Nevada Test Site

BN-NTS-05-0025

Waste Management Monitoring Report Area 3 and Area 5 Radioactive Waste Management Sites

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LIST OF FIGURES

LIST OF ACRONYMS

AGL	Above Ground Level
AMSL	Above Mean Sea Level
BEIDMS	Bechtel Environmental Integrated Data Management System
BJY	Buster-Jangle Y
BN	Bechtel Nevada
CFR	Code of Federal Regulations
C	Celsius
cm	centimeter
CFR	Code of Federal Regulations
DCG	Derived Concentration Guide
DOE	U.S. Department of Energy
E	Evaporation
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
F	Fahrenheit
ft	feet
GCD	Greater Confinement Disposal
in	inches
km	kilometer
LLW	Low-Level Waste
MDC	Minimum Detectable Concentration
m	meter
mi	mile
mm	millimeter
mph	miles per hour
mR	milliroentgen
mrem	millirem
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NPCF	Neutron Probe Calibration Facility
NTS	Nevada Test Site
PA	Performance Assessment
pCi/m^2	picocuries per square meter
PET	Potential evapotranspiration
rem	Roentgen-equivalent-man
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
s	second
TDR	Time Domain Reflectometry
TLD	Thermoluminescent Dosimeter
VWC	Volumetric Water Content

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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 (NTS). The data are associated with radiation exposure, air, groundwater, meteorology, vadose zone, subsidence, and biota. This report summarizes the 2004 environmental data to provide an overall evaluation of RWMS performance and environmental compliance. Some of these data (e.g., radiation exposure, air, and groundwater) are presented in other reports (U.S. Department of Energy [DOE], 2004; Grossman, 2005; Bechtel Nevada [BN], 2005). Direct-radiation monitoring data indicate that exposure levels at and around the RWMSs are at or below background levels. Air-monitoring data indicate that tritium concentrations are slightly above background levels, and groundwater monitoring data indicate that the groundwater in the uppermost aquifer beneath the Area 5 RWMS is not impacted by facility operations. Precipitation during 2004 totaled 262.7 millimeters (mm) (10.34 inches [in]) at the Area 3 RWMS and 205.8 mm (8.10 in) at the Area 5 RWMS. Vadose zone data show that 2004 precipitation infiltrated approximately 120 centimeters (cm) (3.9 feet [ft]) before being returned to the atmosphere by evapotranspiration. Soil-gas tritium monitoring continues to show slow subsurface migration consistent with previous results. Biota monitoring was not conducted in 2004. All 2004 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility Performance Assessments (PAs).

INTRODUCTION

This document summarizes the calendar year 2004 Waste Management monitoring environmental data for the Area 3 and Area 5 RWMSs. The RWMS Integrated Closure and Monitoring Plan (BN, 2001a) describes details of the RWMS monitoring program. This report summarizes environmental data monitored for various media, 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 Emissions Standard for Hazardous Air Pollutants (NESHAP).
- Groundwater monitoring - conducted, as required by U.S. Environmental Protection Agency (EPA) regulations and DOE Orders, to assess the water quality of the aquifer beneath the RWMS, and confirm that RWMS activities are not affecting the aquifer.
- Vadose zone monitoring - conducted to assess the water balance of the RWMSs, confirm the assumptions made in the PAs (including no downward pathway), and evaluate the performance of the operational monolayer evapotranspiration (ET) waste covers.
- Soil-gas monitoring for tritium - conducted to evaluate tritium movement at waste containment cell GCD-05U.
- Biota monitoring for tritium (not done in 2004) - 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 BN as required by under BN/DOE Contractual Work Smart Standards, which include various DOE orders and regulations from the Code of Federal Regulations (CFRs). For a detailed description of these regulatory drivers, refer to BN (2001a). These regulatory drivers exist to mitigate risk to the public and environment and include:

- DOE Order 435.1 (Radioactive Waste Management)
- DOE Order 450.1 (Environmental Protection Program)
- DOE Order 5400.1 (General Environmental Protection Program)
- DOE Order 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 per Quality Assurance, Analysis, and Sampling Plans which can be found in the Routine Radiological Environmental Monitoring Plan (RREMP) (DOE, 2003). The RREMP was written with a Data Quality Objectives driven process to identify what and how technically defensible environmental monitoring data are collected.

SITE DESCRIPTIONS

Area 3 RWMS

The Area 3 RWMS is located on Yucca Flat within the 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 approximately 16 km (10 mi). Yucca Flat is bounded by Quartzite Ridge and Rainer 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 1). The Yucca Flat basin slopes from the north at an elevation of approximately 1,402 meters (m) (4,600 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 the several primary nuclear test areas and most of the length of the valley is marked with subsidence craters.

The thickness of the unsaturated zone at the Area 3 RWMS is estimated to be 488 m (1,600 ft) and the water table is assumed to occur in Tertiary tuff, based on data from surrounding boreholes. The tuff-alluvium contact is estimated to occur at a depth of between 305 and 457 m (1,000 and 1,500 ft) below land surface.

Daily air temperatures can vary from -18 degrees Celsius (^{o}C) (0 degrees Fahrenheit [^{o}F]) to 24 ^{o}C (75 ^{o}F) in winter and from 16 ^{o}C (60 ^{o}F) to 41 ^{o}C (105 ^{o}F) in summer. The climate of Yucca Flat is arid. The average annual precipitation based on a 44-year record (1961-2004) at a station located 4.5 km (2.8 mi) northwest of the Area 3 RWMS is 164 mm (6.46 in). The average annual precipitation based on the 9-year record (1996-2004 collected at the Area 3 RWMS is 162 mm (6.38 in). Precipitation is highly variable at the Area 3 RWMS. The standard deviation of the 9-year record of annual precipitation is 102 mm (4.02 in) with a maximum of 374 mm (14.72 in) in 1998 and a minimum of 26 mm (1.02 in) in 2002. Potential evapotranspiration (PET) at the Area 3 RWMS, calculated using local meteorology data, is approximately 10 times the annual average precipitation.

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 bounded 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 1). The valley floor slopes gently toward a central playa. 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 m) at the northeast corner of the RWMS (Well Ue5PW-2), and 271.5 m (891 ft) to the northwest of the RWMS (Well Ue5PW-3). The boreholes for Wells Ue5PW-1 and Ue5PW-2 penetrate only alluvium, while the borehole for Well Ue5PW-3 encounters Tertiary tuff at a depth of approximately 189 m (620 ft).

Air temperatures can vary from -15 ^{o}C (5 ^{o}F) to 24 ^{o}C (75 ^{o}F) in winter and from 16 ^{o}C (60 ^{o}F) to 45 ^{o}C (113 ^{o}F) in summer. The climate of Frenchman Flat is arid. The average annual precipitation based on a 42-year record (1963-2004) at a station located 6.4 km (4 mi) south of the Area 5 RWMS is 125 mm (4.92 in). The average annual precipitation based on the 10-year record (1995-2004) collected at the Area 5 RWMS is 129 mm (5.08 in). Precipitation is highly variable at the Area 5 RWMS. The standard deviation of the 10-year record of annual precipitation is 64 mm (2.56 in) with a maximum of 259 mm (10.20 in) in 1998 and a minimum of 38 mm (1.50 in) in 2002 Average annual PET at the Area 5 RWMS, calculated using local meteorology data, is approximately 13 times the annual average precipitation.

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; the annual average temperature at Area 3 is about 2 ^{o}C (4 ^{o}F) cooler than at Area 5; and soils at Area 3 are generally finer-grained than at Area 5.

Hydrologic Conceptual Model of the Area 3 and Area 5 RWMSs

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 contents 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 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 begins between approximately 49 to 119 m (160 to 390 ft) in Area 3, and between approximately 40 to 90 m (131 to 295 ft) 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). 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), in Levitt et al. (1999), and in Levitt and Yucel (2002), 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 1 percent of the annual rainfall at Area 5, and 10 percent of annual rainfall at Area 3, based on conservative one-dimensional modeling results (Levitt et al., 1999). In addition, monitoring data from a bare-soil weighing lysimeter located in Area 5 indicate that the soil water storage has increased slowly with time, although no free drainage has been measured through the bottom of the lysimeter.

PROJECT DESCRIPTION

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

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, at the time of formation, ranged from 122 to 177 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth (Plannerer, 1996). Disposal in the U-3ax crater began in the late 1960s. Disposal began in U-3bl 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 closure cover that is at least 2.4 m (8 ft) thick. For details of the final closure plan of CAU 110, refer to BN (2001b). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at is currently being 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. The U-3bh unit remains open for waste disposal from other approved generators. The remaining two craters are not in use (Figure 3). For a detailed description of the facilities at the Area 3 RWMS refer to Shott et al. (1997).

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 4). Some previous documents list fewer landfill cells, but new cells continue to be constructed and Trench 4 was separated into T04C and T04C-1 in BN (2001a). Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). Disposal consists of placing waste in various sealed containers in the unlined pits and trenches. Soil backfill is pushed over the containers in a single lift, approximately 2.4 m (8 ft) thick, as rows of containers reach approximately 1.2 m (4 ft) below original grade. 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 (2001a) and Cochran et al. (2001).

There are currently 9 active pits receiving waste, 16 closed trenches, and 7 closed pits. The landfill cells that remain open include Pit 3 (P03U), Pit 6 (P06U), Pit 9 (P09U), Pit 10 (P10C), Pit 12 (P12C), Pit 13 (P13U), Pit 14 (P14U), Pit 15 (P15U) and Pit 16 (P16C). PO3U is the only active mixed waste disposal cell. All other active units contain low-level radioactive waste. Landfill cells that have been closed, to date, include 16 trenches and 7 pits. The seven closed pits are Pit 1(P01U), Pit 2 (P02U), Pit 4 (P04U), Pit 5 (P05U), Pit 7 (P07U), Pit 8 (P08U), and Pit 11 (P11U).

Construction was completed on 5 new pits in 2004: Pit 11 (P11U), Pit 12 (P12C), Pit 13 (P13U), Pit 14 (P14U) and Pit 15 (P15U).

ENVIRONMENTAL MONITORING DATA

Types of RWMS Environmental Data

Area 3 RWMS monitoring locations are shown in Figure 3, and Area 5 RWMS monitoring locations are shown in Figures 4 and 5. Environmental monitoring data are archived in BN's environmental monitoring database: Bechtel Environmental Integrated Data Management System (BEIDMS). 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 alpha concentrations
- Weekly beta concentrations
- Bi-weekly tritium concentrations

- Monthly gamma concentrations
- Monthly americium concentrations
- Monthly plutonium concentrations
- Radon flux measurements from waste covers

Groundwater Monitoring Data

- Quarterly water-level measurements (manual)

- *Semi-Annual Indicators of Contamination:*
    - pH (field measurement)
    - Specific conductance (field measurement)
    - Total organic carbon (TOC)
    - Total organic halides (TOX)
    - Tritium (^{3}H)

- *Semi-Annual 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 as ^{238}Pu and $^{239+240}$Pu

Meteorology Monitoring Data

- *Daily Meteorology Data:*
    - Average air temperature at heights of 3 m (10 ft) and 9.5 m (31 ft) above ground level (AGL)
    - Maximum air temperature at heights of 3 m and 9.5 m AGL
    - Minimum air temperature at heights of 3 m and 9.5 m AGL
    - Average relative humidity at heights of 3 m and 9.5 m AGL
    - Maximum relative humidity at heights of 3 m and 9.5 m AGL
    - Minimum relative humidity at heights of 3 m and 9.5 m AGL
    - Average wind speed at heights of 3 m and 9.5 m AGL
    - Maximum wind speed at heights of 3 m and 9.5 m AGL
    - Average barometric pressure
    - Maximum barometric pressure
    - Minimum barometric pressure
    - Total precipitation

- *Hourly Meteorology Data:*
    - Average air temperature at heights of 3 m and 9.5 m AGL
    - Average relative humidity at heights of 3 m and 9.5 m AGL

  - Average wind speed at heights of 3 m and 9.5 m AGL
  - Average wind direction at heights of 3 m and 9.5 m AGL
  - Average barometric pressure
  - Average solar radiation
  - Total precipitation

Vadose-zone Monitoring Data

- *Annual Soil Gas-Phase Monitoring Data:* Soil gas tritium concentrations measured at GCD-05U gas sampling ports (nine depths)

- *Daily Weighing Lysimeter Data (Area 5):*
  - Daily evaporation from the bare-soil weighing lysimeter
  - Daily evapotranspiration from the vegetated weighing lysimeter

- *Daily Drainage Lysimeter Data (Area 3):*
  - Soil volumetric water content (VWC), soil matric potential, and temperature with depth
  - Total soil water storage

- *Daily Automated Vadose-Zone Monitoring System Data:*
  - Soil VWC with depth in waste covers
  - Soil VWC beneath waste cells
  - Soil matric potential with depth in waste covers
  - Soil temperature with depth in waste covers
  - Soil temperature beneath waste cells

- *Periodic Neutron Logging Data:* Soil VWC with depth at selected neutron access tubes

- *Periodic Subsidence Monitoring Data (quarterly and/or after significant rainfall events):* Locations and description of subsidence features on waste covers

Biota Monitoring Data: Locations of sampled plants and plant water tritium concentrations

Bechtel Environmental Integrated Data Management System (BEIDMS)

BEIDMS is an Oracle®-based, relational database management system developed by Bechtel for the comprehensive management and processing of environmental data. This database management system has been licensed and tailored to support both small and large environmental projects at BN. BEIDMS will ensure consistency and promote advanced planning, while providing a central repository for all unclassified environmental data. BEIDMS is currently operational for environmental monitoring data from the NTS.

Radiation Exposure Data

The goals of direct radiation monitoring are to assess the state of the external radiation environment, detect changes in that environment, and measure gamma radiation levels near potential exposure sites. Performance objectives in DOE Order 435.1 state that LLW disposal facilities shall be sited, designed, operated, maintained, and closed so that a reasonable expectation exists that dose to representative members of the public shall not exceed 25 millirem per year (mrem/year) total effective dose equivalent from all exposure pathways, excluding the dose from radon. Given that the RWMSs are located well within the NTS boundaries, there are no members of the public which could access these areas for significant periods of time. TLDs are located at the RWMSs (Figures 3 and 4) to measure direct radiation and show the potential dose to a hypothetical person residing year-round at the RWMS. There are 5 TLD locations in and around the Area 3 RWMS and there are 12 TLD locations in and around the Area 5 RWMS.

The TLDs measure ionizing radiation exposure from all sources, including natural and man-made radioactivity. The TLD used was the Panasonic UD-814AS, consisting of four elements housed in an air-tight, water-tight, ultraviolet-light-protected case. A slightly shielded lithium borate element was used to check low-energy radiation levels and the average of three calcium sulfate elements were used to measure penetrating gamma radiation. At each TLD monitoring location (Figures 3, 4, and 5), a pair of TLDs were placed 1 ± 0.3 m (28 to 51 in) AGL and were exchanged for analysis on a quarterly basis. Quarterly analyses were performed using automated TLD readers that were calibrated and maintained by the BN Radiological Control Department.

Within 400 m (1,312 ft) of the Area 3 RWMS boundary, 60 nuclear weapons tests were conducted between 1952 and 1972. Fourteen of these tests were atmospheric tests which left radionuclide contaminated surface soil and, therefore, elevated radiation exposure rates across the area. Waste pits in the Area 3 RWMS are subsidence craters from seven subsurface tests that are being filled with LLW and covered with clean soil. As a result, average measured exposure rates are lower inside the Area 3 RWMS than at the fence line or from the fence line out to 2.2 km (1.4 mi). Annual exposure rates during 2004 in and around the Area 3 RWMS are shown in Figure 6. The exposure rate measured inside the Area 3 RWMS and three of four measurements at the boundary were within the range of background exposure rates. Five TLD locations outside the Area 3 RWMS: T3, T3 West, T3A, RWMS-S, and U-3CO N had the highest exposure rates observed and all are near ground zero locations for past atmospheric nuclear tests. During 2004, the average exposure rate at these five locations and near the ground zero sites was 1.05 milliroentgen (mR/day). During 2004, the exposure rate at NTS background locations averaged 0.30 mR/day.

Ten underground nuclear weapons tests were conducted within 3 km (1.9 mi) of the Area 5 RMWS between 1965 and 1971. Nine of these released radioactivity to the surface which contribute to the exposure rates in the area. No nuclear weapons testing occurred within the boundaries of the Area 5 RWMS. During 2004, the annual exposure rates at Area 5 RWMS boundary locations were within the range of exposure rates measured at NTS background locations (Figure 7). Significant variation was recorded in the first quarter at one Area 5 RWMS location (Figure 8) and during the third and fourth quarters at one of the TLD locations at the

NTS entry Gate 100 (Figure 9). These variations are thought to be associated with waste operations at the site. At the RWMS location, the higher exposure is believed to be from waste shipments being placed into Pit 11 which is adjacent to the RWMS Northwest Corner TLD. At Gate 100, the higher exposures measured during the last two quarters of 2004 are believed to be from trucks carrying waste shipments entering the NTS which park next to the Gate 100 Truck Parking TLD location.

Comparisons of 1998 – 2004 direct radiation exposure data using TLDs from the two RWMSs and NTS background locations are presented in Figures 10 and 11. These data indicate that direct radiation exposure at the RWMSs is low. Over the past seven years, all sites had direct radiation less than 1.8 mR/day, and all but the five previously mentioned TLD locations near ground zero sites outside the Area 3 RWMS had exposure rates less than 0.6 mR/day. The 2004 average exposure rate at the RWMSs boundaries and inside the RWMSs was 0.36 mR/day. This is comparable to the average exposure rate of 0.30 mR/day measured during 2004 at the NTS background TLD locations. From common fission product gamma radiation, the dose from one roentgen can be approximated by one roentgen-equivalent-man (rem). Therefore, the exposure rate measured during 2004 corresponds to a net average dose (average minus background average) of approximately 0.06 mrem/day (22 mrem/year) in or at the RWMS boundaries.

Air Monitoring Data

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 collected at the Area 3 and Area 5 RWMSs and analyzed for tritium. Approximately 11 m^3 of air is drawn across a desicant during a two week period to collect atmospheric moisture. The moisture is distilled from the desiccant and the tritium activity is measured by liquid scintillation. Past monitoring (through 1997) at the Area 3 RWMS indicated no detectable airborne tritium. Due to the lack of detectable tritium, and the lesser quantities of tritium sources disposed of within the Area 3 RWMS (in comparison to the Area 5 RWMS), monitoring for airborne tritium was terminated in 1997. However, due to recent and possible future disposal of tritium sources at Area 3 RWMS, bi-weekly sampling for atmospheric moisture was begun at U-3h/at S and U-3bh N (Figure 3) on November 8, 2004. Sampling at the NE station of the Area 5 RWMS was terminated on June 19, 2003. This was done to eliminate costs for moving the station and electrical power lines when additional disposal pits are added. However, the U. S. Department of Defense and Sugar Bunker stations are in prevailing downwind locations (north and south of the RWMS, respectively) from the buried tritium sources and continue to provide adequate environmental monitoring for the area.

Tritium concentrations in air for Schooner and Guard Station 510 are also included with those for Area 3 and Area 5 RWMSs in Figure 12 for comparison. Schooner is located near the northwest corner of the NTS at the site of a test that was conducted as part of the “Plowshare” series of tests. The test resulted in elevated tritium concentrations in surface soils. Data from Guard Station 510, located at the southwest edge of the NTS, can be considered background. As shown in Figure 12 and in previous reports, the tritium concentrations near the Area 3 and Area 5

RWMSs are below the DOE Derived Concentration Guide (DCG) for tritium. The DCG is the concentration of a radionuclide in air that could be inhaled for one year and not exceed the DOE primary radiation standard to the public of 100 mrem/year effective dose equivalent.

Particulates

Air particulate samples are collected on glass-fiber filters weekly 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 2004 analysis results indicate that no man-made radioactivity was detected by gamma spectroscopy. However, concentrations of americium and plutonium near the minimum detectable concentrations (MDCs) of the measurements were detected. Figures 13, 14, and 15 compare the concentrations of americium and plutonium at the RWMSs with the results for other sampling stations. The concentrations near the RWMSs in 2004 were similar to the concentrations at stations in other NTS areas. The americium and plutonium concentrations at the Area 3 RWMS were slightly higher than the other NTS stations. However, the contaminated areas surrounding the Area 3 RWMS make it difficult to determine how much waste operations contributed, if anything, to the measured concentrations. Nevertheless, as shown in these figures, all the concentrations were below the DCG for each radionuclide.

Radon

The performance objective (DOE Order 435.1), and regulatory limit (40 CFR 61, subpart Q) for radon emissions from DOE facilities is 20 pCi/m^2 s. Radon flux measurements were made during 2004 on the Area 5 RWMS for comparison with the regulatory limit. Specifically, radon flux measurements were conducted on the expansion area north of the Area 5 RWMS, on the P01U (Pit 1), and on the north end of the P13U (Pit 13) (Figure 16). Measurements within the expansion area were made January 7-8 and 15-20, 2004 on undisturbed areas where Pit 13 was excavated in mid 2004. Measurements on Pit 1 and on the north end of Pit 13 were made on December 20 – 22, 2004 and control measurements were made at the Area 5 Lysimeter Facility on December 20 – 22, 2004. Pit 1 has a relatively high radium inventory and Pit 13 in the expansion area has high thorium-bearing waste. Measurements were made using radon flux domes (Rad Elec, Inc.) placed on the ground surface. Electrets inserted in the domes measure the flux of radon from the ground.

Radon flux results are summarized in Figure 17. All radon flux measurements are at least five times lower than the regulatory limit and flux rates from waste caps are not higher than those from undisturbed or control locations.

Groundwater Monitoring Data

Three pilot wells (designated as Ue5PW-1, Ue5PW-2, and Ue5PW-3) were drilled around the perimeter of the Area 5 RWMS in 1993 (see Figure 5). 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 detail in the *Nevada Test Site 2004 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site* (BN, 2005). 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 18. These data indicate that the water table beneath the Area 5 RWMS is flat, with little or no groundwater flow.

Meteorology Monitoring Data

Meteorology monitoring data collected in 2004 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 a meteorology station near the Area 3 RWMS and a meteorology station near the Area 5 RWMS (see Figures 3 and 4). The Area 3 RWMS meteorology station is located approximately 30 m (100 ft) northwest of the Area 3 RWMS. The Area 5 RWMS meteorology station is located southeast of the Area 5 RWMS, about 100 m (328 ft) from Well Ue5PW-1.

Air Temperature

Air temperatures at the Area 3 RWMS are slightly cooler than air temperatures at the Area 5 RWMS. The 2004 maximum recorded 3 m temperature at the Area 3 RWMS was 38.9 ºC (100.4 ºF) and the 2004 maximum recorded 3 m temperature at the Area 5 RWMS was 41.1 ºC (106.0 ºF). The 2004 minimum recorded 3 m temperature at the Area 3 RWMS was -13.3 ºC (8.1 ºF) and the 2004 minimum recorded 3 m temperature at the Area 5 RWMS was -9.7 ºC (14.5 ºF) (Figure 19).

Relative Humidity

Measured relative humidity at the Area 3 RWMS and the Area 5 RWMS are similar. The average relative humidity during 2004 at these two arid sites is 38.8% (Figure 20).

Barometric Pressure

Figure 21 depicts average daily barometric pressure changes measured at meteorology stations located in Area 3 and Area 5 in 2004. The difference in barometric pressure readings between the two stations is caused by the 261 m (856 ft) difference in elevation.

Wind Speed and Direction

The average wind speed in higher at the Area 3 RWMS than at the Area 5 RWMS. During 2004, the average wind speed at the Area 3 RWMS was 3.0 meters per second (m/s) (6.7 mph) and the maximum gust was 20.3 m/s (45.4 mph). During 2003, the average wind speed at the Area 5 RWMS was 2.6 m/s (5.8 mph) and the maximum gust was 20.4 m/s (45.6 mph). Daily maximum and average wind speeds are in Figures 22 and 23.

Wind rose diagrams illustrate wind direction (direction of wind source) and the occurrence of wind speed groupings in each direction, using hourly wind data, measured at a height of 3.0 m

(10 ft) AGL. Generally, low wind speeds tend to originate from the north, whereas high wind speeds tend to originate from the south. Wind roses from the Area 3 and Area 5 RWMS meteorology stations are presented in Figures 24 and 25, respectively. The one-year wind roses presented here are very similar to the multiple-year wind roses presented in BN (2001c).

Precipitation

Rainfall at the Area 3 RWMS in 2004 was well above average, totaling 263 mm (10.35 in). The maximum daily rainfall at the Area 3 RWMS was 26 mm (1.02 in) on October 20, 2004. The annual average precipitation at this station for 1996 to 2004 is 162 mm (6.38 in). Rainfall at the Area 5 RWMS in 2004 was also above average, totaling 206 mm (8.11 in). The maximum daily rainfall at the Area 5 RWMS was 27 mm (1.06 inches) on October 20, 2004. The average annual precipitation at this station for 1995 to 2004 is 129 mm (5.08 in). Figures 26 and 27 depict the 2004 daily total precipitation at the Area 3 and Area 5 RWMSs, respectively.

Historical precipitation data recorded at the Buster-Jangle Y (BJY) station (located about 3 km northwest of the Area 3 RWMS) and at the Area 3 RWMS are in Figure 28. The BJY station is a Meteorological Data Acquisition (MEDA) station operated by the Air Resources Laboratory, Special Operations and Research Division (ARL/SORD). Historical precipitation data recorded at the Well 5B station (located about 5.5 km south of the Area 5 RWMS) and the Area 5 RWMS are provided in Figure 29. The Well 5B station is also an ARL/SORD MEDA station.

Potential Evapotranspiration

The total calculated PET in 2004 for Area 3 is 1,597.4 mm (63 in) and for Area 5 is 1,650 mm (65 in). Total PET for Areas 3 and 5 are derived using a modified version of the radiation-based equation of Doorenbos and Pruitt (1977). This equation calculates PET 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 employed for the data reports through 2001 (Jensen et al., 1990). The Doorenbos and Pruitt equation reduces data input requirements because no net radiation data are used. PET in 2004 for the Area 3 RWMS is six times greater than precipitation, and PET in 2004 for the Area 5 RWMS is eight times greater than precipitation. The ration of PET to precipitation is lower than normal because there was above average rainfall in 2004.

Vadose Zone Monitoring Data

Monitoring Strategy

Vadose-zone monitoring is conducted at the Area 3 and Area 5 RWMSs to demonstrate compliance with DOE Orders 5400.1 and 435.1. The monitoring is also performed to substantiate the assumptions made in the PA for each RWMS (e.g., hydrologic conceptual models including soil water contents, upward and downward flux rates, 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 current vadose-zone monitoring program at the RWMSs is designed based on an understanding of the vadose-zone system acquired through extensive characterization studies (BN, 1998a; Blout et al., 1995; Reynolds Electrical and Engineering Company, Inc. [REECo], 1993a, 1993b, 1994; Schmeltzer et al., 1996; Shott et al., 1998, 1997; Tyler et al., 1996) and modeling studies (Levitt et al., 1999). The current program is also designed, in part, as a result of an Alternative Evaluation Study on vadose-zone monitoring (BN, 1998b) using an organized team approach and from vadose-zone monitoring field experiences.

The objectives of the vadose-zone monitoring program are accomplished, in part, by measuring water balances at each RWMS. Water-balance surveillance involves the use of meteorology data to calculate PET values (the driving force of upward flow), directly measuring evapotranspiration and bare-soil evaporation at the Area 5 RWMS weighing lysimeter facility, 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 well GCD-05U.

Gas-phase Tritium

Gas-phase tritium monitoring is conducted via soil gas sampling at Greater Confinement Disposal (GCD)-05U located near the center of the Area 5 RWMS (see Figure 4). This unit has a large tritium inventory (~2.2 million curies at time of disposal) which is buried from 20 to 37 m (65 to 120 ft) below ground surface. Two strings of nine soil-gas sampling ports are buried at depths of 10 ft (3.0 m), 20 ft (6.1 m), 30 ft (9.1 m), 40 ft (12.2 m), 50 ft (15.2 m), 65 ft (19.8 m), 85 ft (25.9 m), 110 ft (33.5 m), and 119 ft (36.3 m) 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. Approximately 30 L of soil gas sample provides approximately 0.3 g of water. Tritium sampling at GCD-05U provides a direct measure of changes in tritium activity with depth due to degradation of waste containers, advection, and diffusion. Sampling started in 1990 and has continued at least annually through 2004.

Tritium in soil-gas was sampled from the 9 GCD-05U sampling depths in June 2004. The 15-year trends in results indicate that upward migration of tritium through soil from the waste level is extremely slow. Tritium concentrations have remained constant and low from the surface to 40 ft deep. Tritium concentrations at 50 and 65 ft increased rapidly in 1993 and have continued to slowly increase. For each year of sampling since 1990, soil-gas tritium concentrations have been the highest at the 85 ft depth. Tritium concentrations at 85, 110, and 119 ft slowly increased until 2001 and have since decreased.

The sample ports at depths of 65, 85, 110, and 119 ft are adjacent to the tritium source, but tritium concentrations at these depths are a fraction of the 2.2 million curies originally buried at the site. Soil-gas tritium concentrations with depth and time are illustrated in Figures 30 and 31.

The 2000 tritium in soil-gas data were incorrectly reported in past year's reports. The corrected data are as much as 50 percent lower in concentration than previously reported.

Area 5 Weighing Lysimeter Facility

The Area 5 weighing lysimeter facility consists of two precision weighing lysimeters located about 400 m (0.25 mi) southwest of the Area 5 RWMS (see Figure 5). Each lysimeter consists of a 2 x 4 m (6.6 x 13 ft) by 2 m (6.6 ft) deep steel box filled with soil. Each lysimeter is mounted on a sensitive scale, which is continuously monitored using an electronic loadcell. Each loadcell can measure approximately 0.1 mm (0.004 in) of precipitation or evapotranspiration. One lysimeter is vegetated with native plant species at the approximate density of the surrounding desert, and one lysimeter is kept bare to simulate the bare operational waste covers at the Area 5 RWMS. The loadcells have been monitored continuously since March 1994 and provide an accurate dataset of the surface water balance at the Area 5 RWMS.

The weighing lysimeter data represent a simplified water balance: the change in soil water storage is equal to precipitation minus evaporation (E) (on bare lysimeters) or evapotranspiration (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 run-off. Total soil water storage for the period of March 30, 1994, through December 31, 2004, is illustrated in Figure 32.

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). Soil water storage decreases rapidly in the vegetated lysimeter following high-rainfall periods. Increases in soil water storage observed early in the data record in the vegetated lysimeter were a result of irrigation conducted to ensure that transplanted vegetation survived. Although, no water has accumulated at the bottom of the lysimeters, long-term numerical simulations (30-year) using a unit gradient bottom boundary indicate that 1.1 cm/year reaches the bottom of the bare lysimeter and <0.1 cm/year reaches the bottom of the vegetated lysimeter.

During 2004, E from the bare lysimeter was slightly lower than ET from the vegetated lysimeter, and soil water storage increased in both lysimeters (Figure 33). The vegetated lysimter dried out as cumulative ET exceeded cumulative precipitation from April 27 to October 20. Similarly, the bare-soil lysimeter dried out as cumulative E exceeded cumulative precipitation from April 19 to October 20. ET was greater than E in March, April, May, June, July, September and December (Figure 34).

Automated Waste Cover Monitoring System

In 1998, an automated monitoring system was installed in Area 5 adjacent to Well Ue5PW-1 at the Neutron Probe Calibration Facility (NPCF). Time domain reflectometry (TDR) sensors are used to measure water content around different types of casings used in neutron probe access holes. These measured water contents are used for calibrating neutron probes. This TDR system has 36 TDR probes buried at depths of 30, 60, and 90 cm (1, 2, and 3 ft) around 4 different neutron probe access hole casing types. There are 3 replicate TDR sensors at each depth for each casing type. The Tektronic 1502C cable tester was replaced with a Campbell Scientific TDR100 at the NPCF during August 2004 because the original cable tester malfunctioned. During the installation process, one TDR probe at 3 ft was broken and not repaired. In 2004, precipitation infiltrated into the soil and percolated below 0.9 m (3 ft) at the NPCF. No neutron probes were calibrated during 2004.

In 1998 at the Area 5 RWMS, TDR probes were buried 1.2 m (4 ft) beneath the open pit floors of Pits 3 and 5. Waste and an operational cover were placed above these probes during disposal operations. In January 2002, the TDR probes in the floor of Pit 3 were destroyed. Measured water content in the floor of Pit 3 and Pit 5 has remained constant at approximately 10 percent volumetric water content (Figure 35). The constant measured water content indicates that no moisture has percolated to 4 ft below the waste.

In 1999, TDR probes were also installed in the operational cover of Pit 3 at two sites (north and south) at depths ranging from 10 to 180 cm (0.3 to 5.9 ft). The fall precipitation from late October 2004 through December 2004 infiltrated into the operational cover and percolated past a depth of 120 cm at the north location (Figure 36) and past a depth of 150 cm at the south location (Figure 37). This moisture could be below the range of surface evaporation and may continue to move downward. This is the deepest observed moisture percolation in the Pit 3 operational cover.

In 2000, TDR probes were installed in the operational covers of Pits 4 and 5 at depths ranging from 20 to 180 cm (0.7 to 5.9 ft). The Fall 2004 precipitation infiltrated into the operational cover of Pit 4 and Pit 5 and percolated deeper than 120 cm in Pit 4 (Figure 38) and deeper than 60 cm in Pit 5 (Figure 39). Slight seasonal variation in water contents at greater depths may be observed, but these are likely the result of thermal effects rather than actual liquid wetting fronts.

In December 2000, TDR probes were installed in the waste cover of the U-3ax/bl waste disposal unit at the Area 3 RWMS. Eight vertically arranged TDR probes were installed at four locations. These probes are wired into two data logger stations. Measured soil water contents for one location (East Nest B) in the U-3ax/bl waste cover are shown in Figure 40. The TDR data indicate the soil water content in the cover generally decreased over time as the vegetation on the cover grew.

The amount of living vegetation on the cover of U-3as/bl is critical to its effectiveness. A long-term goal of 12 percent vegetative cover has been established for U-3ax/bl, where vegetative cover is the percent of the soil cap area that is covered by living plant material. This goal is based on the vegetative cover of similar native environments. Obtaining the optimal vegetative cover of 12 percent is dependent upon the seed germination success and seedling survival of native plants seeded or transplanted on the soil cap. The maximum infiltration ever observed at the cover was approximately 2 m (6 ft) (BN, 2001c; 2002b) and resulted from applied irrigation to enhance vegetation survival. Moisture from these depths was quickly removed by ET within several months. A quantitative analysis of the vegetative cover on the U-3ax/bl soil cap and the vegetated drainage lysimeters was conducted in the spring of 2002 (BN 2002a). The percent cover for U-3ax/bl and the seeded lysimeters were found to be 6 and 12 percent, respectively. For more information on the closure and monitoring of U-3ax/bl, refer to BN (2001b).

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 (see Figure 3). This facility is designed to collect gravity drainage from eight 10 ft (3.05 m) diameter by 8 ft (2.44 m) 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 0.25 ft (7.6 cm), 0.5 ft (15 cm), 1.0 ft (30 cm), 2.0 ft (61 cm), 3.0 ft (91 cm), 4.0 ft (122 cm), 6.0 ft (183 cm), and 8 ft (244 cm) deep. Drainage from the lysimeters provides 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 Russian thistle, halogeton, and tumble mustard), and native species (primarily shadscale, winterfat, ephedra, and Indian rice grass). The climate treatments are natural precipitation and three times natural precipitation. The increased precipitation lysimeters receive natural precipitation and are irrigated with sprinklers at a rate equal to two 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 three times natural precipitation, Lysimeter C is invader species with natural precipitation, Lysimeter D is invader species with three times natural precipitation, Lysimeter E is native species with natural precipitation with natural precipitation, Lysimeter F is native species with three times natural precipitation, Lysimeter G is invader species with natural precipitation, and Lysimeter H is invader species with 3 times natural precipitation.

Volumetric water contents at all measurement depths through time are illustrated in Figure 41 for bare-soil, natural precipitation lysimeter (Lysimeter A) and in Figure 42 for the native species, natural precipitaion lysimeter (Lysimeter E). Lysimeter A mimics bare-soil operational soil covers and Lysimeter E mimics final ET monolayer covers. Since 2000, the vegetated lysimeter has been significantly drier than the bare lysimeter. The water content in the vegetated lysimeter has been approximately 8 percent below 90 cm while the water content below 90 cm in the bare lysimeter has been approximately 14 percent. The vegetated lysimeter also has a more uniform water content throughout the soil profile.

Figure 43 shows the calculated total water storage for all eight lysimeters using the TDR data. The vegetated lysimeters (both native and invaders species cells) are significantly drier (lower soil water storage) than the bare cells. The vegetated lysimeters have similar soil water storage with the exception of the Lysimeter G which had much less vegetative cover until the spring 2004 precipitation when the vegetative cover increased and the water storage decreased.

In 2004, the natural precipitation in Area 3 was 263 mm (10.35 in). An addition 525 mm (20.67 in) of irrigation was applied to the surface of Lysimeter B, D, F, and H. The 2004 natural spring rains increased the water storage in the lysimeters receiving only natural precipitation (Lysimeters A, C, E, and G) but this water was removed by evaporation and transpiration by the end of summer. The 2004 natural fall precipitation again increased the water storage in these lysimeters and it had not been removed by the end of 2004. The 2004 spring 3 times natural precipitation lysimeters increased the water storage in Lysimeters B, D, F, and H to the highest ever observed storage. The increased water storage in the invader species lysimeters (Lysimeter D and Lysimeter H) was removed by evapotranspiration. Less water storage was removed by the native species (Lysimeter F) because the native species were not well established on this lysimeter. The increased water storage from the 2004 spring 3 times natural precipitation was not removed form the bare-soil lysimeter (Lysimeter B). The water storage increased and was not removed. Drainage from this lysimeter began on May 23, 2004 and continued though the end of 2004. There were 897.1 liters (237.0 gallons) of drainage from Lysimeter B during 2004. This is equivalent to 12.3 cm of drainage.

Neutron Logging

Measurements of VWC in waste covers using the neutron probe method have been terminated with the installation of the automated TDR systems at various locations, as described above. Therefore, routine vadose-zone water content monitoring by neutron logging was not conducted in the Area 3 or Area 5 RWMSs in 2004. Future water content monitoring at Areas 3 and 5 will be conducted using only the automated TDR systems. For a detailed history of the Neutron Logging Monitoring Program at Area 3 and Area 5 RWMSs, refer to BN (1997 and 2001c).

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 to ensure that vadose-zone monitoring data are representative of the entire RWMS. Subsidence monitoring began in October 2000. The program included coordination with waste operations personnel to facilitate timely repair of subsidence features. The locations of subsidence features observed at the Area 5 RWMS in 2004 are shown in Figure 44. Subsidence occurred mainly on the cover of Pit 5 where 17 separate subsidence locations were recorded. Only three were recorded on the north end of the Pit 4 cap. Altogether, 62 cubic yards of fill dirt were required to cover the cracks and depressions that had occurred due to soil settling. These features were in locations of recently covered waste and were concentrated in areas where compaction of the cover may be incomplete. In other locations within the Area 5 RWMS, only a few minor cracks and depressions required maintenance.

Biota Monitoring Data

No biota monitoring was conducted in 2004. In the past, vegetation monitoring within the disposal facilities has been performed to help characterize and define trends in potential transport of radionuclides from deposited waste. Tritium is a dominant radionuclide observed due to its high mobility as tritiated water. The primary mechanisms that transport tritium upward through waste covers and into the atmosphere include gaseous diffusion, gaseous advection, bioturbation, plant uptake and transpiration, and soil evaporation. Sampling of plant water for tritium has provided a direct measure of the plant uptake of tritium. Additionally, analysis of plant tissues for alpha- and gamma-emitting radionuclides and Sr-90 has provided information on uptake of those radionuclides.

The amount of tritium released into the atmosphere by plant transpiration is affected by several factors including plant size, species, and available moisture. For example, plants under drought conditions may use water from deeper in the vadose-zone and consequently have higher concentrations due to the proximity of the water to the waste zone. For this reason, plants were generally sampled in late summer in prior years. Because of the dry conditions, measured plant water tritium concentrations may be a conservative representation of year-round concentrations. The range of tritium concentrations observed in vegetation from the last sampling event in 2002 was within that observed during the previous three years, but still much lower than that measured at the Area 5 RWMS in 1995 to 1996 (see BN 2001c, 2002b). Detectable concentrations of radionuclides in plants indicate that plants provide an upward pathway for radionuclide migration. Monitoring of this pathway provides data on trends of radionuclides available for uptake over time.

CONCLUSIONS

The 2004 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. Air monitoring data indicate that tritium concentrations 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 at GCD-05U indicates little natural migration of tritium away from this disposal borehole. Vadose zone monitoring data indicate that infiltrating precipitation generally reached depths of less than 120 cm (4 ft) before returning to the atmosphere. Long-term vadose-zone monitoring data from the weighing lysimeters indicate no drainage through the bottoms of the lysimeters during the past ten years of their operation.

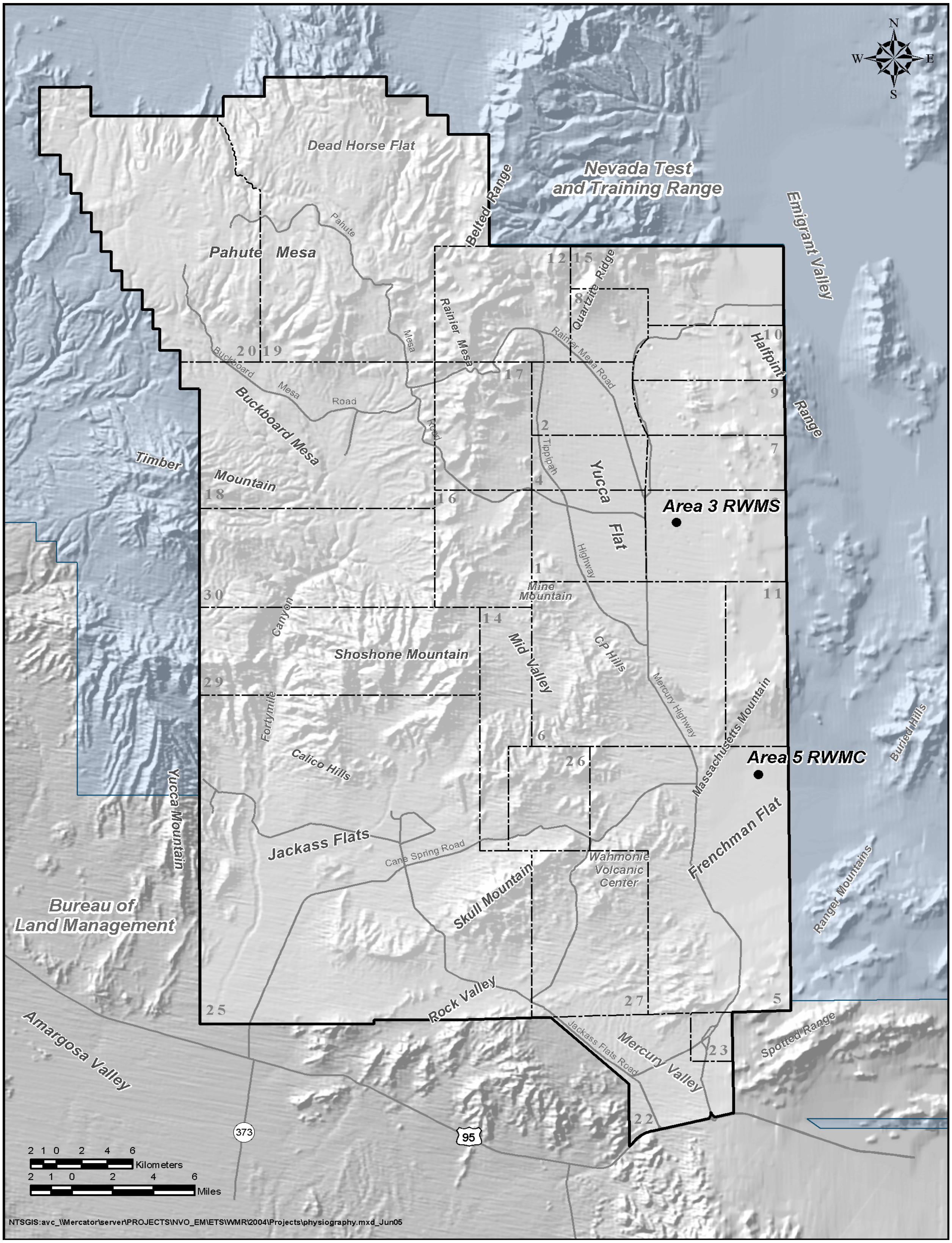

Figure 1. Location of the Area 3 and Area 5 RWMSs on the NTS

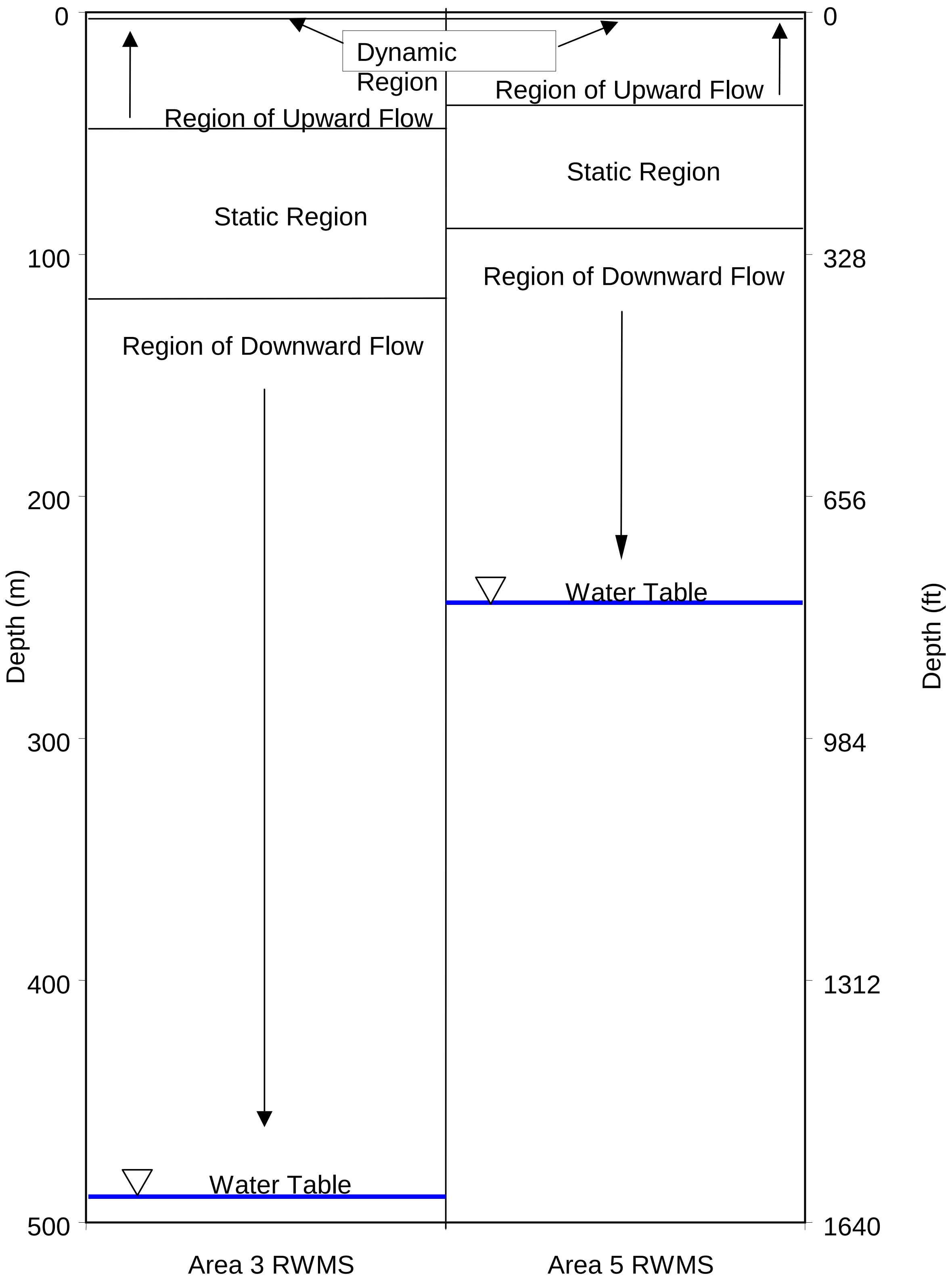

Figure 2. Vadose zone hydrologic conceptual models of the Area 3 and Area 5 RWMSs

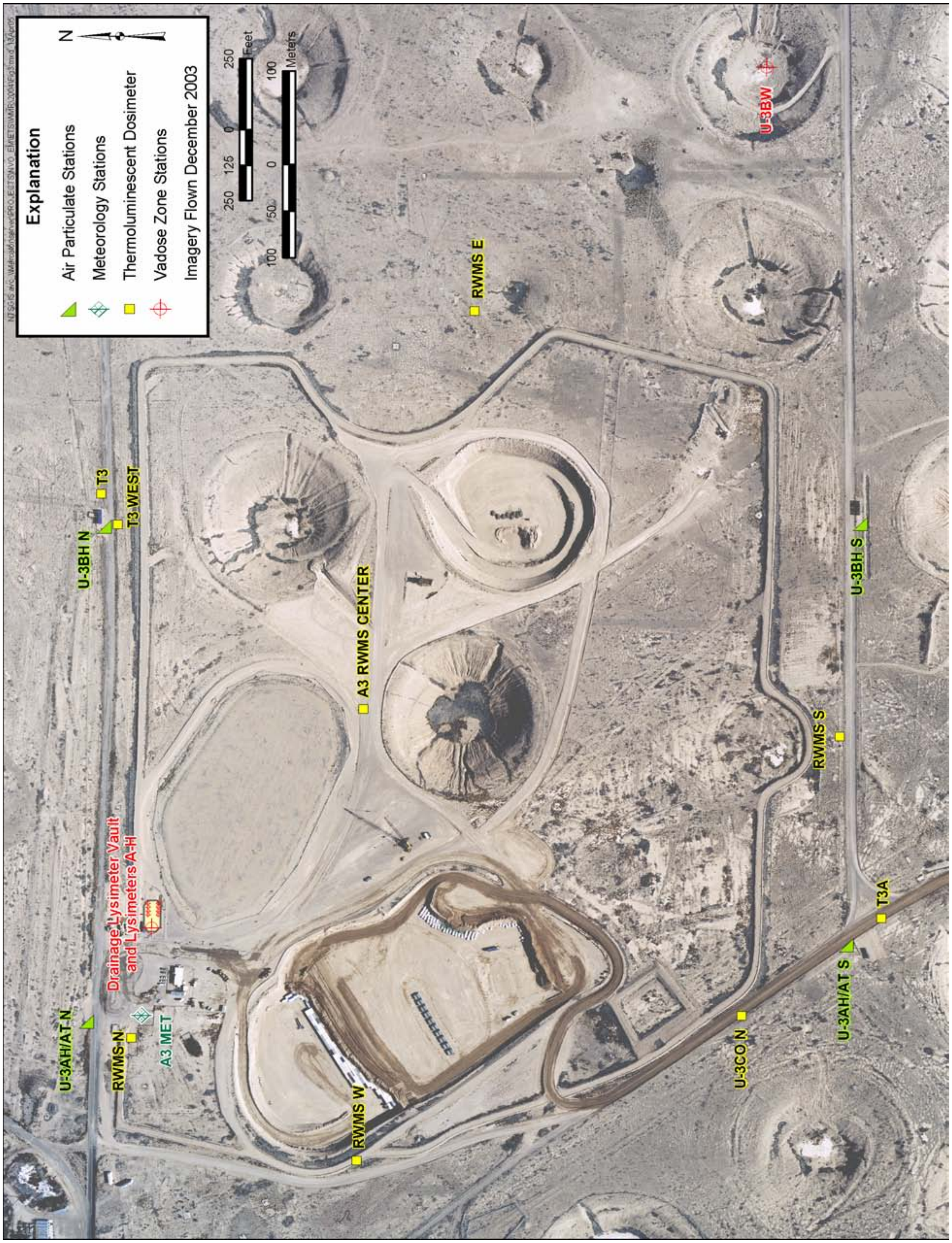

Figure 3. Monitoring locations at the Area 3 RWMS

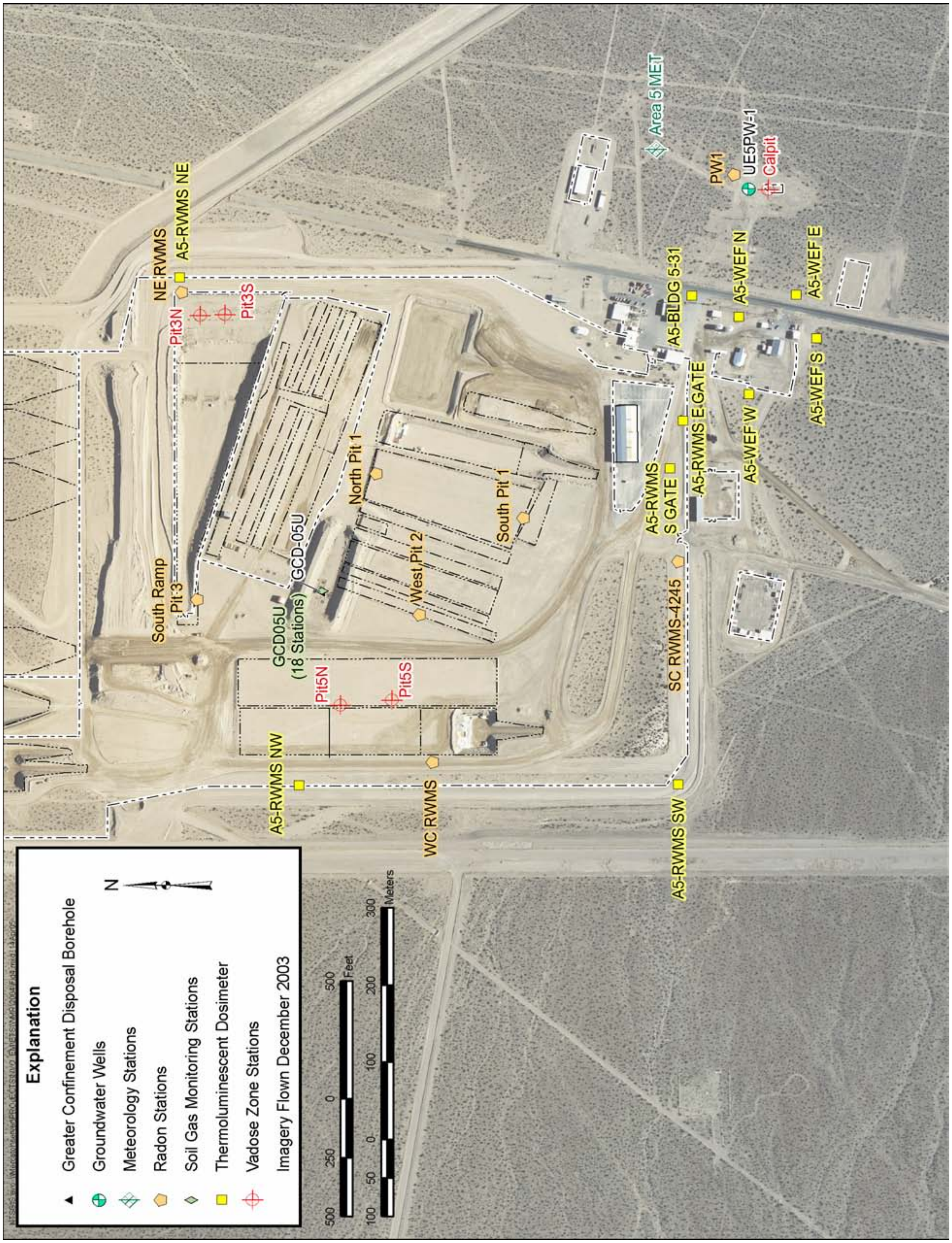

Figure 4. Monitoring locations at the Area 5 RWMS

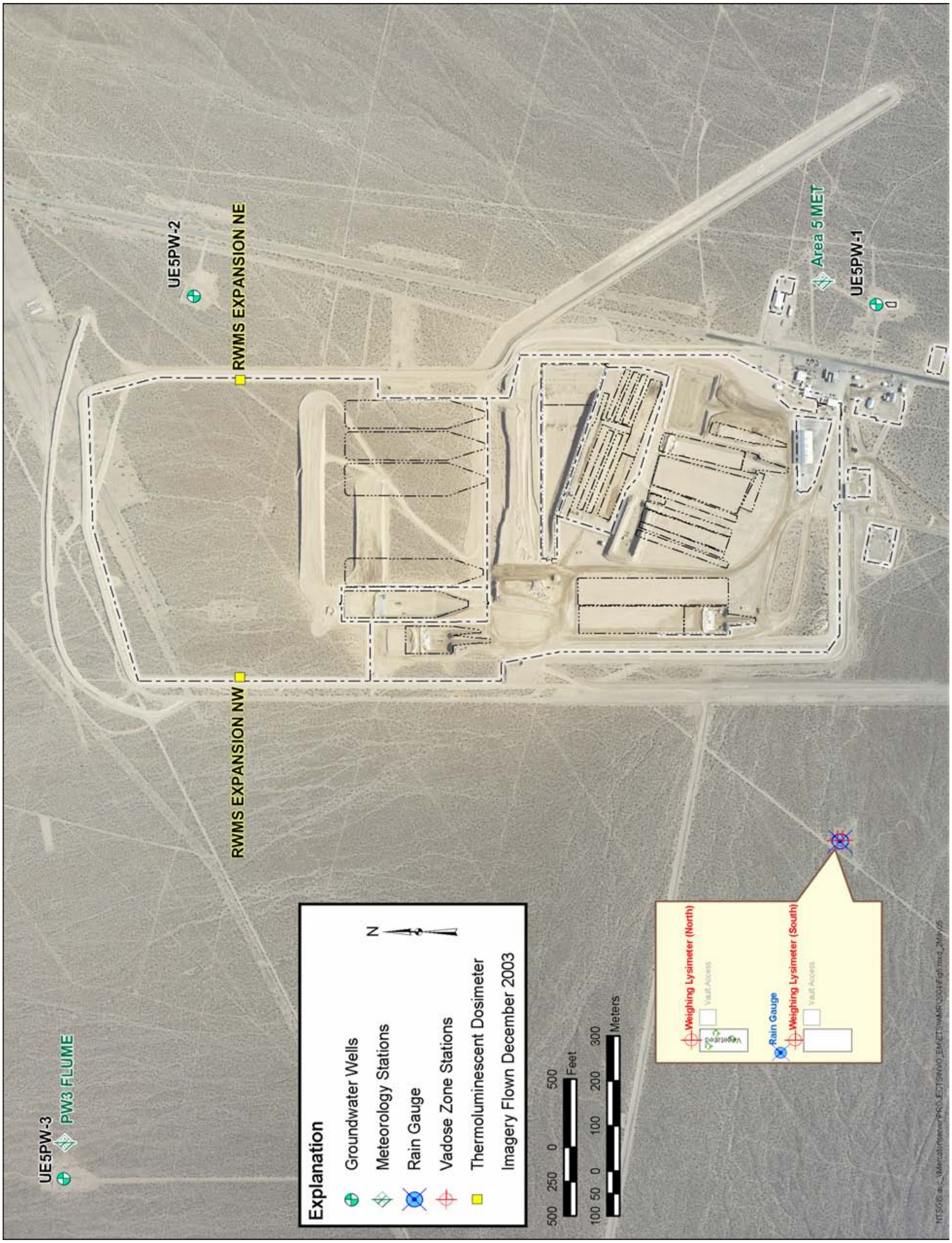

Figure 5. Location of the Area 5 RWMS pilot wells and Weighing Lysimeter Facility

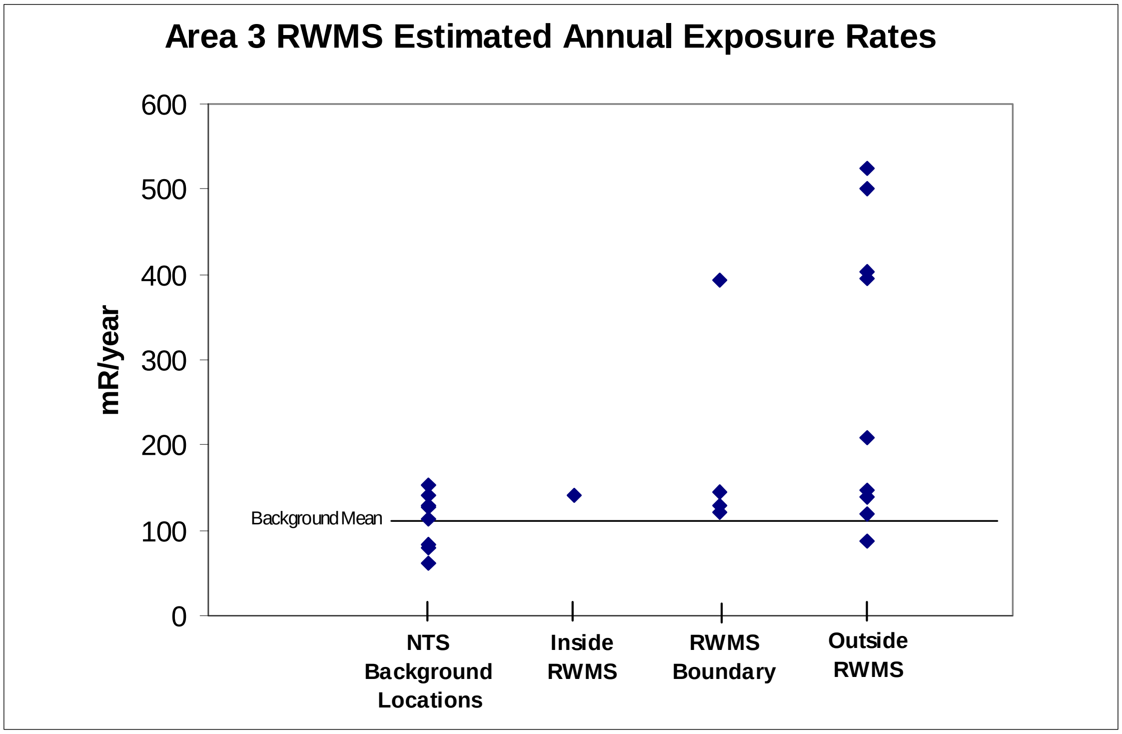

Figure 6. Annual exposure rates at the Area 3 RWMS during 2004

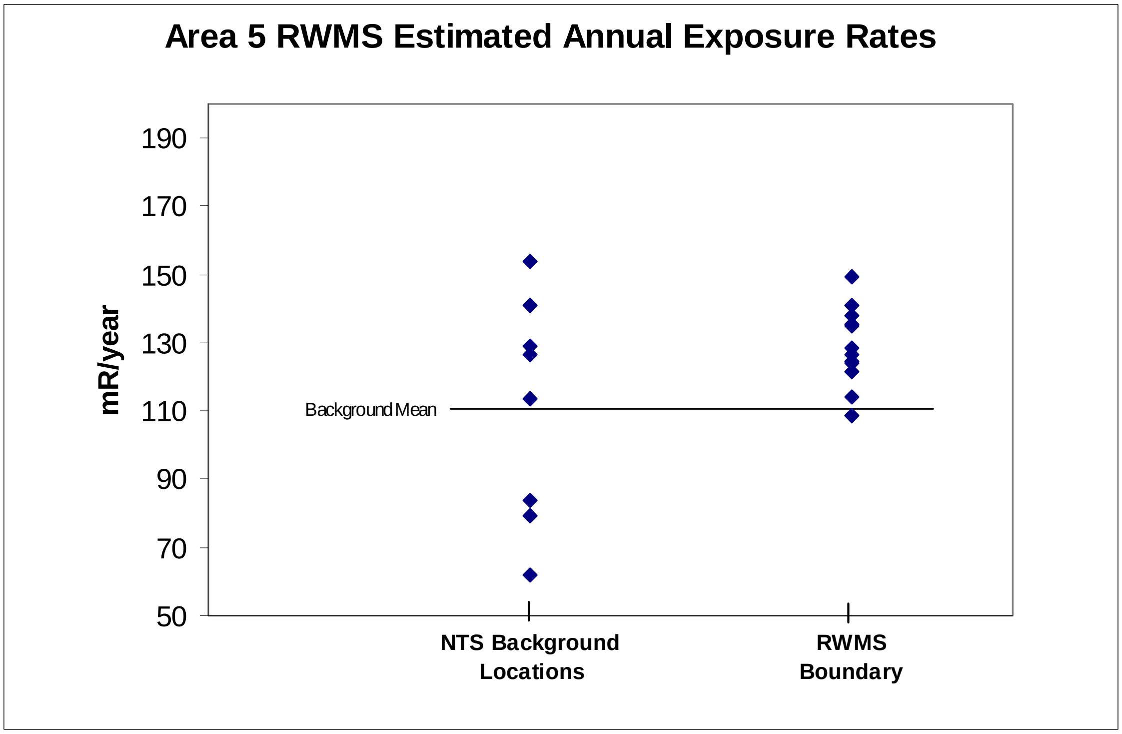

Figure 7. Annual exposure rates at the Area 5 RWMS during 2004

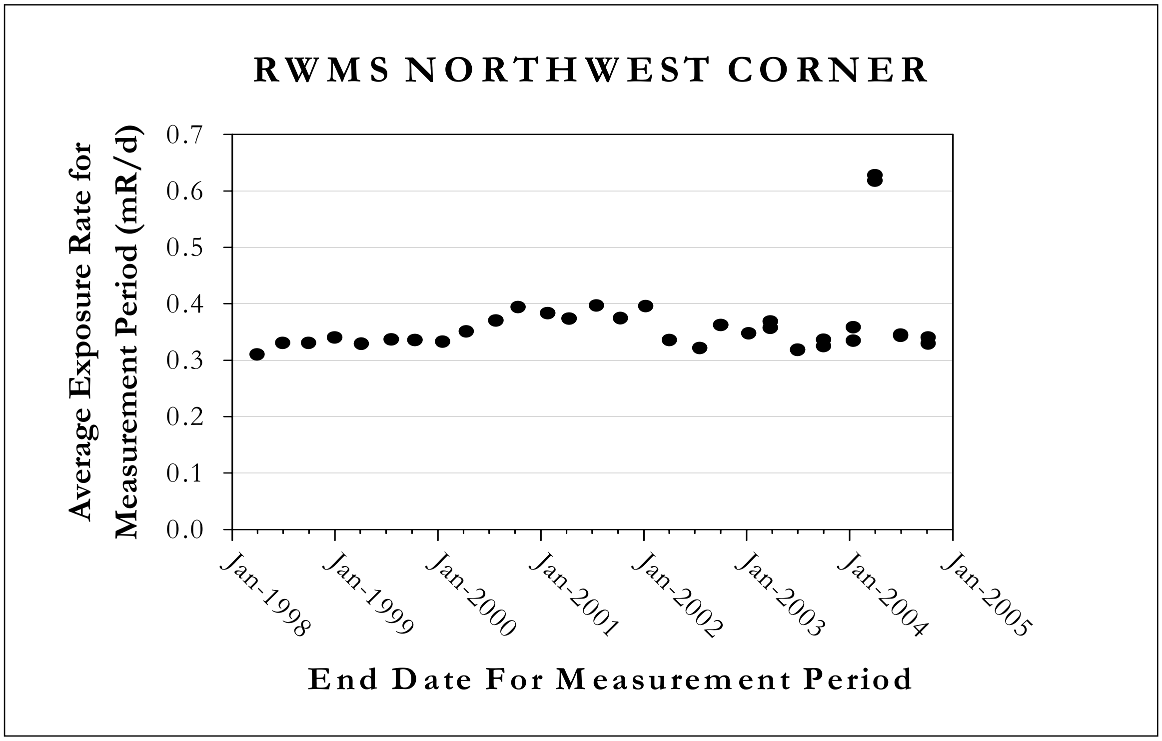

Figure 8. Quarterly average daily exposure rate at the Area 5 RWMS Northwest Corner TLD Location

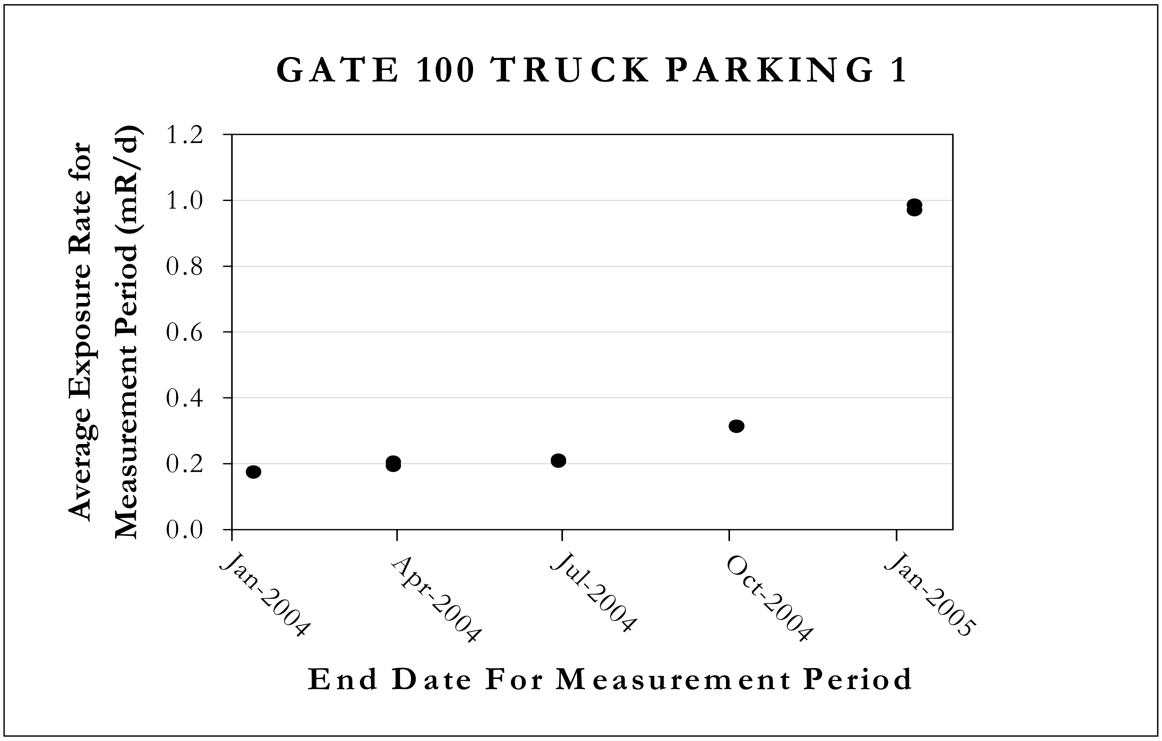

Figure 9. Quarterly average daily exposure rates at the Gate 100 Truck Parking Location

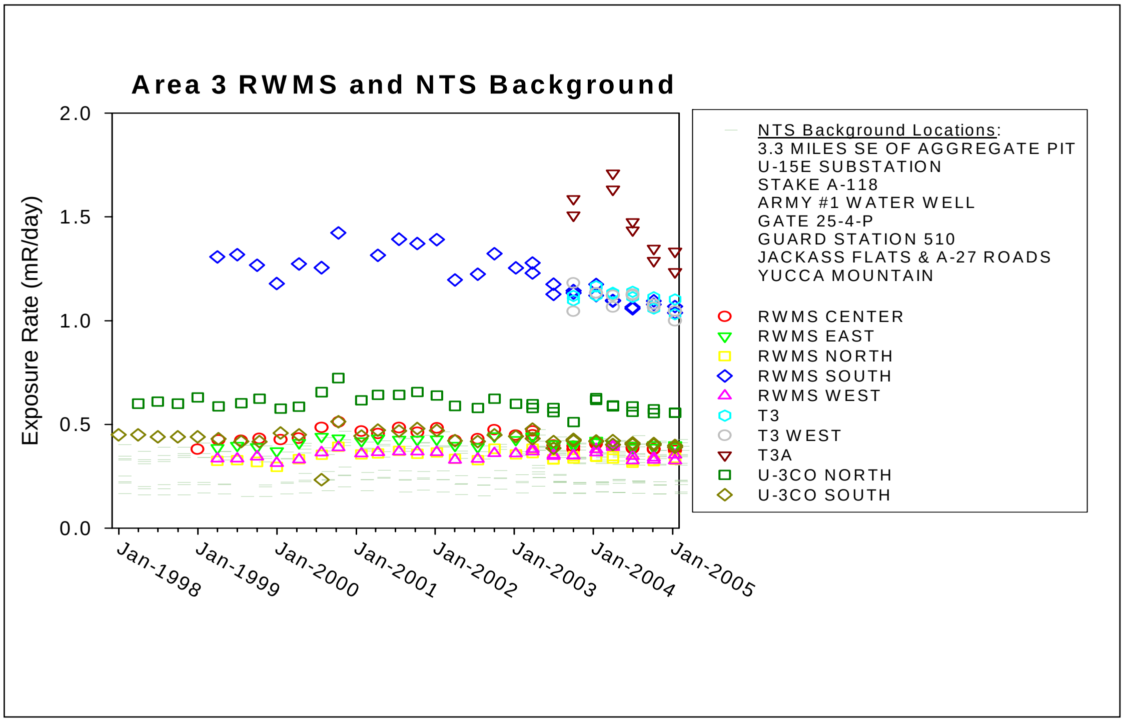

Figure 10. Quarterly average daily exposure rates at Area 3 RWMS and NTS Background TLD Locations, 1998 - 2004

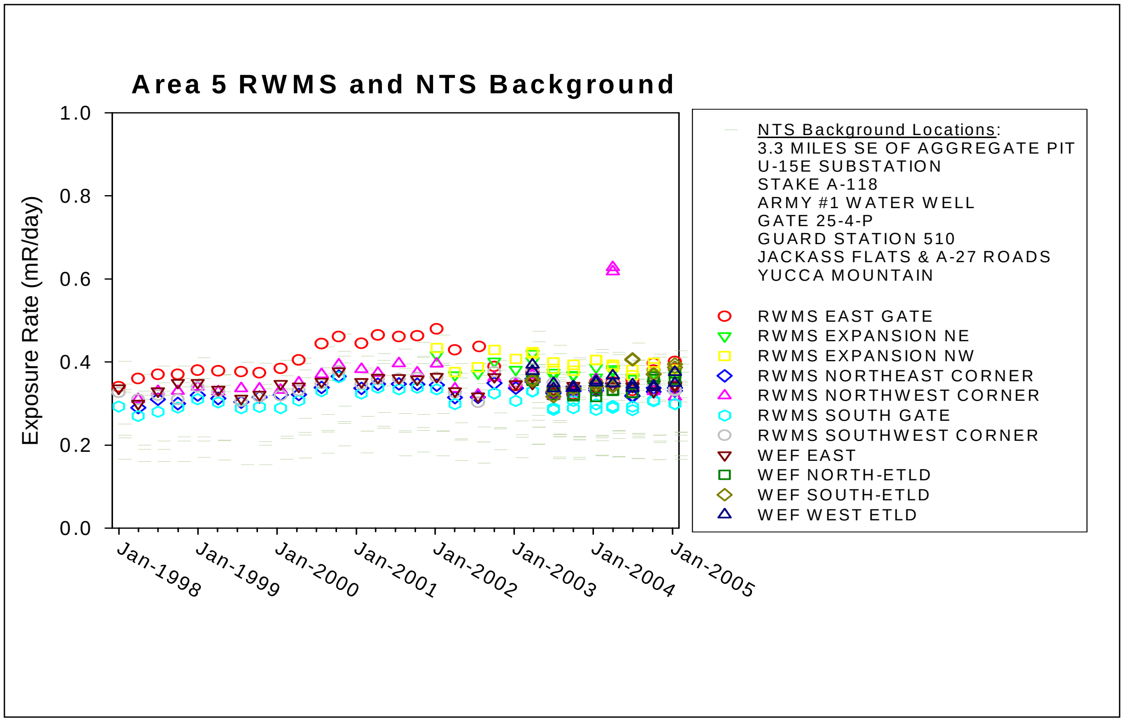

Figure 11. Quarterly average daily exposure rates at Area 5 RWMS and NTS Background TLD Locations, 1998 - 2004

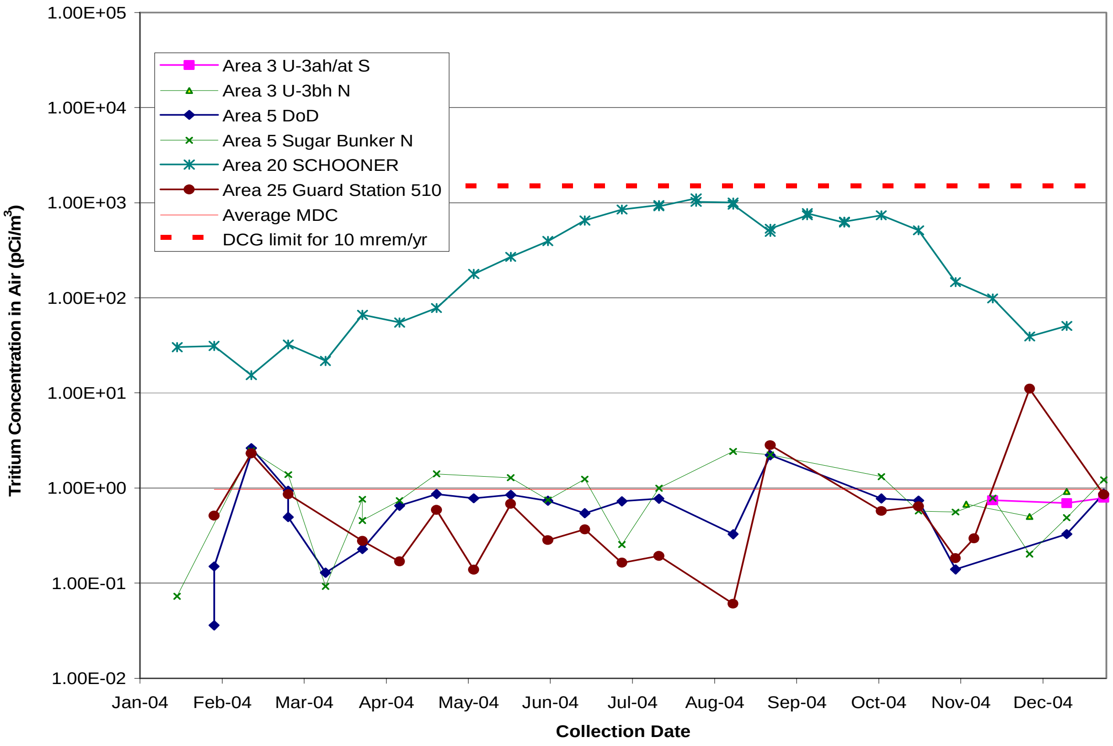

Figure 12. Tritium concentrations in air

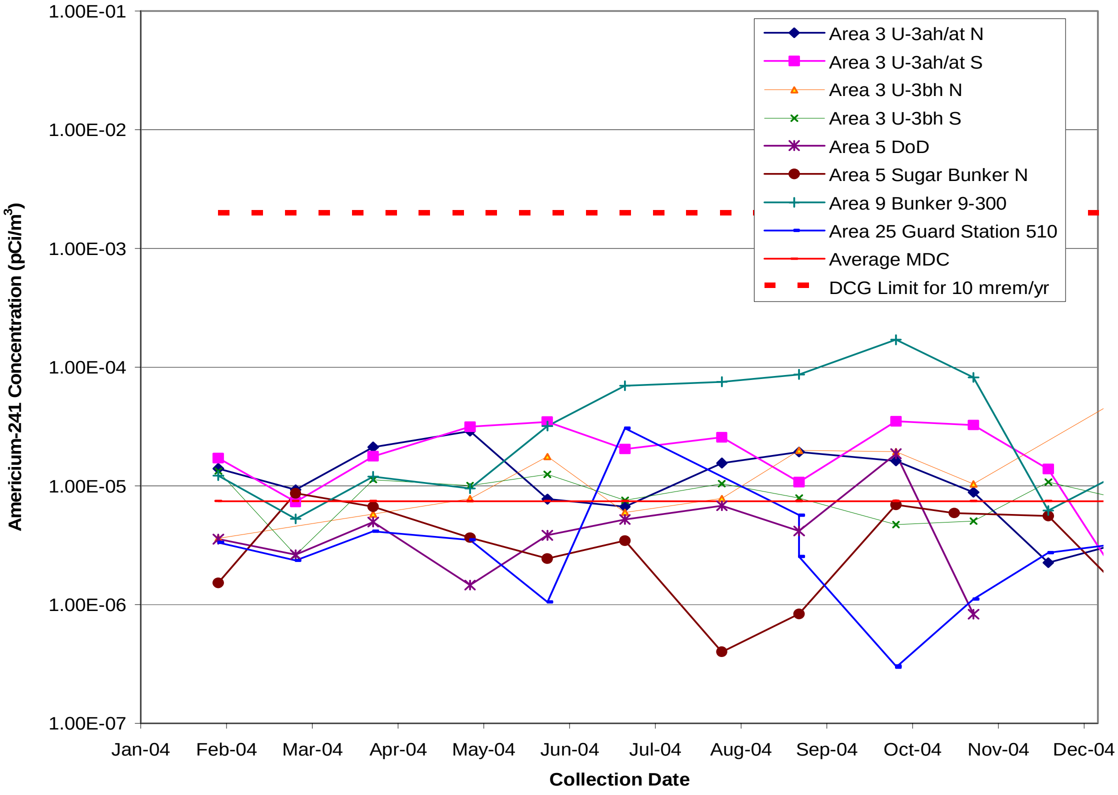

Figure 13. Americium-241 concentrations in air at the RWMSs and other locations

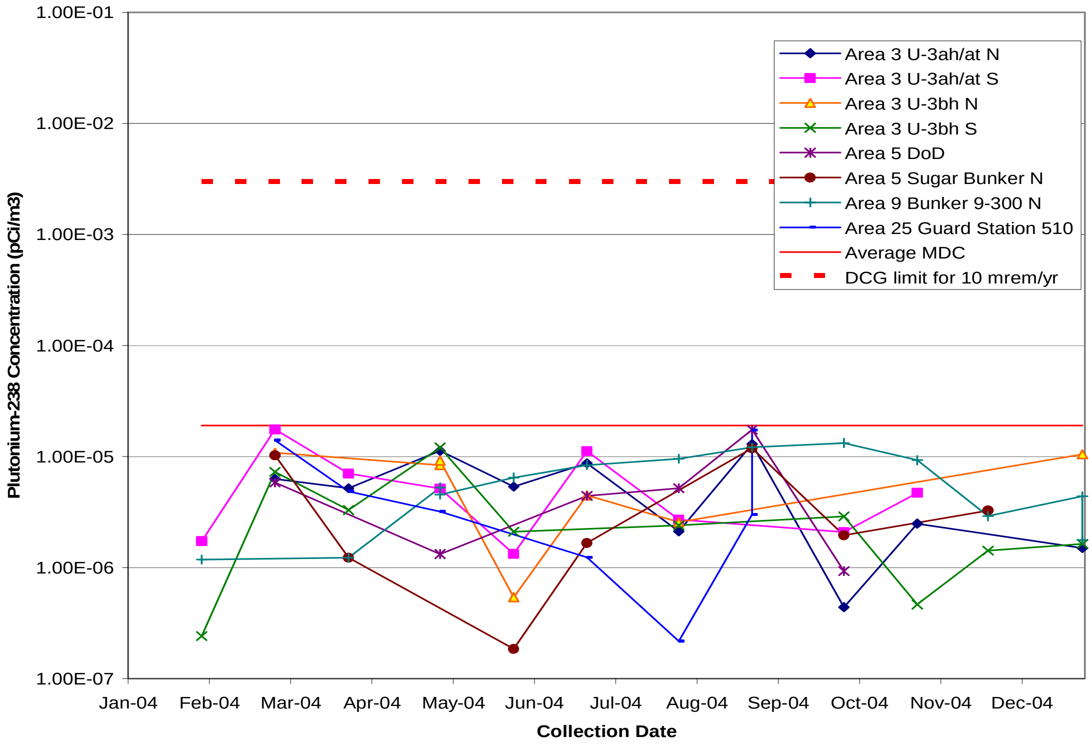

Figure 14. Plutonium-238 concentrations in air at the RWMSs and other locations

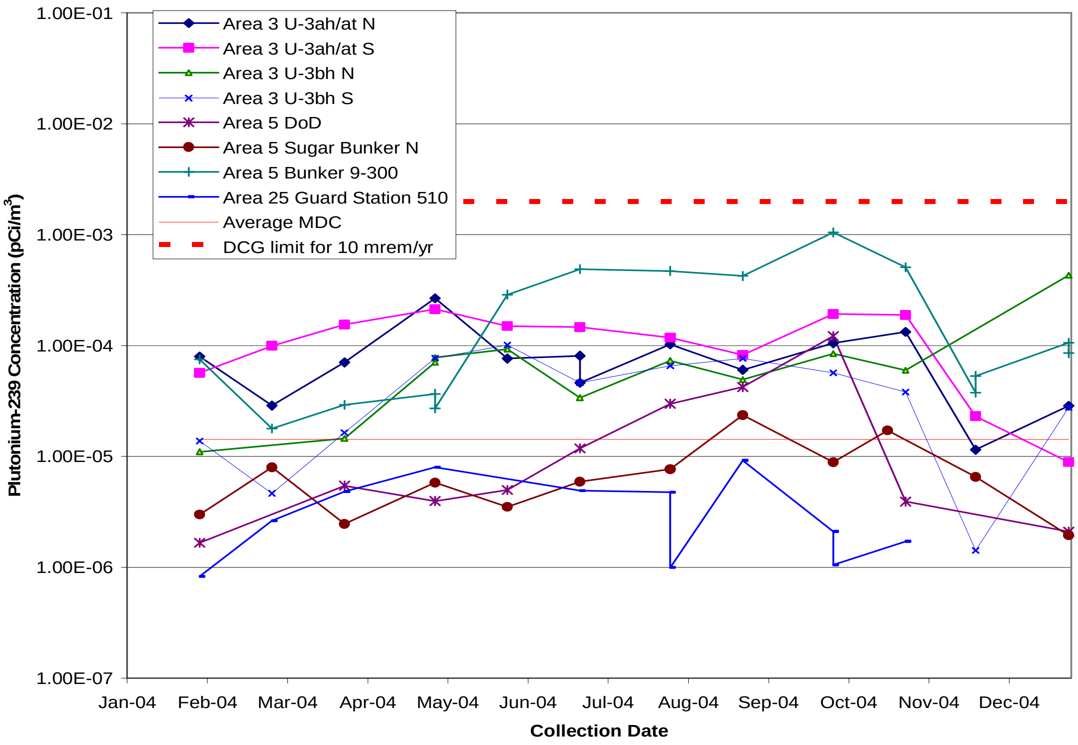

Figure 15. Plutonium-239 concentrations in air at the RWMSs and other locations

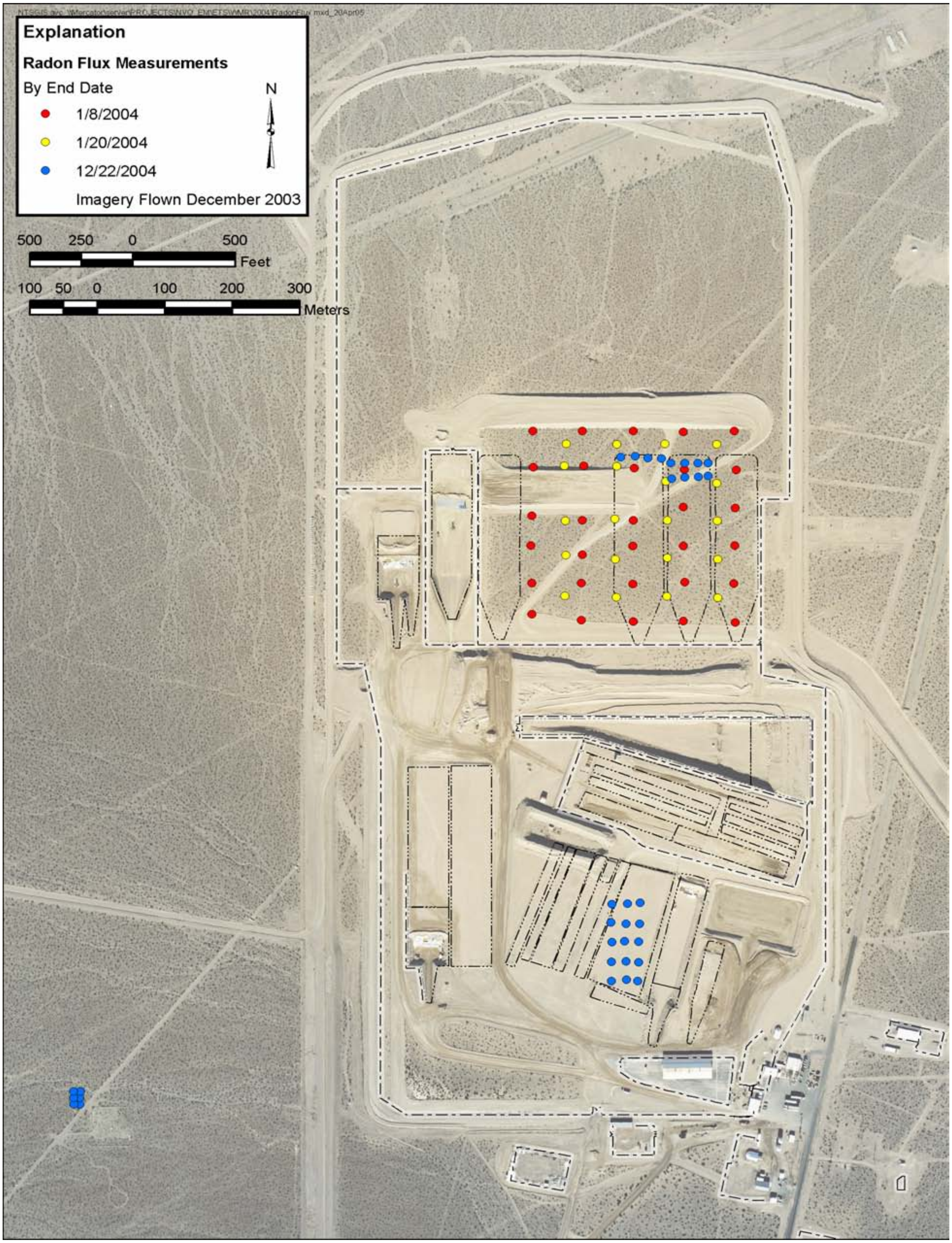

Figure 16. Radon flux measurement locations

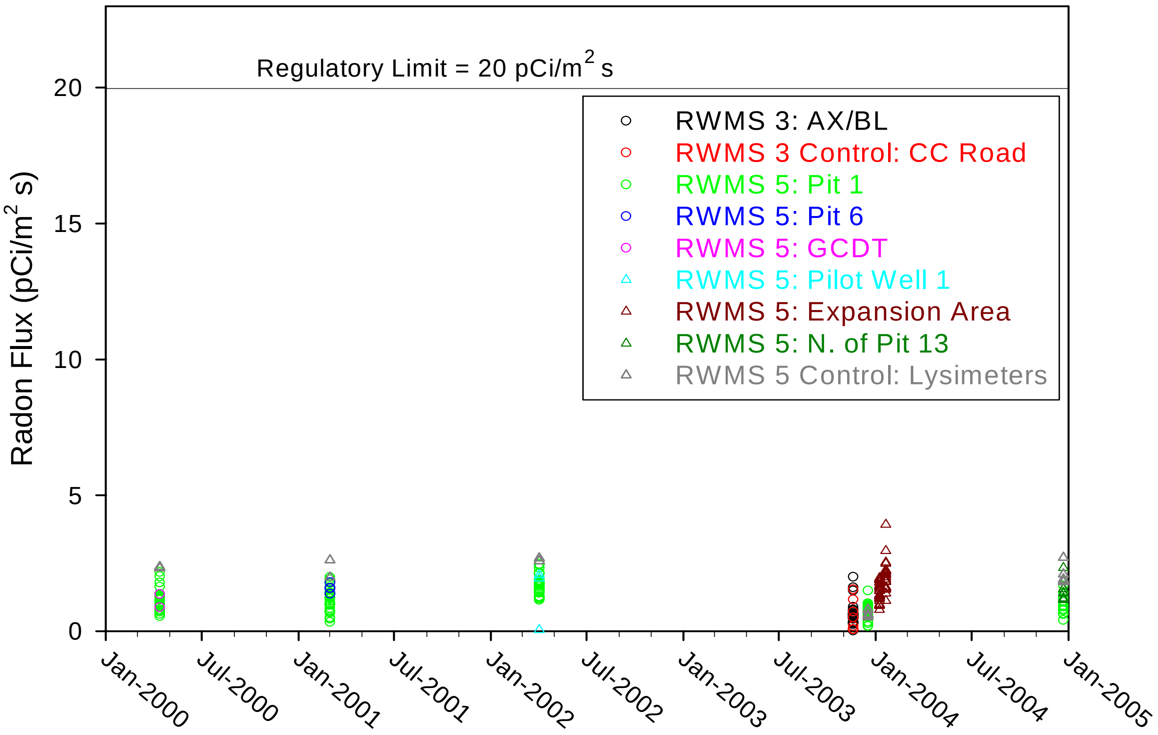

Figure 17. Radon flux results 2000 - 2004

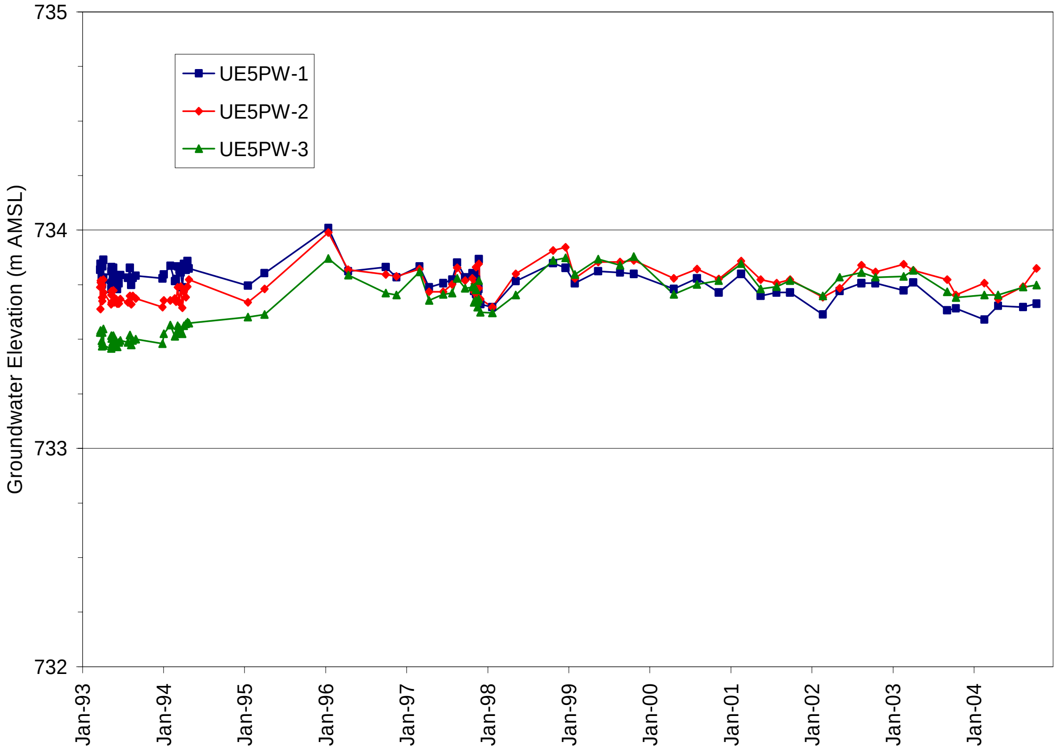

Figure 18. Groundwater elevation measurements recorded at the three Area 5 RWMS pilot wells by tagging

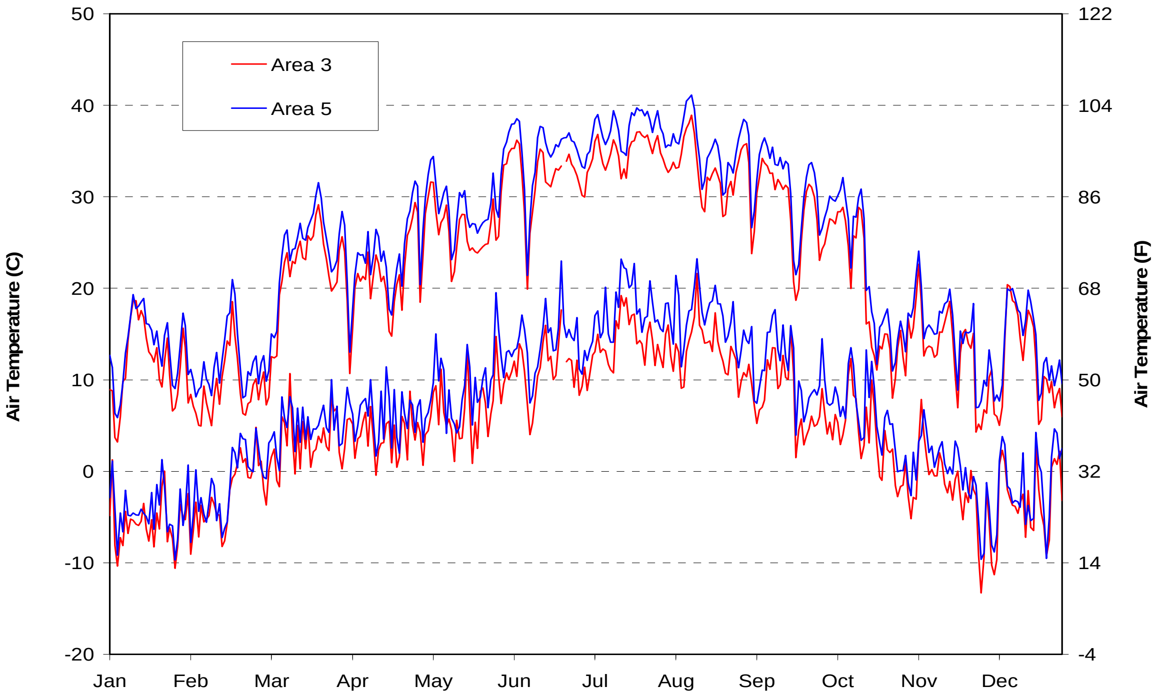

Figure 19. Daily maximum and minimum air temperatures at Area 3 and Area 5 RWMS

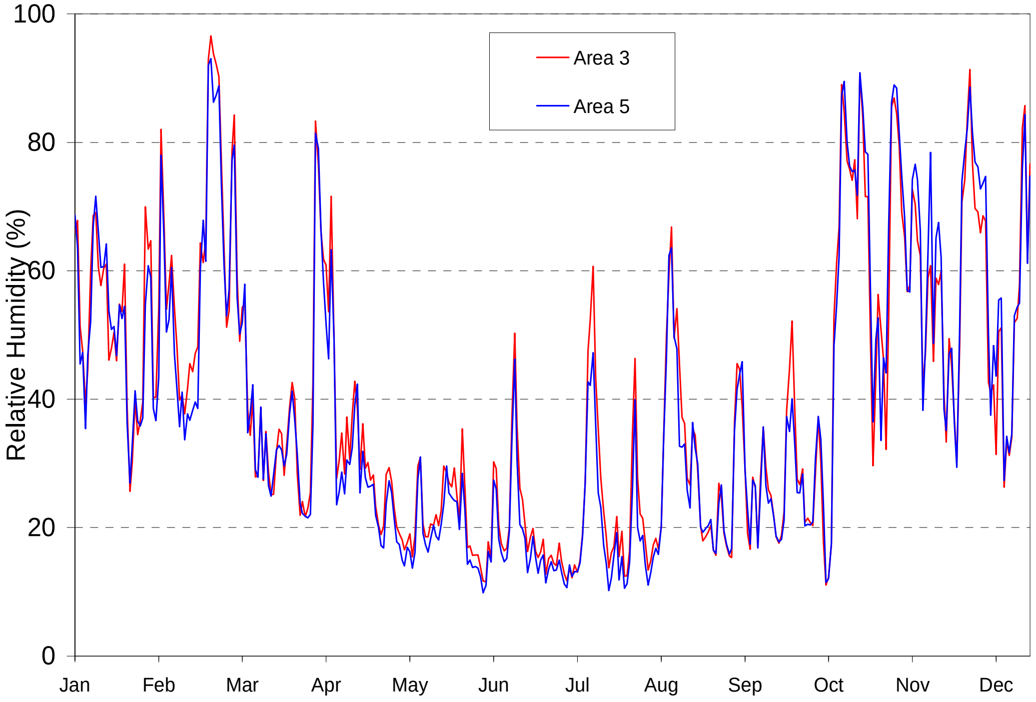

Figure 20. Daily average humidity recorded at Area 3 and Area 5 RWMS Meteorology Stations

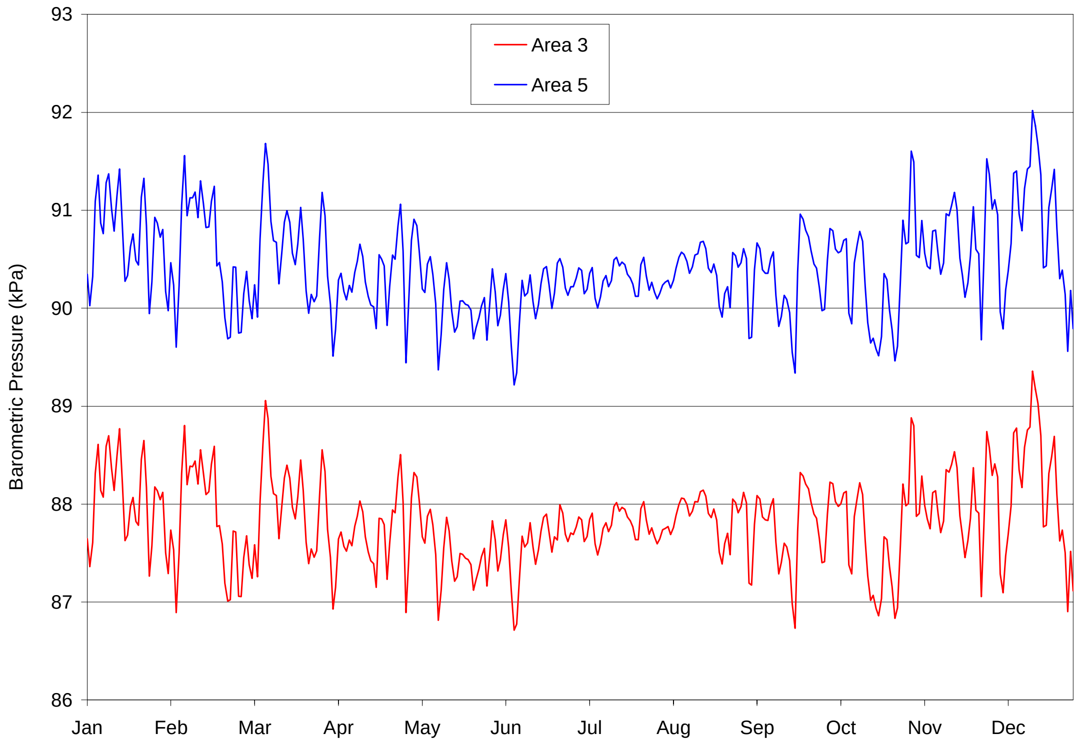

Figure 21. Daily average barometric pressure recorded at Area 3 and Area 5 RWMS Meteorology Stations

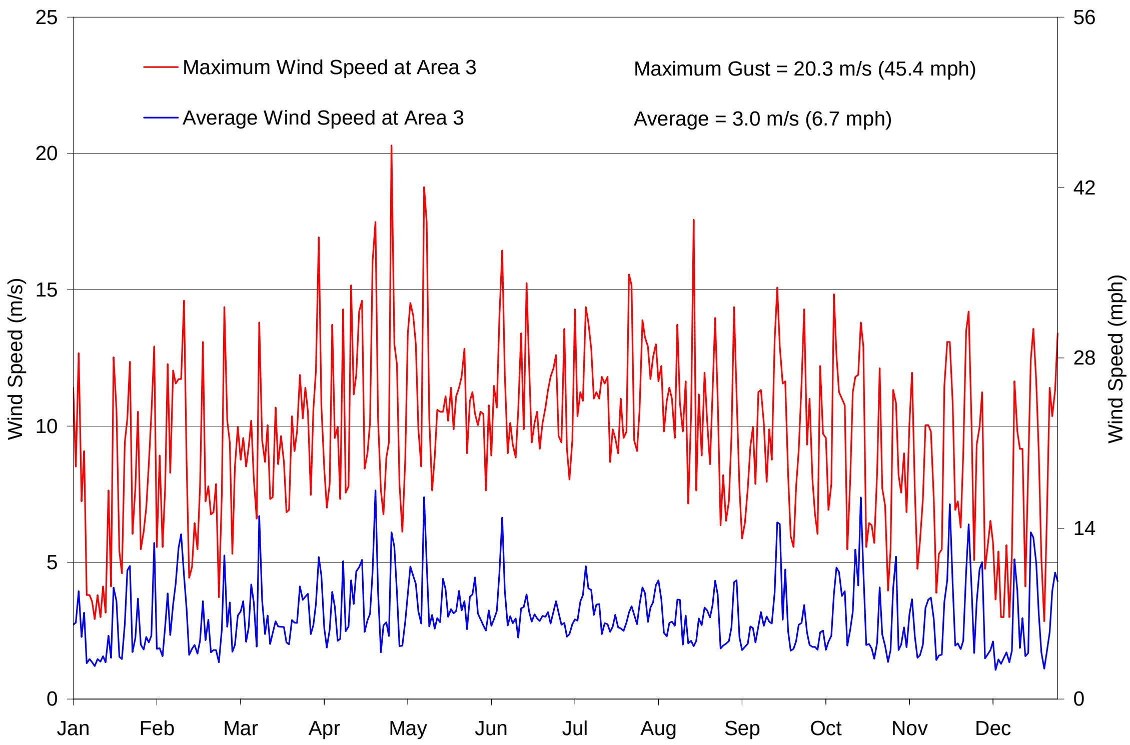

Figure 22. Daily wind speed recorded at Area 3 RWMS Meteorology Station at a height of 3 m

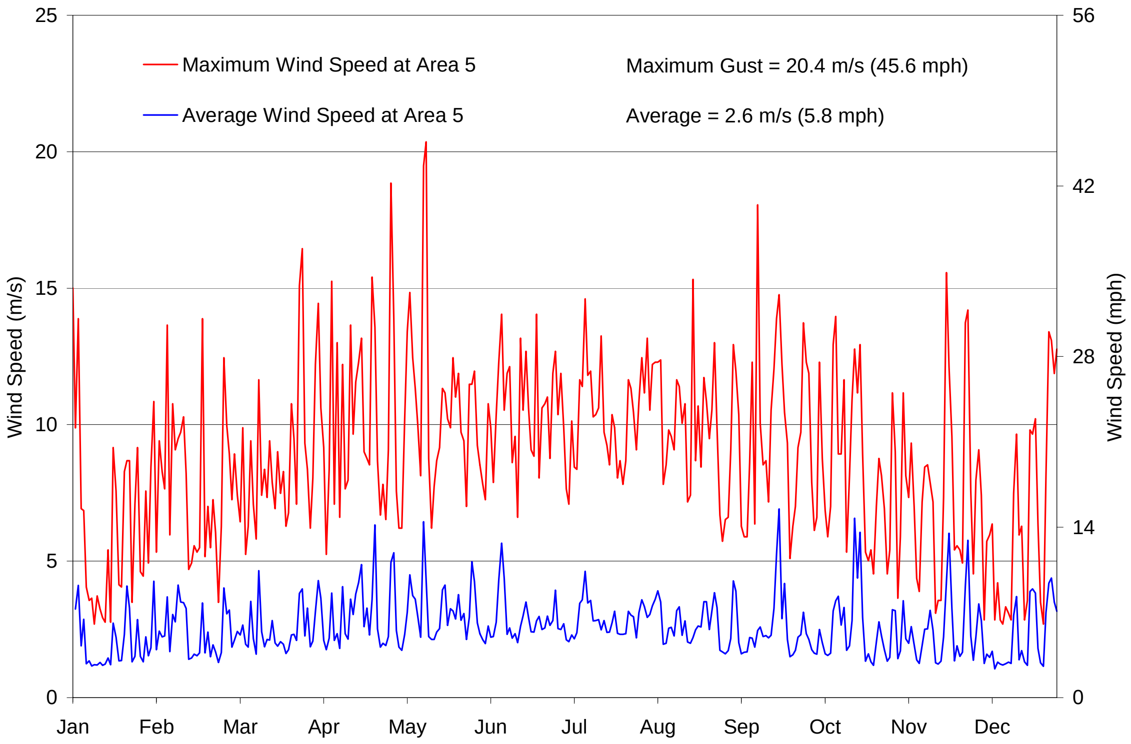

Figure 23. Daily wind speed recorded at Area 5 RWMS Meteorology Station at a height of 3 m

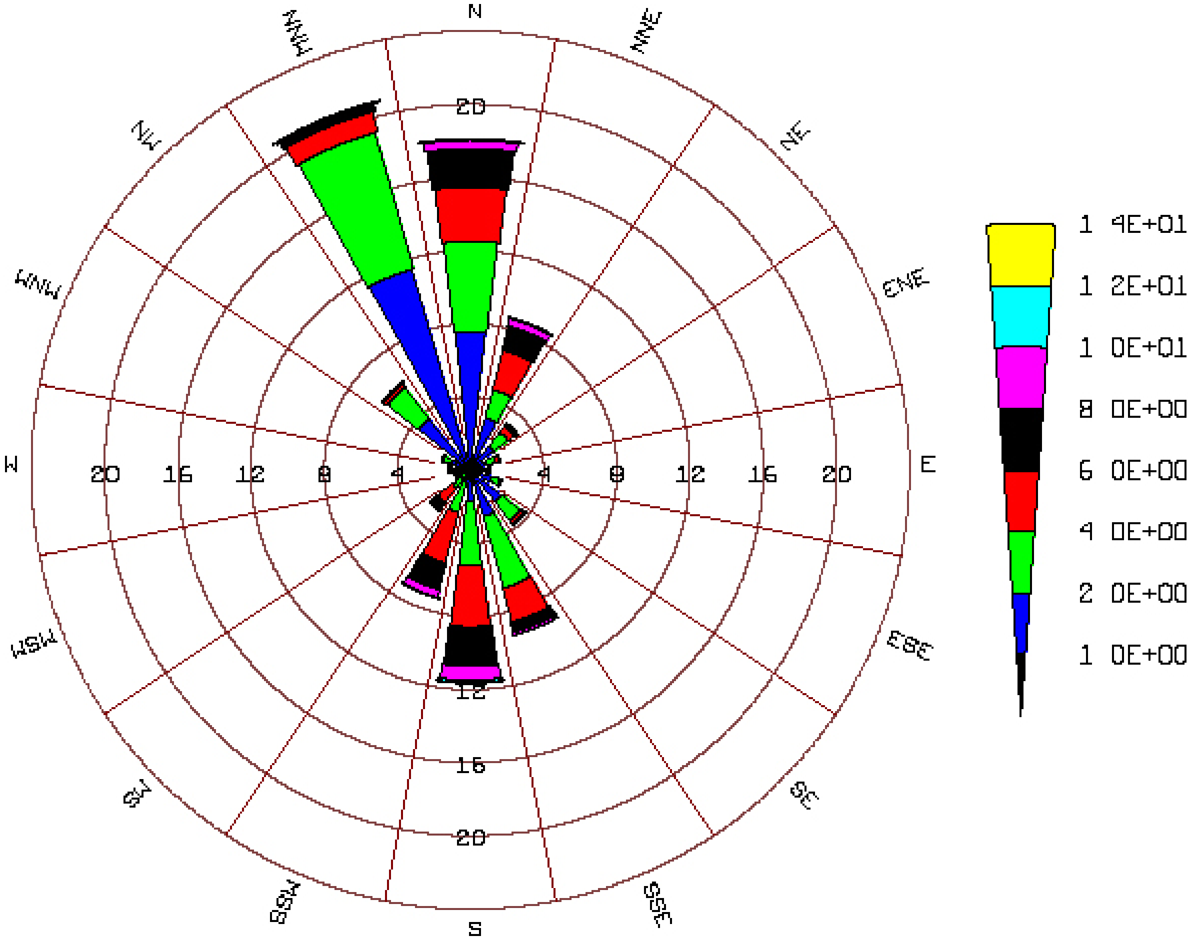

Figure 24. Wind rose diagram for the Area 3 RWMS Meteorology Station. Concentric labels indicate percent frequency, petal shading indicates wind speed in meters per second at a height of 3 m, and petal direction indicates direction of wind source

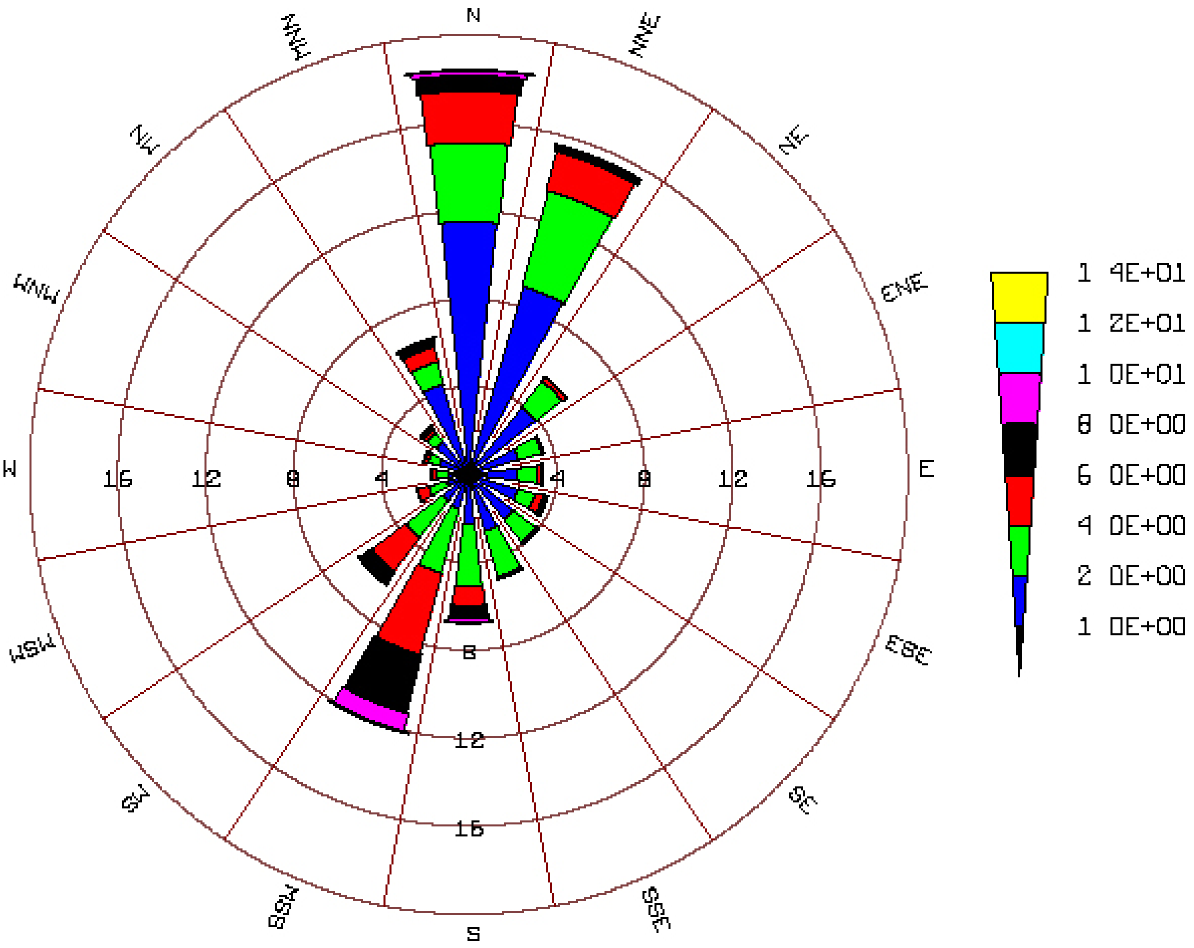

Figure 25. Wind rose diagram for the Area 5 RWMS Meteorology Station. Concentric labels indicate percent frequency, petal shading indicates wind speed in meters per second at a height of 3 m, and petal direction indicates direction of wind source

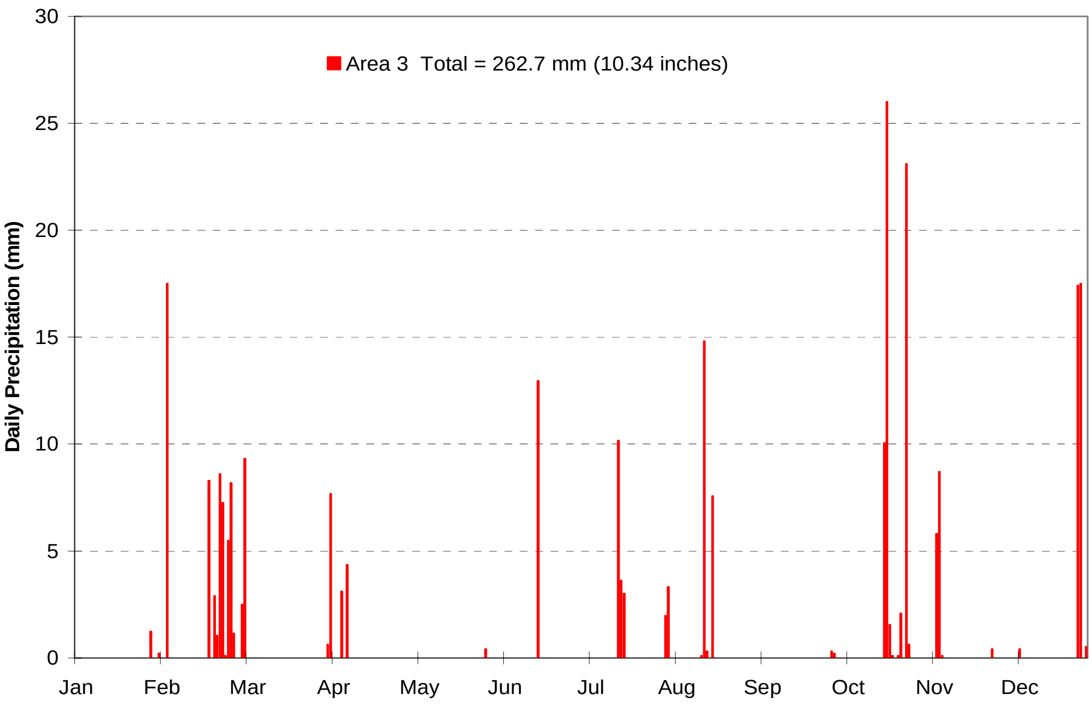

Figure 26. Daily precipitation recorded at Area 3 RWMS Meteorology Station

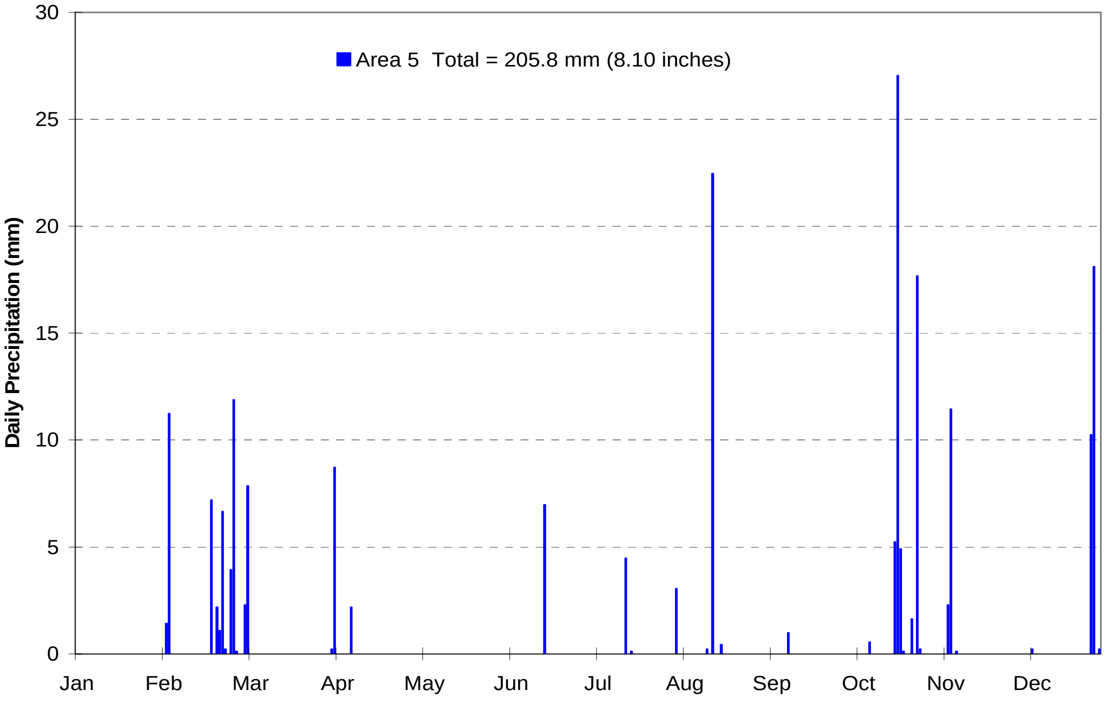

Figure 27. Daily precipitation recorded at Area 5 RWMS Meteorology Station

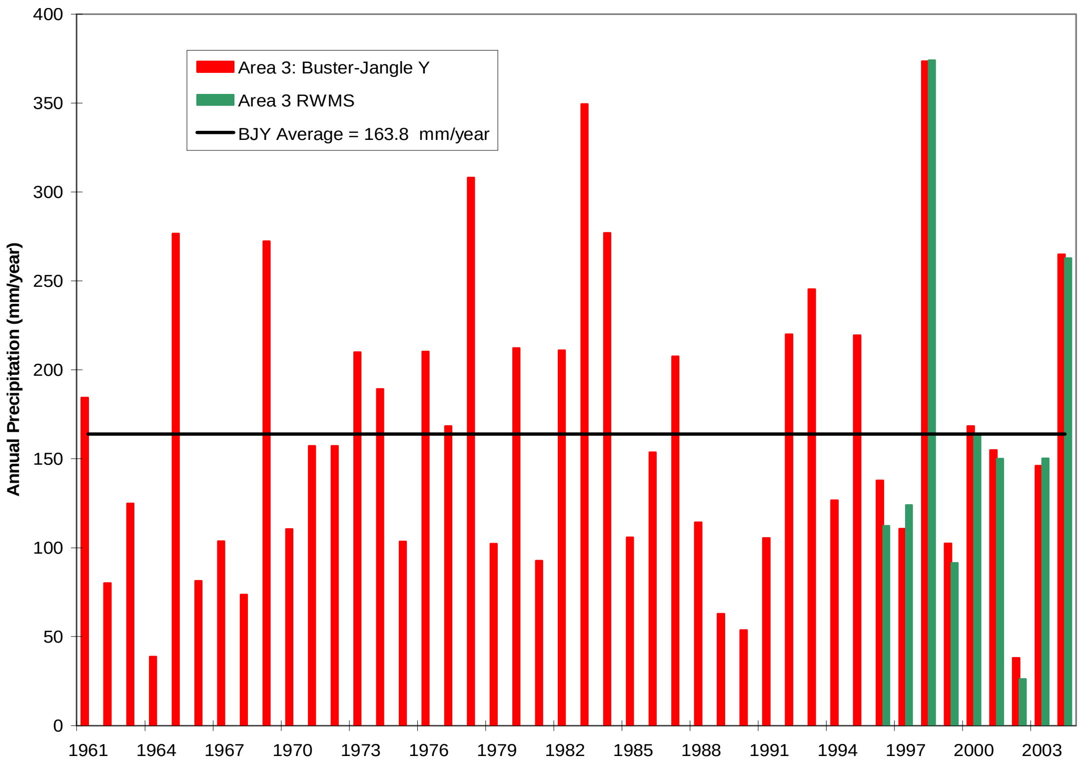

Figure 28. Historical precipitation record for Area 3 Buster-Jangle Y and Area 3 RWMS

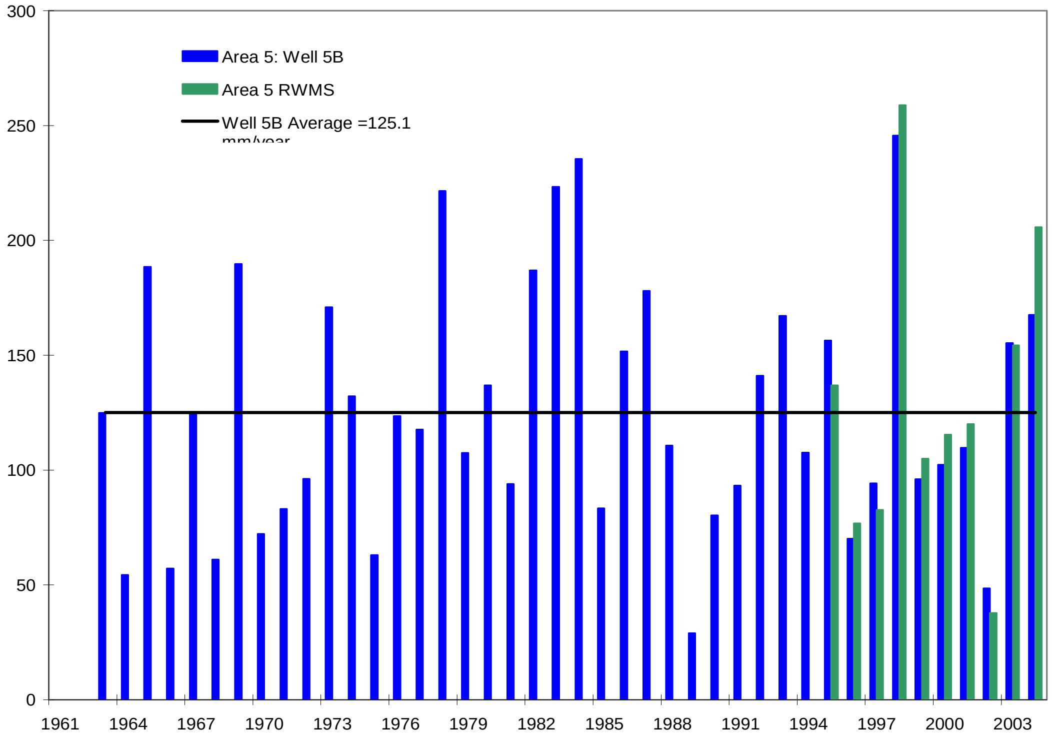

Figure 29. Historical precipitation record for Area Well 5B and Area 5 RWMS

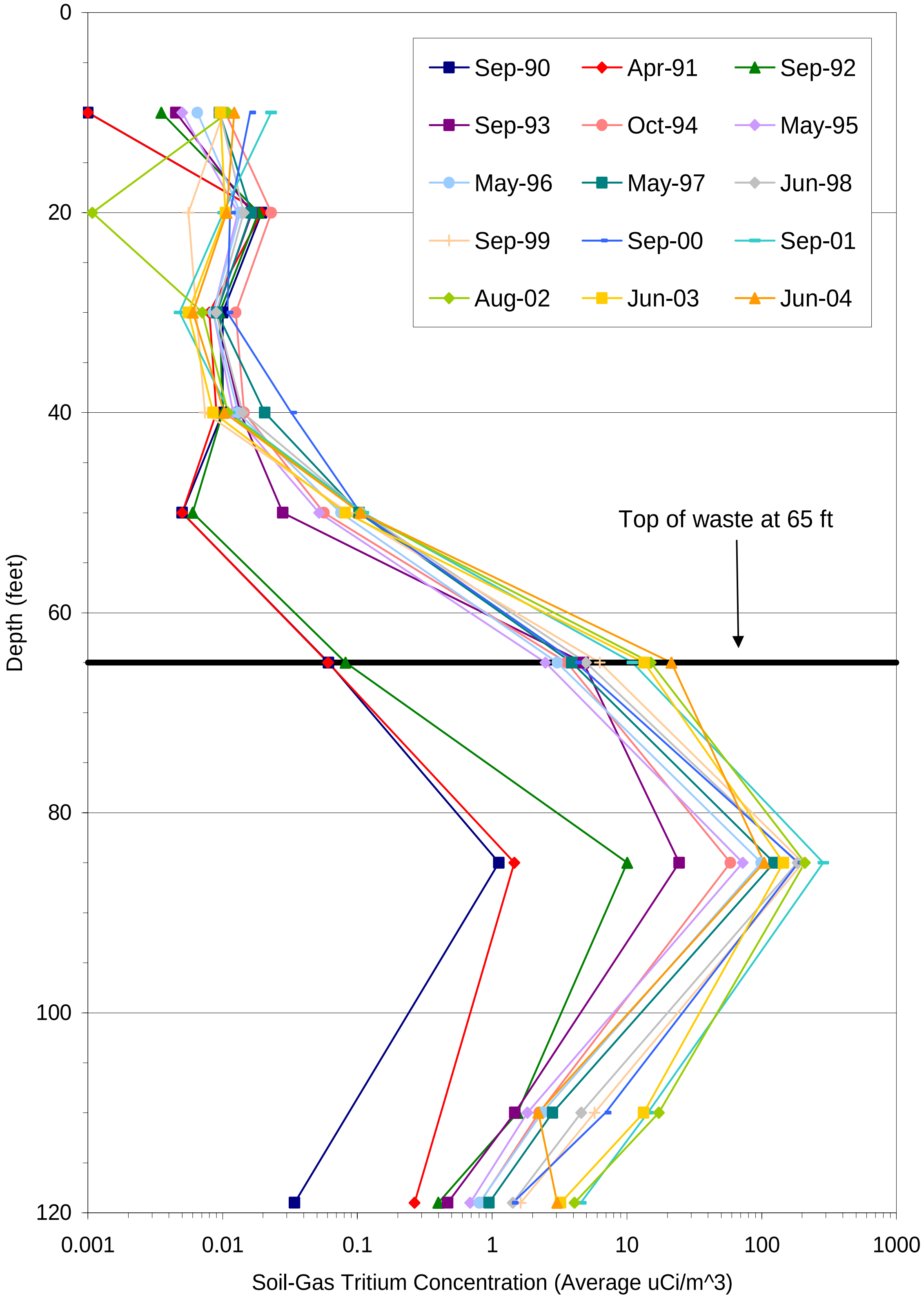

Figure 30. Soil-gas tritium concentrations with depth at GCD-05U

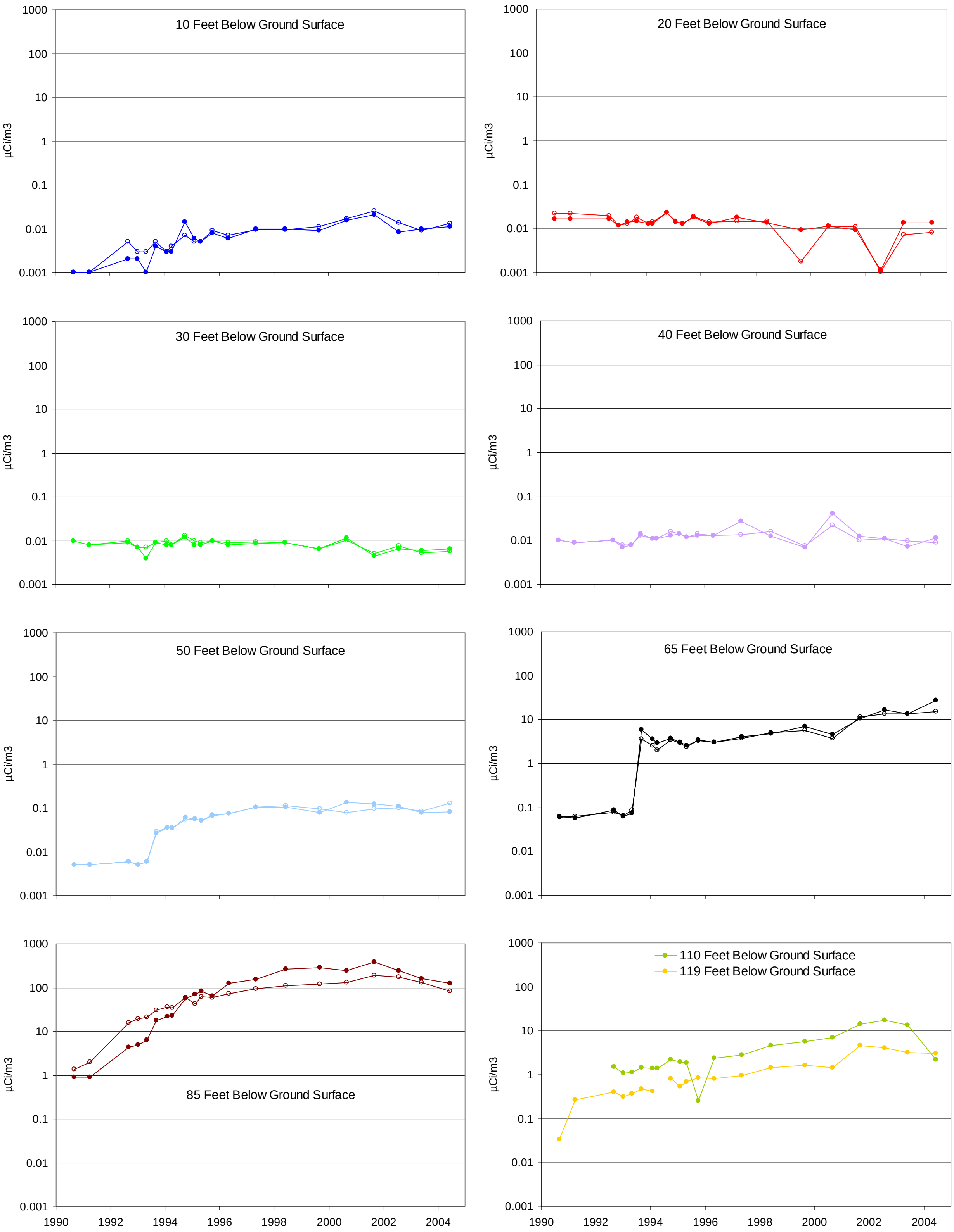

Figure 31. Soil-gas tritium concentrations at each depth in GCD-05U

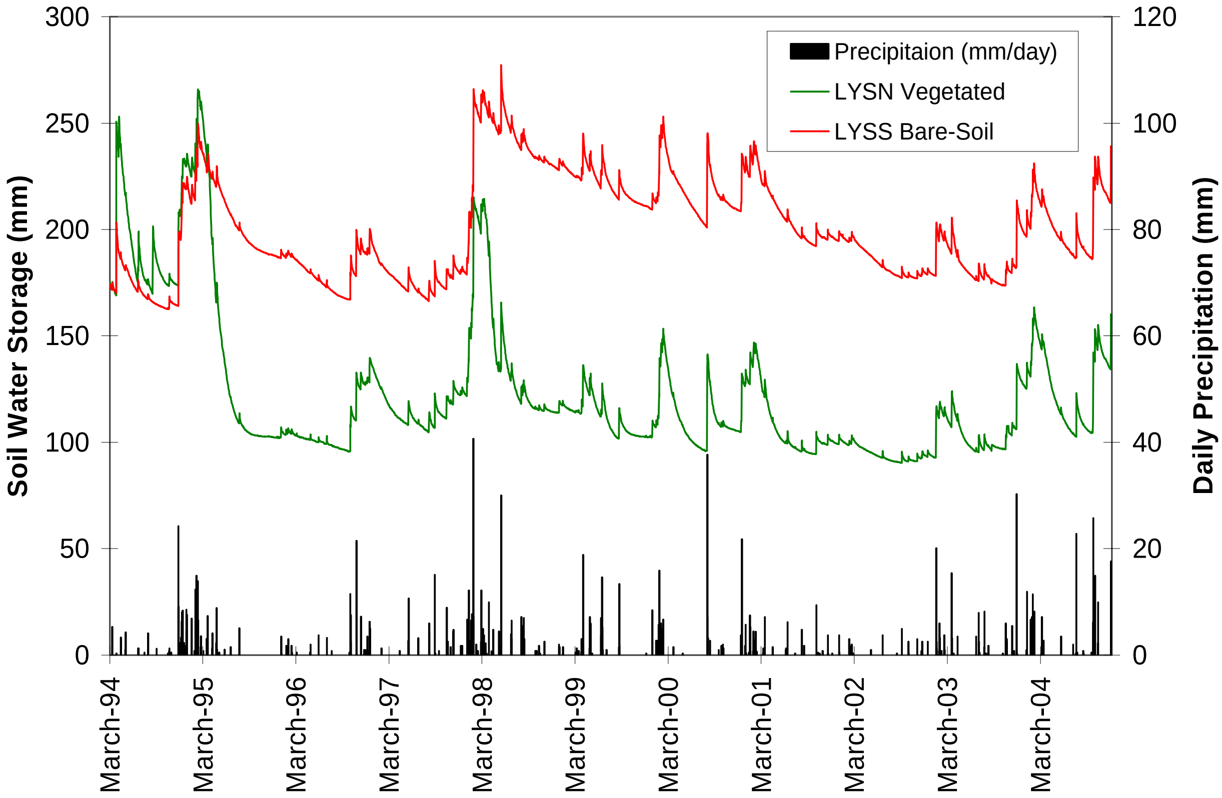

Figure 32. Weighing lysimeter and precipitation data from March 1994 to December 2004

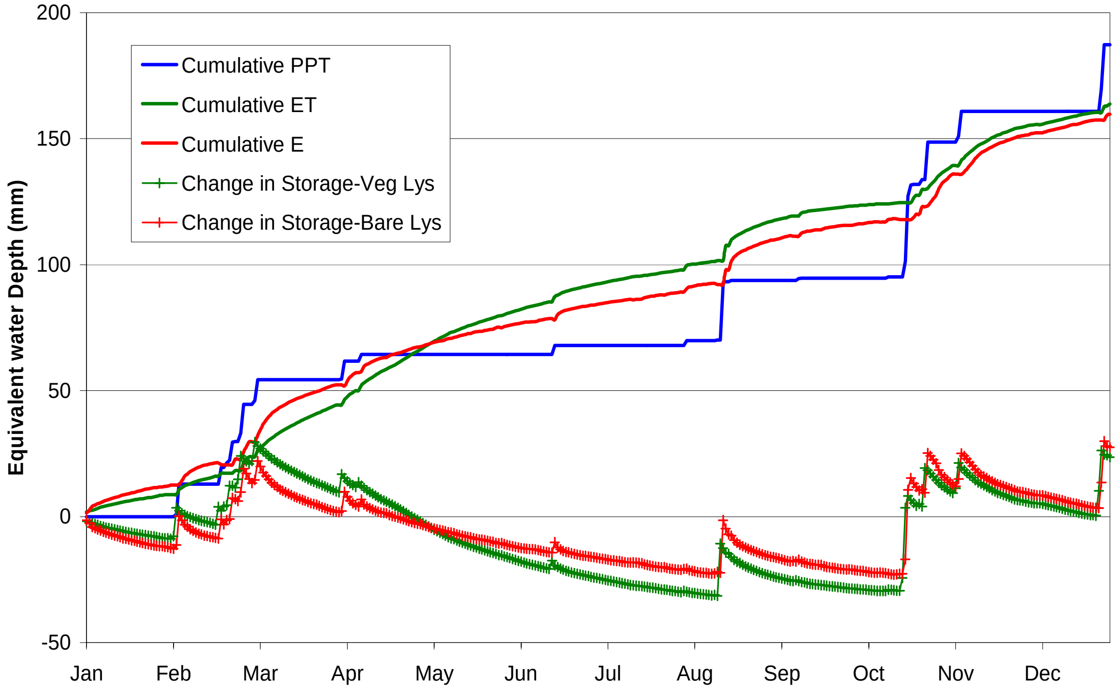

Figure 33. Cumulative PPT, ET, E, and change in storage for the weighing lysimeters in 2004

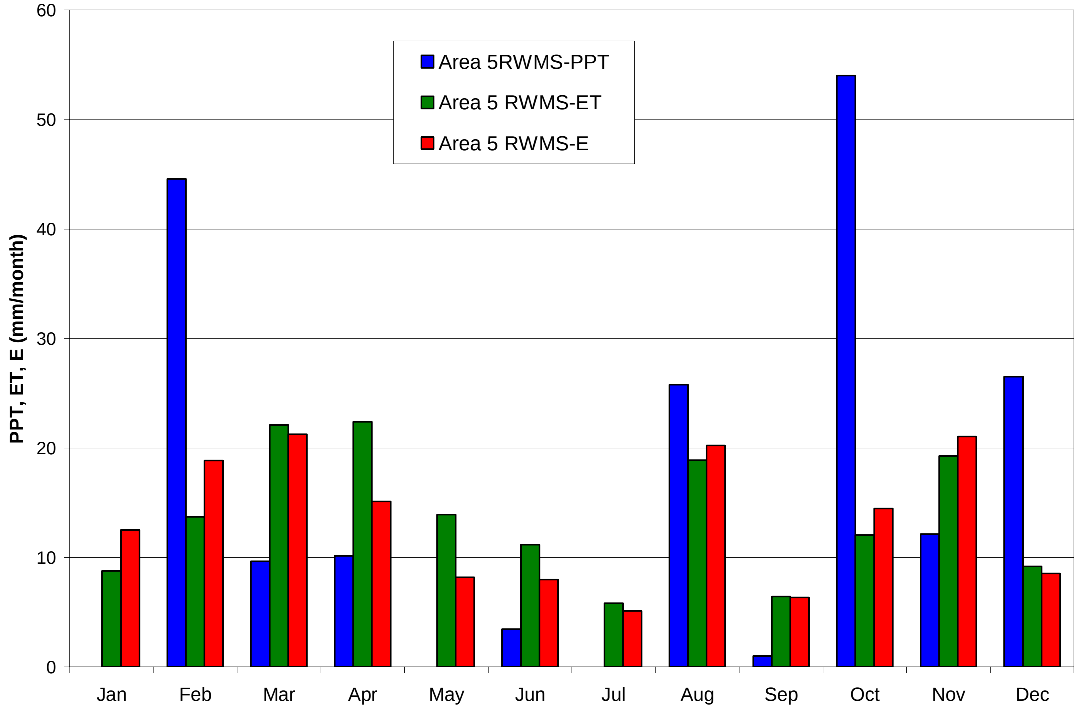

Figure 34. Monthly PPT, E, and ET measured in weighing lysimeters in 2004

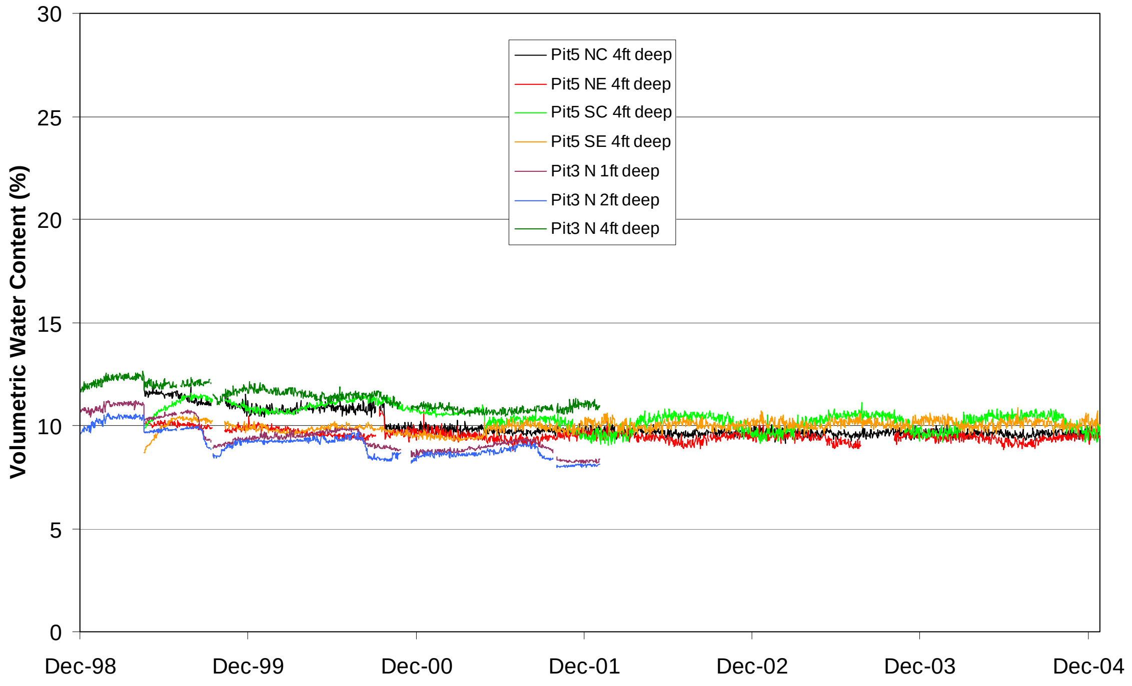

Figure 35. Soil water content in Pit 3 and Pit 5 floors using automated TDR systems

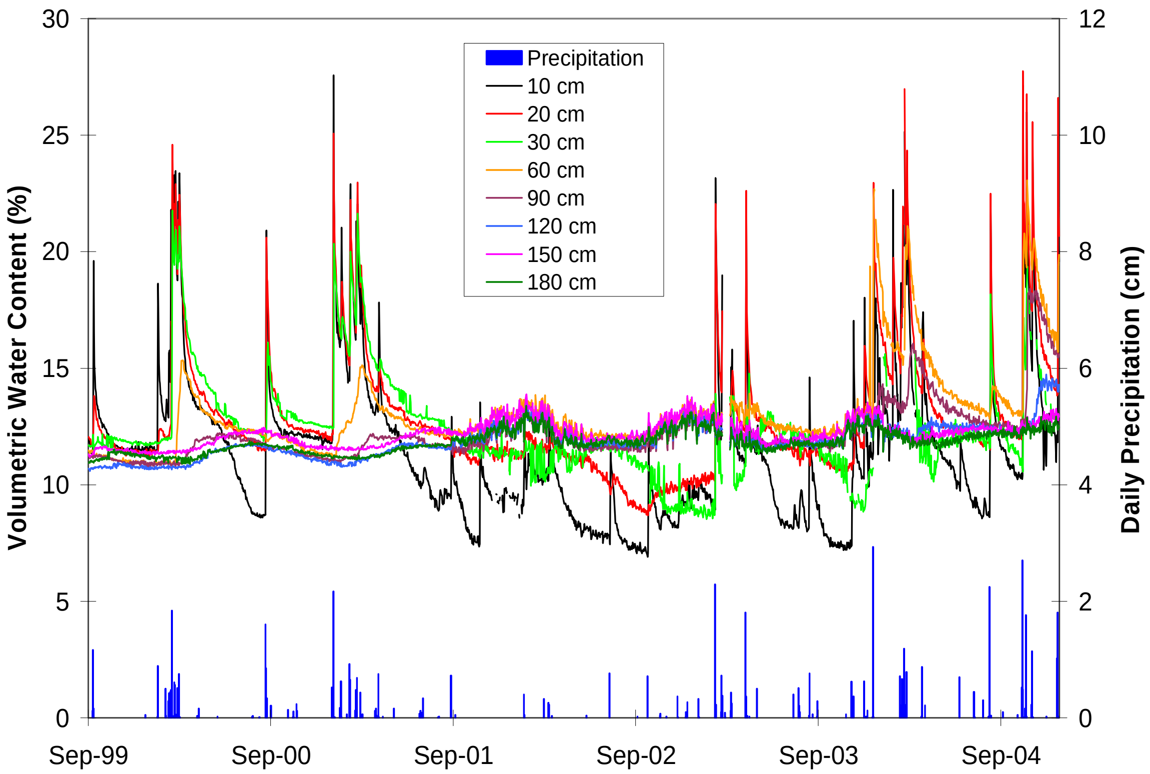

Figure 36. Soil water content in Pit 3 waste cover (north site) using an automated TDR system

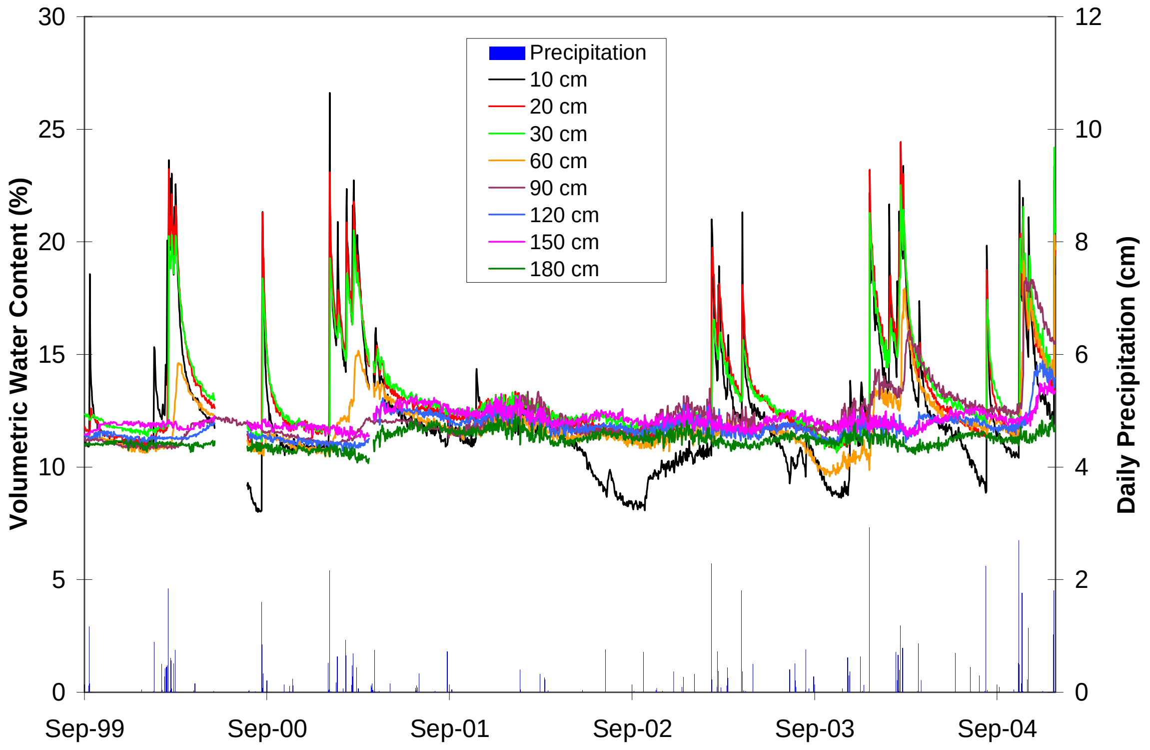

Figure 37. Soil water content in Pit 3 waste cover (south site) using an automated TDR system

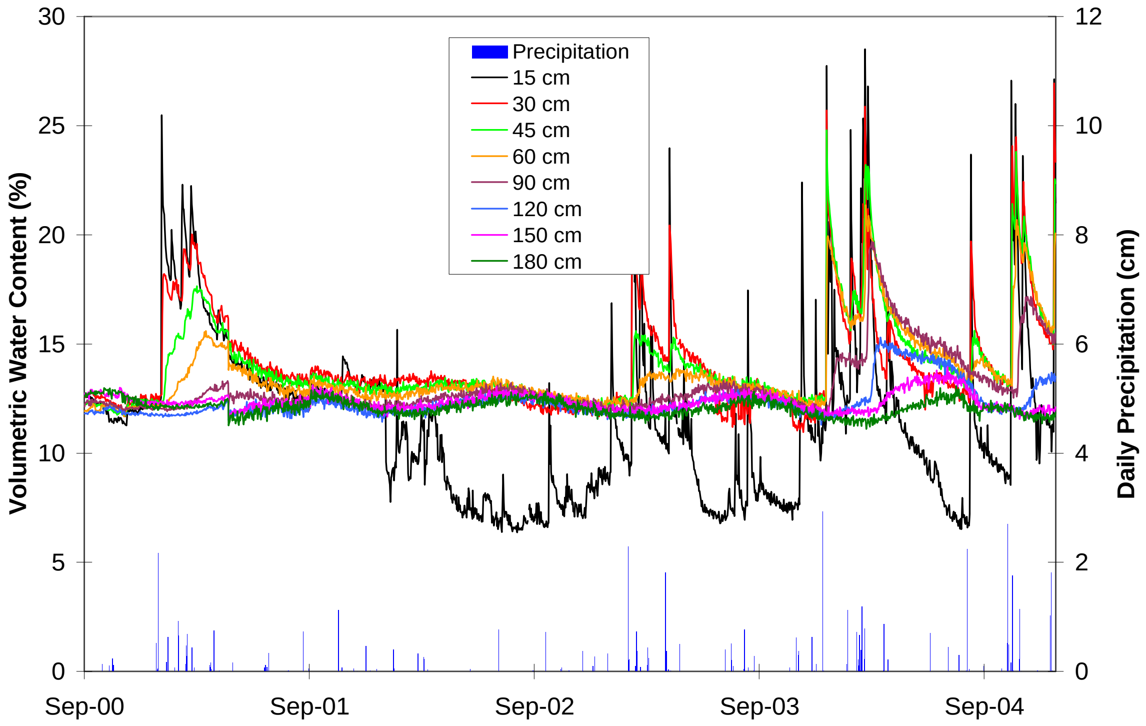

Figure 38. Soil water content in Pit 4 waste cover using an automated TDR system

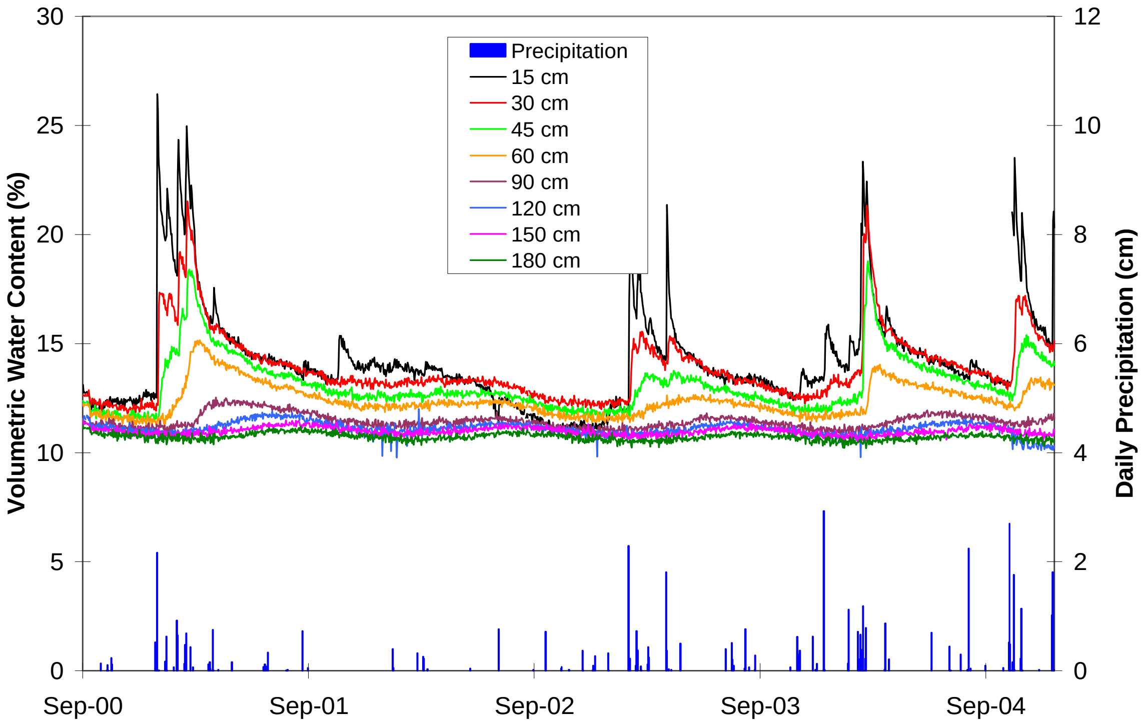

Figure 39. Soil water content in Pit 5 waste cover using an automated TDR system

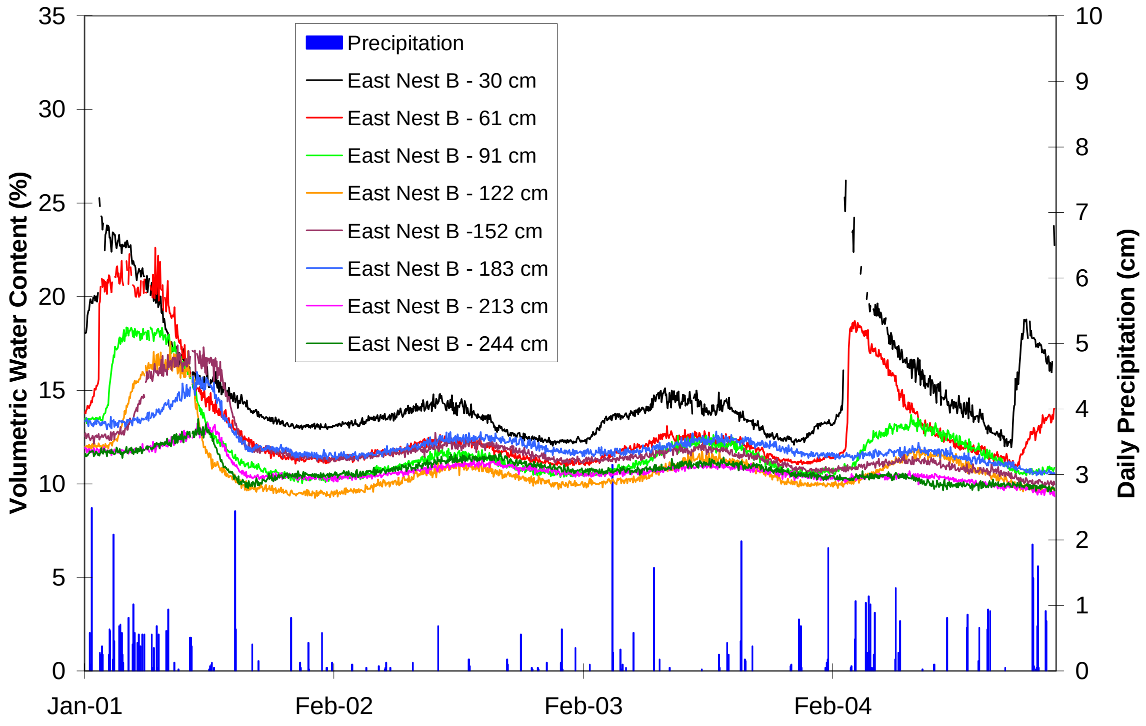

Figure 40. Soil water content in U-3ax/bl waste cover (East Nest B location) using a TDR system

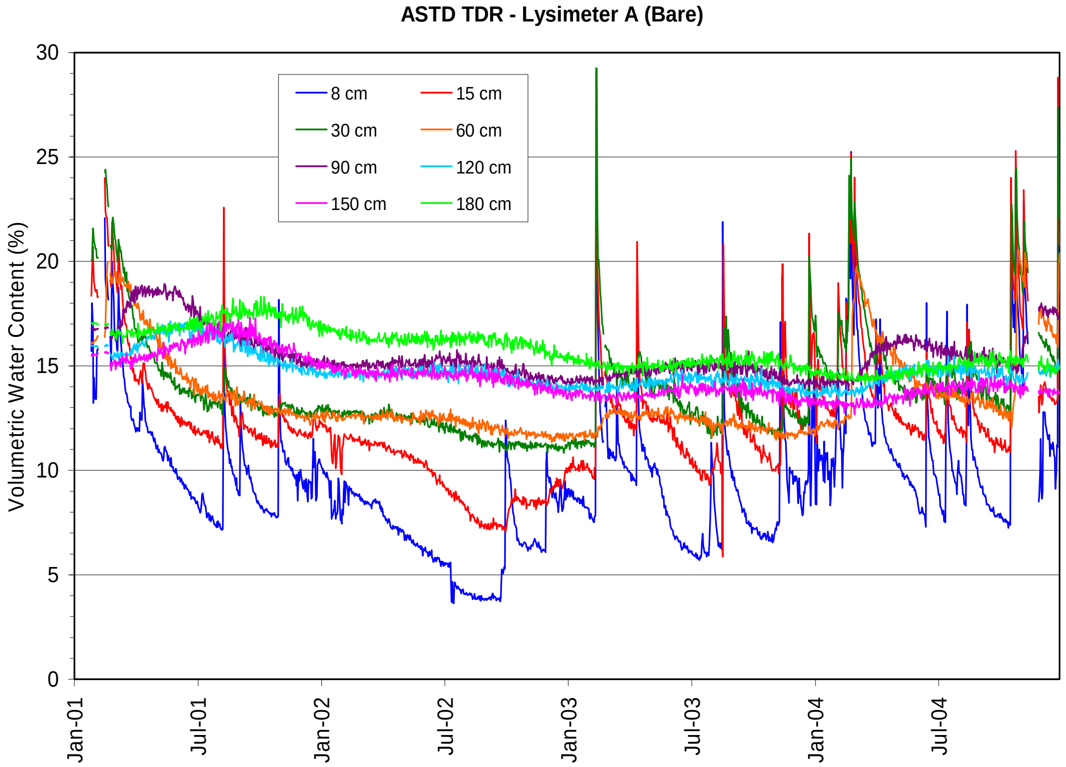

Figure 41. Soil water content in bare drainage lysimeter (A) using a TDR system

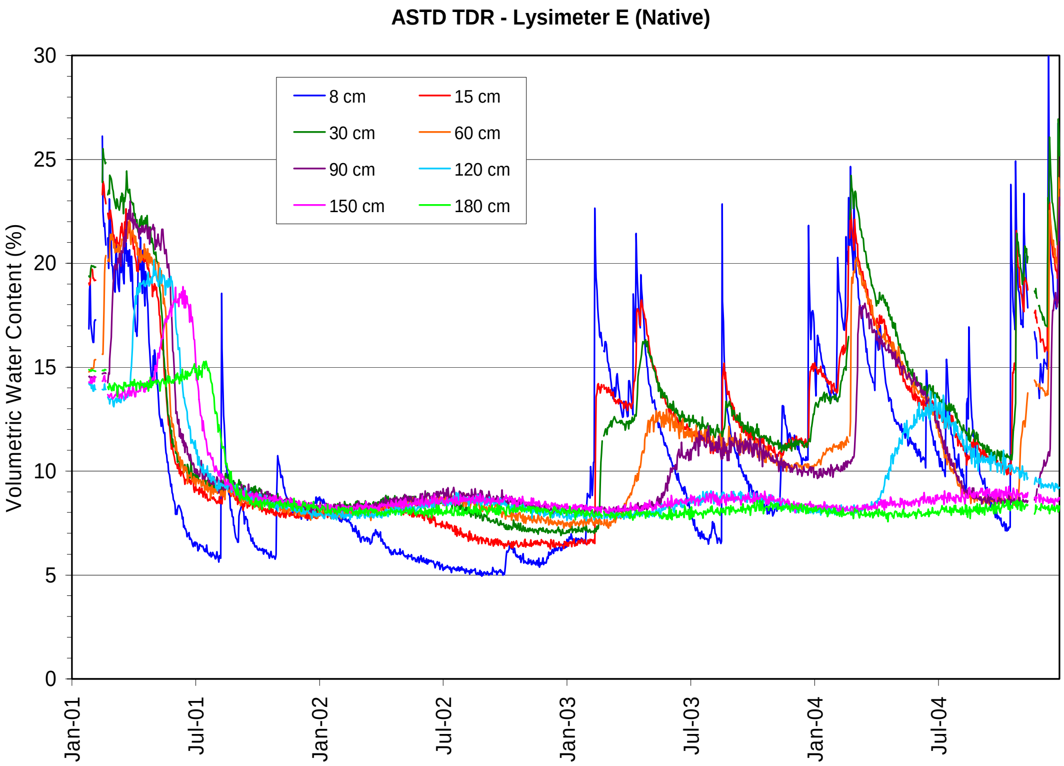

Figure 42. Soil water content vegetated drainage lysimeter (E) using TDR system

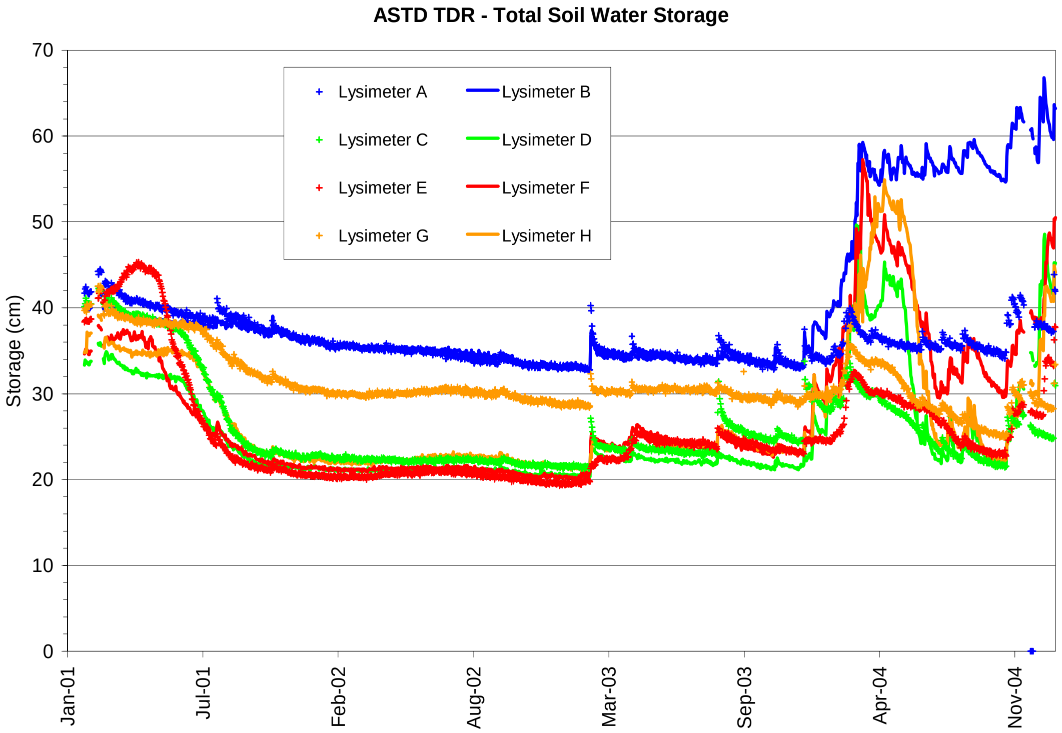

Figure 43. Soil water storage in drainage lysimeters

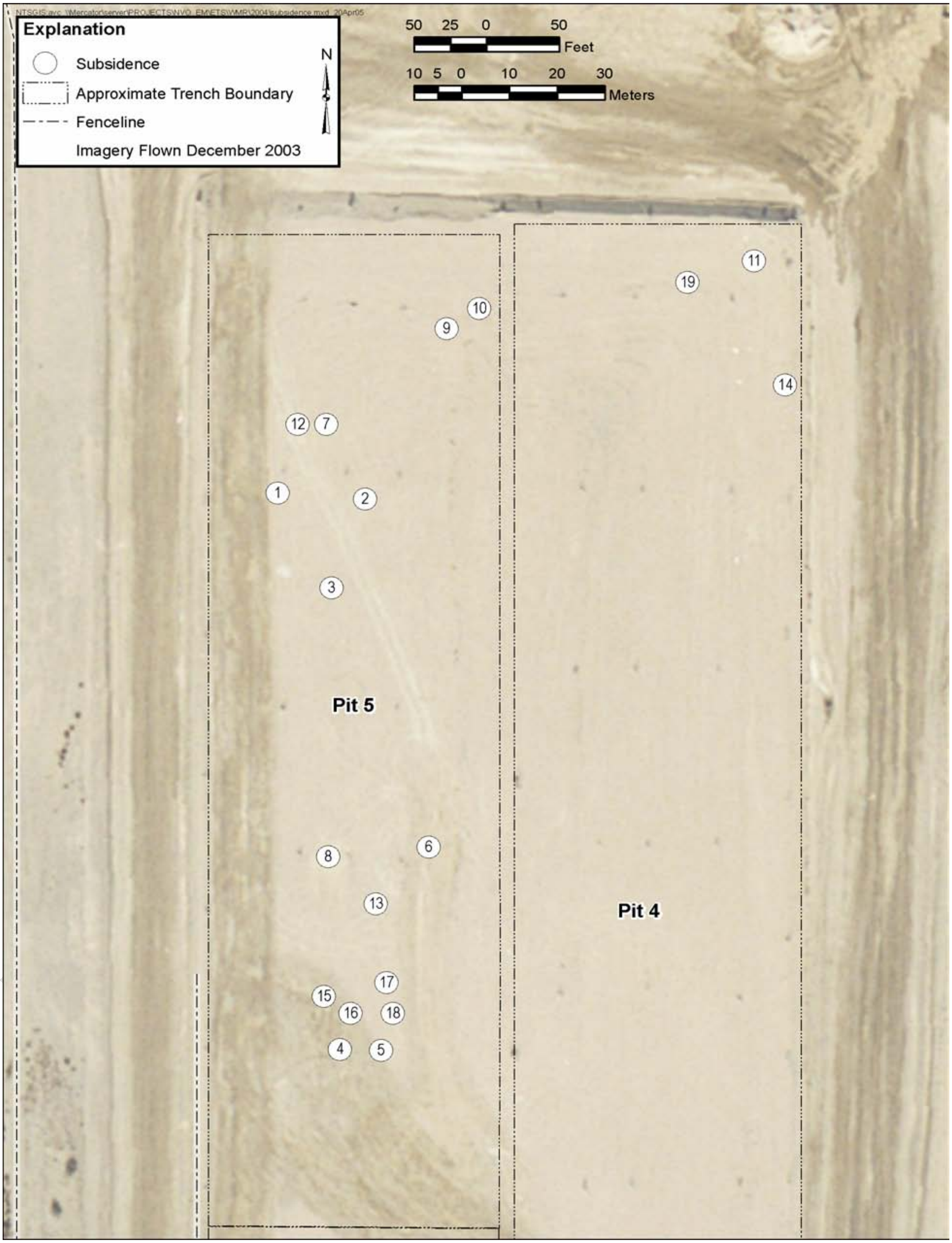

Figure 44. Subsidence locations in 2004

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