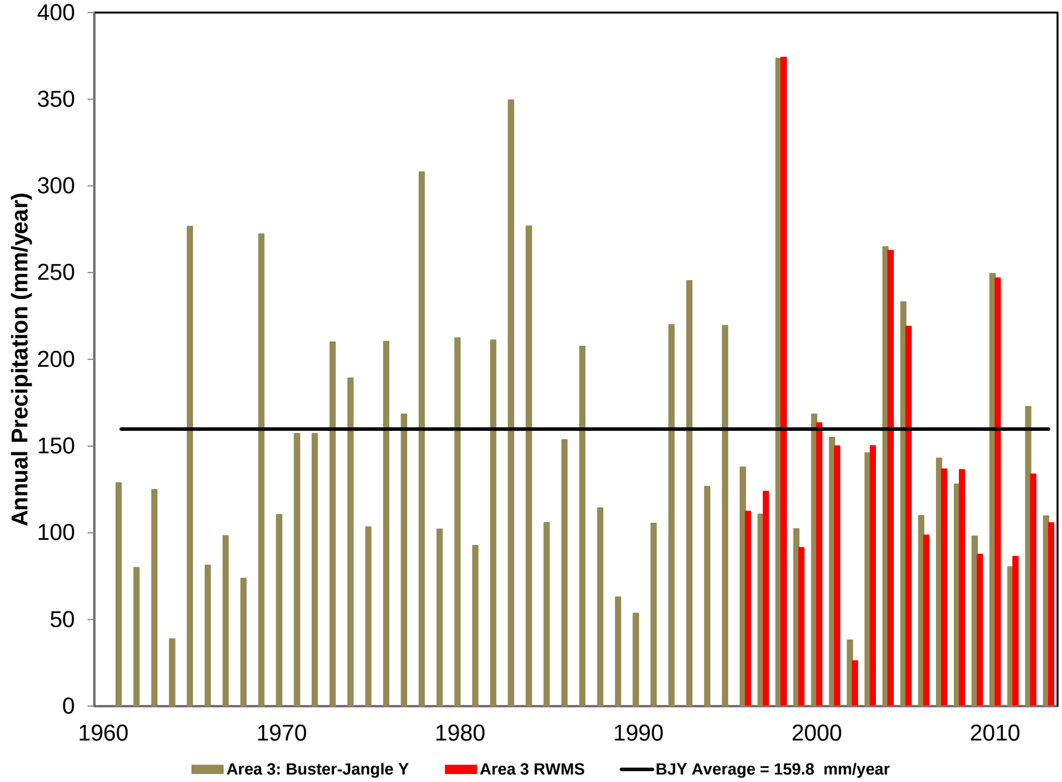

Figure 4-22 Historical Precipitation Record for Buster-Jangle Y and Area 3 RWMS

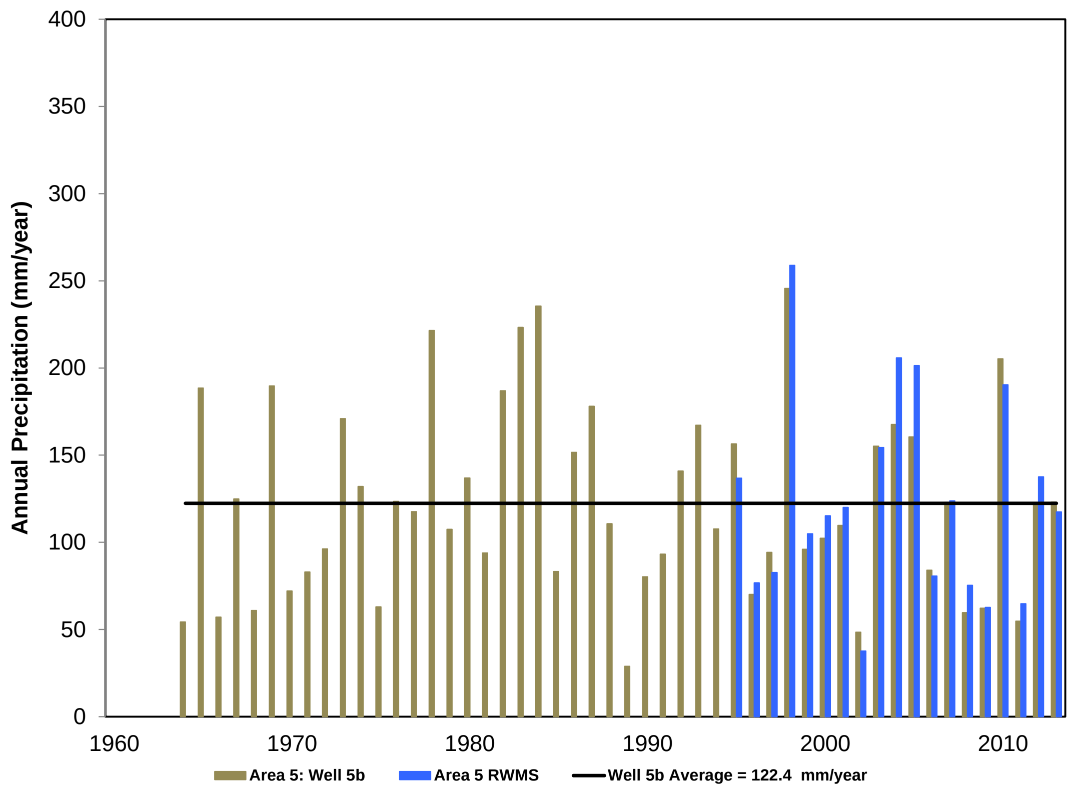

Figure 4-23 Historical Precipitation Record for Well 5B and Area 5 RWMS

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). 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.

4.6.2 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 (Figure 3-2). Each lysimeter is an open-top steel box, measuring 2 m wide by 4 m long by 2 m deep (6.6 ft wide by 13 ft long by 6.6 ft deep), 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 tridentata* (creosote bush), *Lycium andersonii* (Anderson's wolfberry), and *Schismus arabicus* (Arabian schismus) 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 lysimeters have provided surface water balance data 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 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, 2013, is provided in Figure 4-24.

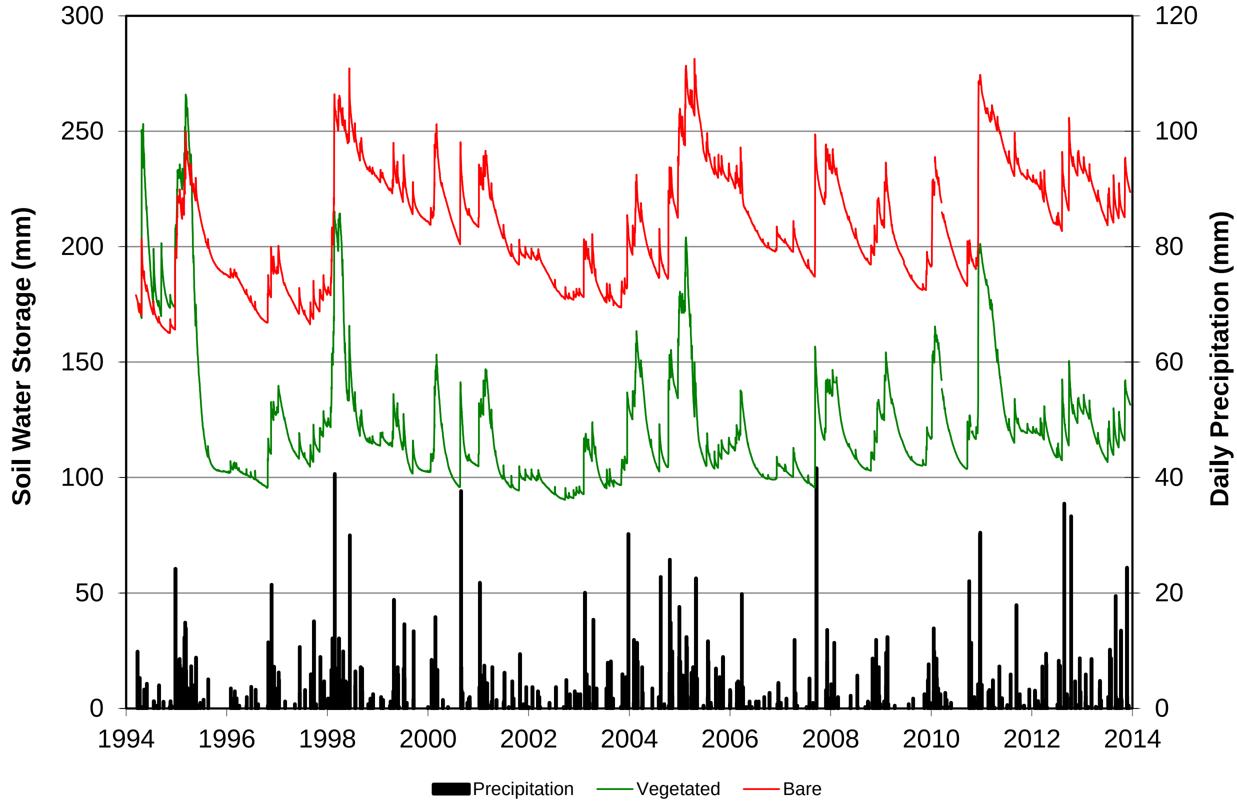

Figure 4-24 Weighing Lysimeter Data from March 1994 to December 2013

The vegetated lysimeter is considerably drier than the bare-soil lysimeter despite the small number of plants on the vegetated lysimeter. Typically the vegetated lysimeter has 12.5% plant cover. Cover was measured for both the vegetated and bare-soil weighing lysimeters on May 20, 2013 using an ocular projection device. Although the measured plant cover on the vegetated lysimeter is 0%, the perennial plant population did not change from 2012, and over 500 small *Schismus arabicus* (Arabian schismus) plants were counted for plant species density measurements. The results are summarized in Table 4-4.

Table 4-4 Weighing Lysimeters Percent Cover

Lysimeter	Plant Cover (percent)	Bare (percent)	Gravel (percent)	Litter (percent)
Vegetated	0.0	47.5	37.5	15.0
Bare Soil	0.0	22.5	75.0	2.5

The average soil water storage depth in the vegetated lysimeter from January 1, 1996, through December 31, 2013, is 118 mm (4.6 in.). This is equivalent to the average volumetric water content (VWC) of 5.9%. For the same period, the average soil water storage depth in the bare lysimeter is 211 mm (8.3 in.), which is equivalent to an average VWC of 10.6%. During 2013, the average soil water storage depth in the vegetated lysimeter was 121 mm (4.8 in.), and the average water storage depth in the bare lysimeter was 222 mm (8.7 in.).

Following rainfall in the winter, soil water storage decreases in the vegetated lysimeter due to ET from rapid plant growth in the spring. As the vegetated lysimeter dries out, plant growth and ET slow. Eventually E from the bare lysimeter exceeds ET from the vegetated lysimeter in the summer due to the higher water content in the bare lysimeter (Figure 4-24).

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 porous suction candles on the bottom of the bare lysimeter May 5–June 19, 2008; March 2–May 12, 2009; and February 3–April 27, 2010. No water effluent was collected from the suction candles during these periods. Long-term numerical simulations (30 years) using a unit gradient bottom boundary estimate the amount of drainage that would have occurred if water could drain from the lysimeters. These simulations indicate an average of 1.0 cm (0.4 in.) per year 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 2013, E from the bare lysimeter was 145.3 mm (5.7 in.) and ET from the vegetated lysimeter was 132.2 mm (5.2 in). Water content in the vegetated lysimeter was approximately equal at the beginning and end of 2013 because annual ET from the vegetated lysimeter was almost equal to the 133.3 mm of precipitation. Water content in the bare lysimeter decreased slightly during 2013 (Figure 4-25).

During 2013, E from the bare lysimeter was greater than ET from the vegetated lysimeter during January and June through December, ET was greater than E during February through April, and ET and E were equal in May. Relatively high precipitation from July and August was removed from the lysimeters by E and ET during July through September (Figure 4-26).

Monthly precipitation was less than ET during February through June, September, and December, and monthly precipitation was less than E during January through June, September, and December (Figure 4-26).

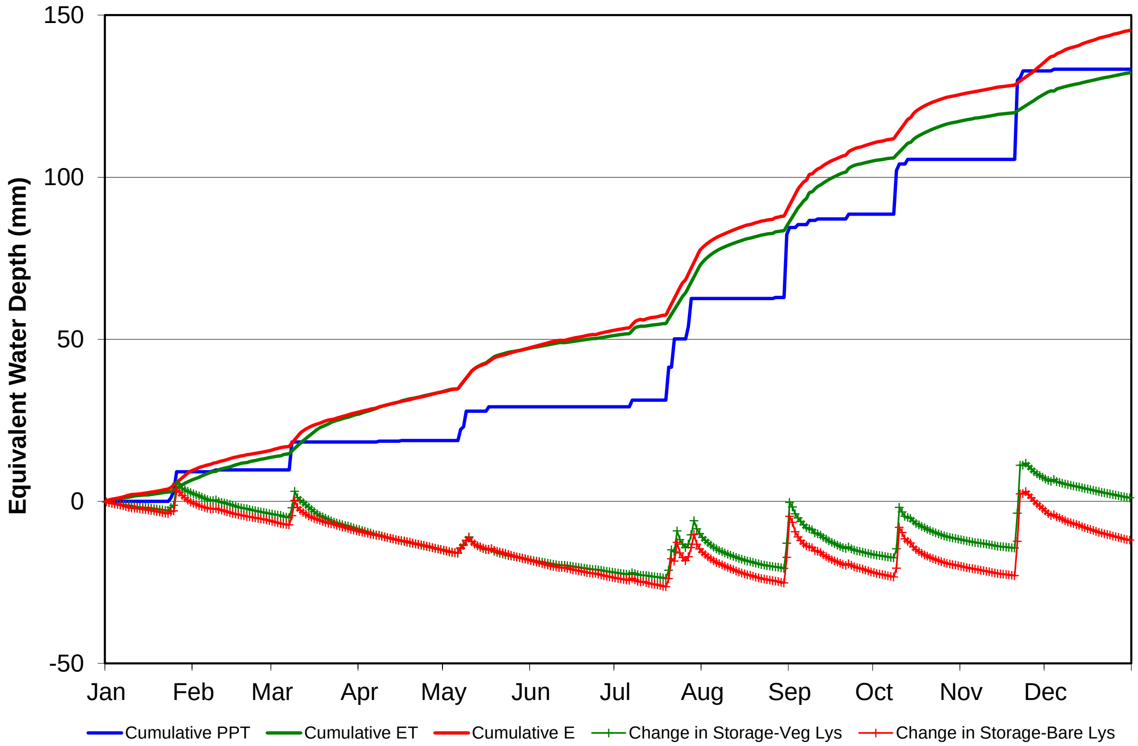

Figure 4-25 Precipitation, ET, E, and Storage for the Weighing Lysimeters during 2013

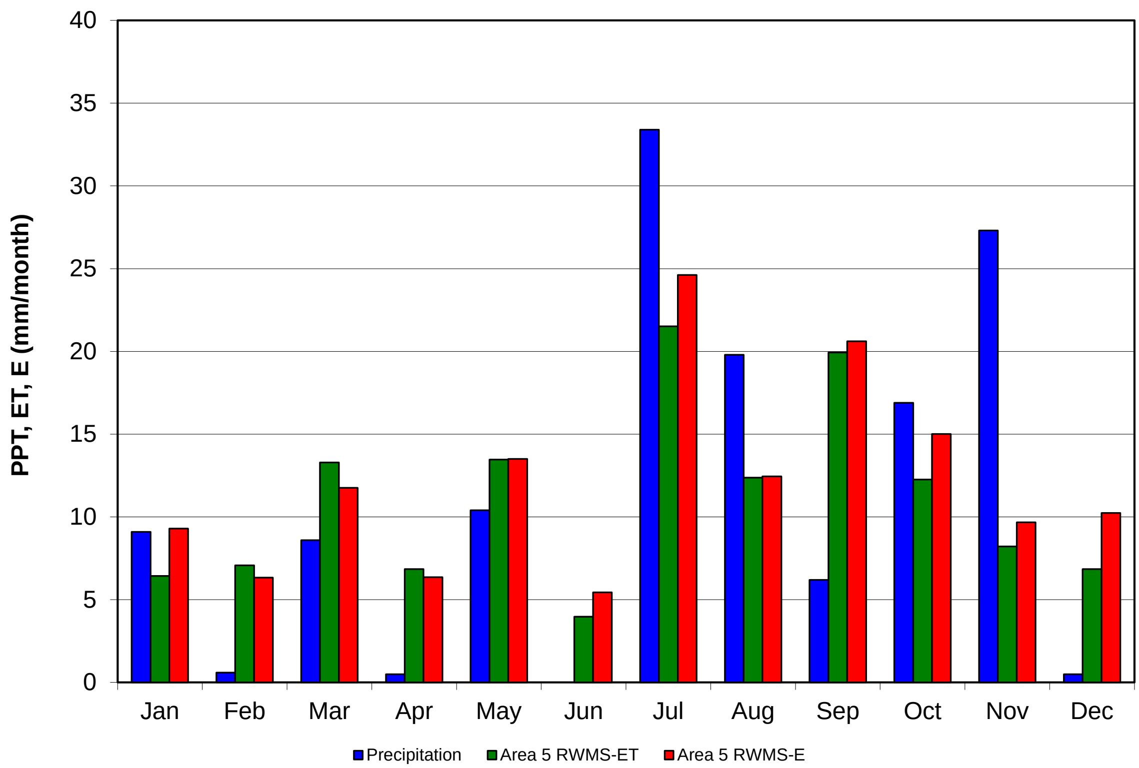

Figure 4-26 Monthly Precipitation, E, and ET during 2013

4.6.3 Automated Waste Cover Monitoring System

In 1998, time-domain reflectometry (TDR) probes were buried 1.2 m (4 ft) beneath the floor of open Cell 5 at the Area 5 RWMS. The four probes are adjacent to the Cell 5N and Cell 5S monitoring locations. At each monitoring location, one probe is buried near the center line and one probe is buried near the eastern edge (Figure 3-2). Approximately 4.4 m (14 ft) of waste and approximately 2.4 m (8 ft) of cover were placed above these probes during disposal. The depth of these probes is now approximately 7.9 m (26 ft).

Measured VWC in the floor of Cell 5 has remained constant at approximately 10% since measurements began in early 1999 (Figure 4-27). The constant measured water content indicates that no moisture has percolated to 1.2 m (4 ft) below the waste. The missing data in 2011 are during the construction of the final cover. The original TDR probes were used after the final cover was completed, but the data appear slightly more variable. This variability may be related to construction of the cover or damage to the probes during construction.

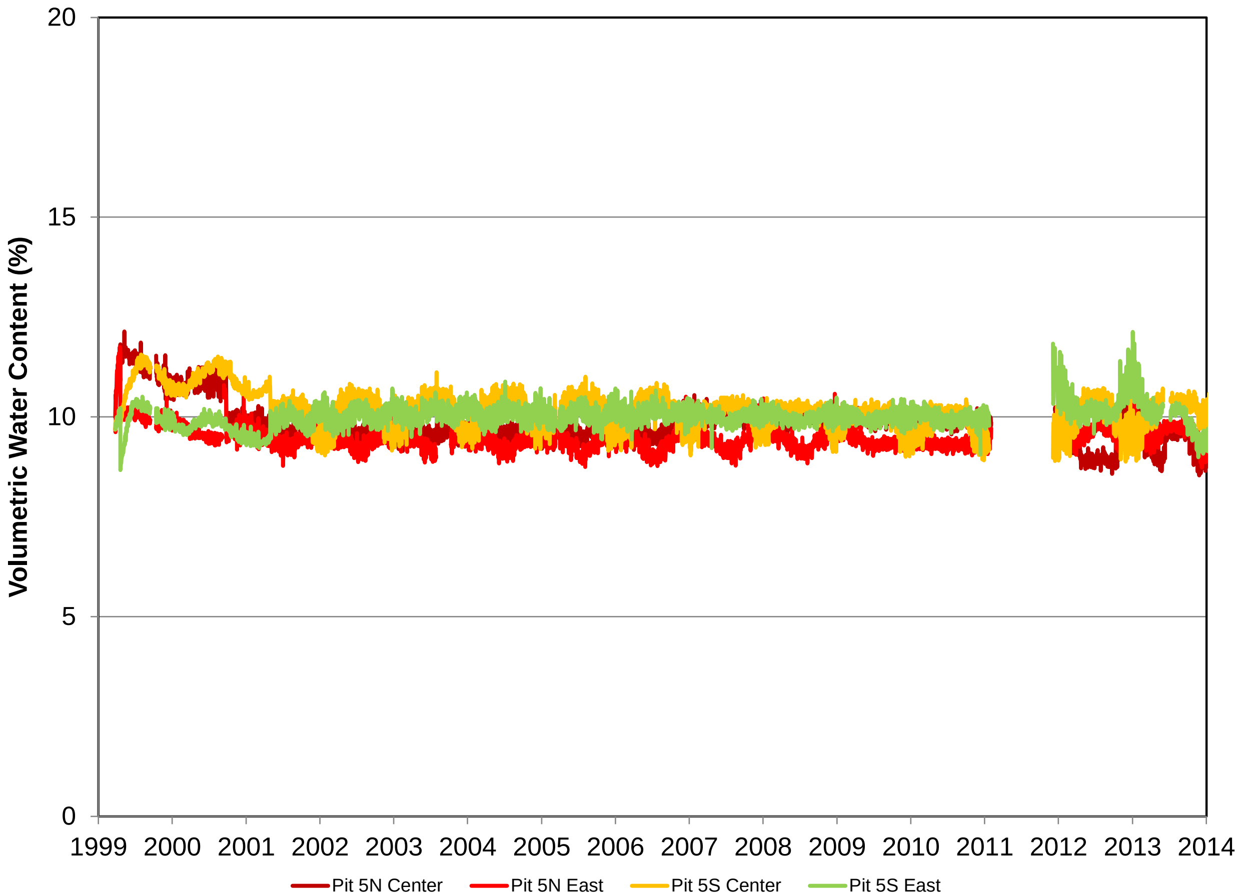

Figure 4-27 Soil Water Content in the Cell 5 Floor

TDR probes were installed in the final cover of the 92 Acre Area after cover construction was completed. Moisture monitoring began at Cell 1, Cell 3W, Cell 5N, and Cell 5S by December 2011. Eight vertically arranged TDR probes were installed at each of the four locations at depths ranging from 15 to 180 cm (0.5 to 6 ft). The measured VWC profiles are similar at the four locations. Measured VWC values for Cell 5N are shown in Figure 4-28. Initially, water applied to the cover during construction resulted in a uniform VWC distribution between 8% and 10%. ET from plant growth during the spring and early summer of 2012 decreased the measured water contents even though 10.9 cm (4.3 in.) of supplemental irrigation was applied to the cover to help establish vegetation. Precipitation during the fall of 2012 wetted the soil to approximately 35 cm (18 in.). Precipitation during 2013 wetted the soil to 45 cm, but this moisture was removed by ET without moving below 45 cm.

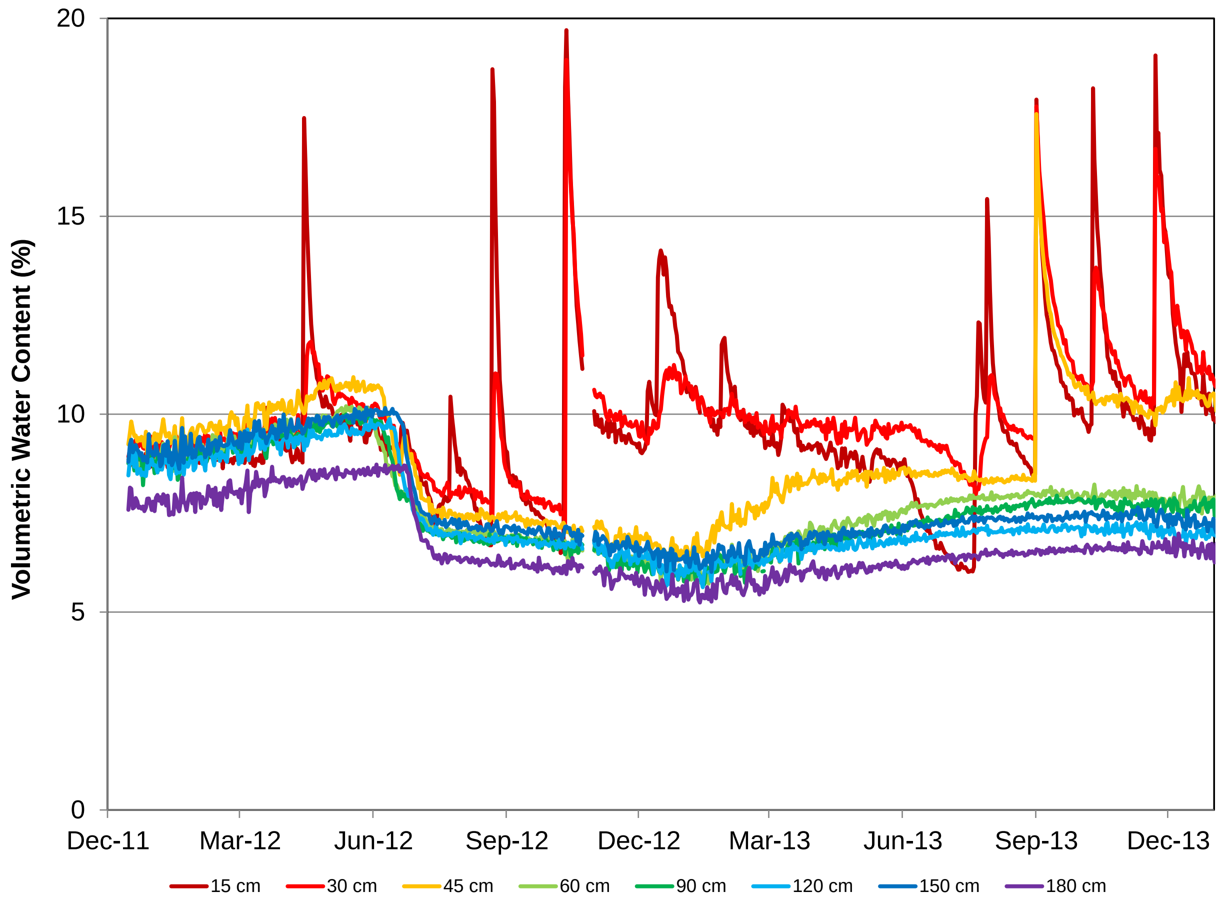

Figure 4-28 Soil Water Content in the 92 Acre Cover at Cell 5 N

Four strontium-90 (^{90}Sr) radioisotope thermoelectric generators (RTGs) were disposed at Cell 5 on September 27, 2007. The power output of these four RTGs is approximately 450 watts. Area 5 RWMS disposal requirements are that RTG surface temperatures remain below 300°C (572°F), soil temperatures within 2 m (6.6 ft) of the surface remain less than 100°C (212°F), and temperatures in LLW adjacent to the RTGs are below 38°C (100°F). Platinum resistance temperature detectors (RTDs) were installed to measure vertical and horizontal temperature profiles around an RTG. RTDs in the vertical profile were placed directly on top of an RTG to

400 cm (13 ft) above the RTG. The top of the RTG is approximately 550 cm (18 ft) below the soil surface. RTDs in the horizontal profile were placed on the side of the same RTG to 400 cm (13 ft) away from the side of the RTG. The RTGs in the horizontal profile are approximately 550 cm (18 ft) deep. Figure 4-29 provides the measurements from the vertical temperature profile above the RTG. Locations are given as the distance above the RTG followed by the depth from the soil surface in parentheses. Data gaps in Figure 4-29 are from sensor malfunction or removal. Temperatures at the top of the RTD and approximately 550 cm (18 ft) below the ground surface were near 110°C (230°F) at the end of 2013. Temperature measurements 270 cm (8.9 ft) above the RTG and approximately 280 cm (9.1 ft) below the ground surface are not affected by the heat flux from the RTGs.

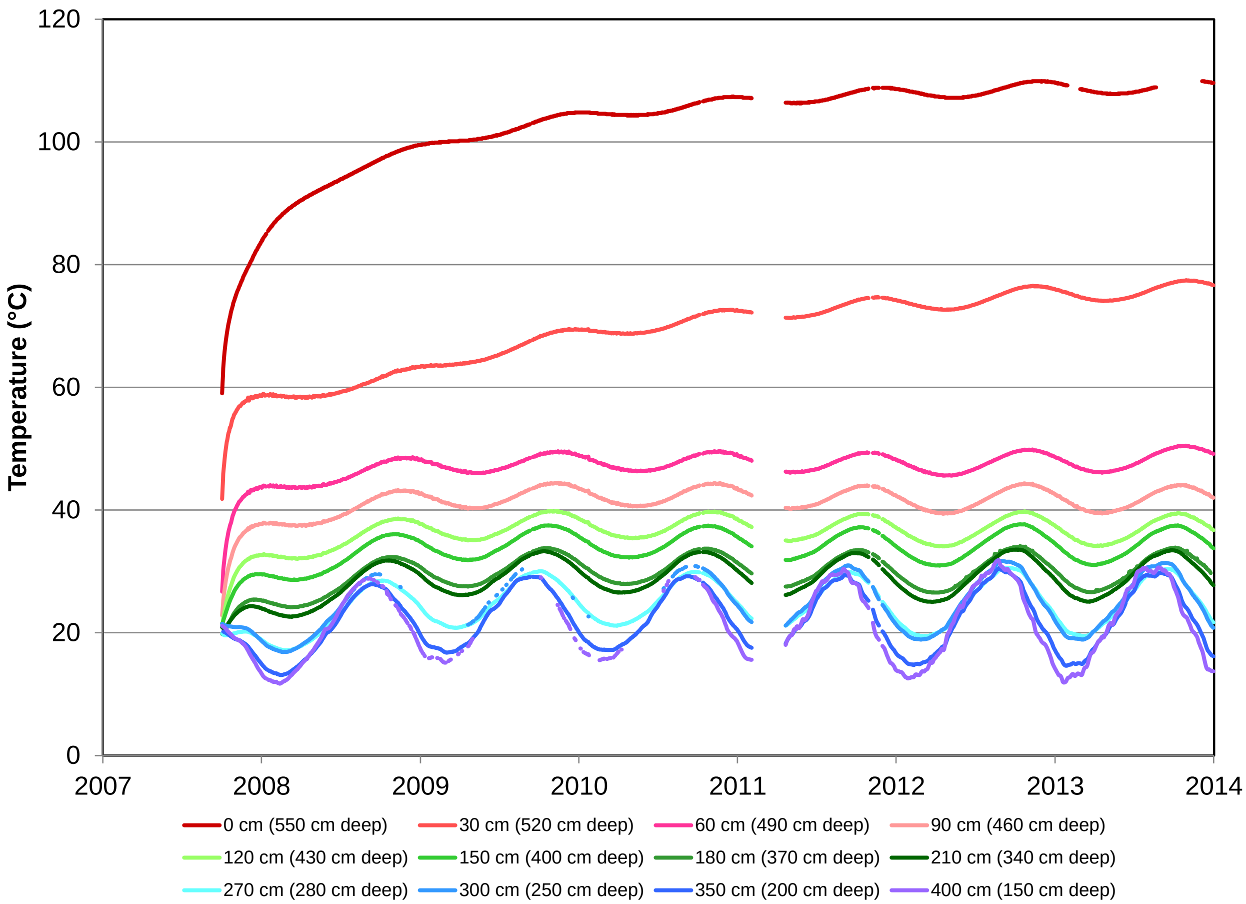

Figure 4-29 Temperatures above an RTG at Cell 5

In December 2000, TDR probes were installed during construction of the final vegetated cover of the U-3ax/bl waste disposal unit at the Area 3 RWMS (Figure 3-1). Eight vertically arranged TDR probes were installed at four locations at depths ranging from 30 to 240 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 4-30. From 2001 to 2005, 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 cover of U-3ax/bl, but the moisture was removed without percolating below the 240 cm (8 ft) deep sensor. The wetting front from the 6.6 cm (2.6 in.) precipitation event on September 21 and September 22, 2007, only reached 30 cm (1 ft) deep. Precipitation during January and February 2009 increased water contents to a depth of 30 cm (1 ft). Precipitation during January and February 2010 increased water contents to a depth of 60 cm (2 ft). The 8.6 cm (3.4 in.) of precipitation from December 18 to 23, 2010, increased water contents in the cover to a depth of 122 cm (4 ft) by May 2011. This moisture did not percolate to 150 cm (4.9 ft) deep. ET removed this moisture from the cover by October 2011. Neither 50 mm (2.0 in.) of precipitation on October 11, 2012, nor 40 mm (1.6 mm) of precipitation on September 9, 2013, wet the soil below 60 cm (2 ft) deep.

Initial water contents are lower in the vegetated U-3ax/bl cover, so more moisture 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, about 12% of the surface area is covered by plant material. Obtaining 12% vegetative cover on the soil caps is dependent upon the seed germination success and seedling survival of native plants seeded or transplanted onto the cover. The dominant perennial plant on the U-3ax/bl cover is *Atriplex confertifolia* (shadscale saltbush), which accounted for 17.4% cover in 2013.

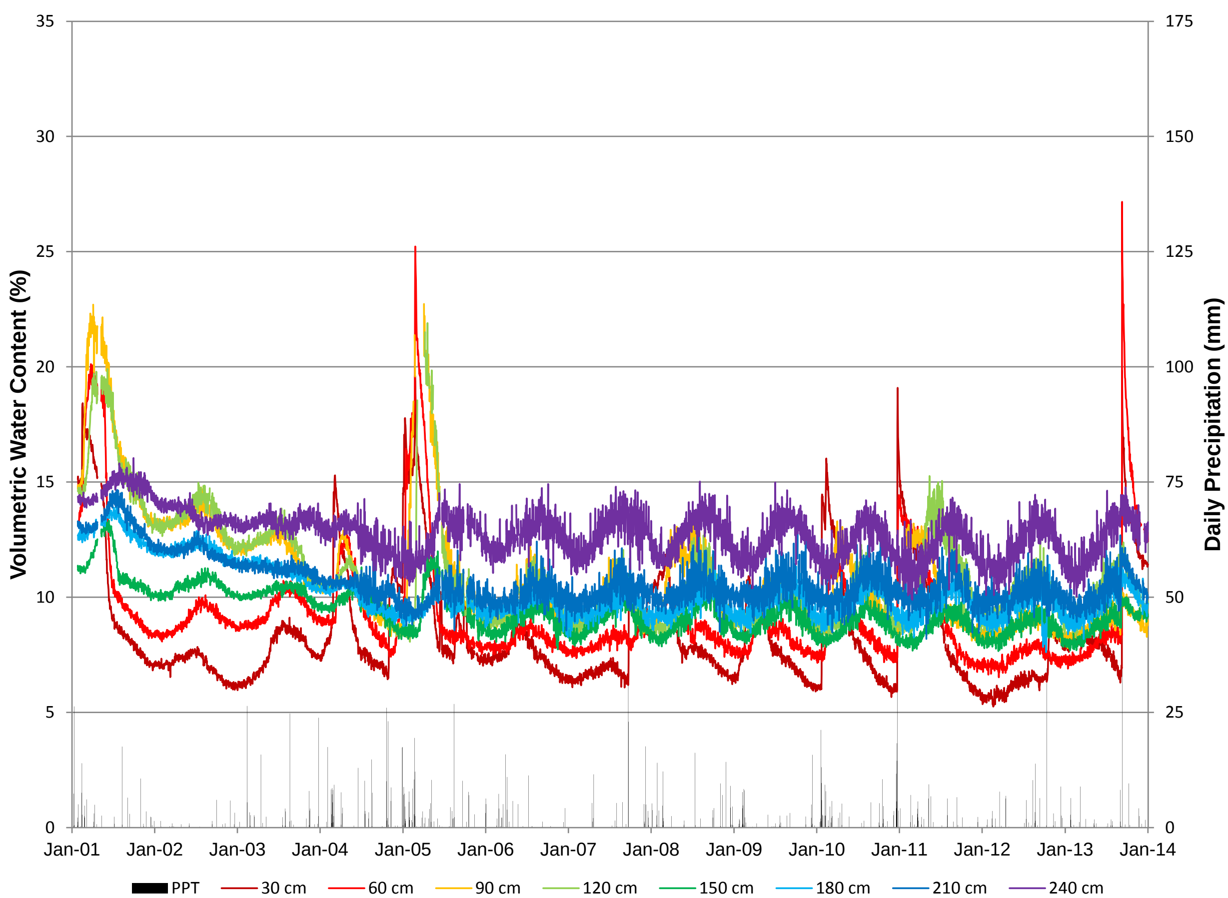

Figure 4-30 Soil Volumetric Water Content in the U-3 ax/bl Cover

4.6.4 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 lysimeters measuring 3.1 m (10 ft) in diameter by 2.4 m (8 ft) deep. The lysimeters are 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 cm (0.25 ft), 15 cm (0.5 ft), 30 cm (1 ft), 60 cm (2 ft), 90 cm (3 ft), 120 cm (4 ft), 180 cm (6 ft), and 240 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 needed to reduce 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 *Bromus tectorum* [cheatgrass] and *Halogeton glomeratus* [halogeton]), and native species (primarily *Atriplex confertifolia* [shadscale saltbush], *Krascheninnikovia lanata* [winterfat], *Ephedra nevadensis* [Nevada jointfir], *Achnatherum hymenoides* [Indian ricegrass], and *Elymus elymoides* [squirreltail 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 2013 lysimeter treatments, precipitation, irrigation, and drainage are summarized in Table 4-5. 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 2013 precipitation at the drainage lysimeters was 108 mm (4.3 in.). The 2013 irrigation applied to Lysimeter B was 213 mm (8.4 in.), and the 2013 irrigation applied to Lysimeters D, F, and H was 228 mm (9.0 in.).

There were 482 liters (127 gallons) of drainage from Lysimeter B during 2013. The equivalent depth of this drainage is 6.6 cm (2.6 in.). Drainage from Lysimeter B occurred throughout the entire year. The 2013 Lysimeter B drainage is 21% of total 2013 precipitation and applied irrigation. There was no drainage from any other lysimeter during 2013. Drainage has only occurred from the irrigated lysimeters. Total cumulative drainage from each irrigated lysimeter is 140.0 cm (55.1 in.) from Lysimeter B, 5.8 cm (2.3 in.) from Lysimeter D, 26.1 cm (10.3 in.) from Lysimeter F, and 11.0 cm (4.3 in.) from Lysimeter H (Figure 4-31).

Cover was measured for each of the eight drainage lysimeters on May 20, 2013. The results are summarized in Table 4-6.

Table 4-5 Area 3 Drainage Lysimeter Treatments in 2013

Lysimeter	Climate	Precipitation (mm)	Irrigation (mm)	Drainage (mm)	Surface Vegetation
A	Natural precipitation	108	0	0	Bare-soil
B	3-times natural precipitation	108	213	66	Bare-soil
C	Natural precipitation	108	0	0	Invader species
D	3-times natural precipitation	108	228	0	Invader species
E	Natural precipitation	108	0	0	Native species
F	3-times natural precipitation	108	228	0	Native species
G	Natural precipitation	108	0	0	Native species
H	3-times natural precipitation	108	228	0	Native species

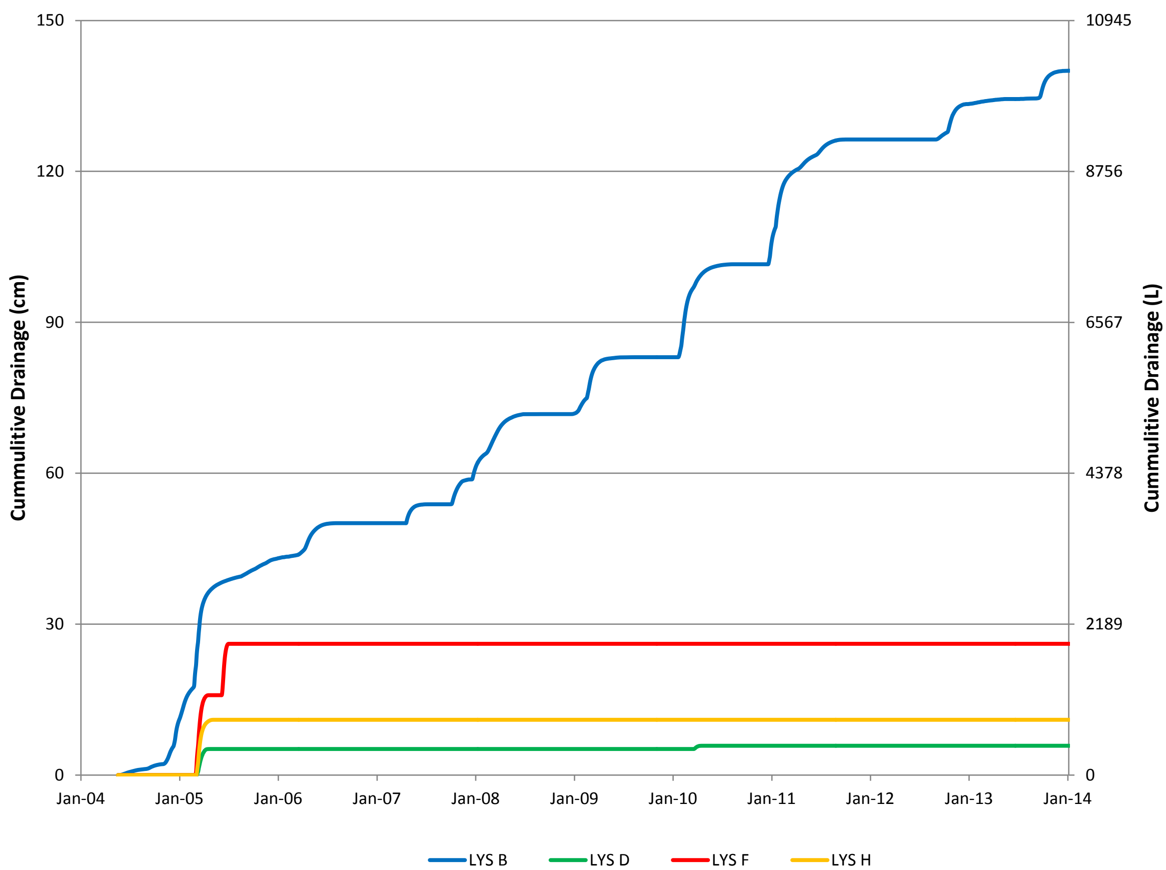

Figure 4-31 Cumulative Drainage from the Drainage Lysimeters

Table 4-6 Area 3 Drainage Lysimeter Percent Cover

Lysimeter	Plant Cover (percent)	Bare (percent)	Gravel (percent)	Litter (percent)
A	0.0	32.5	57.5	10.0
B	0.0	47.5	40.0	12.5
C	0.0	30.0	25.0	45.0
D	52.5	7.5	0.0	40.0
E	5.0	15.0	0.0	80.0
F	42.5	2.5	0.0	55.0
G	2.5	20.0	0.0	77.5
H	20.0	5.0	0.0	75.0

Figure 4-32 shows the total water storage for all eight lysimeters from 2004 through 2013. Water storage is calculated using TDR data. The two bare-soil lysimeters (Lysimeters A and B) have the highest water storage. Evaporation and drainage are the only processes that remove water from these two lysimeters. The water storage in Lysimeter D was high at the end of 2012 due to heavy rainfall and irrigation during the fall of 2012. The water in Lysimeter D was removed by ET in March and April 2013 as the annual invader species on Lysimeter D began to grow. Heavy rainfall and irrigation in September 2013 increased water storage in all eight lysimeters. The water storage remained higher than normal at the end of 2013.

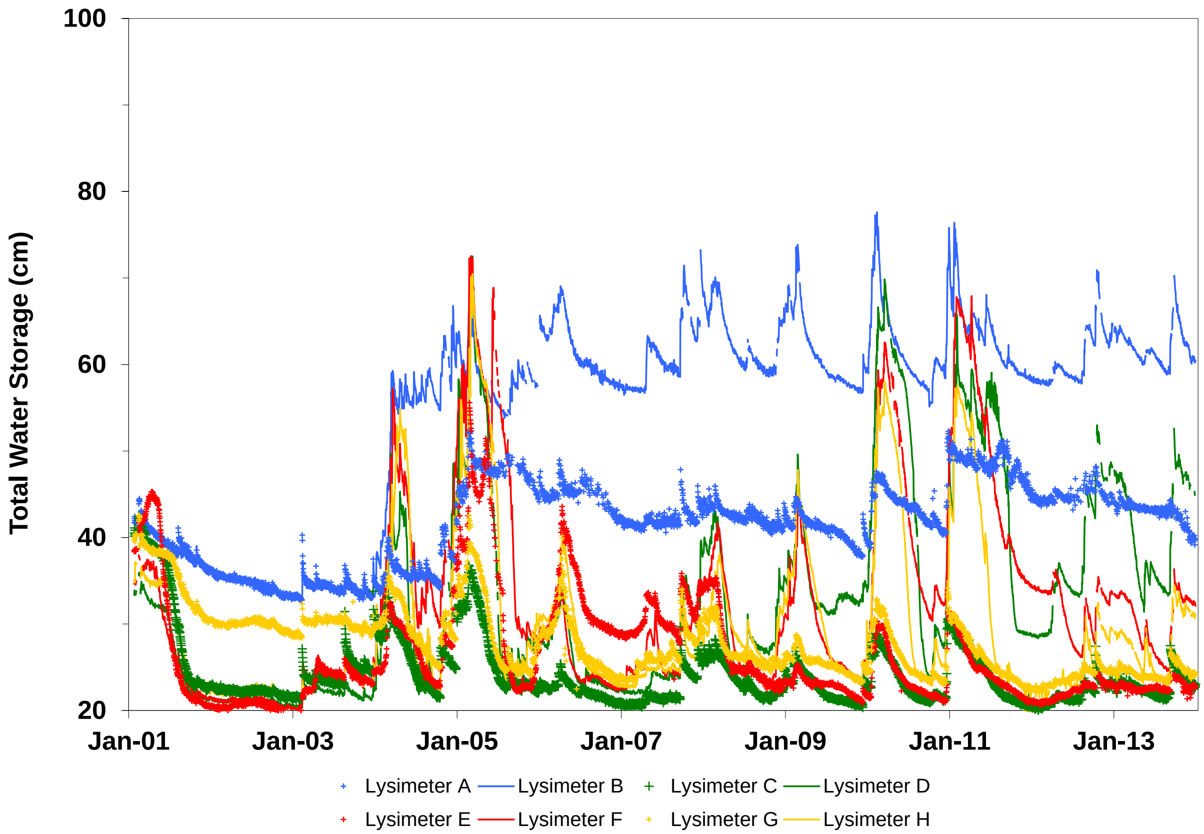

Figure 4-32 Soil Water Storage in the Drainage Lysimeters

4.7 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 and also helps ensure that vadose zone monitoring data are representative of the entire RWMS. Typically, as small depressions or cracks are observed in operational covers, they are filled before large subsidence features develop.

Quarterly inspections of the U-3ax/bl final ET cover look for evidence of cracks, settling, erosion, and subsidence. Inspections were done on March 12, June 12, September 17, and December 16, 2013. As a result of these inspections, several small cracks, erosion rills on the south slope cover, and two subsidence areas were repaired during 2013. Seven subsidence markers were installed in U-3ax/bl cover, and an initial elevation survey of these markers was completed in December 2000. Subsidence surveys were done approximately twice a year through March 2012, and the most recent subsidence measurements were made on March 22, 2012. The measured subsidence at each marker was 1.5, 1.8, 1.2, 1.8, 4.0, 1.8, and 1.8 cm (0.05, 0.06, 0.04, 0.06, 0.13, 0.06, and 0.06 ft). The subsidence survey interval was increased to 2 years after the March 2012 survey (U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office [NNSA/NFO], 2014) so there was not a U-3ax/bl subsidence survey during 2013.

Quarterly inspections of the 92-Acre Area final ET cover look for evidence of cracks, settling, erosion, and subsidence. This cover is also inspected when more than 2.5 cm (1.0 in.) of precipitation occurs during a day. Quarterly inspections were done on March 12, June 18, September 17, and December 16, 2013. As a result of these inspections, seven fractures, eight subsidence areas, and erosion rills on the cover side slope were repaired during 2013. Three of the subsidence areas were greater than 1 m long and greater than 15 cm deep (NNSA/NFO, 2014). Fifty-two subsidence markers were installed in the 92-Acre Area cover, and an initial elevation survey of these markers was completed in January 2012. Subsidence was last measured at each marker on November 21 and 22, 2012. The average subsidence at the 52 subsidence markers was 0.02 ft (0.6 cm), and the median subsidence was 0.03 ft (0.9 cm). There was not a subsidence survey on the 92-Acre Area during 2013.

4.8 BIOTA MONITORING DATA

No radiological biota monitoring data was collected during 2013.

The U-3ax/bl cover was seeded with native vegetation during December 2000. Quantitative analyses of the vegetative cover on the U-3ax/bl cover have been conducted annually in the spring since 2001. Results from the May 8, 2013, plant cover survey show 23.8% plant cover, 56.0% bare soil or rock, and 19.8% plant litter. The primary plant species observed in 2013 was *Atriplex confertifolia* (shadscale saltbush), which accounted for 17.4% cover. The percent cover for the established U-3ax/bl cover has ranged from 20.2% in 2005, to 19.6% in 2006, to 10.6% in 2007, to 26.8% in 2008, to 12.2% in 2009, to 19.8% in 2010, to 21.2% in 2011, to 13.0% in 2012, and to 23.8% in 2013.

Figure 4-33 provides the plant cover data for the U-3ax/bl cover. After significant fluctuations in plant cover and plant density during the first 5 years after seeding, the U-3ax/bl cover has an established, stable plant community that is very similar to native plant communities. Perennial plant cover and density are at steady levels with both persistent perennial shrubs and younger plants. Quantitative plant survey intervals at the U-3ax/bl cover will increase from annually to every 5 years.

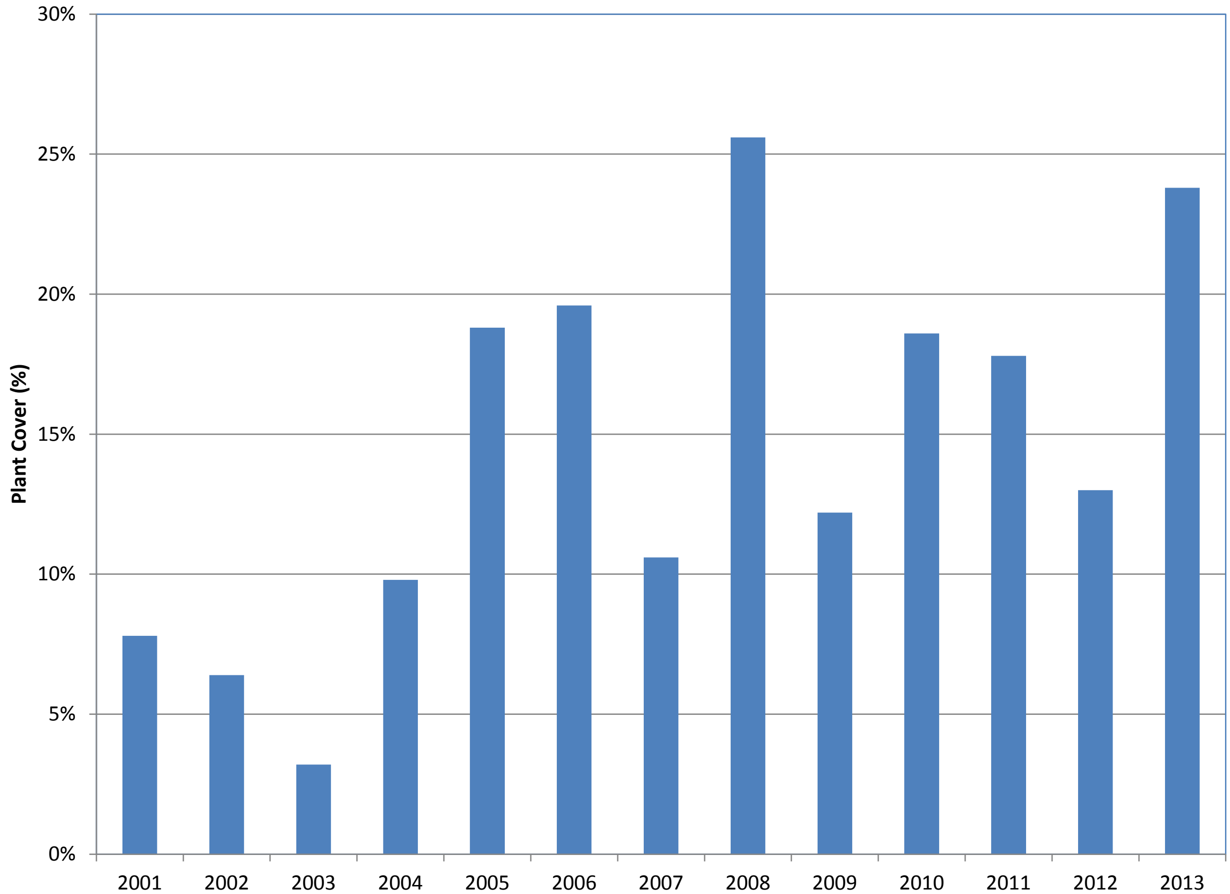

Figure 4-33 Percent Plant Cover on the U-3ax/bl Cover

The 92-Acre Area cover at the Area 5 RWMS was seeded with native vegetation during December 2011. An initial vegetation survey was completed on May 7, 2013, to assess seed germination and survival. Forty 100-m transects were sampled on the 92-Acre Area cover. There was a low germination rate and poor survival of the plants that did germinate. There were more dead plants than live plants and an unexpectedly high invasive weed population consisting primarily of *Halogeton glomeratus* (halogeton) and *Salsola tragus* (Russian thistle). These results indicate that re-seeding will be necessary to establish a viable native species plant community on the 92-Acre Area cover.

5.0 CONCLUSION

The 2013 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. 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 2013 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.

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6.0 REFERENCES

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