SNL MWL 05

National Nuclear Security Administration
Sandia Site Office
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Hazardous
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Mr. James Bearzi, Chief
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Rd. East, Building 1
Santa Fe, NM 87505

Dear Mr. Bearzi:

On behalf of the Department of Energy (DOE) and Sandia Corporation (Sandia), DOE is submitting the Mixed Waste Landfill (MWL) Corrective Measures Implementation (CMI) Plan, November 2005, for planned activities at Sandia National Laboratories, New Mexico, EPA ID No. NM589011518. On May 26, 2005, the Secretary of the New Mexico Environment Department selected a vegetative soil cover with bio-intrusion barrier as the final remedy for the MWL, and approved the associated Class 3 permit modification request.

The enclosed MWL CMI Plan incorporates the final remedy described in Section V.2 of the Class 3 permit modification for the MWL. The CMI Plan documents the plans for construction of the cover for the landfill, and includes the results of a comprehensive fate and transport model that was used to assess the performance of the MWL. The CMI Plan also includes triggers for future action that identify and detail specific monitoring results that would initiate a defined evaluation process, which includes supplemental sampling, if necessary.

If you have any questions, please contact me at (505) 845-6036, or John Gould at (505) 845-6089.

Sincerely,

Patty Wagner

Patty Wagner
Manager

Enclosure

NOV 3 2005

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AOP 95-45, 06

CERTIFICATION STATEMENT FOR APPROVAL AND FINAL RELEASE OF DOCUMENTS

Document title: **Mixed Waste Landfill Corrective Measures Implementation Plan, November 2005**

Document authors: **Tim Goering, Dept. 6147 and Jerry Peace, Dept. 6116 Cliff Ho, Dept. 6115, and Mark Miller, Dept. 10331**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

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and

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Date

Sandia National Laboratories/New Mexico
Environmental Restoration Project

MIXED WASTE LANDFILL CORRECTIVE MEASURES IMPLEMENTATION PLAN

November 2005

United States Department of Energy
Sandia Site Office

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

EXECUTIVE SUMMARY

Sandia National Laboratories/New Mexico (SNL) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico. KAFB occupies 52,233 acres. SNL is managed by the U.S. Department of Energy (DOE) and is operated by Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation. SNL performs research and development in support of various energy and weapons programs and national security. It also performs work for the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission, and other government agencies.

The Mixed Waste Landfill (MWL) is located 4 miles south of SNL's central facilities and 5 miles southeast of Albuquerque International Sunport. The landfill is a fenced, 2.6-acre compound in the north-central portion of Technical Area (TA)-3. The MWL was established in 1959 as a disposal area for low-level radioactive and mixed waste generated by SNL research facilities. The landfill accepted low-level radioactive and minor amounts of mixed waste from March 1959 through December 1988. Approximately 100,000 cubic feet of low-level radioactive and mixed waste containing approximately 6,300 curies of activity were disposed of in the landfill.

The MWL consists of two distinct disposal areas. The classified area occupies 0.6 acres and the unclassified area occupies 2.0 acres. Low-level radioactive and mixed waste was disposed of in each of these areas. Classified wastes were buried in unlined, cylindrical pits in the classified area. Unclassified wastes were buried in shallow, unlined trenches in the unclassified area.

A Phase 1 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL. The Phase 1 RFI indicated that tritium had been released to the environment. A Phase 2 RFI was conducted from 1992 to 1995 to determine the contaminant source, define the nature and extent of contamination, identify potential contaminant transport pathways, evaluate potential risks posed by the levels of contamination identified, and provide remedial action alternatives for the landfill.

The Phase 2 RFI confirmed that tritium is the contaminant of primary concern. Tritium has been a consistent finding at the MWL since environmental studies were initiated at SNL in 1969. Tritium occurs in surface and near-surface soil in and around the classified area of the landfill at levels ranging from 1,100 picocuries (pCi)/gram (g) in surface soil to 206 pCi/g in subsurface soil. The highest tritium levels are found within 30 feet of the surface in soil adjacent to and directly below classified area disposal pits. Below 30 feet from the ground surface, tritium levels fall off rapidly to a few pCi/g of soil. Tritium also occurs as a diffuse air emission from the landfill, releasing 0.09 curies/year to the atmosphere.

The State of New Mexico is authorized by the U.S. Environmental Protection Agency (EPA) to implement the hazardous waste management provisions of RCRA for treatment, storage, and disposal facilities within the state. On August 26, 1993, EPA Region 6 issued the Part B Hazardous and Solid Waste Amendment (HSWA) Permit Module to the DOE and Sandia. The purpose of the permit was to establish specific guidelines for assessment, characterization, and remediation of Solid Waste Management Units (SWMUs) at SNL. Under Module IV of the RCRA Part B Permit (HWSA Module), the MWL is identified as Activity Data Sheet 1289, Environmental Restoration Site No. 76, and RCRA Facility Assessment Site No. 24, 25, 26, 27, 28, 29, 30, 11, 5, and 116. The MWL is a SWMU regulated by the New Mexico Environment Department (NMED) under the corrective action provisions of the HSWA. In addition, DOE Orders provide requirements for landfill closure cover design and establish performance requirements for the closed facility.

HSWA corrective action regulations establish corrective action authority but, due to the delay in finalizing more definitive implementing provisions, do not provide prescriptive requirements. Because the HSWA regulations do not address technical specifications, such as those required for a SWMU cover, the more detailed RCRA operating unit regulations are often used as guidance. For the MWL cover design, Sandia has elected to use RCRA landfill (referred to here as “Subtitle C facilities”) regulations as guidance.

The goal of the EPA-recommended design of final covers for RCRA Subtitle C facilities is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize erosion and further maintenance, to promote surface runoff and drainage, and to protect human health and the environment taking into consideration the future use of the site. The EPA accepts alternative cover designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. A fundamental concern of the EPA with cover designs is that all cover components be stable, and that the cover performs as intended without posing a significant risk to human health and the environment.

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the Mixed Waste Landfill.

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8-9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer’s report. The Secretary requested that a Corrective Measures Implementation Plan incorporating the final remedy be developed within 180 days following the selection of the remedy.

This Corrective Measures Implementation Plan incorporates the final remedy selected by the NMED. The document contains a description of the selected remedy, the objectives for the remedy, detailed engineering design drawings and construction specifications, and a construction quality assurance plan and health and safety plan.

The remedy, a vegetative soil cover, will consist of a thick layer of native soil. The design would rely upon soil thickness and evapotranspiration to provide long-term performance and stability, and would be inexpensive to build and maintain because of the availability of suitable soil in TA-3.

This design is hereby formally submitted to the NMED for final closure of the MWL. The cover is a 3-foot-thick, vegetated soil cover. The cover will be underlain by a 1-foot-thick biointrusion barrier and a subgrade layer up to 40 inches in thickness. The proposed cover meets the intent of RCRA Subtitle C regulations, which include the following:

- Water migration through the cover is minimized.
- Maintenance is minimized by using a monolithic soil layer.
- Cover erosion is minimized by using erosion control measures.
- Subsidence is accommodated by using a “soft” design.
- Permeability of the cover is less than or equal to that of natural subsurface soil present.

Performance of the cover will be integrated with the natural site conditions at TA-3, producing a “system performance” that will ensure that the cover protects both human health and the environment. The natural site conditions at the site include:

- Extremely low precipitation and high potential evapotranspiration
- Negligible recharge to groundwater
- An extensive vadose zone
- Groundwater approximately 500 feet below the surface
- A versatile, native flora that will persist indefinitely as a climax ecological community with little or no maintenance

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ACRONYMS AND ABBREVIATIONS

Am	americium
amsl	above mean sea level
bgs	below ground surface
Be	beryllium
CFR	Code of Federal Regulations
Ci	curie(s)
cm	centimeter(s)
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CPN	California Pacific Nuclear
°F	degrees Fahrenheit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FOP	field operating procedure
g	gram
HELP-3	Hydrologic Evaluation of Landfill Performance Model, Version 3
hr	hour
HSWA	Hazardous and Solid Waste Amendment
HWB	Hazardous Waste Bureau
IP	instantaneous profile
KAFB	Kirtland Air Force Base
m	meter(s)
m^2	square meter(s)
mph	mile(s) per hour
mrem	millirem
MUSLE	modified universal soil loss equation
MWL	Mixed Waste Landfill
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NOD	Notice of Deficiency
pCi	picocurie(s)
PET	potential evapotranspiration
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RSI	request for supplemental information
s	second(s)
Sandia	Sandia Corporation
SNL	Sandia National Laboratories/New Mexico
SWMU	Solid Waste Management Unit
TA	Technical Area
TEDE	total effective dose equivalent
UNSAT-H	Unsaturated Soil Water and Heat Flow Model
USGS	U.S. Geological Survey
USLE	universal soil loss equation

ACRONYMS AND ABBREVIATIONS (Concluded)

VS2DT	Variably-Saturated 2-D Flow and Solute Transport Model
WEQ	wind erosion equation
yd^3	cubic yard(s)
yr	year

1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico (Figure 1-1). KAFB occupies 52,233 acres. SNL research and administration facilities are divided into five technical areas (TAs), designated 1 through 5, and several additional test areas, occupying 2,842 acres. TA-1, TA-2, and TA-4 are separate research facilities in the northwestern portion of KAFB. TA-3 and TA-5 are contiguous research facilities forming a 4.5-square-mile, rectangular area in the southwestern portion of KAFB (Figure 1-2). TA-3 alone occupies 2,000 acres. The Mixed Waste Landfill (MWL) is a 2.6-acre, fenced compound located in north-central TA-3 at SNL (Figure 1-3).

The goal of the U.S. Environmental Protection Agency (EPA)-recommended design of final covers for Resource Conservation and Recovery Act (RCRA) Subtitle C facilities is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize erosion and further maintenance, and to protect human health and the environment by taking into consideration the future use of the site. In general, the EPA provides the performance-based requirements for Subtitle C landfill cover design. These requirements are specified in Title 40 of the Code of Federal Regulations (CFR), Section 264.310. However, the EPA accepts alternative cover designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. A fundamental concern of the EPA with cover design is that all cover components be stable, and that the cover performs as intended without imposing a significant risk to human health and the environment.

In this Corrective Measures Implementation (CMI) Plan, the U.S. Department of Energy (DOE) and Sandia Corporation (Sandia) have demonstrated that the MWL alternative cover meets EPA performance-based criteria in 1) minimizing infiltration of water through the cover; 2) minimizing erosion and further maintenance; 3) promoting surface runoff and drainage; 4) accommodating subsidence; and 5) having a permeability equal to or less than the MWL subsurface soil.

Sandia Corporation (Sandia), a wholly owned subsidiary of Lockheed Martin Corporation, has a Management and Operations Contract with DOE/NNSA for SNL. SNL, which is owned by the DOE, is co-operated by both the DOE and Sandia for purposes of hazardous waste management and corrective action, per Sandia's RCRA Permit. SNL performs research and development in support of various energy and weapons programs. It also performs work for the U.S. Department of Defense, the U.S Nuclear Regulatory Commission, and other government agencies.

The MWL is designated as a Soil Contamination Area and a Hazardous and Solid Waste Amendments (HSWA) Solid Waste Management Unit (SWMU) subject to corrective action under state and federal regulations. The New Mexico Environment Department (NMED), the lead regulatory agency, will oversee the corrective action process for the MWL.

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the Mixed Waste Landfill.

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8-9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer's report. The Secretary requested that a Corrective Measures Implementation Plan incorporating the final remedy be developed within 180 days following the selection of the remedy.

This Corrective Measures Implementation Plan incorporates the final remedy selected by the NMED. The document outlines the deployment of an alternative cover at the MWL (Chapter 2), the regulatory basis (Chapter 3), MWL characteristics (Chapter 4), the technical basis for the cover (Chapter 5), the MWL alternative cover design (Chapter 6), and cover performance monitoring (Chapter 7).

This document outlines the deployment of an alternative cover at the MWL (Chapter 2), the regulatory basis (Chapter 3), MWL characteristics (Chapter 4), the technical basis for the cover (Chapter 5), the MWL alternative cover design (Chapter 6), and cover performance monitoring (Chapter 7).

Appendices include construction specifications (Appendix A), a construction quality assurance plan (Appendix B), the identification and qualifications of key persons implementing the remedy (Appendix C), a health and safety plan (Appendix D), and a comprehensive fate and transport model with triggers for monitoring (Appendix E).

1.1 Acknowledgements

The alternative cover design presented in this document is based upon fruitful collaborations with engineering firms, industry, and state and federal regulatory agencies. The authors benefited greatly from visits and discussions with the following individuals and organizations: William Moats, Rich Kilbury, and Bill McDonald of the NMED; Howard Stone, Gordon Walhood, and Sarah Ganley of Bohannan-Huston; and Paul Knight of Marron and Associates, Inc. The authors also acknowledge valuable discussions with Mike Fayer of Pacific Northwest National Laboratory. Charles Reith, Jack Caldwell, Jack Nyhan, Tom Hakonson, and Glendon Gee deserve special recognition for their pioneering work on alternative landfill covers.

2.0 ALTERNATIVE COVER FOR THE MWL

Due to the lack of specific HSWA technical requirements, Sandia has elected to use RCRA landfill regulations as guidance. The design of a final cover for RCRA Subtitle C facilities recommended by the EPA is, at a minimum, made up of three layers: (1) a vegetated or armored top layer comprised of 24 inches of soil graded at a slope of 3 to 5 percent; (2) a drainage layer, 12 inches thick, composed of a high-conductivity sand layer; and (3) a 24-inch-thick, low-conductivity compacted soil layer with a geomembrane (EPA 1991). The design of the cover elements must take into consideration failure caused by desiccation cracking, settling, and subsidence. The goal of the EPA-recommended design is to limit the formation of leachate by minimizing the contact of waste with water, minimize further maintenance, and protect human health and the environment under future land-use conditions.

The fundamental concern of the EPA with cover designs is ensuring that all cover components are stable and the cover performs as intended, without posing a risk to human health and the environment (EPA 1991). The EPA accepts alternative designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. The EPA acknowledges that in arid regions where vegetation cannot be maintained, other materials for the surface cover layer should be selected to prevent erosion and allow for surface drainage, and the middle drainage layer can be eliminated from the design.

The alternative cover for the MWL is a 3-foot-thick, vegetated soil cover underlain by a 1-foot-thick biointrusion barrier that will be built by placing subgrade fill and lifts of native soil over the existing landfill surface. The topsoil layer will be seeded with native vegetation to mitigate surface erosion and promote transpiration. During the long-term care plan period, native soil can be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers and rills that result from surface erosion. If necessary, additional native soil can be added to compensate for future subsidence and erosion. Because the cover will be constructed without rigid layers, it can accommodate differential subsidence without undue impairment of its performance. This “soft” cover design provides additional assurance for adequate long-term performance of the cover.

The alternative cover meets the RCRA requirements of 40 CFR 264.310, as follows:

- Water migration is minimized through the cover. The 3-foot-thick, vegetated soil cover will minimize water migration into waste disposal cells.

- Maintenance will be minimized by using a monolithic soil layer. Individual layers, such as those used in traditional RCRA covers, are rigid and would require extensive maintenance and repair due to eventual degradation as well as tensile and shear failure.

- Cover erosion will be minimized by using erosion control measures. The cover will be centrally crowned and sloped at 2 percent. The topsoil layer will be vegetated and admixed with 25 percent 3/8-inch crushed gravel.

- Subsidence will be accommodated by using a “soft” cover. During the long-term care period, soil can be added to the cover to repair erosion and subsidence as it occurs. At the end of this time, additional soil can be added to mitigate future erosion and subsidence.

- Permeability of the cover soil will be less than or equal to the permeability of MWL subsurface soil. The "bathtub" effect is unlikely to occur.

Performance of the cover cannot be isolated from the performance of the site itself. Natural site conditions, integrated with the cover, produce a "system performance" that will ensure that the alternative design adequately meets the regulatory requirements. The natural site conditions of TA-3 that will be relied upon as part of the system include:

- Extremely low precipitation and high potential evapotranspiration (PET).

- Negligible recharge to groundwater. Chloride data collected from boreholes at the MWL (Peace et al. 2002) indicate significant rainfall has not percolated beyond the upper 20 feet of soil for tens of thousands of years.

- An extensive vadose zone. Groundwater lies approximately 500 feet below ground surface (bgs).

- The site has low potential for volcanic and seismic activity, with low hazard potential. The Albuquerque volcanoes were active for only a short period about 190,000 years (yrs) ago (Clary et al. 1984).

- The vegetated soil cover will adapt to climatic change, will recover from severe damage (fire and drought), and will persist indefinitely with little or no maintenance.

Performance of the cover will not be impacted by natural environmental events such as flooding or earthquakes. The MWL is not located within the 100-yr or 500-yr floodplains (Figure 2-1) and the expected low recurrence interval and low expected ground motion of seismic events in the Albuquerque basin renders earthquakes of little significance (Figure 2-2).

2.1 Proposed Schedule for Implementation and Periodic Progress Reports

The DOE and Sandia anticipate initiating construction activities for the MWL alternative cover in July 2006. Completion of the alternative cover is expected within 4 months provided the project enjoys favorable weather conditions. Adverse weather conditions may extend the project 4 to 6 weeks.

The DOE and Sandia will submit quarterly progress reports to the NMED during construction of the MWL alternative cover. These reports will include a description of the work completed during the reporting period.

A CMI Report for the MWL will be submitted to the NMED within 180 days after implementation of the remedy is complete. The CMI Report will include a summary of the work completed, as-built drawings and specifications signed and stamped by a registered professional engineer, copies of the results of monitoring and sampling data generated during remedy implementation, and a legal certification that the information is true, accurate, and complete.

2.2 Waste Management

The DOE and Sandia do not anticipate generating any waste during construction of the MWL alternative cover. All construction activities will be nonintrusive and above the existing landfill surface.

2.3 Maintenance and Performance Monitoring

A long-term maintenance and monitoring plan, which contains all necessary physical and institutional controls and long-term monitoring to be implemented at the site in the future, will be submitted by the DOE and Sandia to the NMED for review and approval. The plan will be submitted after the alternative cover has been deployed, and within 180 days of the NMED's approval of the CMI Report. Planned maintenance and monitoring activities and the frequency at which these will be performed will be determined in consultation and collaboration with the NMED and described in detail in the long-term care document.

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3.0 REGULATORY BASIS

The MWL is subject to regulations governing both radioactive and hazardous waste. The DOE meets its responsibility for conducting and overseeing radioactive material operations at its contractor-operated facilities, under the Atomic Energy Act authority, through DOE Orders, which set requirements and standards for closures. DOE Orders and federal and state regulations that contain pertinent requirements for corrective action at the MWL are as follows:

- DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (DOE 1993)
- DOE Order 435.1, "Radioactive Waste Management" (DOE 1999)
- DOE Order 6430.1A, "General Design Criteria" (DOE 1989)
- 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (used as guidance)
- 10 CFR 835 "Occupational Radiation Protection"
- New Mexico Administrative Code (NMAC), 20 NMAC 4.1, Subpart V, 40 CFR 264.101, "Corrective Action for Solid Waste Management Units"

Requirements under federal and state regulations and DOE Orders are summarized in the following sections.

3.1 Corrective Action Requirements under HSWA

The MWL was identified as a SWMU in the August 1993 issuance of the HSWA Module, the corrective action portion of the SNL RCRA operating permit. Under the corrective action program, SNL is required to investigate and remediate, if necessary, the SWMUs identified in the HSWA Module of the permit. For the MWL, SNL has completed the assessment and characterization phase and has proposed to design and deploy an alternative cover as the final remedy. The NMED selected a final remedy (a vegetative soil cover with biointrusion barrier) on May 26, 2005.

Due to both the lack of prescriptive corrective action guidance and the practical similarities of landfill corrective action and landfill closure under RCRA, SNL has elected to use the RCRA landfill closure requirements as guidance for the MWL final remedy. The purpose of closure is to contain and prevent migration of hazardous waste and hazardous constituents from MWL disposal cells. Closure includes construction of engineered controls (i.e., closure cover); the post-closure phase will include implementation of a post closure environmental monitoring and surveillance plan.

Hazardous waste landfill closure requirements are codified under 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart G (Facility Closure Standards) and Subpart N (Landfills). These standards are performance-based regulations that specify performance criteria without specifying design, construction materials, or operating parameters. The EPA has provided numerous guidance documents to aid in interpreting the level of performance required to design, construct, and operate a compliant closure system. The closure performance standard is defined in 40 CFR 264.111 as follows:

> "The owner or operator must close the facility in a manner that:
>
> (a) Minimizes the need for further maintenance; and
>
> (b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and
>
> (c) Complies with the closure requirements of this subpart, including, but not limited to, the requirements of . . . ."

The following performance-based requirements for landfill covers are established in 40 CFR 264.310:

> "At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:
>
> (1) Provide long-term minimization of migration of water through the closed landfill;
>
> (2) Function with minimum maintenance;
>
> (3) Promote drainage and minimize erosion or abrasion of the cover;
>
> (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and
>
> (5) Have permeability less than or equal to the permeability of any bottom liner system or natural subsoil present."

The NMED, the lead regulatory agency, has adopted the federal regulations as written, which are incorporated into 20.4.1.500 New Mexico Administrative Code (NMAC), incorporating the landfill closure requirements of 40 CFR 264.111 and 264.310 as well as 40 CFR 264.101, "Corrective Action for Solid Waste Management Units."

3.2 Closure Requirements under DOE Orders

Low-level radioactive and mixed waste disposal operations at the MWL followed the requirements set by DOE Order 5820.2, "Radioactive Waste Management" (DOE 1984) and those requirements subsequently set by DOE Order 5820.2A, "Radioactive Waste Management" (DOE 1988). On July 9, 1999, DOE Order 5820.2A was cancelled and replaced by DOE Order 435.1 "Radioactive Waste Management" (DOE 1999). The objective of these

Orders is to ensure that all DOE radioactive waste is managed in a manner that protects the health and safety of both workers and the public, and the environment.

DOE Order 435.1 does not set specific closure system design criteria, but establishes performance objectives for the closed facility. The objectives and limits are as follows:

a) Doses to representative members of the public shall not exceed 25 millirem (mrem) in a year total effective dose equivalent (TEDE) from all exposure pathways, excluding the dose from radon and its progeny in air.

b) Dose to representative members of the public via the air pathway shall not exceed 10 mrem in a year TEDE, excluding the dose from radon and its progeny in air.

c) Release of radon shall be less than an average flux of 20 picocuries (pCi)/ square meters (m^2)/second (s) at the surface of the disposal facility.

3.3 Regulatory Review and Response Actions

In order to meet the challenge that came with approval and fielding of an innovative technology at the MWL, SNL Environmental Restoration (ER) Project engineering design staff met with the NMED Hazardous Waste Bureau (HWB) on a regular basis throughout the alternative cover research and design process. The design of alternative covers has to date been an isolated activity at various sites in the United States. Meetings were held with the HWB to determine both specific risks at the MWL and construction and performance requirements. The HWB reviewed 30-percent, 60-percent, and 90-percent design specifications and grading plans for appropriateness. The final design report was submitted to the NMED on September 23, 1999.

The MWL alternative cover design was reviewed internally by the NMED, and externally by TechLaw Inc., a Lakewood, Colorado, civil engineering firm under contract to the NMED. The NMED issued a formal request for supplemental information (RSI) to Sandia on June 5, 2000, to address technical comments and questions raised by TechLaw Inc. and NMED technical and regulatory staff. Sandia submitted its response to the RSI to the NMED on September 8, 2000. The NMED issued a second RSI on February 16, 2001, to clarify certain subject areas of the September 8, 2000, Sandia response. The RSI process was closed in 2001 with no further technical comments or questions.

A design similar to the MWL alternative cover design has received regulatory approval for implementation at the Chemical Waste Landfill, a landfill at SNL that closed under RCRA interim status. At the CWL, the alternative cover was reviewed by the EPA Region 6 in 2001 and 2002 and determined to be adequate for Toxic Substances Control Act substances remaining in the closed CWL. EPA approval was obtained on June 26, 2002. Deployment of the CWL alternative cover design was approved by the NMED in April 2004 as an interim measure at the CWL under the RCRA interim status closure regulations. These regulatory approvals indicate that the alternative cover design is appropriate for implementation in the semi-arid environment at SNL and that the underlying premises of the MWL design are sound.

3.4 Corrective Measures Study

On October 11, 2001, the NMED directed the DOE and Sandia to conduct a Corrective Measures Study (CMS) for the MWL. A CMS Workplan (SNL December 2001) was written by the SNL Environmental Restoration Project in accordance with requirements set forth in Module IV (Hazardous and Solid Waste Amendments) of the DOE and SNL RCRA Permit. The CMS Workplan was submitted to the NMED on December 19, 2001, and approved with conditions by the NMED on October 10, 2002.

The MWL CMS Report was submitted to the NMED on May 21, 2003 for technical review and comment. The purpose of the CMS was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, the DOE and Sandia recommended that a vegetative soil cover be deployed as the preferred corrective measure for the MWL.

The NMED issued a Notice of Deficiency (NOD) to the DOE and Sandia on November 5, 2003. The DOE and Sandia responded to the NOD on December 19, 2003. On January 5, 2004, the NMED determined that the MWL CMS Report was complete.

3.5 Remedy Selection

The NMED held a public comment period on the MWL CMS from August 11, 2004 to December 9, 2004. A public hearing was conducted on the MWL CMS on December 2-3 and 8–9, 2004. On May 26, 2005, the Secretary of the NMED selected a vegetative soil cover with bio-intrusion barrier (Corrective Measures Study Alternative III.c) as the remedy for the MWL. The selection was based on the administrative record and the Hearing Officer's report. The Secretary requested that a CMI Plan incorporating the final remedy be developed within 180 days following the selection of the remedy. The draft permit modification issued by the NMED in the matter prior to the hearing was revised by the NMED in accordance with the Secretary's final decision.

4.0 MWL CHARACTERISTICS

The weather for Albuquerque and vicinity, including SNL, is typical of high-altitude, dry continental climates. The normal daily temperature ranges from 23 to 52 degrees Fahrenheit (°F) during winter months and from 57 to 91°F during summer months. The average annual relative humidity is 46 percent; however, the relative humidity can range from as low as 5 percent to as high as 70 percent (Bonzon et al. 1974).

Under normal conditions, wind speeds seldom exceed 32 miles per hour (mph) and are generally less than 8 mph (Bonzon et al. 1974). Strong winds, often accompanied by blowing dust, occur mostly in late winter and early spring. During these months, the prevailing surface winds are from the southwest. Rapid night-time ground-cooling produces strong temperature inversions and strong winds through mountain canyons.

The average annual precipitation for the Albuquerque area is 8.5 inches (21.6 centimeters [cm]). Monthly precipitation can range from a minimum of less than 0.5 inch during winter months to 1.5 inches during summer months. Average annual snowfall in the Albuquerque area is 11 inches. Summer precipitation, particularly in July through August, is usually in the form of heavy thundershowers that typically last less than 1 hour (hr) at any given location (Williams 1986). Average annual Class A pan evaporation at Albuquerque International Sunport Station 224 is 89 inches, approximately 10 times the average annual precipitation.

TA-3 is situated within coalescing alluvial fans emanating from the Manzanita Mountains to the east that form an expansive, relatively featureless, arid mesa. TA-3 is underlain by an extensive vadose zone comprised of unconsolidated, braided channel, interchannel, flood plain, and aeolian deposits. The water table beneath TA-3 occurs within the Santa Fe Group approximately 500 feet bgs. The MWL lies in the north-central portion of TA-3. Elevations at the MWL range from 5,385 feet above mean sea level (amsl) on the east to 5,375 feet amsl on the west. Mean elevation is 5,381 feet amsl.

There are no permanent structures at the MWL. All disposal pits and trenches were excavated below grade. The only visible surface features are the earthen berms above unclassified area trenches, and security fences that surround the compound. There are no perennial streams in the immediate area of the MWL. Surface runoff is regionally controlled and generally to the west. There are no man-made surface runoff controls. Surface runoff flows from the landfill surface to dirt roads that surround the fenced compound.

The MWL accepted containerized and uncontainerized low-level radioactive and mixed waste from SNL research facilities and off-site generators from 1959 to 1988. Approximately 100,000 cubic feet of low-level radioactive and mixed waste (excluding waste containers, packaging, construction and demolition debris, and contaminated soil) containing 6,300 curies of activity (at the time of disposal) were disposed of at the MWL, which contains minor quantities of RCRA hazardous metals and solvents. Disposal cells at the landfill are unlined and have been compacted to grade with native soil.

There are two distinct disposal areas at the MWL that include the classified area (occupying 0.6 acres) and the unclassified area (occupying 2.0 acres) (Figure 1-3). Wastes in the classified area were disposed of in a series of vertical, cylindrical pits. Historical records indicate that early pits were 3 to 5 feet in diameter and 15 feet deep. Later pits were 10 feet in diameter and

25 feet deep. Once pits were filled with waste, they were backfilled with soil and capped with concrete. Wastes in the unclassified area were disposed of in a series of parallel, north-south, excavated trenches. Records indicate that the trenches were 15 to 25 feet wide, 150 to 180 feet long, and 15 to 20 feet deep. Trenches were reportedly backfilled with soil on a quarterly basis and, once filled with waste, capped with the original soil that had been excavated and locally stockpiled.

Containment and disposal of waste commonly occurred in tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, 55-gallon steel and polyethylene drums. Larger items, such as glove boxes and spent fuel shipping casks, were disposed of in bulk without containment. Disposal of free liquids was not allowed at the MWL. Liquids such as acids, bases, and solvents were solidified with commercially available agents including Aquaset, Safe-T-Set, Petroset, vermiculite, marble chips, or yellow powder before containerization and disposal.

Most pits and trenches contain routine operational and miscellaneous decontamination waste including gloves, paper, mop heads, brushes, rags, tape, wire, metal and polyvinyl chloride piping, cables, towels, quartz cloth, swipes, disposable lab coats, shoes covers, coveralls, high-efficiency particulate air filters, prefilters, tygon tubing, watch glasses, polyethylene bottles, beakers, balances, pH meters, screws, bolts, saw blades, Kleenex, petri dishes, scouring pads, metal scrap and shavings, foam, plastic, glass, rubber scrap, electrical connectors, ground cloth, wooden shipping crates and pallets, wooden and lucite dosimetry holders, and expended or obsolete experimental equipment.

A detailed MWL waste inventory, by pit and trench, is provided in the Environmental Restoration Project "Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996" (SNL 1998).

5.0 TECHNICAL BASIS

The MWL alternative cover design is based upon federal regulations and guidance, DOE Orders and guidance, NMED regulations and guidance, an extensive review of published studies conducted over the past 20 yrs, and the geological, hydrological, and ecological conditions specific to TA-3 and the MWL. Performance of the overall “system” relies on both the cover design and natural site characteristics. The objective was to capture and condense these design “elements,” as appropriate, to design a cover that meets the intent of the regulations and that improves, rather than degrades, over time as inevitable natural processes act on the system. Engineered covers must be viewed as evolving components of larger, dynamic ecosystems (Waugh 1997).

The DOE has been actively pursuing alternative cover design and construction for more than 20 yrs. Most of the research to date has been conducted in arid and semiarid regions. Much of this research was evaluated and incorporated, as appropriate, in the design proposed for the MWL. Research and published information to date is limited to short-term demonstrations and monitoring, predictive models, and natural analogs. There is little information published on the long-term performance of alternative cover systems.

5.1 Potential Evapotranspiration

PET estimates have been made for TA-3 in support of predictive modeling. The Hydrologic Evaluation of Landfill Performance Model, Version 3 (HELP-3) (Schroeder et al. 1994) was used to estimate PET data with its built-in functions and localized database for Albuquerque, New Mexico. The resulting PET data are shown along with pan evaporation data from four New Mexico National Weather Service Stations in Figure 5-1. The average annual PET modeled by HELP-3 for the 65-yr period (1932 to 1996) is 75.4 inches, approximately nine times the average annual precipitation recorded at Albuquerque International Sunport.

5.2 MWL Vadose Zone Characteristics

Extensive field investigations and analytical studies have been undertaken in TA-3 and at the MWL to address regulatory-driven assessment and characterization requirements. A comprehensive RCRA Facility Investigation (RFI) Report (Peace et al. 2002) and two NMED Notice of Deficiency submittals, including an extensive inventory of wastes disposed of at the MWL, are available for review (SNL 1998, SNL 1999). Data collected from boreholes, groundwater monitoring wells, and instantaneous profile (IP) tests were used to measure saturated and unsaturated zone characteristics, augment characterization and assessment, and support final closure of the site. These data included volumetric water content, saturated and unsaturated hydraulic conductivity, bulk density, and isotopic chloride content. The data are summarized in Goering et al. (1995), Wolford (1998), and Peace and Goering (2005).

5.2.1 Water Movement in the Unsaturated Zone under Natural Conditions

MWL Phase 2 RFI characterization data show no evidence of significant water migration past the root zone of plants or the upper 2 feet of soil. Infiltrating surface water returns to the atmosphere via evapotranspiration. Recharge to the water table at the MWL is insignificant under current climatic and vegetative conditions.

The following characteristics summarize the vadose zone in TA-3 and at the MWL.

- The underlying alluvium, which makes up the vadose zone, is well-graded, very fine sand with occasional layers of gravel, coarse sand, silt, and clay. The relative percentages of silt and clay increase with depth, and predominate at depths greater than 250 feet bgs.

- Water content of the alluvium is very low near the surface and may decrease with depth. Soil-water contents average approximately 3 percent by weight and peak at about 13 percent by weight.

- Very little infiltration of water occurs beyond the upper 2 feet of the surface. Unsaturated hydraulic conductivities are extremely low due to low soil-water contents. The operational unsaturated hydraulic conductivities of these soils are on the order of 10^{-9} to 10^{-10} cm/s.

- Soil profiles show an enrichment of stable chloride near the surface (Figure 5-2). Chloride in the top 20 feet of soil represents the accumulation of atmospheric chloride over tens of thousands of years. The implication of this chloride accumulation is that very little water has infiltrated beyond 20 feet bgs during that period of time. Water that exists deeper in the vadose zone probably entered the system much earlier and under much wetter climatic conditions.

5.2.2 The Bathtub Effect

RCRA Subtitle C regulations, specifically 40 CFR 264.310 (a) (5), state that at final closure of a landfill, the operator must cover the landfill with a final cover designed and constructed to: "have permeability less than or equal to the permeability of any bottom liner system or natural subsoil present." This prescriptive requirement was established to prevent what is commonly referred to as the bathtub effect, which occurs when a more permeable cover is constructed over a less permeable bottom liner or natural subsurface soil. If the more permeable cover were to remain saturated during its design life, water would eventually accumulate in disposal cells, filling pits and trenches as if they were basins. Such an event could accelerate deterioration of waste containers, initiate subsidence of the cover, and mobilize hazardous constituents.

The cover has been carefully designed using native soil selected from appropriate borrow areas to prevent the bathtub effect. This section presents the permeability (hydraulic conductivity) data for MWL subsurface soil and for the soil that will be used to construct the cover. These data demonstrate that the MWL alternative cover meets the permeability requirements of 40 CFR 264.310, and that the bathtub effect is unlikely to occur.

5.2.2.1 MWL Subsurface Soil Hydraulic Conductivities

During the MWL Phase 2 RFI and in subsequent hydrologic studies, the permeability of MWL subsurface soil was determined by directly measuring the saturated hydraulic conductivity in the field, and by measuring the hydraulic conductivity of core samples in the laboratory.

5.2.2.1.1 Field measurements of Subsurface Soil Hydraulic Conductivity

The most representative measurement of saturated hydraulic conductivity is obtained in situ in the field, because the sampled areas are undisturbed and the area tested is considerably larger than the cross-sectional area of a core sample analyzed in the laboratory. In addition, field conductivity values reflect the presence of naturally occurring macropores (or channels of preferential flow), which may significantly affect the saturated hydraulic conductivity. Two in situ tests were conducted on surface soil west of the MWL to obtain measurements of the saturated hydraulic conductivity. The results from these tests are summarized in Table 5-1.

The first test was an IP test conducted on a 16- by-16-foot area that was flooded with more than 5,000 gallons of water. Water infiltration through the upper 6 feet of soil was monitored and measured over 890 days. The saturated hydraulic conductivity determined from steady-state flow is 4.0×10^{-4} cm/s.

The second in situ test was conducted on an adjacent 10- by-10-foot area. This site was flooded to emulate a rainfall event, and the saturated hydraulic conductivity was determined to be 5.3×10^{-4} cm/s. The average (geometric mean) hydraulic conductivity from these two in situ tests is 4.6×10^{-4} cm/s.

5.2.2.1.2 Laboratory Measurements of Subsurface Soil Hydraulic Conductivity

During the MWL Phase 2 RFI, laboratory measurements of saturated hydraulic conductivity were obtained from 18 core samples collected from subsurface soil directly below the MWL at depths ranging from 10 to 104 feet bgs. Core samples were collected ahead of the drill bit using a California split-spoon sampler and brass rings. Laboratory measurements of hydraulic conductivity were also obtained from six core samples collected from the IP test site at depths ranging from 1 to 6 feet bgs. The IP test core samples were collected with a sliding hammer core sampler and brass rings. Hydraulic conductivities for core samples obtained from Phase 2 RFI drilling and from the IP test site were measured using the relatively undisturbed soil samples, without remolding. Two additional hydraulic conductivity measurements were obtained by remolding soil from the IP test site. The results from these tests are summarized in Table 5-1.

The average (geometric mean) of the 26 laboratory measurements of hydraulic conductivity is 1.1×10^{-4} cm/s. These results are very similar to the results obtained from the in situ hydraulic conductivity test at the IP test site west of the MWL, which yielded an average hydraulic conductivity of 4.6×10^{-4} cm/s.

5.2.2.2 MWL Alternative Cover Hydraulic Conductivity

Nine composite soil samples were collected from borrow areas west of the MWL and from existing Corrective Action Management Unit (TA-3 borrow pits) soil stockpiles in TA-3. The cover will be constructed of soil from each of these borrow areas. Borrow soil was analyzed for a full suite of geotechnical parameters, including saturated hydraulic conductivity, moisture-density relationships, Atterberg Limits, grain-size analysis, and shear strength.

Saturated hydraulic conductivities were obtained at 90 percent of the maximum dry bulk density to satisfy earthwork specifications for percent (relative) compaction. Hydraulic conductivity data for the cover soil are presented in Table 5-2. The saturated hydraulic conductivity for borrow soil from areas west of the MWL averaged 3.6×10^{-5} cm/s, while the saturated hydraulic conductivity for the soil in the TA-3 borrow pits averaged 1.6×10^{-5} cm/s. Fill for the subgrade layer, the native soil layer, and the topsoil layer will come from the TA-3 borrow pits. The average (geometric mean) hydraulic conductivity of all soil samples from both borrow areas is 2.1×10^{-5} cm/s, which is a realistic estimate of the saturated hydraulic conductivity of the final cover.

These data demonstrate that the saturated hydraulic conductivity of the cover will be lower than the saturated hydraulic conductivity of the underlying natural subsurface soil. The estimated saturated hydraulic conductivity of the natural subsurface soil is 4.6×10^{-4} cm/s. The estimated saturated hydraulic conductivity of the final cover is 2.1×10^{-5} cm/s. Thus, the bathtub effect is unlikely to occur.

5.2.2.3 Natural Analog of the MWL Cover

The most convincing evidence that the bathtub effect will not occur at the MWL lies in the analog of natural moisture conditions in soil in the vicinity of the MWL. Existing moisture contents in this soil provide an excellent natural analog for predicting moisture contents in the cover. Soil moisture content at the MWL averages 3 percent by weight. Although the upper few inches of soil may become saturated briefly following rainfall events, evapotranspiration causes the soil to dry rapidly. Even during winter months, when plants are dormant and transpiration is low, saturated conditions rarely occur.

The vegetated soil cover for the MWL is designed to simulate natural conditions, utilizing evapotranspiration to remove excess moisture. When excess moisture is removed, water is no longer available to percolate downward into waste disposal cells. Because the alternative cover was designed to simulate natural site conditions, the cover is predicted to be unsaturated during most of its design life, which is consistent with the cover performance modeling results presented in Section 5.3.

Under these unsaturated conditions, the "operational hydraulic conductivity" of the cover will be orders of magnitude lower than the saturated hydraulic conductivity of both the cover and the natural subsurface soil. The operational hydraulic conductivity of the MWL cover is equal to the average flux through the cover, assuming a unit gradient. Performance modeling at the MWL using the Unsaturated Soil Water and Heat Flow Model (UNSAT-H) (Fayer and Jones 1990) predicted an average flux through the 3-foot cover to be 4.1×10^{-9} cm/s (see Section 5.3.3). HELP-3 and Variably-Saturated 2-D Flow and Solute Transport Model (VS2DT) (Healy 1990) predicted this value to be 7.1×10^{-11} cm/s and 2.1×10^{-10} cm/s, respectively. Thus, the operational hydraulic conductivity of the final cover is conservatively estimated to be 4.1×10^{-9} cm/s, five orders of magnitude lower than the estimated saturated hydraulic conductivity of the MWL subsurface soil (4.6×10^{-4} cm/s), and four orders of magnitude lower than the predicted saturated hydraulic conductivity of the cover (2.1×10^{-5} cm/s).

5.3 Cover Performance

Alteration of the MWL natural site conditions by grading the land surface and removing the established native vegetative cover, deploying an engineered cover, and building drainage swales will alter the site's hydrologic response. The long-range plan is to establish soil and vegetative conditions similar to existing natural conditions. Both the long-term as well as the short-term responses of the cover must be considered in its design. Engineering designs are analyzed under hypothetical scenarios that have a reasonable chance of future occurrence to demonstrate that the potential for infiltration and contaminant migration from waste disposal cells to the vadose zone and groundwater is unlikely, and to ensure that the intent of federal and state regulations and DOE orders is met.

The regulatory requirements for closure and post-closure of landfills are provided in several EPA guidance documents (EPA 1989, EPA 1991, EPA 1994). The primary closure requirement is that the owner must design and construct a low-permeability cover over the landfill to minimize infiltration of water into waste disposal cells and provide long-term care and maintenance in order to prevent releases of hazardous constituents to the environment.

5.3.1 Cover Performance Modeling

In order to demonstrate that the MWL alternative cover design complies with the regulatory guidance, it is necessary to model the hydrologic performance of the cover. The EPA (EPA 1994) suggests that the water-balance model, HELP, be used for these demonstrations. Performance of the cover was evaluated using HELP-3 (Schroeder et al. 1994) and two additional unsaturated flow models, UNSAT-H (Fayer and Jones 1990) and VS2DT (Healy 1990). Although HELP-3 is commonly used to predict infiltration through landfill covers and is widely accepted by the regulatory community, UNSAT-H and VS2DT are more rigorous and were used for comparison with the HELP-3 modeling results.

Performance modeling results were used to predict infiltration through the cover and to determine optimal cover thickness. Because construction costs are directly proportional to the thickness of a cover, the optimal cover design is one that meets the performance criteria with the least amount of thickness. Inherent in the determination of optimal cover thickness is the ability of the cover design to limit infiltration of water into waste disposal cells. In order to model the hydrologic performance of the cover, historical rainfall records from Albuquerque International Sunport, dating from 1919 to 1996, were used. This historical record provides data for assessing both the short- and long-term responses of the cover design as well as determining the performance criteria for the post-closure care and maintenance period.

HELP-3 (Schroeder et al. 1994) was specifically developed for designing landfill covers, but lacks rigorous mathematical flow calculations. This water-balance model uses simplified schemes to model both the infiltration of water through soil layers and the removal of water by evapotranspiration and overland flow. HELP-3 contains databases describing soil parameters, meteorological conditions, and vegetation; however, site-specific data for the MWL were used wherever possible to more accurately model the performance of the cover.

UNSAT-H (Fayer and Jones 1990) was designed to predict performance of waste burial sites at Hanford, Washington, an area with low rainfall and relatively dry soil, conditions similar to Albuquerque, New Mexico. UNSAT-H uses a finite-difference implementation of a modified form of Richards' equation to predict unsaturated liquid and vapor flow in soil layers as well as water removal through plant roots (transpiration). UNSAT-H employs many of the best procedures for simulating the hydrology of soil covers (EPA 2002, Albright et al. 2002) and was used in this analysis to complement HELP-3 results.

VS2DT (Healy 1990) is a U.S. Geological Survey (USGS) code used to model flow and solute transport in variably-saturated, single-phase flow in porous media. VS2DT uses a finite-difference approximation to solve Richards' equation for flow, and the advection-dispersion equation for transport. While it offers rigorous unsaturated flow mathematics, VS2DT is designed more specifically for transport estimation than for landfill cover design, and does not include flows past a particular depth among its output files. VS2DT is the least user-friendly of the three codes, but was used in this analysis primarily because it is a well-validated USGS code commonly used to predict flow and transport of water in the vadose zone.

5.3.2 Model Input Parameters

Input parameters for the models included precipitation and climate data, evapotranspiration data, soil hydrologic properties, thickness, and miscellaneous model-dependent input parameters such as evaporative zone depth and leaf area index. Table 5-3 summarizes the input parameters specific to HELP-3, UNSAT-H, and VS2DT. HELP-3 is the most popular code in use for evaluating landfill covers. UNSAT-H generally provides the most accurate predictions of infiltration (Albright et al. 2002). Input parameters vary between models depending on whether the code is a water-balance model (HELP-3) or a Richards' equation-based model (UNSAT-H).

Numerous preliminary modeling studies of the MWL alternative cover were conducted prior to the formulation of the final results presented in this report. These studies focused on the sensitivity of the selected models to various input parameters. The results of these sensitivity analyses are presented in "Preliminary Unsaturated Flow Modeling and Related Work Performed in Support of the Design of a Closure Cover for the MWL" (Wolford 1998). The modeling results presented in this design report vary slightly from preliminary modeling results, reflecting more consistent use of input parameters between models. During the early modeling efforts for the proposed MWL alternative cover, slight variations existed between the models in parameters including rooting depth, atmospheric tension, and nodal spacing. The modeling results presented in this report used more consistent input parameters between each model to ensure compatibility between models and to facilitate comparison of the results. Modeling results were corroborated in 2004 using UNSAT-H Version 3.0 (Fayer 2000) and conservative site-specific input parameters. These modeling data are provided in Peace and Goering 2005.

5.3.2.1 Precipitation Data

All three models were run using two discrete sets of precipitation data. The first set, the "Historical Precipitation Data," included 65 yrs of daily rainfall recorded from 1932 to 1996 at Albuquerque International Sunport. The second set, the "Maximum Precipitation Data," included the eight heaviest years' rainfall between 1919 and 1996, repeated eight times for a total of 64 yrs. The heaviest rainfall years were 1919, 1929, 1940, 1941, 1982, 1986, 1988, and 1992. These rainfall data are representative of a significant climate change, and would have the greatest influence on the long-term performance of any cover system. Precipitation during these years ranged from 12 inches to more than 15 inches (30.5 to 38.1 cm/yr). These annual totals contrast markedly with the current average annual precipitation for the Albuquerque area of 8.5 inches/yr (21.6 cm/yr).

Ecological studies performed by Waugh (1997), using proxy paleoclimate data (tree rings, packrat middens, lake sediment pollen, and archeological records) indicate bounding conditions for future climate states of twice the current precipitation at Monticello, Utah. This 64-yr (artificial) rainfall data set adequately approximates and addresses a similar climate change in New Mexico for the cover.

5.3.2.2 Soil Parameters

The soil parameters for the models were selected based upon the results from field and laboratory tests conducted in soil near the MWL. Several large-scale infiltration tests were conducted in soil west of the MWL to measure water movement through the soil and the effects of evapotranspiration and unsaturated flow. Data collected during these tests were used to select the most applicable soil parameters and to calibrate the HELP-3, UNSAT-H, and VS2DT models.

5.3.2.3 Evapotranspiration Data

Each model used synthetic PET data generated separately by the HELP-3 code for both the 65-yr historical rainfall and the 64-yr maximum rainfall runs.

5.3.2.4 Lower Boundary Conditions

HELP-3 does not require lower boundary conditions, so it was not necessary to include soil beneath the cover with the HELP-3 model. The UNSAT-H and VS2DT models, however, include soil beneath the cover. This was done to limit the potential for lower boundary conditions to influence predicted infiltration through upper soil layers. The lower boundary condition for the UNSAT-H model was a unit gradient, simulating drainage by gravity. The VS2DT model does not have a unit gradient option for a lower boundary condition. Instead, a coarse sand layer with an initial water content of 0.036 cubic centimeters was used for its lower boundary condition. This water content remained constant during the model runs.

5.3.2.5 Leaf Area Index.

A maximum leaf area index of 1.0 was used in the HELP-3 model and a maximum leaf area index of 0.8 was used in the UNSAT-H model. VS2DT does not use the leaf-area index parameter.

5.3.2.6 Model Calibration and Sensitivity Analysis

Model input parameters were tested by modeling three field infiltration experiments conducted in soil west of the MWL. The data from these infiltration experiments were used to calibrate the three models.

5.3.3 Model Results

HELP-3, UNSAT-H, and VS2DT predicted minimal infiltration through vegetated soil covers of 1, 2, 3, 4, and 5 feet in thickness, with infiltration varying as a function of cover thickness, the precipitation data set, and the model used. In each case, the models predicted an average infiltration rate of less than 4 percent of the total precipitation, regardless of cover thickness or the model used. The modeling results are discussed in detail below.

5.3.3.1 Modeling Results Using Historical Precipitation Data

During the 65-yr historical record (1932 to 1996), a total of 561.2 inches (1,425.6 cm) of precipitation was measured at Albuquerque International Sunport. The average annual precipitation during this period was 8.5 inches/yr (21.6 cm/yr). Daily precipitation values measured during the 65-yr period were input into the three models (HELP-3, UNSAT-H, and VS2DT) and the total infiltration through soil covers varying in thickness from 1 to 5 feet was predicted. These results are summarized in Table 5-4, which presents the cumulative infiltration in cm predicted through each cover during the 65-yr period, as well as the average flux in cm/s and the average infiltration rate in cm/yr. The maximum volumetric moisture content (θ) predicted for the 65-yr period is also presented in Table 5-5.

5.3.3.2 Average Annual Infiltration

The HELP-3 modeling using historical precipitation data predicted average annual infiltration ranging from 0.43 cm/yr for a 1-foot cover to 0 cm/yr for 4- and 5-foot covers (Figure 5-3). The HELP-3 modeling results indicate that average annual predicted infiltration is less than 2 percent of the total precipitation, regardless of cover thickness.

The modeling results for UNSAT-H and VS2DT (Figures 5-4 and 5-5) were similar to the results for HELP-3. In each case, the predicted average annual infiltration through the various covers modeled was only a small percentage of the total precipitation. All three models show a significant decrease in the average annual infiltration as the cover thickness is increased from 1 to 3 feet (Figures 5-3 through 5-5).

5.3.3.3 Cumulative Infiltration

Figures 5-6 and 5-7 present the cumulative infiltration predicted by UNSAT-H and VS2DT using historical precipitation data. The cumulative infiltration through a 1-foot cover over the 65-yr period of record varied from 41.5 cm (UNSAT-H) to 37.5 cm (VS2DT). HELP-3 predicted a cumulative infiltration of 28.0 cm through a 1-foot cover (see Table 5-3). A plot of cumulative infiltration versus time could not be generated for HELP-3 due to the limitations of the code.

For comparison, the total precipitation measured at Albuquerque International Sunport during 1932 to 1996 was 561.2 inches (1,425.6 cm). The cumulative infiltration through a 1-foot cover predicted by HELP-3, VS2DT or UNSAT-H during this 65-yr period was less than 3 percent of the total precipitation, regardless of the model used, and was even less for covers of greater thickness.

5.3.3.4 Predicted Annual Infiltration through the Covers

The performance of the cover was also evaluated on a year-to-year basis to compare infiltration rates between wetter and drier years. During the years of higher precipitation, the moisture content of the cover increases, and as a result, the hydraulic conductivity of the cover, which is a function of percent saturation, increases. Consequently, infiltration is greater during the wetter years. Similarly, during drier years, the lower moisture content of the cover results in a lower hydraulic conductivity and, therefore, lower infiltration.

Annual infiltration predicted by UNSAT-H through each cover using historical precipitation data is shown in Figures 5-8 through 5-12, which demonstrate cover performance under current climatic conditions, with higher infiltration during the wetter years, and lower infiltration during the drier years. Maximum infiltration during wetter years falls significantly as cover thickness is increased from 1 to 3 feet, but less significantly as cover thickness is increased to 4 and 5 feet. Negative infiltration values shown during several years for the 1- and 2-foot covers (Figures 5-8 and 5-9) indicate net upward flux during dry years, as evapotranspiration removes moisture from the soil below the cover.

Figures 5-13 through 5-17 show the corresponding annual flux through each cover in cm/s. The maximum annual flux through a 1-foot cover is predicted to be 8.1×10^{-8} cm/s. The maximum annual flux through a 3-foot cover is significantly lower, at 1.9×10^{-8} cm/s. As cover thickness is increased to 4 and 5 feet, maximum annual flux decreases only slightly, to 1.5×10^{-8} cm/s and 0.8×10^{-8} cm/s, respectively. Thus, the most significant performance is achieved by increasing cover thickness from 1 to 3 feet, with rapidly diminishing performance improvement achieved by increasing cover thickness to 4 and 5 feet.

5.3.3.5 Predicted Moisture Contents at Various Depths within the Cover

Figures 5-18 through 5-22 show predicted moisture contents at various depths in a 5-foot cover. These moisture contents were predicted by UNSAT-H using the historical precipitation data. Moisture contents in the upper few feet of the cover fluctuate dramatically (Figures 5-18 and 5-19), with increases due to precipitation, and decreases due to evapotranspiration. These fluctuations diminish with increasing depth, indicating that precipitation is stored primarily in the upper few feet of the cover, and is rapidly removed by evapotranspiration. Lower water contents at depth and the limited fluctuations of these water contents result in a unit gradient and a very low unsaturated hydraulic conductivity, which limits infiltration to very minute levels.

5.3.3.6 Modeling Results Using Maximum Precipitation Data

To be conservative and to approximate reasonable bounding conditions for future climate states, a second set of precipitation data was modeled. These data included daily rainfall from Albuquerque International Sunport for the eight highest years on record. Precipitation during these years ranged from 12 inches to more than 15 inches (30.5 to 38.1 cm/yr). Maximum precipitation data was constructed by placing these 8 yrs of unusually high rainfall back-to-back, and repeating this procedure eight times for a total of 64 yrs of (artificial) record. The total precipitation applied to the models in the maximum precipitation data was 855.9 inches (2,174.1 cm), approximately 50 percent greater than the precipitation applied in historical precipitation data. The results are summarized in Table 5-5 and discussed below.

5.3.3.7 Average Annual Infiltration.

The HELP-3 model using the maximum precipitation data predicted average annual infiltration ranging from 0.55 cm/yr for a 1-foot cover to less than 0.02 cm/yr for covers ranging from 2 to 5 feet in thickness (Figure 5-23). Thus, even with the maximum precipitation data, average annual infiltration through the soil cover is still less than 2 percent of the total precipitation.

The modeling results for UNSAT-H and VS2DT (Figures 5-24 and 5-25) were similar using the maximum precipitation data. In each case, the average annual infiltration through the various covers was only a small percentage of the total precipitation. All three models showed a significant decrease in average annual infiltration as the cover thickness was increased from 1 to 3 feet (Figures 5-23 through 5-25).

5.3.3.8 Cumulative Infiltration

Figures 5-26 and 5-27 present the cumulative infiltration predicted by UNSAT-H and VS2DT using the maximum precipitation data. All soil covers ranging in thickness from 1 to 5 feet proved to be effective in minimizing infiltration, with cumulative infiltration predicted to be no more than 77.7 cm during the 64-yr period. This corresponds to less than 3.6 percent of the 855.9 inches (2,174.1 cm) of precipitation applied using the maximum precipitation data. These results indicate that even if the climate changes dramatically and precipitation increases by 50 percent, a vegetated soil cover would significantly reduce infiltration.

5.3.3.9 Predicted Annual Infiltration through the Covers

The performance of the cover using maximum precipitation data was also evaluated on a year-to-year basis using the results from UNSAT-H. Figures 5-28 through 5-32 present the predicted annual infiltration through covers of varying thicknesses under significantly wetter climatic conditions. Using maximum precipitation data, infiltration exceeds 2.5 cm/yr through a 1-foot cover. Peak annual infiltration rates decrease to 1 cm/yr for a 3-foot cover and approximately 0.75 cm/yr for a 5-foot cover.

Figures 5-33 through 5-37 show the corresponding annual flux through each cover in cm/s under the maximum precipitation scenario. The maximum annual flux through a 1-foot cover is predicted to be 8.8×10^{-8} cm/s. The maximum annual flux through a 3-foot cover is predicted to be 3.1×10^{-8} cm/s, while the maximum annual flux through a 5-foot cover is 2.3×10^{-8} cm/s. Again, the most significant performance improvements are achieved by increasing cover thickness from 1 to 3 feet, with performance improvements rapidly diminishing when increasing cover thickness to 4 and 5 feet.

5.3.3.10 Performance Modeling Summary

As recommended by the EPA, performance modeling was conducted in order to demonstrate that the cover minimizes infiltration and complies with the minimum 30-yr performance criteria. The water-balance model, HELP-3, along with two additional models, UNSAT-H and VS2DT, were used to predict the performance of soil covers ranging in thickness from 1 to 5 feet. All three models demonstrate that deployment of a vegetated soil cover for final closure of the MWL will reduce infiltration into the landfill to a small percentage of the total precipitation. The models also demonstrate that a 3-foot-thick vegetated soil cover is the optimum design thickness based on predicted performance. It is evident that additional cover thickness does not lead to significantly better performance.

Although the modeling suggests that a 1- or 2-foot-thick cover will significantly limit the average rate of infiltration, "spikes" or peaks may occur during years with higher precipitation. These infiltration spikes are fewer and lower in magnitude as the cover thickness is increased to 3 feet, and as the storage capacity of the cover increases. The storage capacity of a 3-foot cover is 50 percent greater than the storage capacity of a 2-foot cover, and would provide an additional degree of conservatism should there be extreme precipitation events or significant, long-term climatic changes.

Increasing cover thickness to 4 or 5 feet results in limited improvement in cover performance yet increases construction costs. Cover construction costs are directly proportional to the thickness of the cover, and the optimal cover design is one that meets the performance criteria with the least cover thickness (Ankeny et al. 1997). A reduced finished elevation above grade would provide additional environmental benefits, reducing the cover's exposure to wind and water erosion.

Under current climatic conditions, annual infiltration through a 3-foot cover is typically less than 0.3 cm and rarely exceeds 0.5 cm (Figure 5-10). The cover's performance will actually approximate that of a 4- or 5-foot cover due to the placement of subgrade fill. Up to 40 inches of compacted fill will be placed over the existing landfill surface prior to construction of the actual cover to provide a stable, uniform subgrade for the cover (see Plate 5—Final Cover Cross Sections).

5.4 Biointrusion

Burrowing by small and large mammals is a potential pathway for transfer of hazardous constituents to the accessible environment (Kennedy et al. 1985, Hakonson et al. 1992, Gee and Ward 1997). Burrowing animals may physically transfer subsurface contaminated soil and waste to the surface and increase water infiltration by decreasing the bulk density of the soil or creating pathways of preferential flow. Burrows of small mammals have been observed at the MWL and are a potential pathway for transfer of hazardous constituents from waste disposal cells to the accessible environment.

The presence of small and large animal burrows and their effect on cover performance has been a concern for scientists and engineers at the Hanford site in Washington for many years (Gee and Ward 1997). Gee summarizes observations at Hanford as follows:

> From the results of lysimeter tests performed at the Animal Intrusion Lysimeter Facility, the presence of small mammal burrows does not appear to have a

> significant influence on the deep percolation of water. During the summer months, more water is lost from plots with animal burrows than from plots with no animal burrows. During winter months, plots with animal burrows and plots without animal burrows gain water. In addition, water does not infiltrate below 36 in., even though burrow depth exceeds 48 in. The lack of significant infiltration at depth and the overall loss of water in the lysimeters occurs even though 1) no vegetative cover exists, 2) no runoff is allowed, 3) burrow densities in the lysimeter are greater than burrow densities found in natural settings, 4) extreme rainfall events are applied frequently, and 5) animal burrows are deeper in the lysimeter than in natural settings. The overall water loss from soils with small mammal burrows appears to be enhanced by a combination of soil turnover and subsequent drying, ventilation effects, and high ambient temperature.

Similar water loss results have been observed at the Arid Land Ecology Reserve at the Hanford site for large mammal burrows excavated by coyotes and badgers in search of prey. Large mammals do appear to cause increased deep infiltration but much of this water is removed by co-located, dense vegetation. The density of vegetation near large mammal burrows was significantly greater than in adjacent, undisturbed areas away from the burrows (Gee and Ward 1997).

A biointrusion barrier consisting of crushed rock could be placed at depth within a cover to mitigate burrowing mammals. Plant root growth also may be restricted to soil above the biointrusion barrier. If roots are restricted to the soil above the biointrusion barrier, the net transpiration and effective water storage capacity of the cover system could be significantly reduced. In this case, depth of emplacement of a biological intrusion barrier within the soil profile is paramount.

In 1993, researchers at Idaho State University and the Environmental Research Foundation initiated a large-scale experiment to compare the performance of two soil-plant cover designs that included biological intrusion barriers at depths of 0.5 and 1.0 meters (m) (Anderson 1997). The objectives of the study were to examine the effects that placing a rock intrusion layer in a soil cap would have on water infiltration, water storage capacity, and plant rooting depths. Anderson (1997) summarizes their observations as follows:

> Biobarriers are clearly an impediment to root growth. We have only seen extraction below the biobarriers when volumetric water content below the barrier was initially at least 25 percent. There may be a threshold of water content below which plants are unable to detect the presence of extractable water below a biobarrier. Plants can, however, penetrate biobarriers and extract water from the soil if water content is sufficiently high.

Another study performed by Anderson (Anderson and Forman 2002) determined that if a biointrusion barrier is used, a 0.5-m gravel/cobble barrier should be placed at the bottom of a 1.2-m homogeneous soil reservoir.

The final phase of nearly two decades of research on biointrusion by Idaho State University at Idaho National Engineering and Environmental Laboratory (INEEL) was published in 2002 (Anderson and Forman 2002). Two cap configurations were recommended including a soil-only cap consisting of a 2-m depth of homogenous soil or a cap of a 1.2-m depth of homogenous soil overlying a 0.5-m thick gravel/cobble intrusion barrier. Caps constructed according to either of these configurations should preclude virtually any precipitation from reaching interred waste. A major advantage of the soil-only cap is simplicity of construction. Anderson and Forman (2002) recommend that if a biobarrier is used, it should be placed at the bottom of the soil reservoir.

Field studies at the MWL have shown that maximum root density of dominant species occurs in the upper 12 inches (30 cm) of the soil profile (Peace et al. 2004). Lesser root density has been observed to depths of 31 inches (80 cm), and root growth rarely exceeds 39 inches (1 m).

Emplacement of a woven steel mesh at a shallow depth (e.g., below the topsoil layer) would discourage small and large mammals from burrowing deep into the cover and would have little effect on root density and depth or the effective water storage capacity of the cover system. The cost of a woven steel mesh could be significant, however, and the durability of metal biointrusion barriers has not been established. A crushed rock biointrusion barrier placed at the bottom of the soil reservoir would be a more cost-effective approach. Rock is less expensive, readily available from off-site suppliers, and more durable. The size of the crushed rock and the requirements for placement (e.g., thickness) are usually determined in collaboration with the regulatory authority.

5.5 Subsidence

Waste in disposal cells at the MWL may contain voids resulting from incomplete filling of waste containers, limited internal compaction of contents, and voids between containers. These voids may induce subsidence as waste containers deteriorate and/or collapse over time. Rates of decay will vary for different containers. Although subsidence has the potential to damage a landfill cover, predicting subsidence effects is very difficult because of the heterogeneous nature of the waste forms, backfill materials, and local climatic conditions.

Cover designs that include compacted clay soil, flexible membrane liners, and geosynthetic clay liners would not function as intended when subject to tensile and shear stresses during subsidence. These common liners, geomembranes, and geosynthetic materials require rigorous quality control during manufacture and are easily damaged during installation on an operational scale. The MWL alternative cover design, consisting of a thick layer of native soil, is constructed without liners, and thus will accommodate differential subsidence without undue impairment of its performance. During the long-term care period, soil readily available in TA-3 will be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers. Topsoil will be replaced according to original construction specifications. This provides additional assurance for adequate long-term performance of the cover system.

5.6 Runoff and Run-On Control

The amount of water available for infiltration is a function of the amount of precipitation that falls on the cover surface less the amount of water that runs off and away from the cover surface. The surface of the cover has been designed with a central crown and a 2-percent slope to promote runoff of surface water while minimizing erosion of the topsoil layer.

A design requirement of RCRA is that the cover withstands a 25-yr, 24-hr storm event. Storm water run-on will be prevented from impacting the cover by constructing an earthen swale along the eastern perimeter of the site. Run-on will be diverted at the perimeter and directed to the south and the north toward the surrounding landscape. Cover surface erosion from storm water runoff will be mitigated by native vegetation and admixed gravel in the topsoil layer. Cover surface runoff will be directed toward the surrounding landscape.

For the Albuquerque area, the rainfall amount for a 25-yr, 24-hr storm is 2.5 inches (City of Albuquerque 1993).

5.7 Erosion Control

Erosion of the cover by wind and water is a significant design consideration. The design should minimize the effects of wind and water erosion of the surface, side slopes, and toe of the cover. The cover has been designed to have native vegetation growing over the surface, side-slopes, and toe throughout the design life. The presence of vegetation on the cover surface combined with the presence of gravel admixed with the topsoil layer will significantly reduce the amount of fine soil lost from wind and water erosion.

Wind erosion studies by Ligotke and Klopfer (1990) and Ligotke (1993, 1994) at the Pacific Northwest National Laboratory Aerosol Wind Tunnel Research Facility have demonstrated that soil and gravel admixtures with particle sizes of 3 to 7 millimeters provide superior surface protection. The best gravel admixtures reduced surface deflation rates by greater than 96 percent compared to unprotected surfaces. Water erosion studies by Walters et al. (1990) and Gilmore and Walters (1993) determined that the most dominant factor in reducing runoff and sediment yield was the presence of a vegetated cover.

Erosion studies by Finley et al. (1985) and soil water balance studies by Waugh et al. (1994) and Sackschewsky et al. (1995) demonstrate that moderate amounts of gravel mixed into cover topsoil will control both water and wind erosion with little effect on plant growth or soil-water balance. As wind and water pass over the surface, some winnowing of fines from the admixture occurs, leaving a vegetated erosion-resistant pavement (Waugh 1997). The amount of gravel used in the admixture is a major design consideration. If too much gravel is used, plant transpiration and surface evaporation could be significantly reduced which would increase the potential for water infiltration. Overall, the presence of a 15 to 30 percent gravel admixture is effective in reducing the deflation of fine soil from a cover surface by wind and water erosion (Ligotke 1994).

5.7.1 The Universal Soil Loss Equation

The empirical equation known as the universal soil loss equation (USLE) was devised by Wischmeier and Smith in 1965. The EPA recommends use of the equation to estimate average annual soil loss from a cover. The equation is as follows:

$$A = R\ K\ LS\ C\ P$$

where

- A = Estimated average annual soil loss in tons/acre/yr;
- R = Rainfall erosivity factor;
- K = Soil erodibility factor;

LS	= Topographic factor;
C	= Surface-cover factor; and
P	= Management factor.

A modified version of the USLE (EPA 1980) was employed to estimate the soil erosion potential from the surface and side slopes of the cover by overland runoff. The modified universal soil loss equation (MUSLE) is

$$A = R\ K\ (LS)\ (VM)$$

where

A	= Estimated average annual soil loss in tons/acre/yr;
R	= Rainfall factor;
K	= Soil erodibility factor;
LS	= Topographic factor; and
VM	= Erosion control factor.

Soil loss was calculated using the MUSLE for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. The estimated average annual soil loss from the cover surface and side slopes is 0.77 tons/acre/yr and 0.08 tons/acre/yr, respectively. These losses are well below the design requirement recommended by the EPA (EPA 1989) of less than 2 tons/acre/yr.

The MUSLE contains inherent limitations. In general, erosion is not a steady, orderly, easily predictable process. Much of it takes place episodically. A single torrential rainfall striking a barren soil may cause more soil loss in a few hours than a whole season's "normal" rainfall over a fully vegetated cover. Inherent limitations include:

- The MUSLE is not intended for estimating erosion in a particular year, but rather estimating long-term averages.
- The condition of the cover is not static over time, so the erosion will vary from year to year. For example, the cover will initially have little vegetation and will be more susceptible to erosion. After initial erosion, remaining soil may be less susceptible than the initial surface, because the more susceptible fractions are lost first.
- The slope factor, LS, assumes that the central, gently sloping portion of the cover surface does not increase the amount of runoff that occurs down the side slopes, i.e., all rain falling on the cover surface infiltrates rather than running off the surface. This assumption may not be valid for the most intense storms.
- Wind may cause erosion from the cover that is not accounted for by the MUSLE.

5.7.2 The Wind Erosion Equation

The wind erosion equation (WEQ) was used to estimate the soil erosion potential from the surface and side slopes of the cover by wind. The WEQ was introduced in 1963 because it was recognized that wind could be a major geological phenomenon for erosion. In 1997, the WEQ was modified by the U.S. Department of Agriculture (USDA 1997) in the National Agronomy Manual.

The WEQ is

$$E = f\,[(IKC)\;LV]$$

where

E = Estimated average annual soil loss in tons/acre/yr;
I = Soil erodibility index;
K = Ridge roughness factor;
C = Climatic factor;
L = Unsheltered distance; and
V = Vegetative factor.

Soil loss was calculated using the WEQ for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. In both cases, the estimated average annual soil loss from the cover surface and side slopes is 0 tons/acre/yr.

A number of inherent limitations are also present in the WEQ. These limitations include:

- When the unsheltered distance, L, is sufficiently long, the transport capacity of the wind for saltation and creep is reached. If the wind is transporting all of the soil it can carry across a given surface, the inflow into the downwind is equal to the outflow for saltation and creep. The net soil loss is then only the suspension component. This does not imply a reduced soil erosion problem because theoretically there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the surface.

- Surface armoring by nonerodible gravel, snow cover, and inherent seasonal change is not addressed in the soil erodibility factor, I.

- The WEQ does not estimate soil erosion from single storm events.

5.8 Slope Stability

A common problem leading to cover failure is slope failure at barrier interfaces caused by excessive soil moisture, especially on steep side slopes. Documented slope failures have been attributed to slip planes created at synthetic layer interfaces (Daniel and Gross 1995). Covers usually contain multiple layers of earthen and synthetic materials. Performance usually depends upon maintaining discrete boundaries between earthen layers and synthetic materials during construction and throughout the design life of the cover system. Interfaces between layers are susceptible to lateral flow of infiltrating water that leads to reduced friction and subsequent failure. Layer interfaces are also susceptible to root and animal intrusion and soil illuviation.

The cover has been designed to mitigate all such potential failure mechanisms. The cover is centrally crowned and sloped at 2 percent to the side slopes that, in turn, are tied to the surrounding landscape at 6:1. The monolithic cover will not be susceptible to failures common to conventional, multi-layer, multi-component designs.

5.9 Vegetated Cover

The influence of vegetation on the hydrologic relationships of the cover cannot be overemphasized. Vegetation will play a key role in stabilizing the newly constructed surface by mitigating wind and water erosion. Vegetation will also play a key role in maintaining the cover's water balance, significantly reducing the amount of water available for contact with disposal cell waste and subsequent contaminant transport. Vegetated covers are also extremely versatile, adapting to climatic change through natural selection and severe disturbance (fire and drought). Once native flora is established, it will persist indefinitely with little or no maintenance.

The flora in the TA-3 area is predominantly Mesa and Desert Grassland and, to a lesser degree, Sandsage and Chihuahuan Desert Shrubland. Flora exhibit influences from the Great Basin Desert, Rocky Mountains, Chihuahuan Desert, and the Great Plains. Typical plant species occurring in the area include grasses (black grama, dropseed, galleta, burrograss, bush and ring muhly), wildflowers (globemallow, aster, spectacle pod), and shrubs (sandsage, winterfat, mormon tea, yuccas, prickly pear, snakeweed) (Sullivan and Knight 1992; Peace et al. 2004).

The vast majority of TA-3 is dominated by grassland vegetation. Specifically, it represents the Mesa and Desert Grassland habitat types. The extreme western portion of the TA-3 area falls into the Sandsage Shrubland vegetation habitat. Most of the vegetation at the MWL is composed of elements of the Black Grama Grass Series. This series includes black grama, dropseed, threeawn, galleta, Indian ricegrass, and burrograss.

The desired plant community for the MWL vegetated cover is desert grassland. Grasses root at shallower depths than shrubs and, when they do root deeply, the roots are fibrous, thinner, and less damaging to the cover than the woody roots of shrubs and trees. Grass roots form a dense and interwoven fibrous network that binds the soil. Grasses concentrate their biomass close to the surface, forming a protective mat that provides protection against wind and water erosion.

5.10 Radon Gas Emission

Emission of radon gas from the MWL was investigated in 1997 by SNL Environmental Management. No significant difference between the MWL and the background measurements in terms of median, mean, and standard deviation was observed. The radon flux measurement technique employed for this study was capable of detecting radon flux in the range of 1 to 2 percent of the 20 pCi/m^2/s limit listed in 10 CFR 834.

5.11 Tritium Flux Measurements

Sandia conducted studies in 1992/1993 and in 2003 to measure the tritium flux emitted from the MWL to the atmosphere. During each study, emission isolation flux chambers were deployed at various locations across the landfill to measure the tritium flux to the atmosphere. The data collected show that the overall tritium emissions from the MWL were significantly lower in 2003 than in 1992/1993. The estimated tritium emitted from the MWL to the atmosphere in 2003 was 0.090 curies (Ci)/yr, whereas the estimated tritium emitted from the MWL in 1993 was 0.486 Ci/yr. This 82 percent reduction reflects the natural radioactive decay of tritium, and its relatively short half-life of 12.3 yrs.

6.0 MWL ALTERNATIVE COVER DESIGN

The MWL alternative cover design drawings are provided on Plates 1 through 6. The construction specifications and the construction quality assurance plan are included in Appendices A and B, respectively. The qualifications of persons implementing the CMI plan and the health and safety plan are included in Appendices C and D, respectively. The design drawings include plates showing the MWL existing site plan, subgrade grading plan, final cover grading plan, final cover cross-sections, and miscellaneous details. The cover will be placed over the original 2.6-acre landfill surface and tied to the surrounding landscape. A vegetated topsoil layer admixed with 25 percent 3/8-inch crushed gravel will be applied to maintain water balance and mitigate water and wind erosion. The components of the cover are shown in Figure 6-1 and are discussed in the following sections.

6.1 Existing Landfill Surface

The existing landfill surface will be prepared for cover construction by clearing and grubbing. Perimeter fences will be removed and the landfill surface cleared of vegetation and rock. Grubbing will not exceed 6 inches in depth to minimize disturbance to surface soil and conform to radioactive area soil contamination requirements. Grubbed material will be disposed of according to SNL waste management policy and procedures. The landfill surface will be compacted to achieve the appropriate density in preparation for subgrade fill.

6.2 Subgrade Layer

Subgrade fill will be obtained from the TA-3 borrow pits located approximately 1.5 miles south of the MWL. Soil from the TA-3 borrow pits has been tested to verify engineering properties specified in the design. Subgrade fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. Approximately 6,500 cubic yards (yd^3) of subgrade fill will be placed and graded to establish a central crown and uniform 2-percent slope in preparation for the biointrusion barrier.

6.3 Biointrusion Barrier

A crushed rock biointrusion barrier will be placed on the subgrade layer. This bio-barrier will be composed of approximately 4,900 yd^3 of rock fragments 1 to 6 inches in dimension. The rock will be highly siliceous in nature and have 100 percent fracture face. The crushed rock will be placed in a single lift of uniform thickness and compacted until the crushed rock fragments are firmly locked in place.

6.4 Native Soil Layer

Native soil layer fill will be obtained from the TA-3 borrow pits. Approximately 13,200 yd^3 will be placed and graded to construct the native soil layer, which will act as a water storage reservoir, retaining and storing water that infiltrates through the topsoil layer until it can be removed by evapotranspiration. Native soil layer fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. The native soil layer will be graded to maintain the central crown and the uniform 2-percent slope. Any grade stakes used on the project will be removed and backfilled with cover material to meet design specifications.

6.5 Topsoil Layer

Topsoil layer fill will be obtained from the TA-3 borrow pits. Approximately 3,900 yd^3 of surface soil will be obtained from TA-3 borrow pits. The topsoil layer will serve as the vegetative cover and erosion protection layer. A 25-percent (by volume) 3/8-inch crushed gravel will be admixed into the topsoil layer to control erosion without adversely affecting desirable vegetation and soil-water balance. The topsoil layer will be minimally compacted to facilitate plant growth and root development.

6.6 Vegetation

Following installation of the topsoil layer, reclamation seeding activities will take place. The designated native vegetative seed mix will be applied to the cover, lay-down areas, and any other areas disturbed by construction operations. The surface will be fertilized, drill-seeded, mulched and crimped. The native seed mixture is based upon on biological assessments of TA-3 (Sullivan and Knight 1992, Peace et al. 2004). The mixture will consist of black grama, spike dropseed, galleta grass, and ring muhly. The initial plant community is designed to approximate the dominant and subdominant species and will gradually develop into a climax community indistinguishable from the natural analog.

7.0 VADOSE ZONE MOISTURE MONITORING

The MWL alternative cover will incorporate a shallow vadose zone monitoring system deployed directly beneath the landfill. The shallow vadose zone monitoring system will consist of three neutron probe access holes drilled at a 30 degree angle directly below waste disposal cells. The shallow vadose zone monitoring system will function as an "early warning system." Early detection of a potential threat to groundwater will allow corrective action to be initiated before significant contaminant migration occurs. This monitoring approach was designed to protect groundwater resources and is proposed for the MWL because of its simplicity, low cost, and long-term viability.

The shallow vadose zone monitoring system will provide water infiltration and performance information, early detection of potential contaminant migration from the landfill, as well as establishing background and trend analysis information. The shallow vadose zone monitoring system is a simple system designed to meet the intent of long-term RCRA and DOE performance requirements. The shallow vadose zone monitoring system will be monitored regularly once the alternative cover has been deployed. The frequency and duration of long-term monitoring will be established in consultation with the NMED and formally documented in the MWL Long-Term Monitoring and Maintenance Plan.

7.1 Shallow Vadose Zone Moisture Monitoring

Three angled, 4.5-inch-outside-diameter, 3.75-inch-inside-diameter access holes will be installed in the shallow vadose zone directly beneath the MWL: two to the west and one to the east of the cover (Figure 7-1). The vadose zone access holes will be spaced at equal increments, with the east access hole bisecting the two west access holes. The holes will be installed using the Resonant Sonic drilling technique. Resonant Sonic is the preferred drilling technique because it literally fluidizes and displaces the surrounding soil as the drill-string advances, creating a very tight fit between the drill-string and the formation.

Each access hole will be collared approximately 10 feet outside the projected toe of the cover side slopes. Each access hole will be drilled 200 linear feet at 30 degrees to a true vertical depth of 173 feet (Figure 7-2). As each access hole is completed, the 4.5-inch sonic drill-string will be left in place and uncoupled at the surface leaving about 2 feet of drill pipe above grade. Each pipe will remain open to the vadose zone for future vadose zone soil gas sampling. A 3- by-3-foot concrete pad will be placed around each protective cover to prevent preferential flow down the annulus. Protective stanchions, 4 inches in diameter, will be placed at the outer corners of the concrete pad. The stanchions will be set 2 feet below grade and 3 feet above grade.

7.1.1 Neutron Moisture Monitoring

Neutron moisture probes take advantage of the neutron moderation process in which high-energy neutrons emitted from a radioactive source are moderated, or slowed, by collisions with surrounding atoms. Slowed neutrons, also called thermalized neutrons, emit a pulse of detectable energy, which is counted in a neutron detector contained in the neutron probe.

The neutron moderation process is dominated by neutron-hydrogen collisions that result in appreciable neutron moderation. Thus, relatively high hydrogen density (near the source) results in rapid neutron moderation. Hydrogen in geologic materials occurs as water, mineralogically bound H^+, organic soil components, and organic liquids (solvents, petroleum fuels). Water is nearly always the greatest source of hydrogen in soil. Therefore, as dry soil becomes wet, the thermalized neutron density near a neutron source and detector increases. The radius of influence for neutron moisture probes depends upon source strength, hydrogen density, soil density, and chemistry. Practical limits are from 6 to 24 inches from the point between probe source and detector. The cloud of thermalized neutrons is compact in wet and/or dense soil, and expanded in dry and/or loose soil (Jury et al. 1991).

A neutron probe consists of a compact americium (Am)-beryllium (Be) source and a thermal neutron detector that can be lowered into an access hole for readings at discrete footage intervals. The Am-Be source emits high-energy neutrons that collide with hydrogen nuclei (moisture) in the surrounding soil. Hydrogen nuclei substantially slow the neutrons, and thus the neutron counts by the detector are linearly increased with the amount of hydrogen in the soil. A California Pacific Nuclear (CPN) Model 503DR Hydroprobe containing a 50-millicuries Am-241:Be neutron source has been used to date for monitoring the shallow vadose zone.

The neutron moisture probe is increasingly being applied to address characterization and infiltration issues at environmental sites undergoing long-term care. Neutron moisture measurement was established in agriculture in the 1960s before environmental monitoring needs were identified (Kramer et al. 1992). Neutron moisture monitoring has become the industry standard for soil moisture measurement and its operation and data interpretation is well established. The technique's principal advantage is repeatability, precision, and long-term viability. The access-hole casings are not permanently installed, which allows for periodic calibration of the neutron probe.

The number and location of neutron probe access holes is guided by practical considerations and knowledge of vadose zone hydrologic processes. The number and location of shallow vadose zone neutron probe access holes was determined in consultation with the NMED HWB and the Oversight Bureau staff. Neutron moisture monitoring and data collection will follow field operating procedures (FOP) as outlined in SNL ER FOP 95-21, "Use of the CPN Model 503 Hydroprobe for Subsurface Moisture Measurement."

8.0 CONCLUSIONS

The EPA has established performance-based criteria for RCRA Subtitle C covers for hazardous and radioactive waste landfills, but allows for alternative designs based upon a demonstration that the alternative design, together with natural site conditions, prevents the future migration of hazardous constituents into the groundwater or surface water. The NMED, the lead regulatory agency, has adopted EPA's 40 CFR 264 regulations and likewise accepts alternative cover designs as long as the design meets the intent of the regulations.

In this report, Sandia has demonstrated that the MWL alternative cover meets the performance-based criteria in 1) minimizing infiltration of water through the cover; 2) minimizing maintenance and erosion; 3) promoting surface drainage; 4) accommodating subsidence; and 5) having a permeability equal to or less than the MWL subsurface soil.

Performance modeling indicates that a 3-foot-thick, vegetated soil cover is the most propitious design for the MWL. The vegetated soil cover is a simple, elegant, and effective design that takes advantage of TA-3 native soil and natural hydrological processes. The cover adequately protects groundwater resources under historical and projected future climatic conditions.

The 3-foot-thick, vegetated soil cover with a 1-foot-thick biointrusion barrier, integrated with natural site conditions, produces a "system" performance that will ensure that federal and state regulatory requirements and DOE Orders are met. Specifically, the vegetated soil cover will:

- Minimize water infiltration through the closure cover. The combined cover/subgrade with native vegetation will minimize water infiltration into waste disposal cells. Modeling data indicates that water does not migrate significantly past a 3-foot-thick layer of native soil.

- Function with minimum maintenance. Maintenance will be minimized by using a monolithic soil layer. Multi-layer, multi-component covers, such as those used in conventional designs, would require continuous maintenance and are more susceptible to failure.

- Promote drainage and minimize erosion of the cover surface. The cover will be centrally crowned and sloped at 2 percent to the edge of the side slopes which, in turn, tie into the surrounding landscape at a slope of 6:1. Native vegetation will minimize wind and water erosion while promoting water removal from the cover through evapotranspiration.

- Accommodate settling and subsidence so that the integrity of the cover is maintained. Subsidence will be accommodated using a "soft" design. During the cover's design life, soil can be added to the cover to correct subsidence and erosion as it occurs.

- Have a permeability less than or equal to the permeability of the MWL subsurface soil. The cover will be constructed with soil native to TA-3. Evaluation of the bathtub effect demonstrates that the permeability of the cover soil is equal to or less than that of the natural subsurface soil present.

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FIGURES

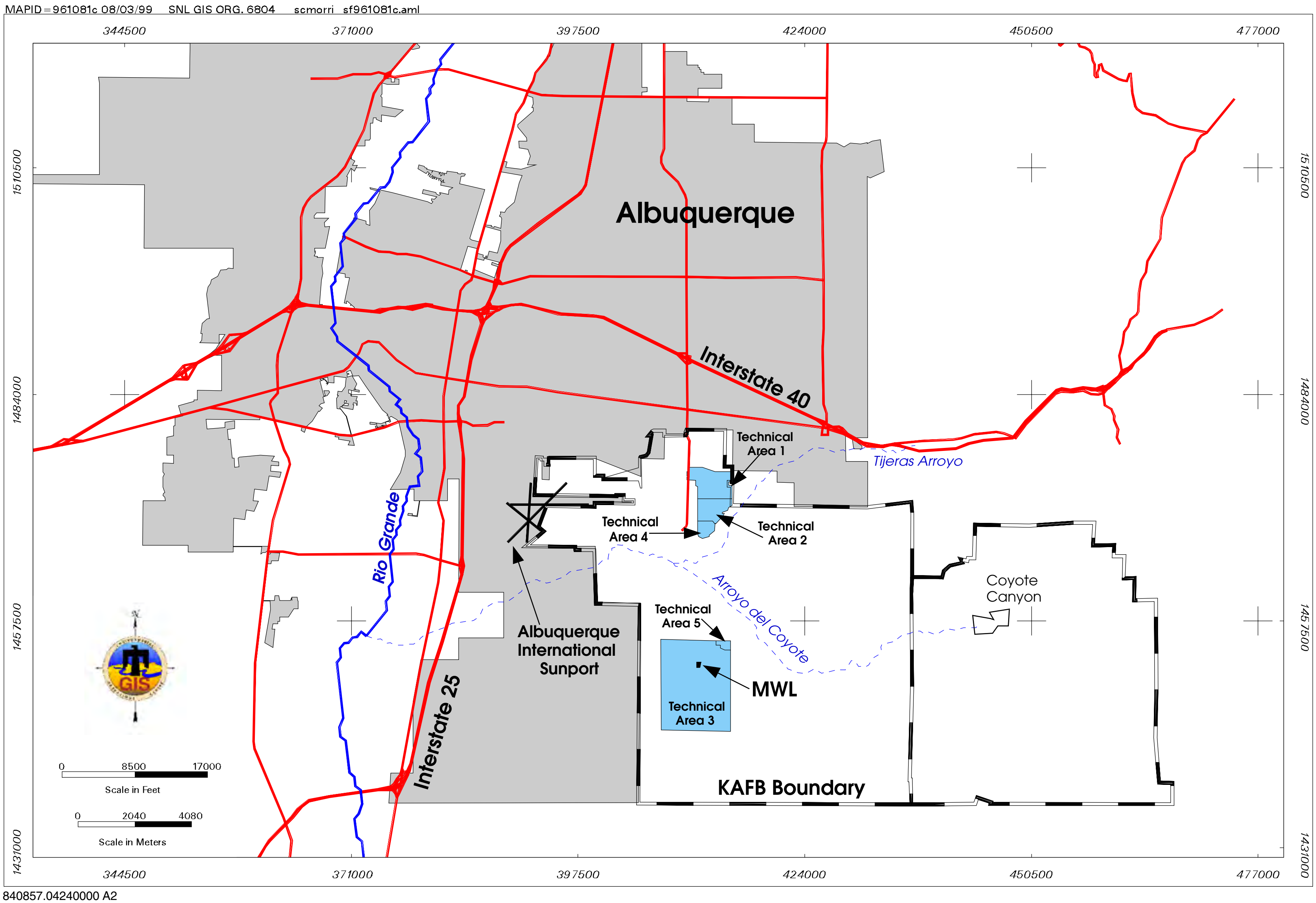

Figure 1-1 Location of Kirtland Air Force Base and Sandia National Laboratories, New Mexico

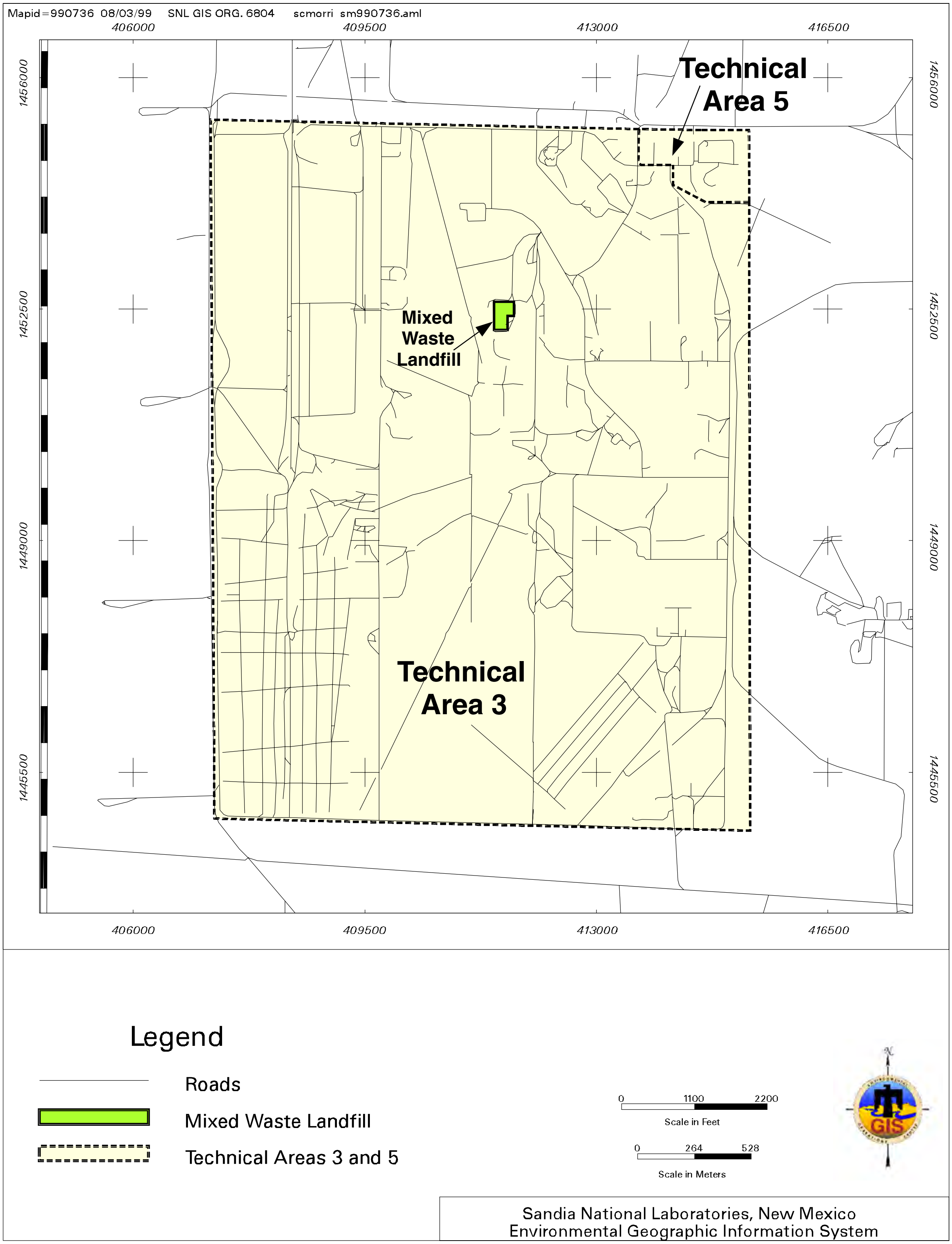

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Figure 1-2 Location of Technical Areas 3 and 5 and the Mixed Waste Landfill

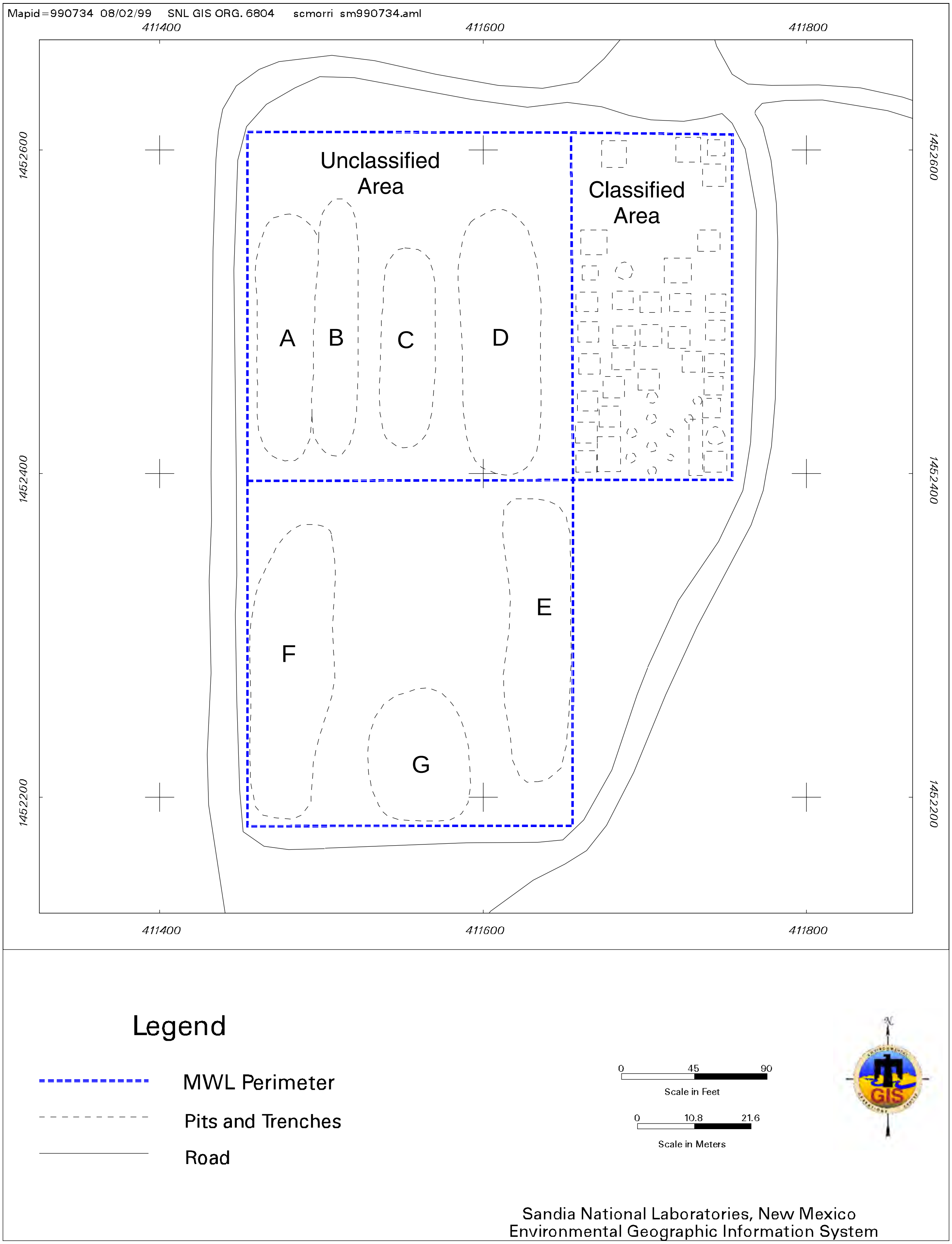

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Figure 1-3 Map of the Mixed Waste Landfill

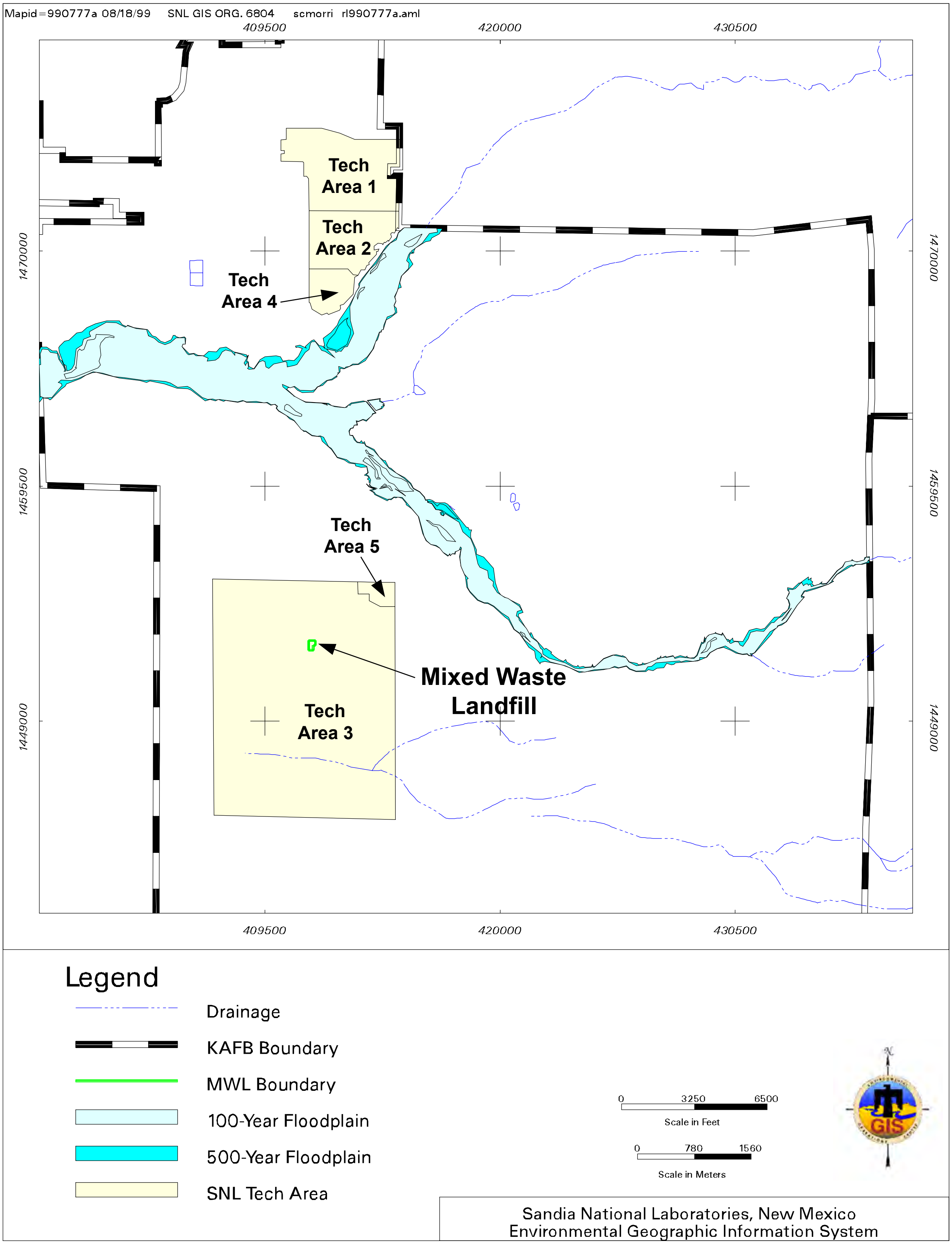

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Figure 2-1 Location of the 100–Year and 500–Year Floodplains at Kirtland Air Force Base

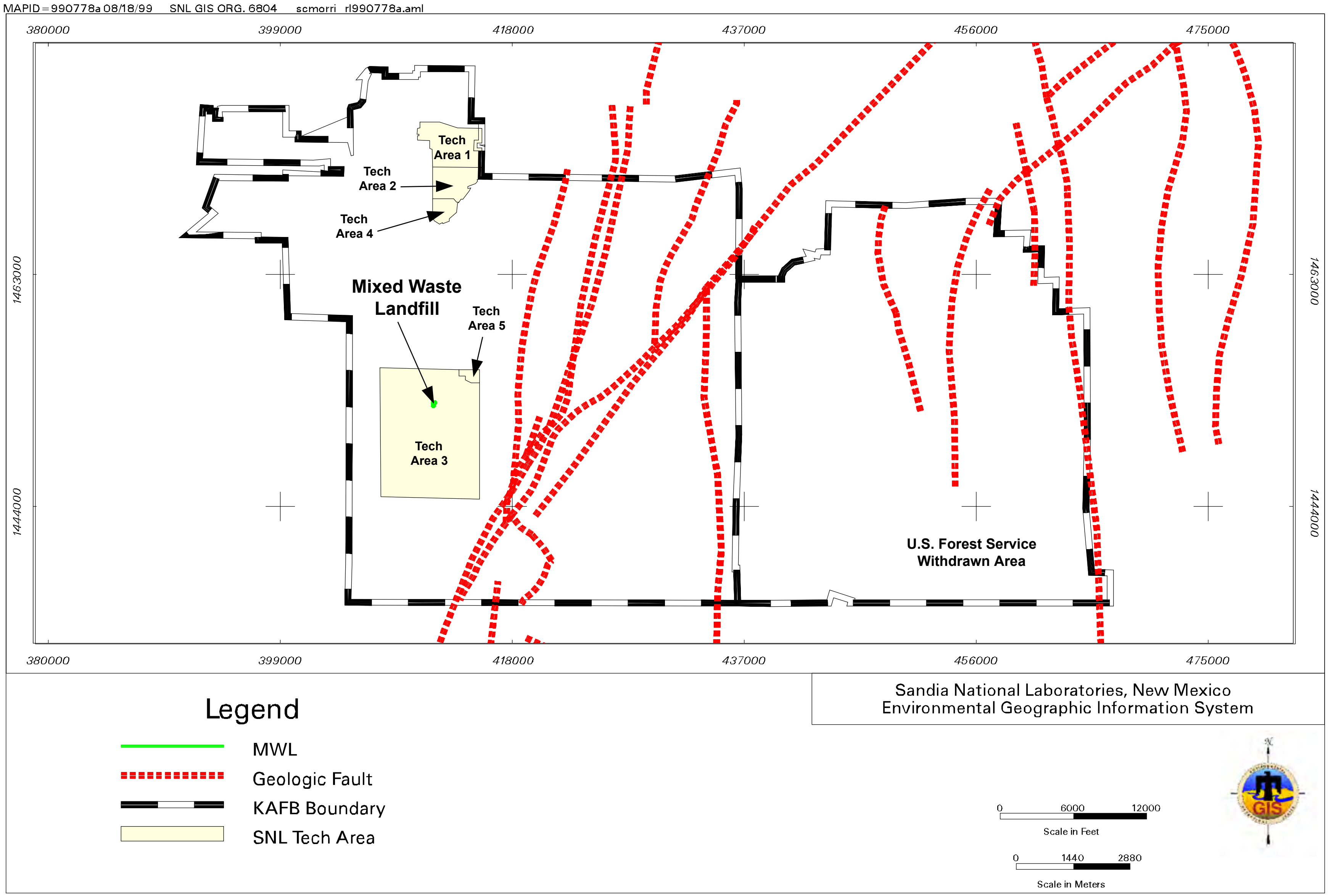

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Figure 2-2 Location of Geologic Faults at Kirtland Air Force Base

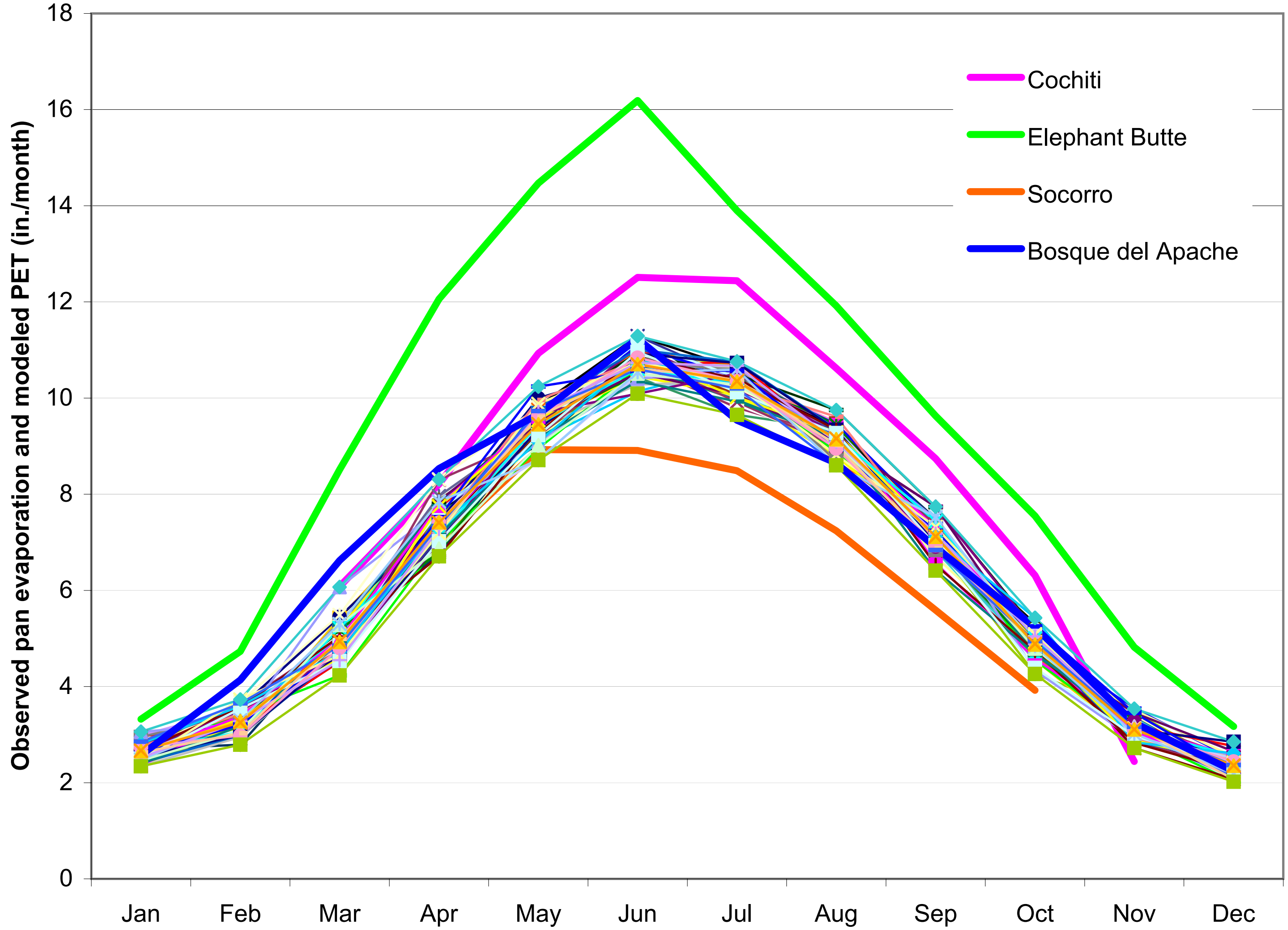

Figure 5-1 65 Years of Monthly PET Predicted by HELP-3 Shown with Average Monthly Pan Evaporation from Four National Weather Service Stations in New Mexico

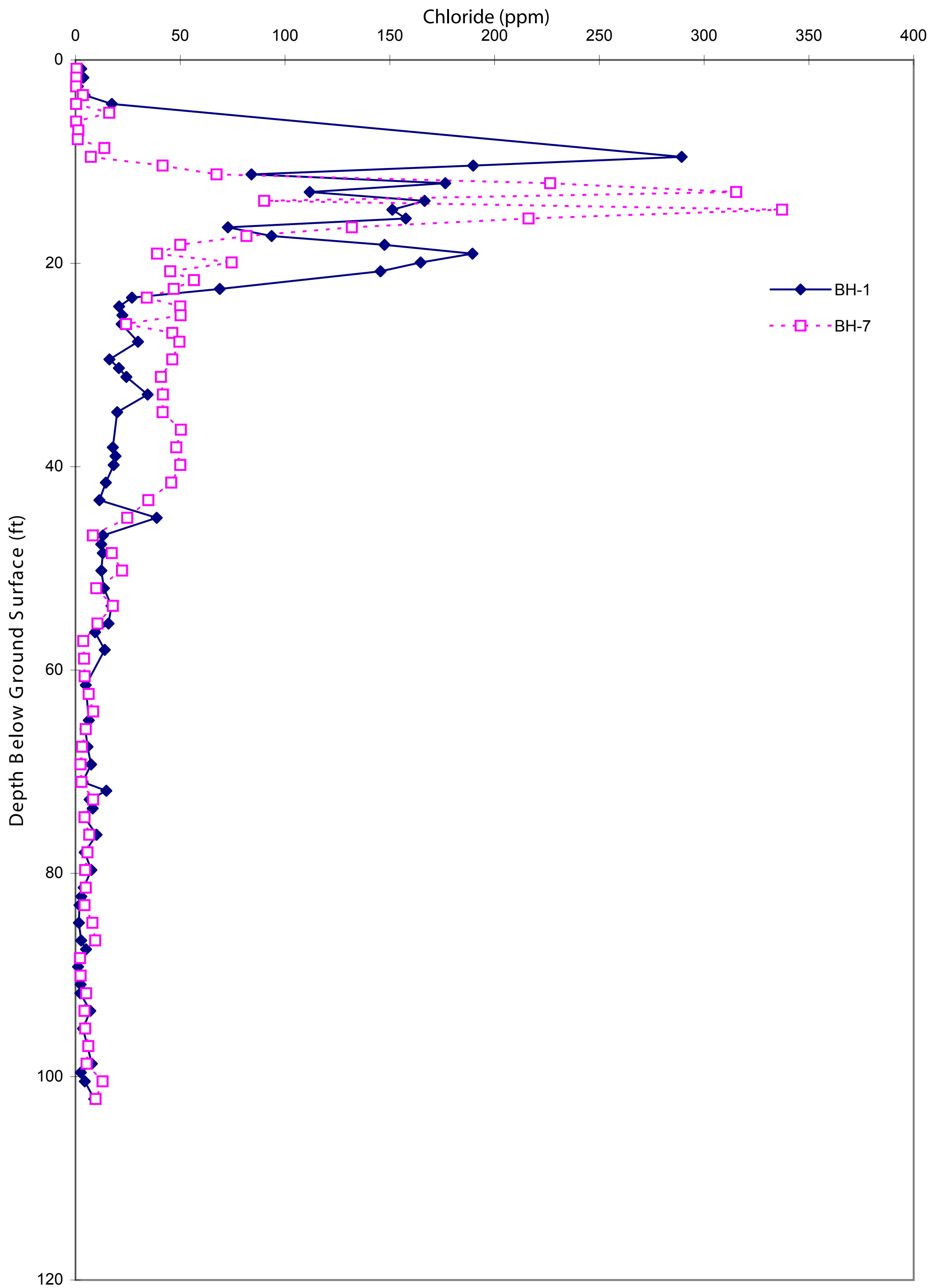

Figure 5-2   Chloride Concentration Profiles in Subsurface Soil at the Mixed Waste Landfill

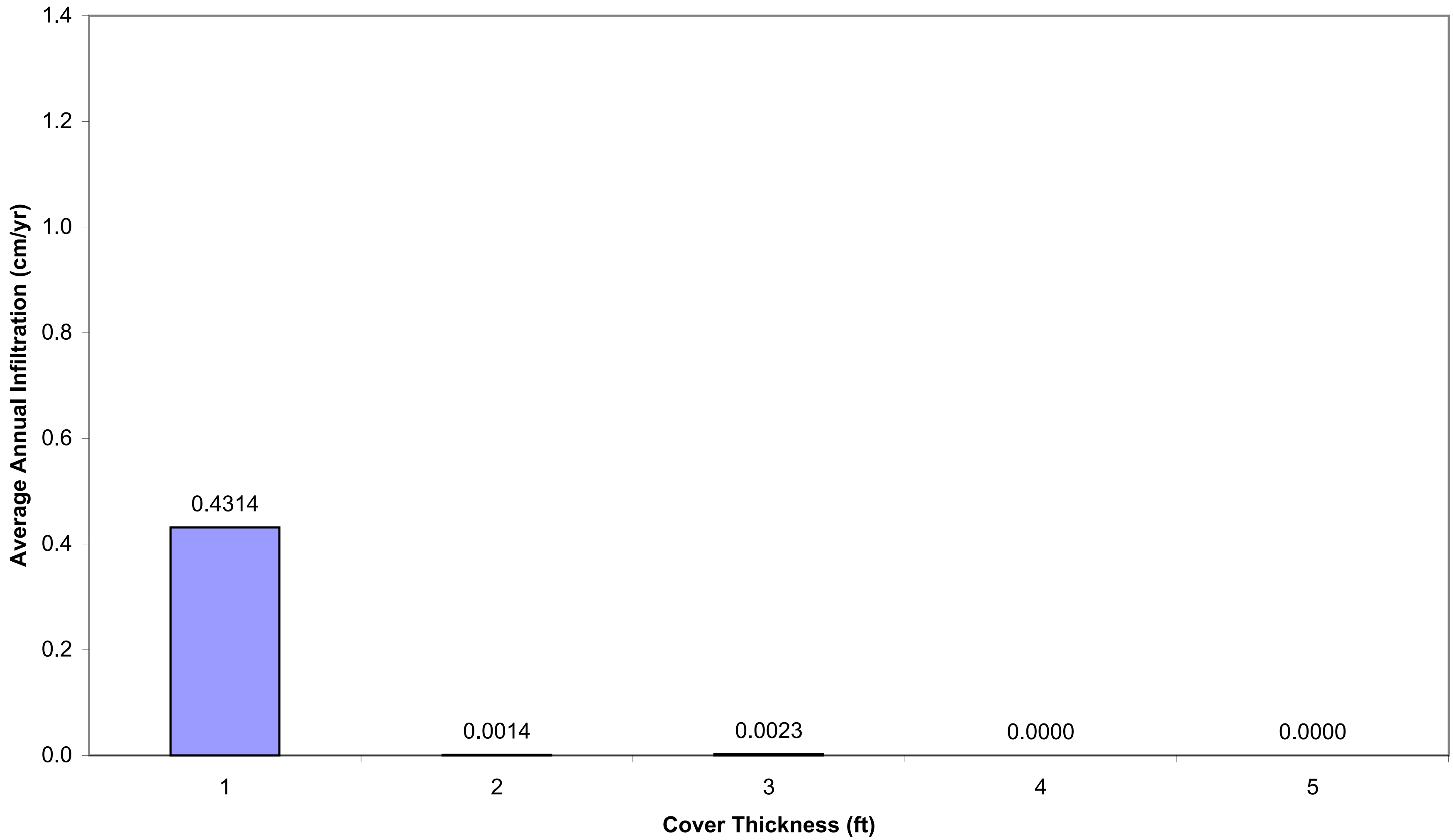

Figure 5-3 Average Annual Infiltration Predicted by HELP-3 Using Historical Precipitation Data

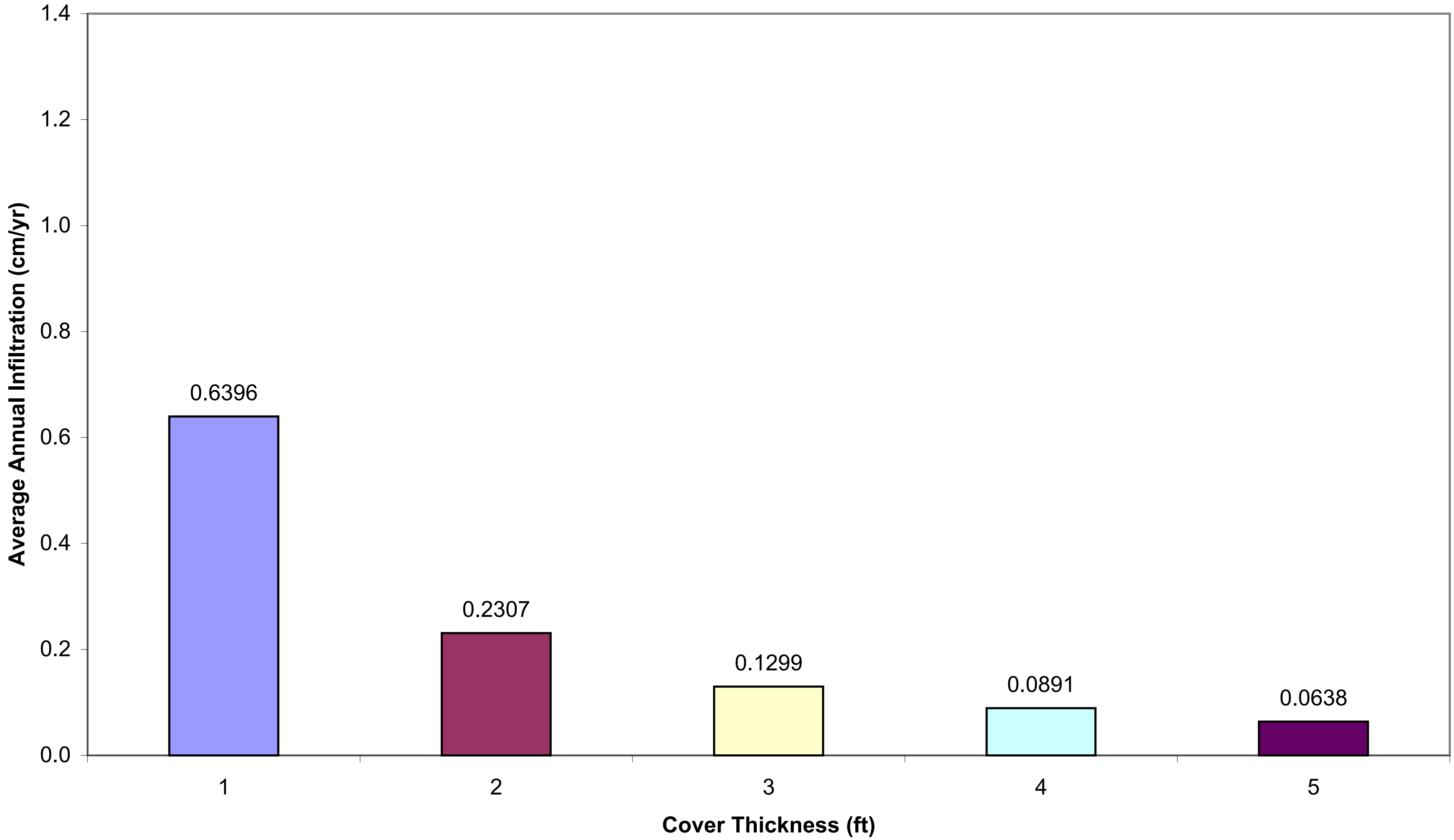

Figure 5-4 Average Annual Infiltration Predicted by UNSAT-H Using Historical Preciptiation Data

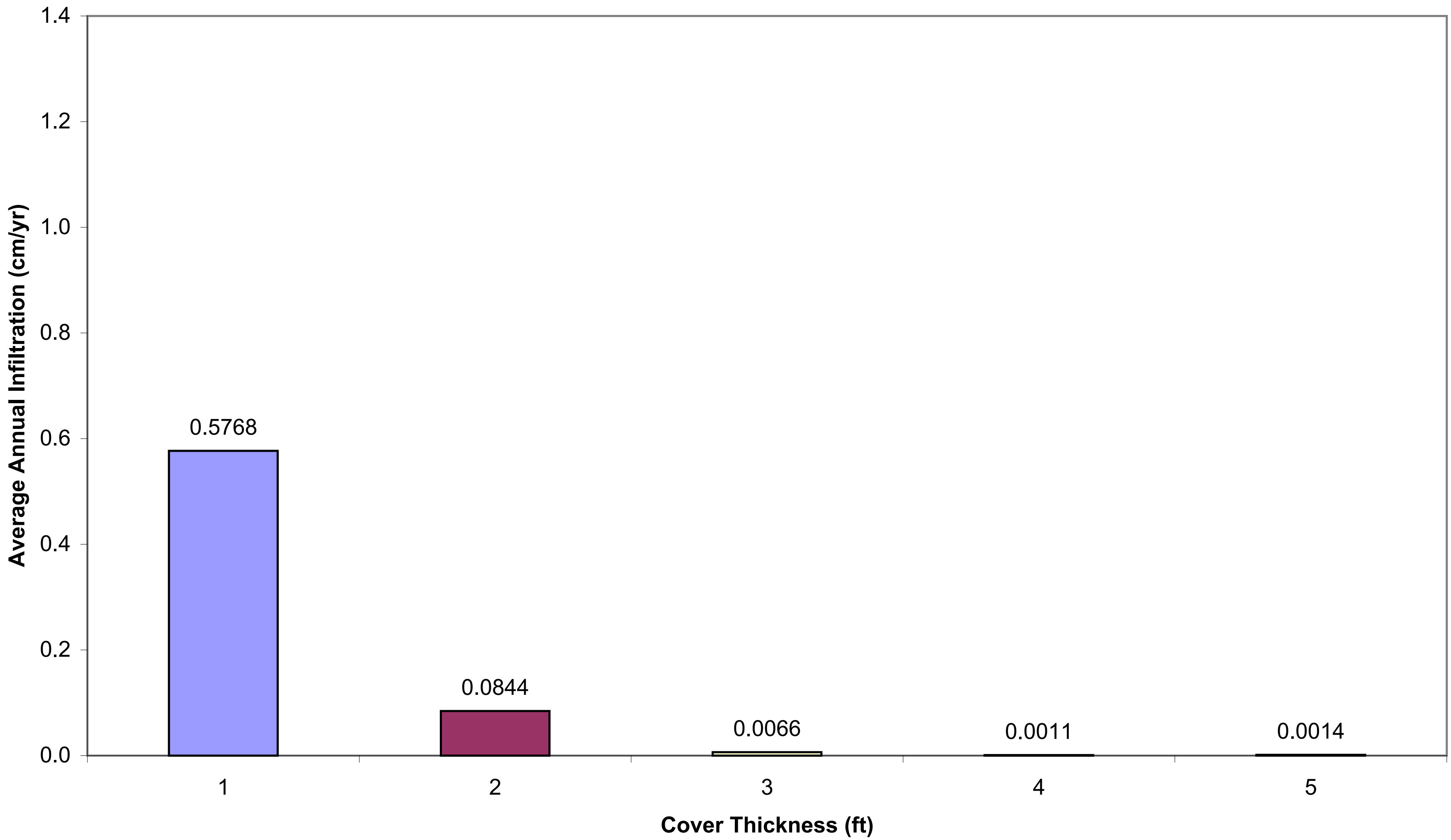

Figure 5-5 Average Annual Infiltration Predicted by VS2DT Using Historical Precipitation Data

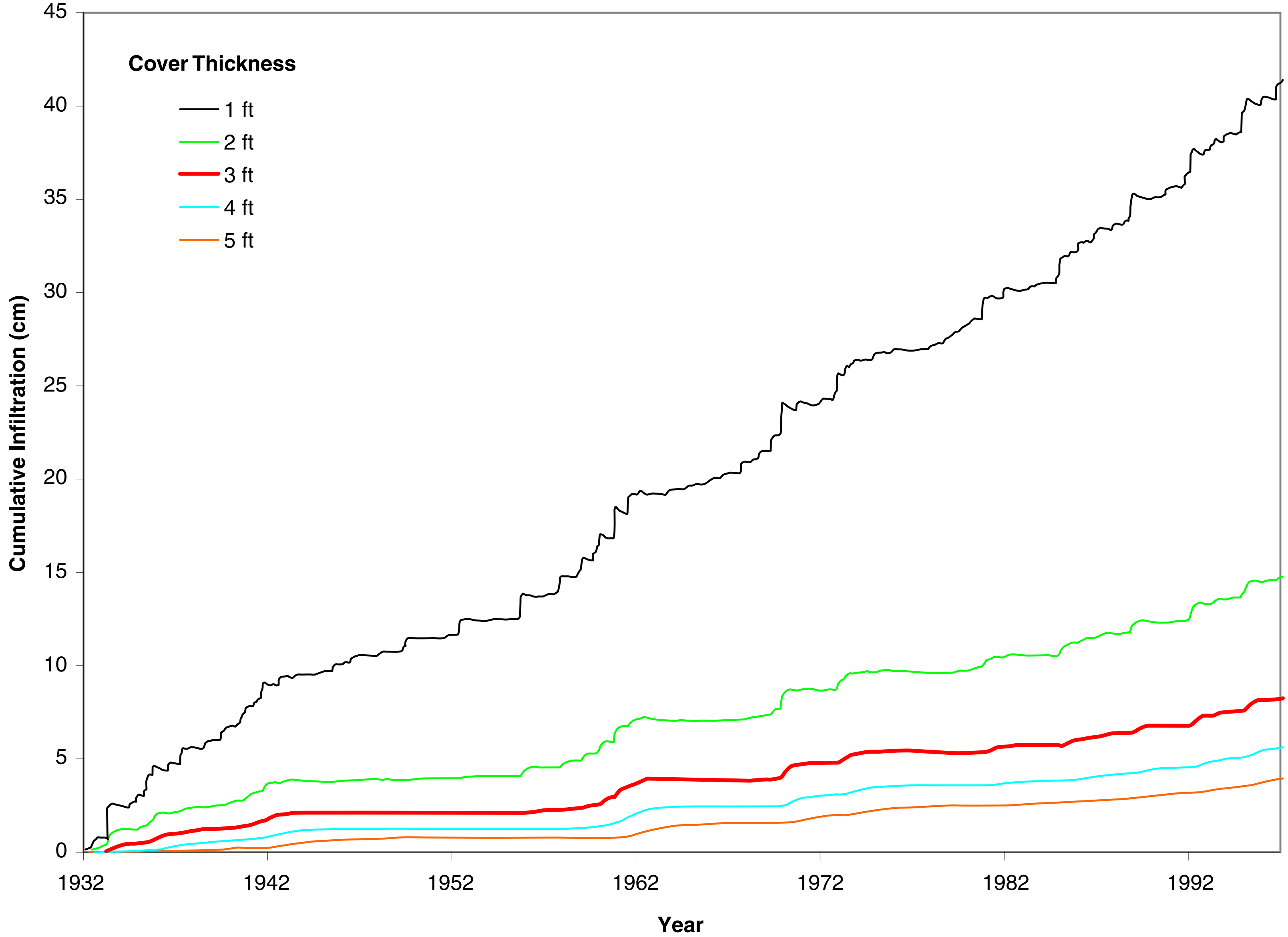

Figure 5-6 Cumulative Infiltration Predicted by UNSAT-H Using Historical Precipitation Data

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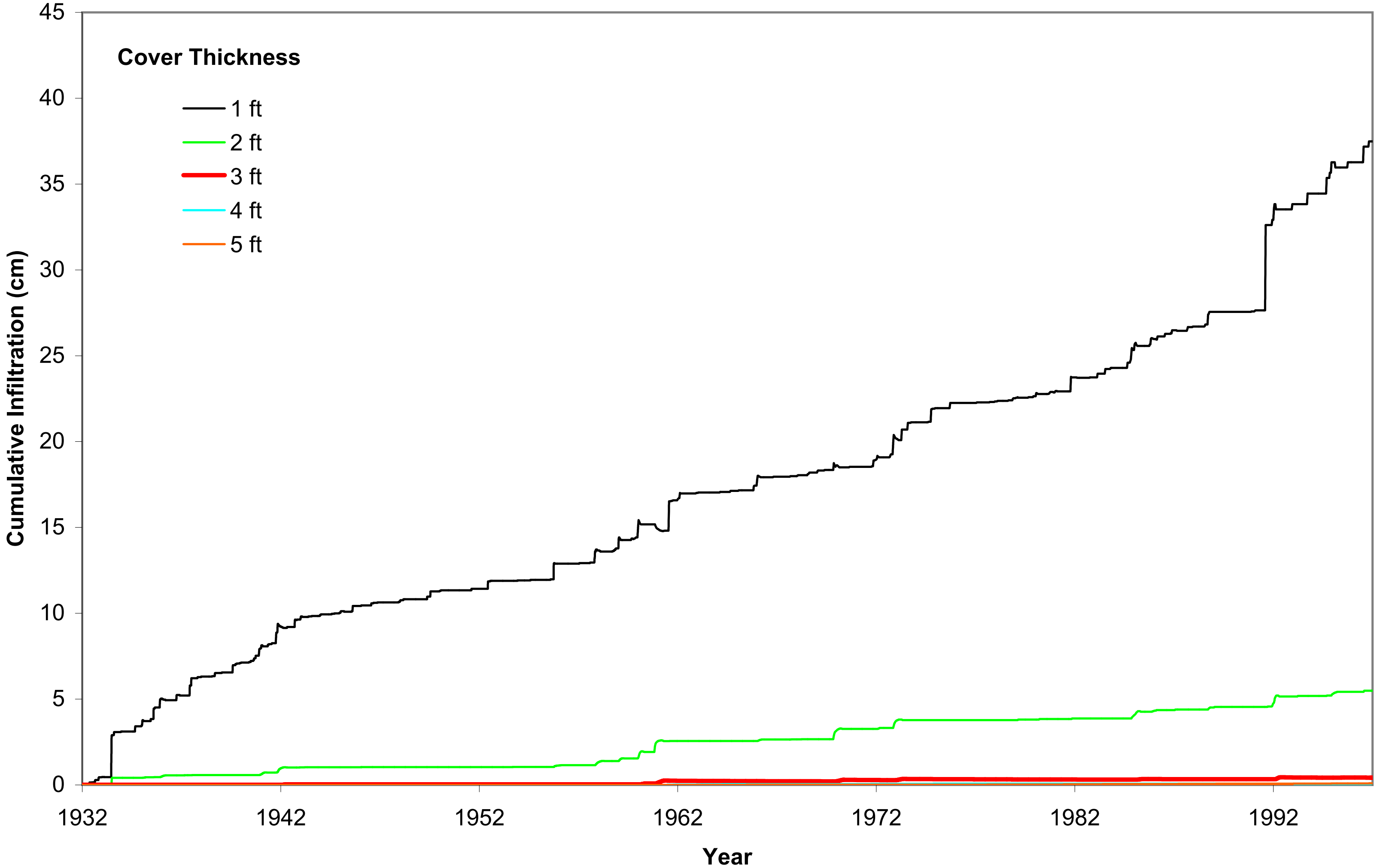

Figure 5-7 Cumulative Infiltration Predicted by VS2DT Using Historical Precipitation Data

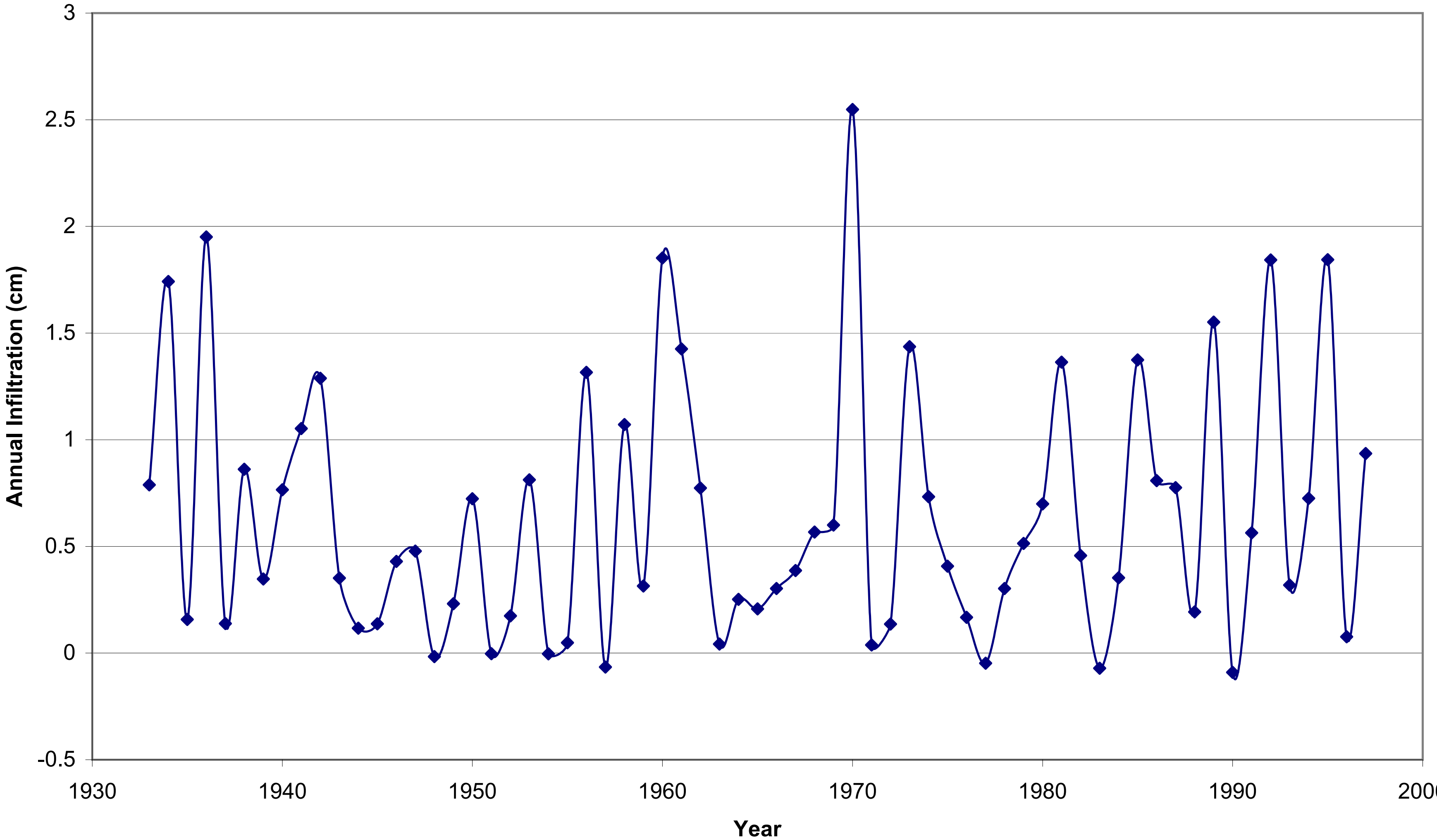

Figure 5-8 Annual Infiltration Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

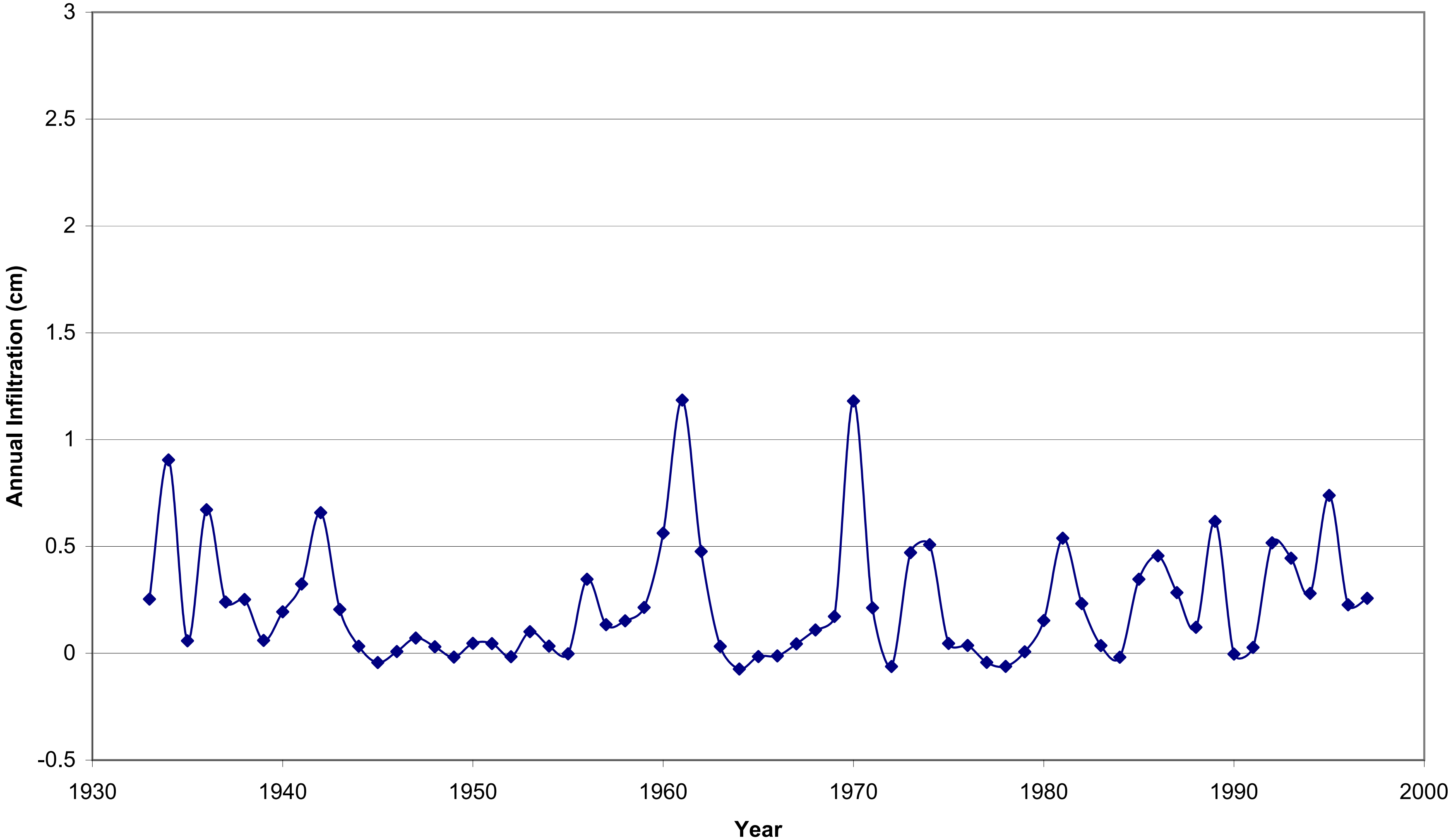

Figure 5-9 Annual Infiltration Through a 2-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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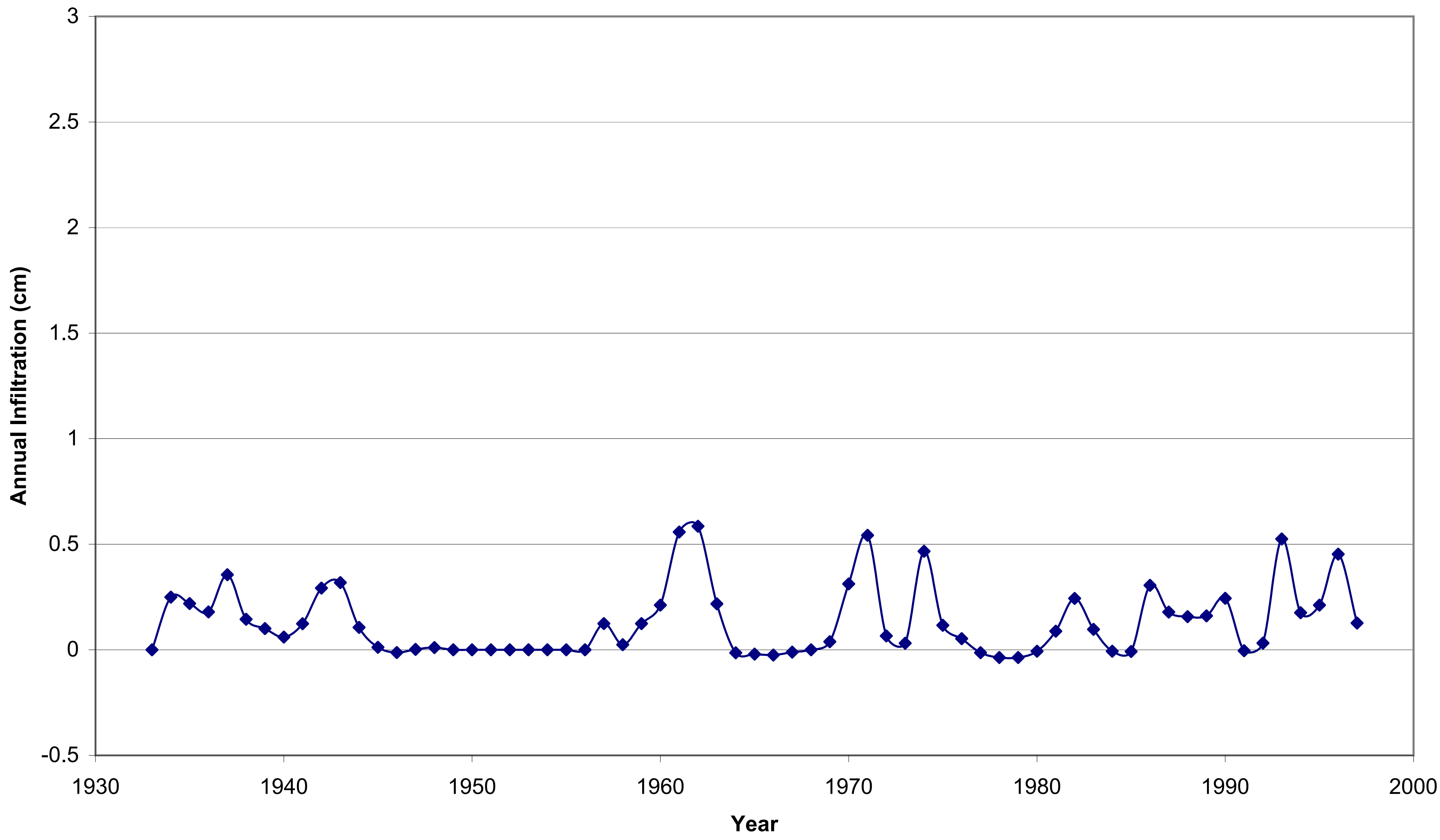

Figure 5-10 Annual Infiltration Through a 3-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

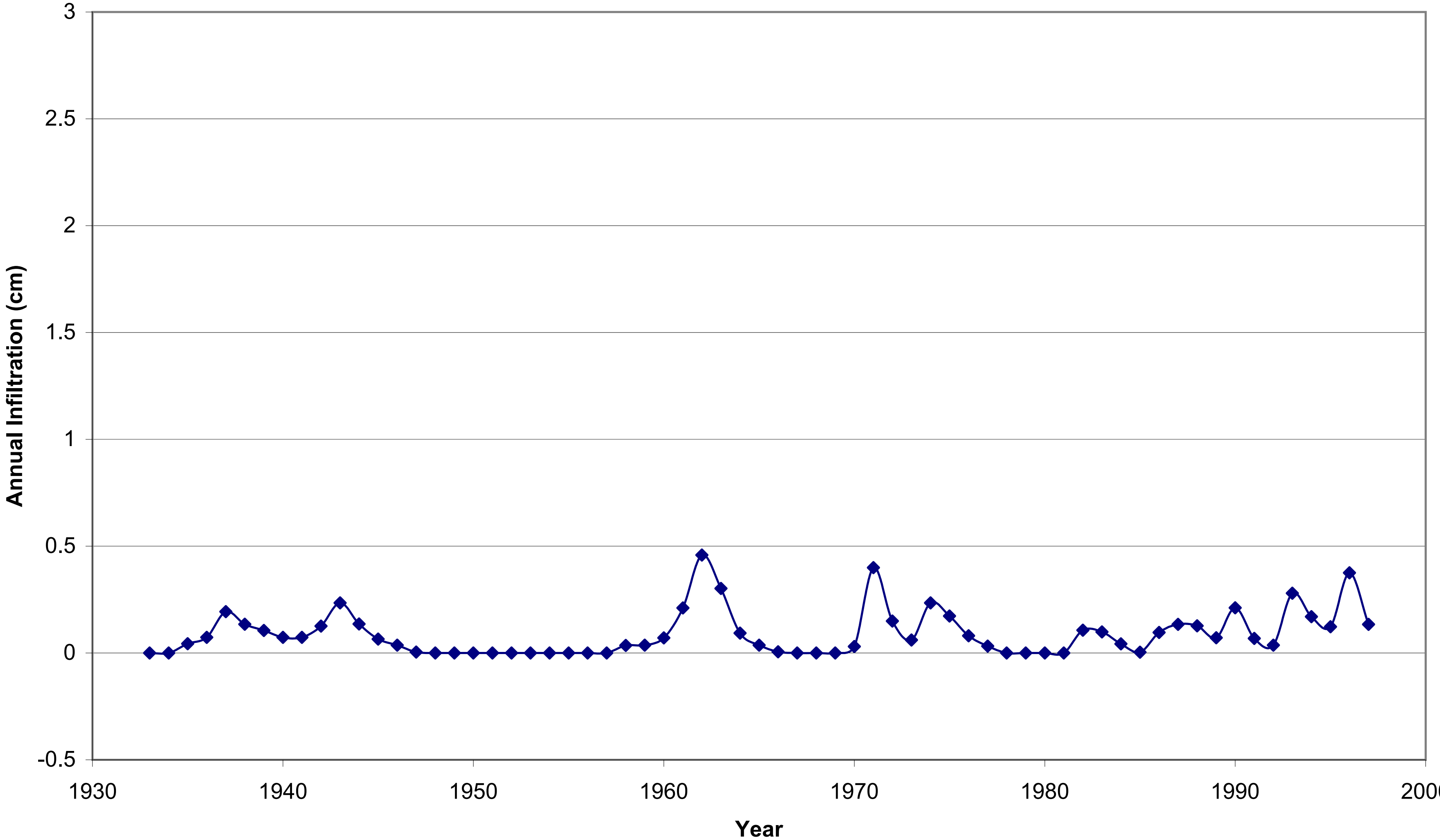

Figure 5-11 Annual Infiltration Through a 4-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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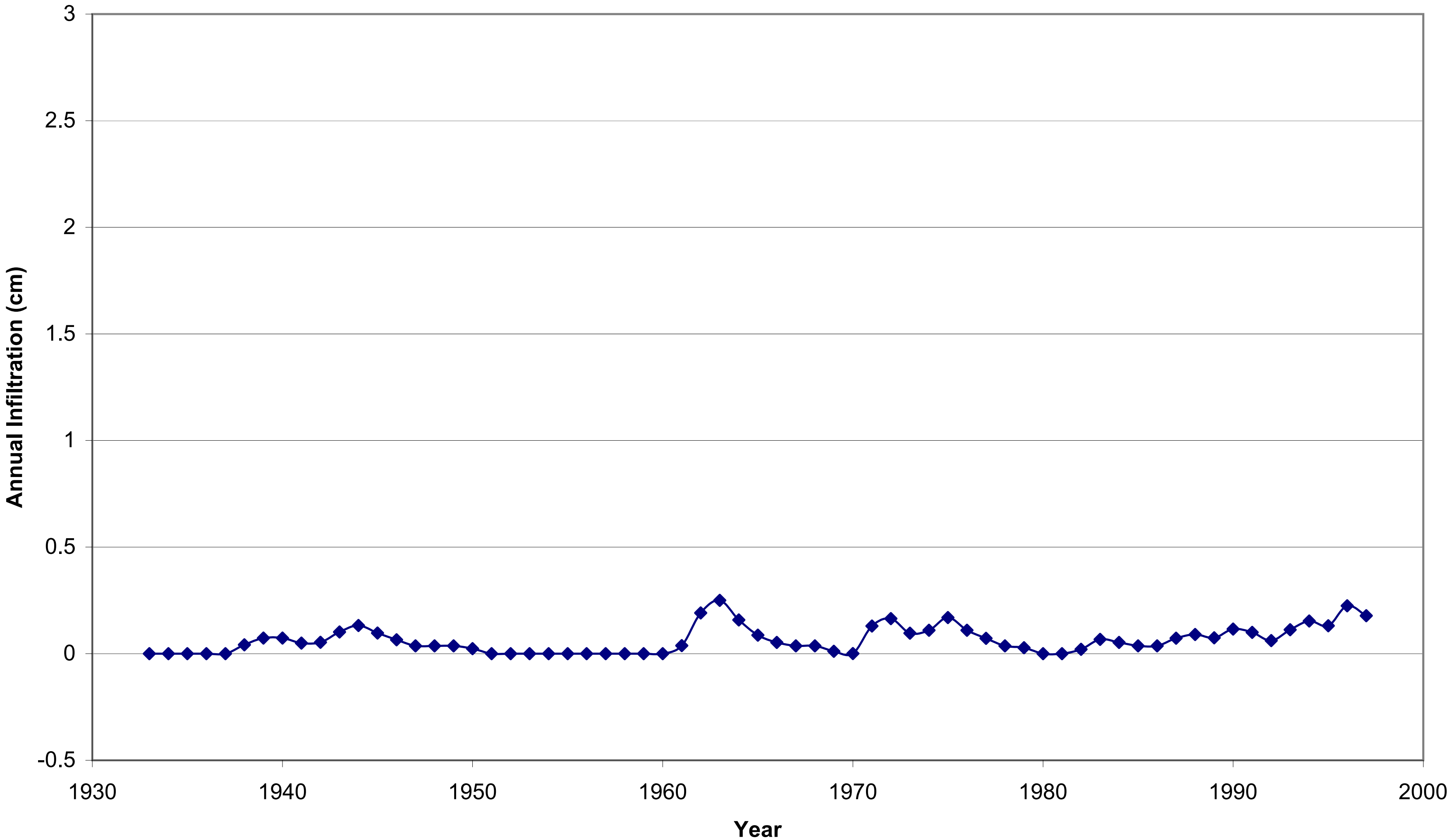

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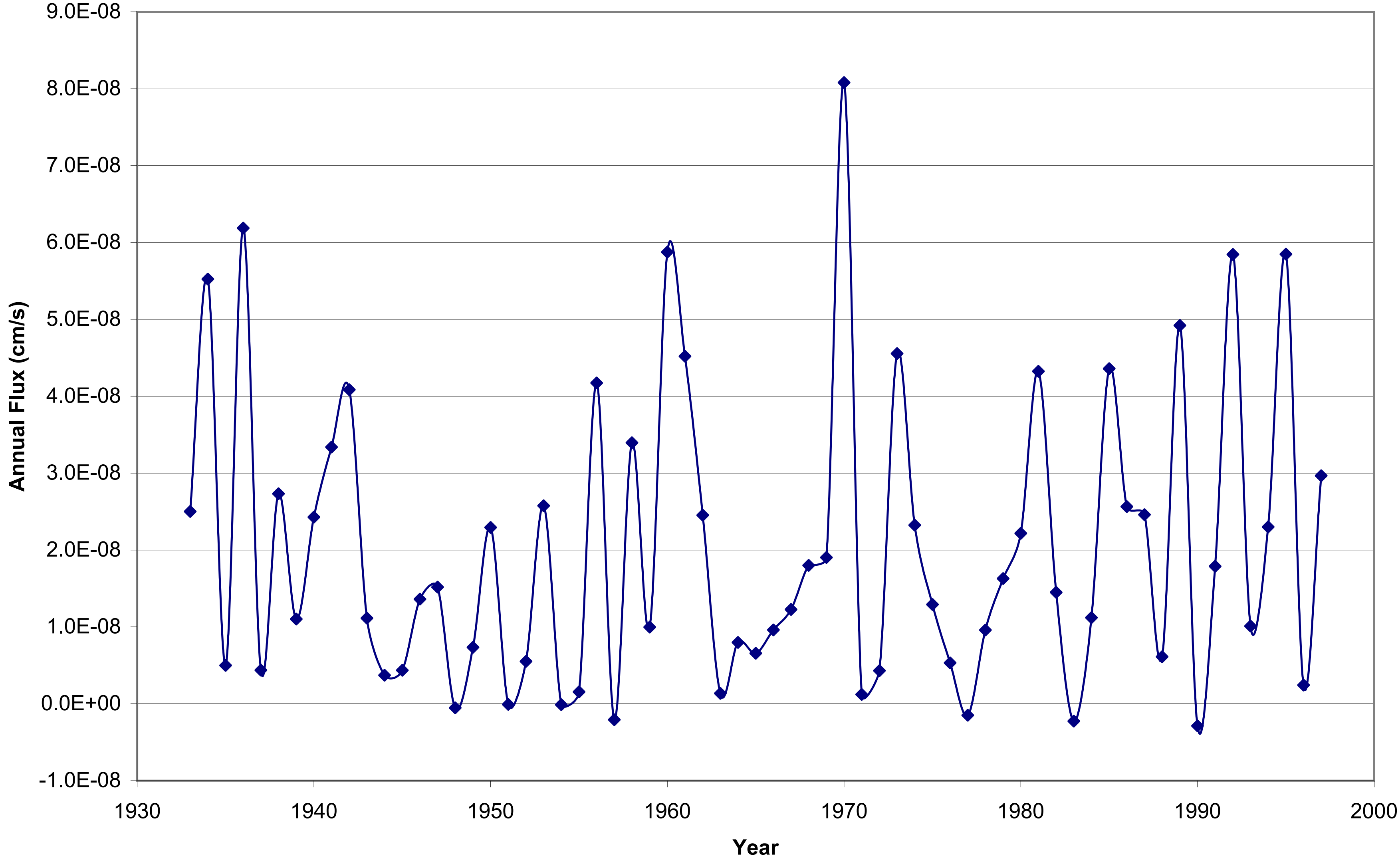

Figure 5-13 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

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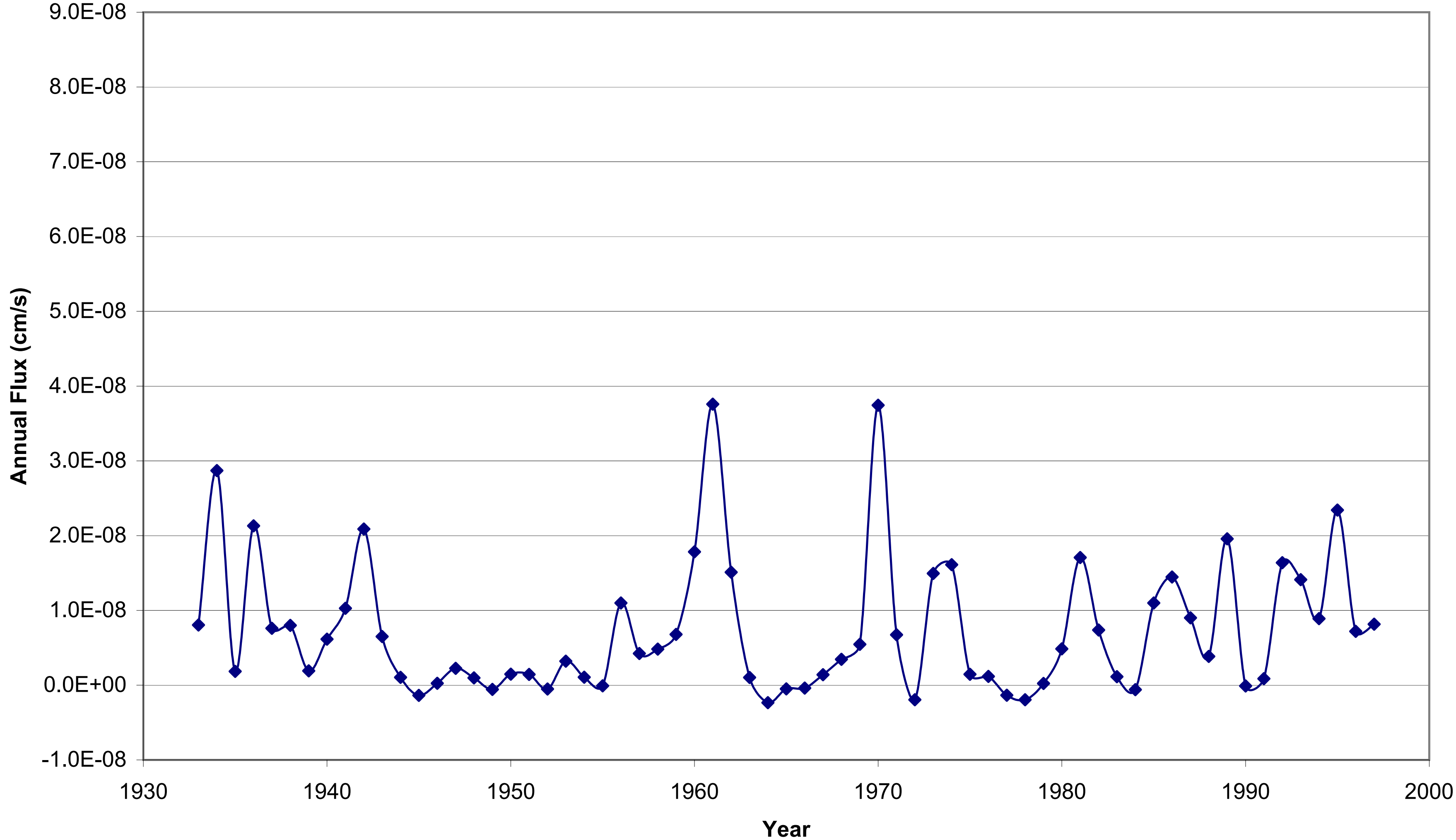

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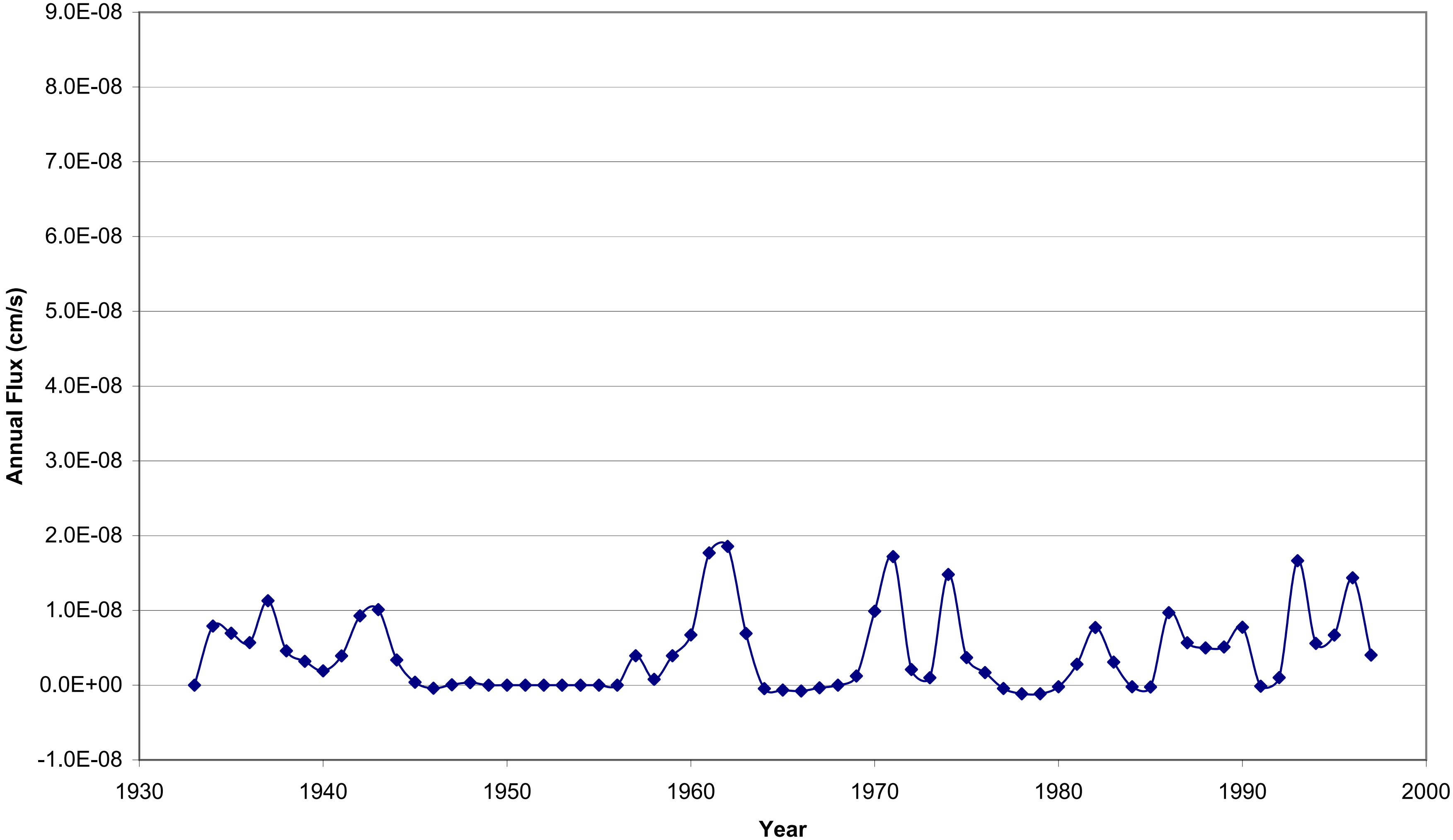

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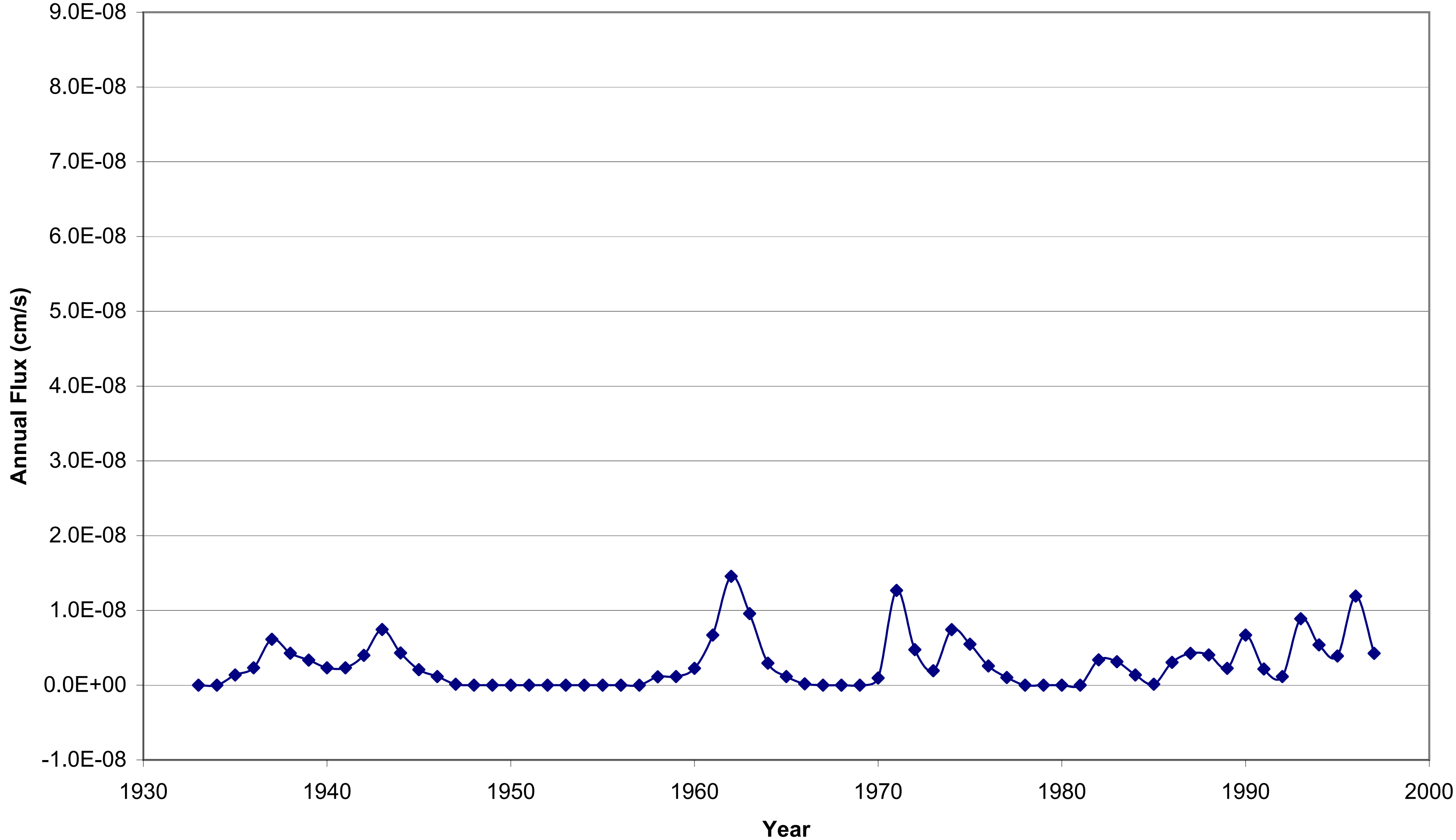

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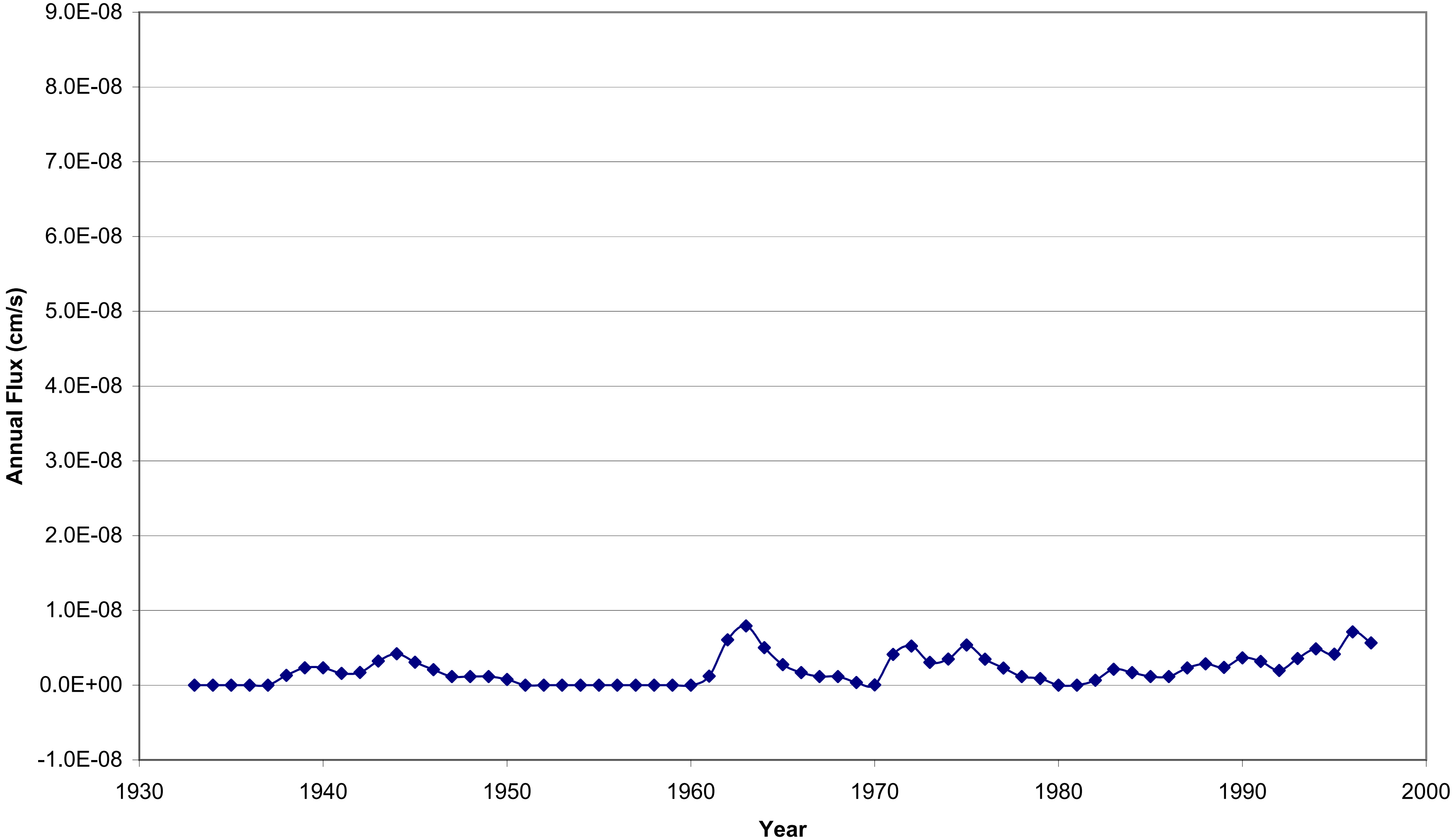

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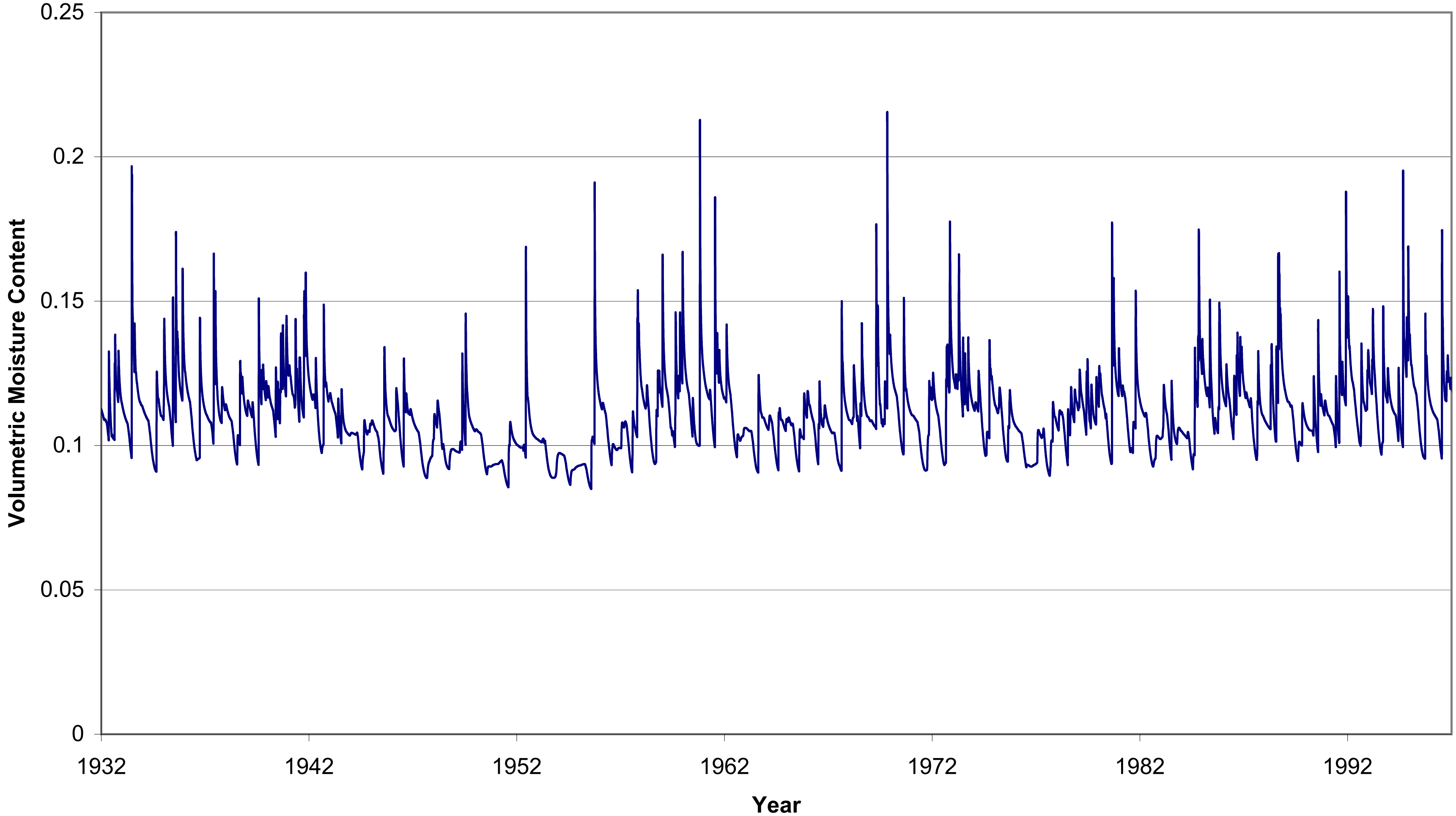

Figure 5-18 Moisture Content at 1-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

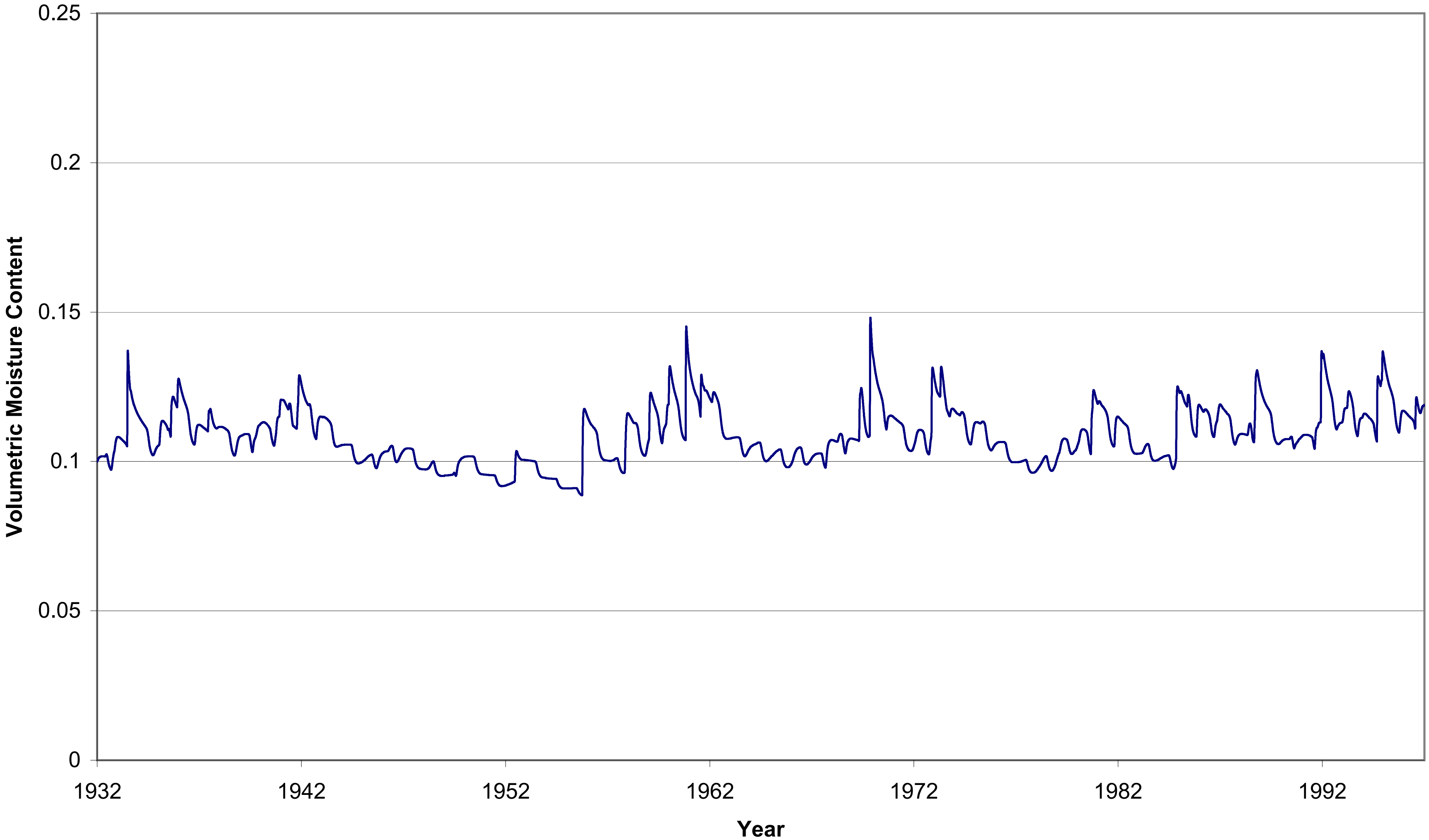

Figure 5-19 Moisture Content at 2-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data

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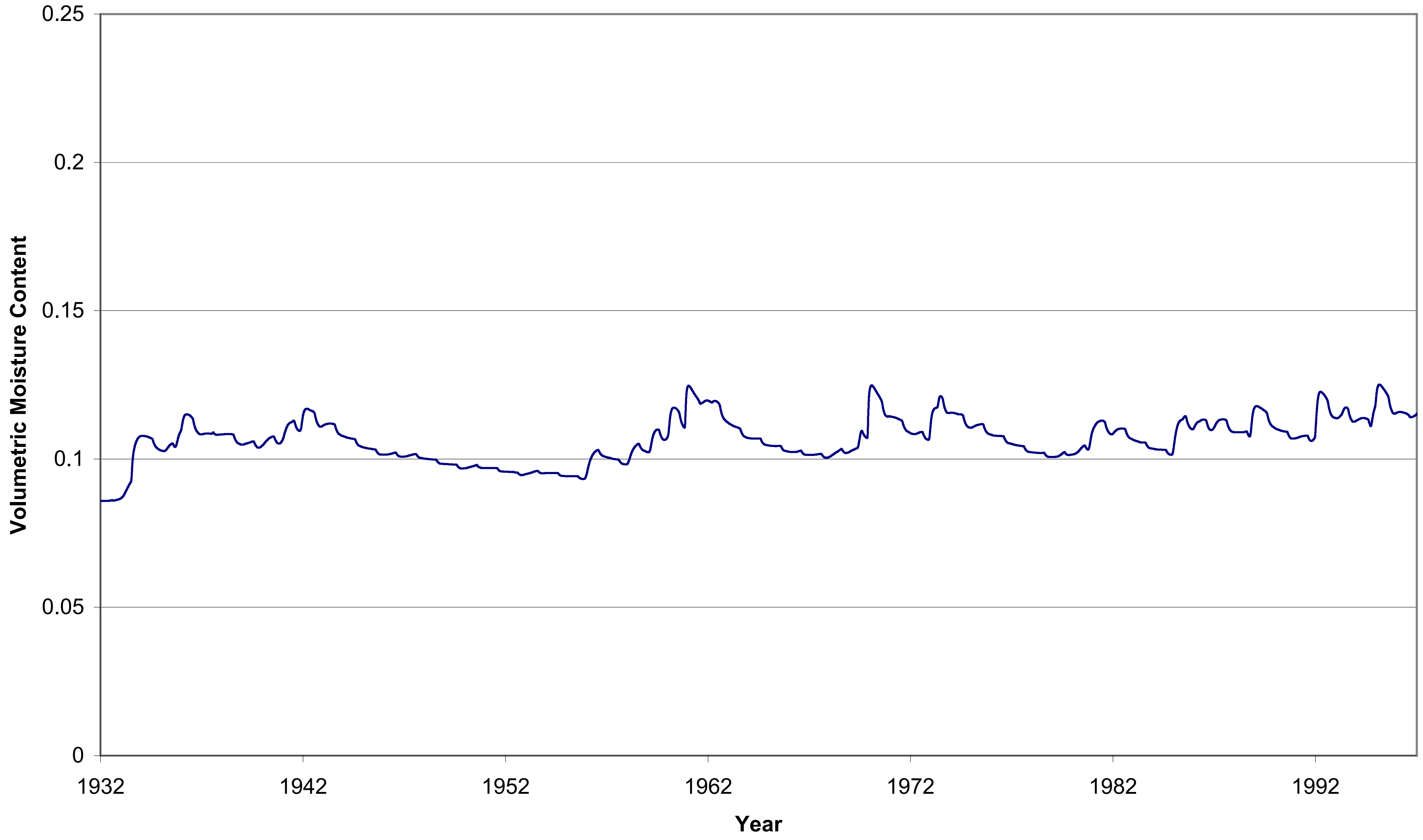
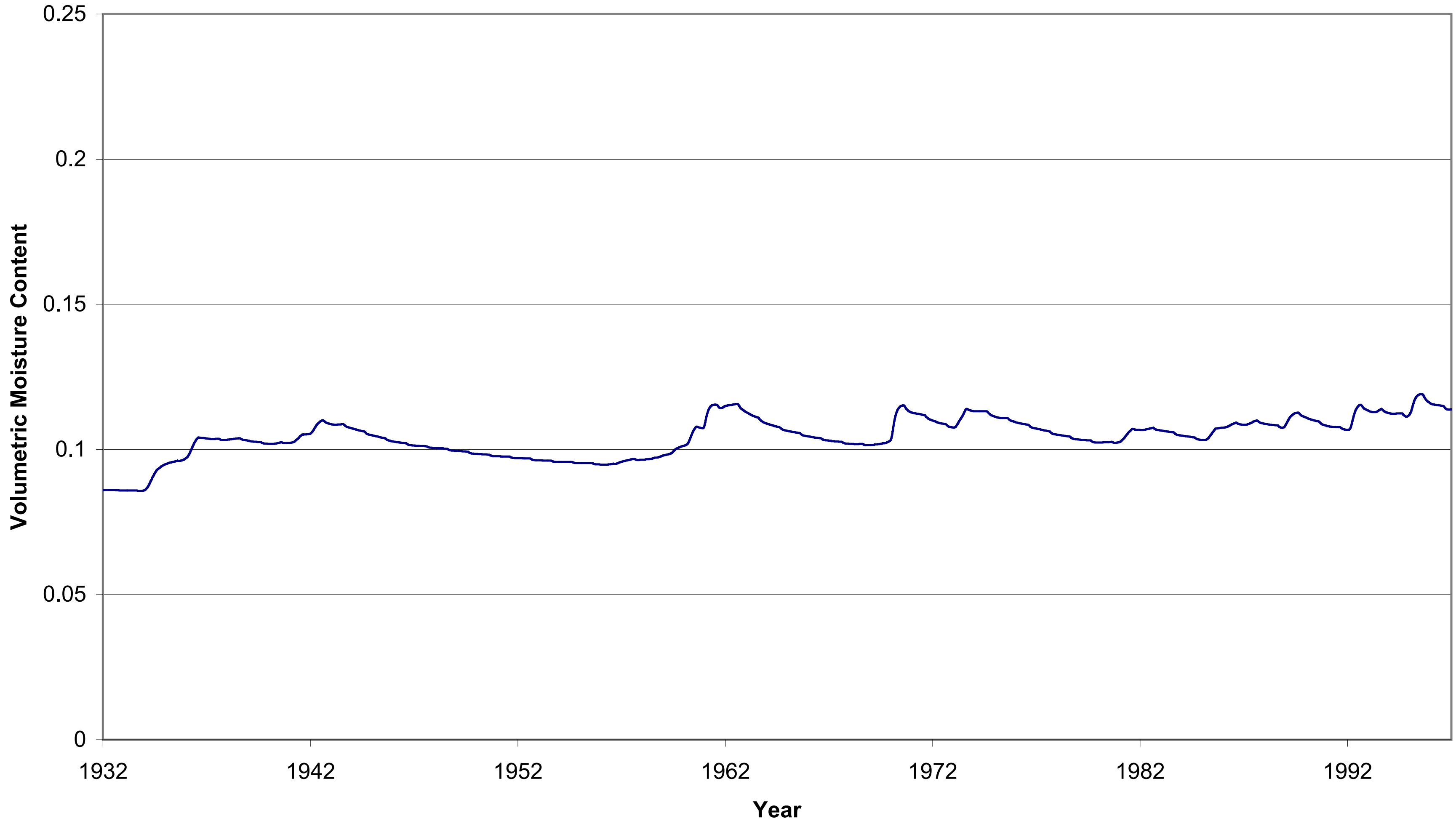


Figure 5-20 Moisture Content at 3-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data



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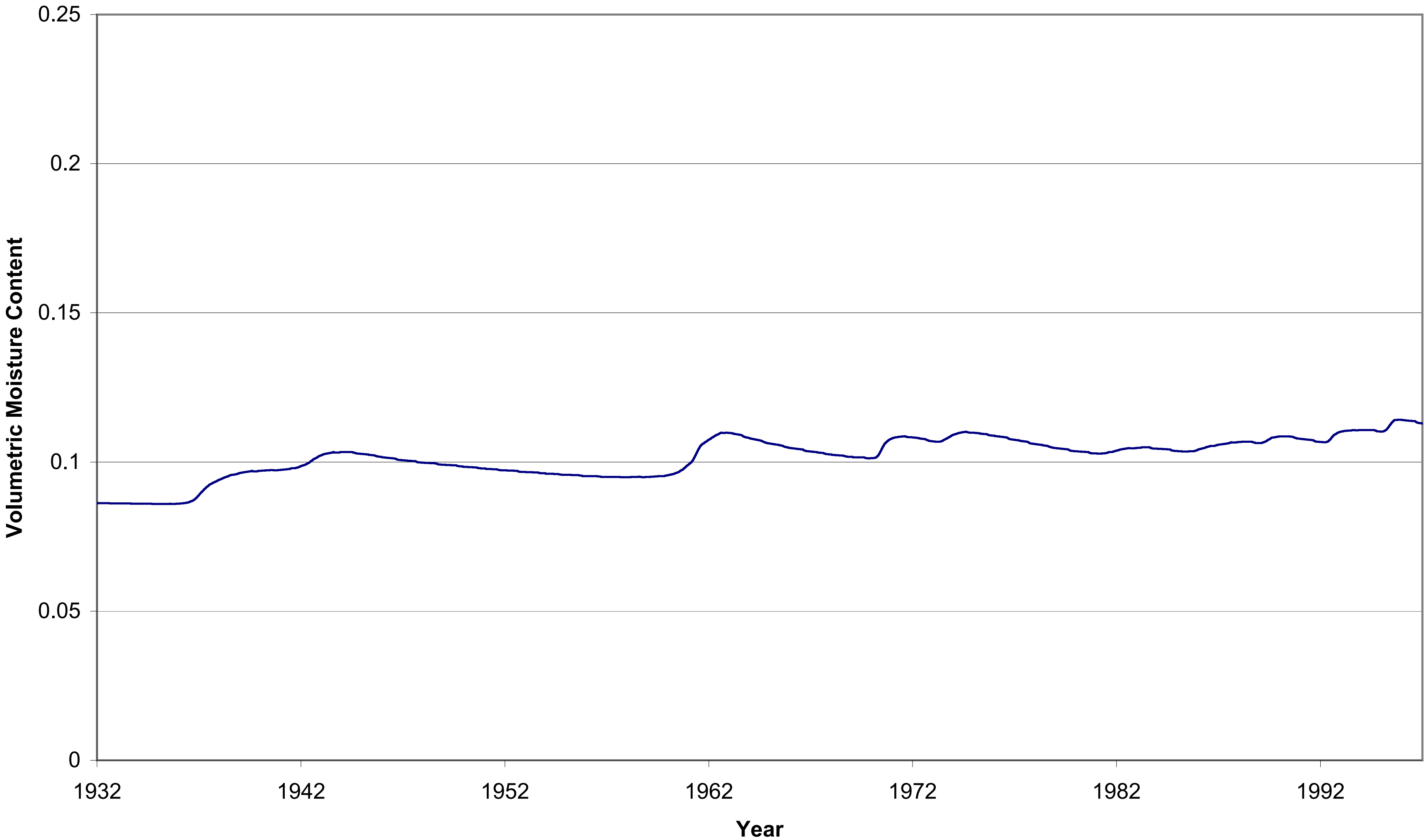

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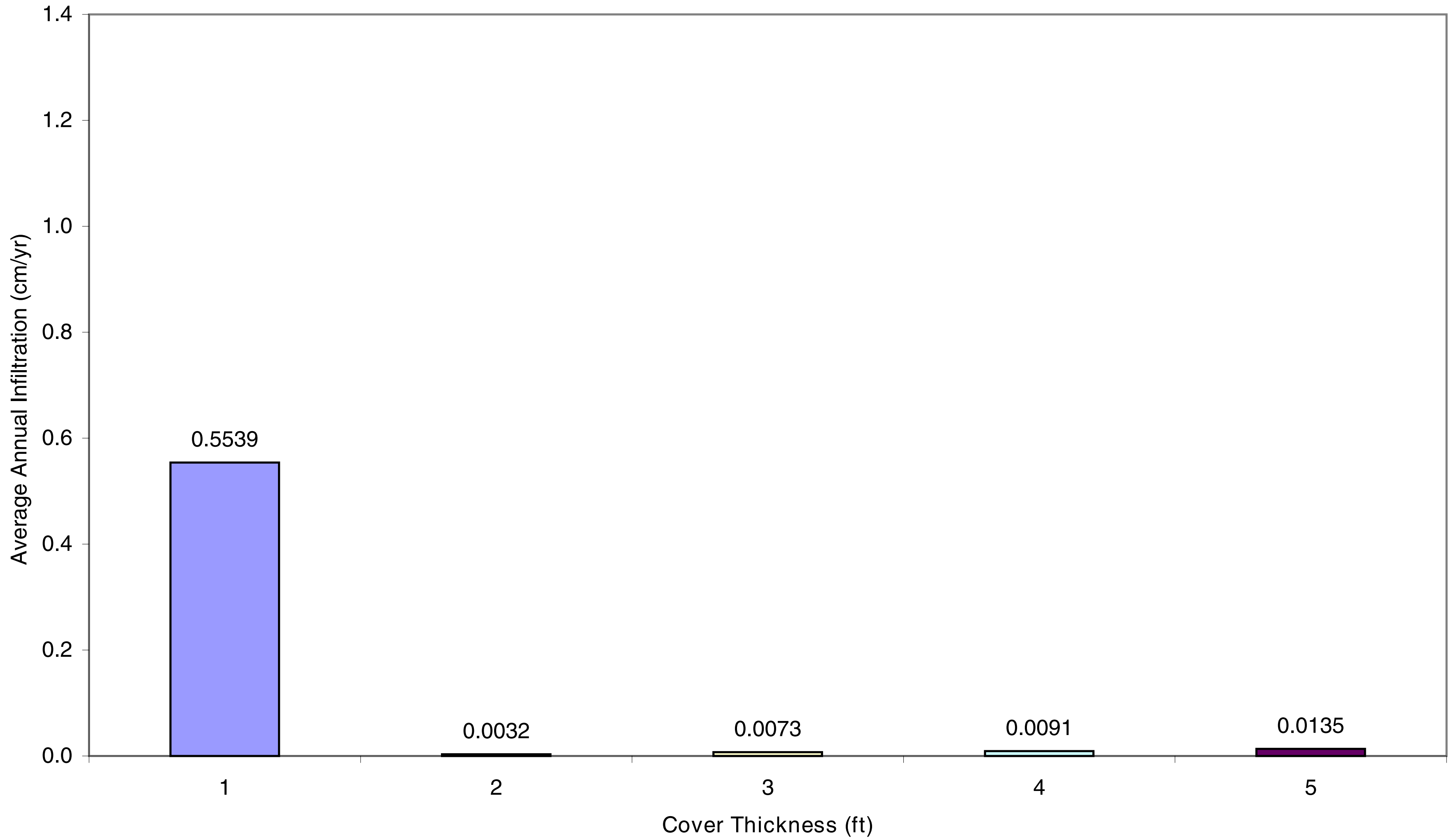

Figure 5-23 Average Annual Infiltration Rates Predicted by HELP-3 Using Maximum Precipitation Data

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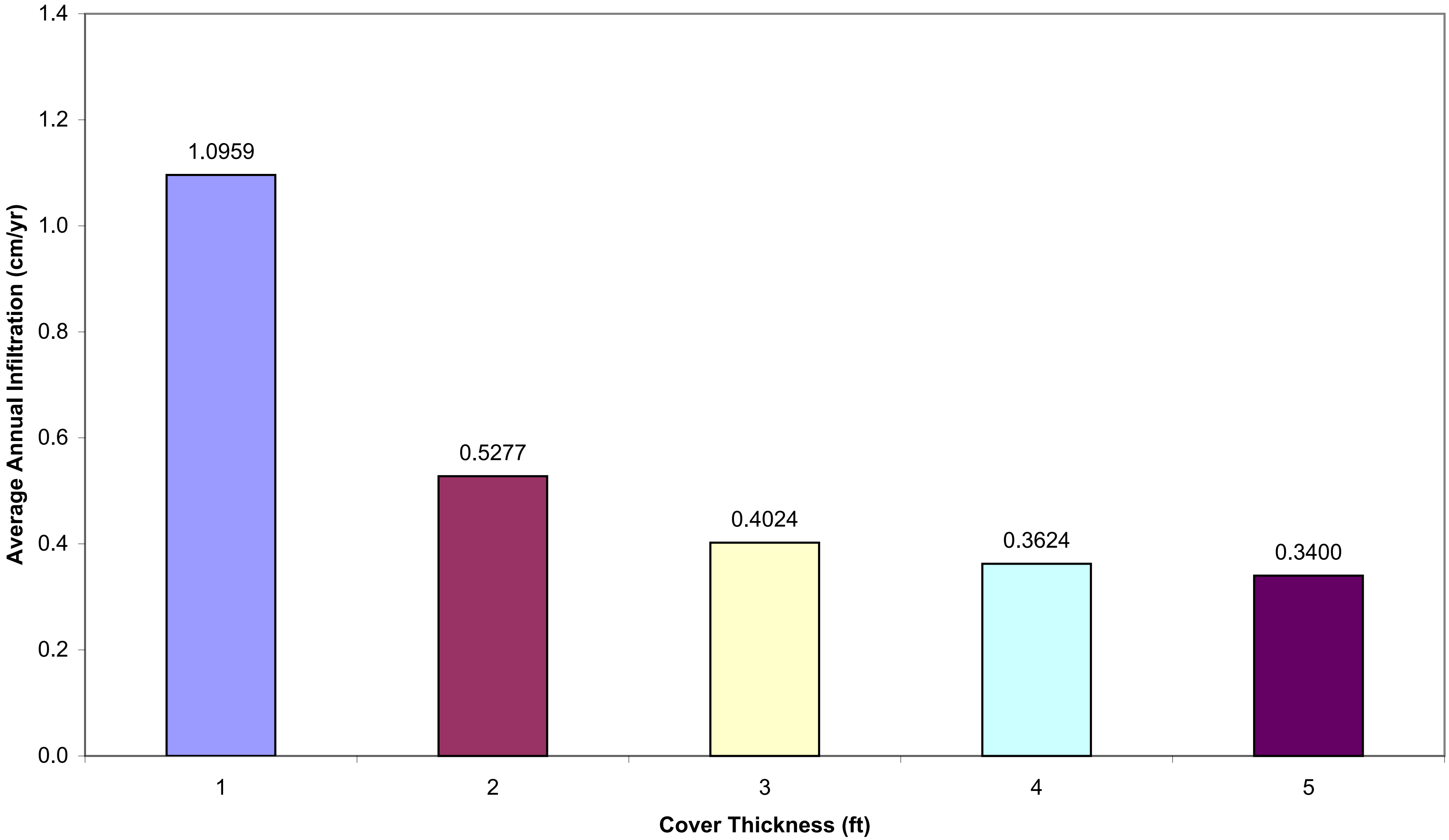

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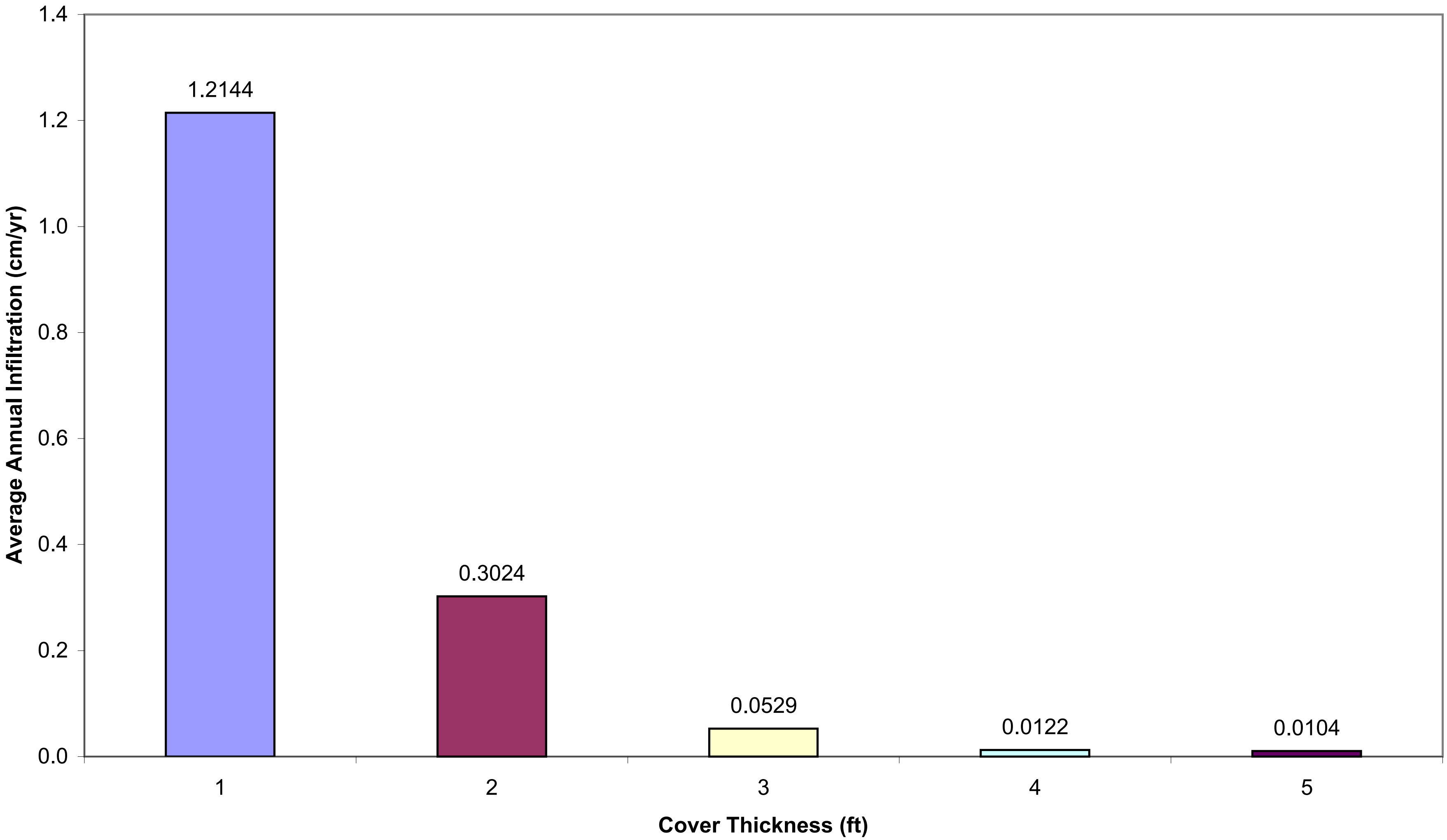
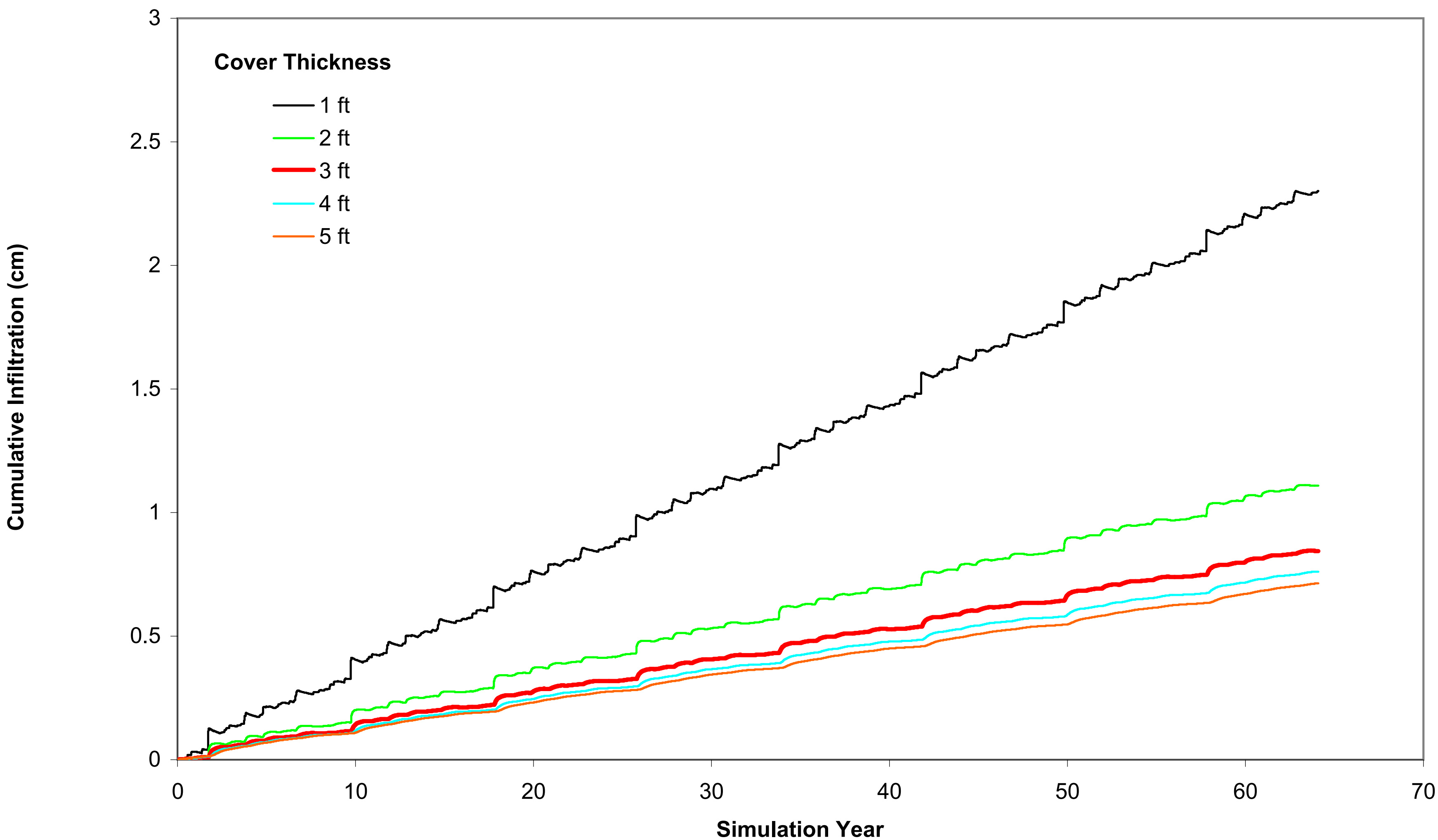


Figure 5-25 Average Annual Infiltration Rates Predicted by VS2DT Using Maximum Precipitation Data



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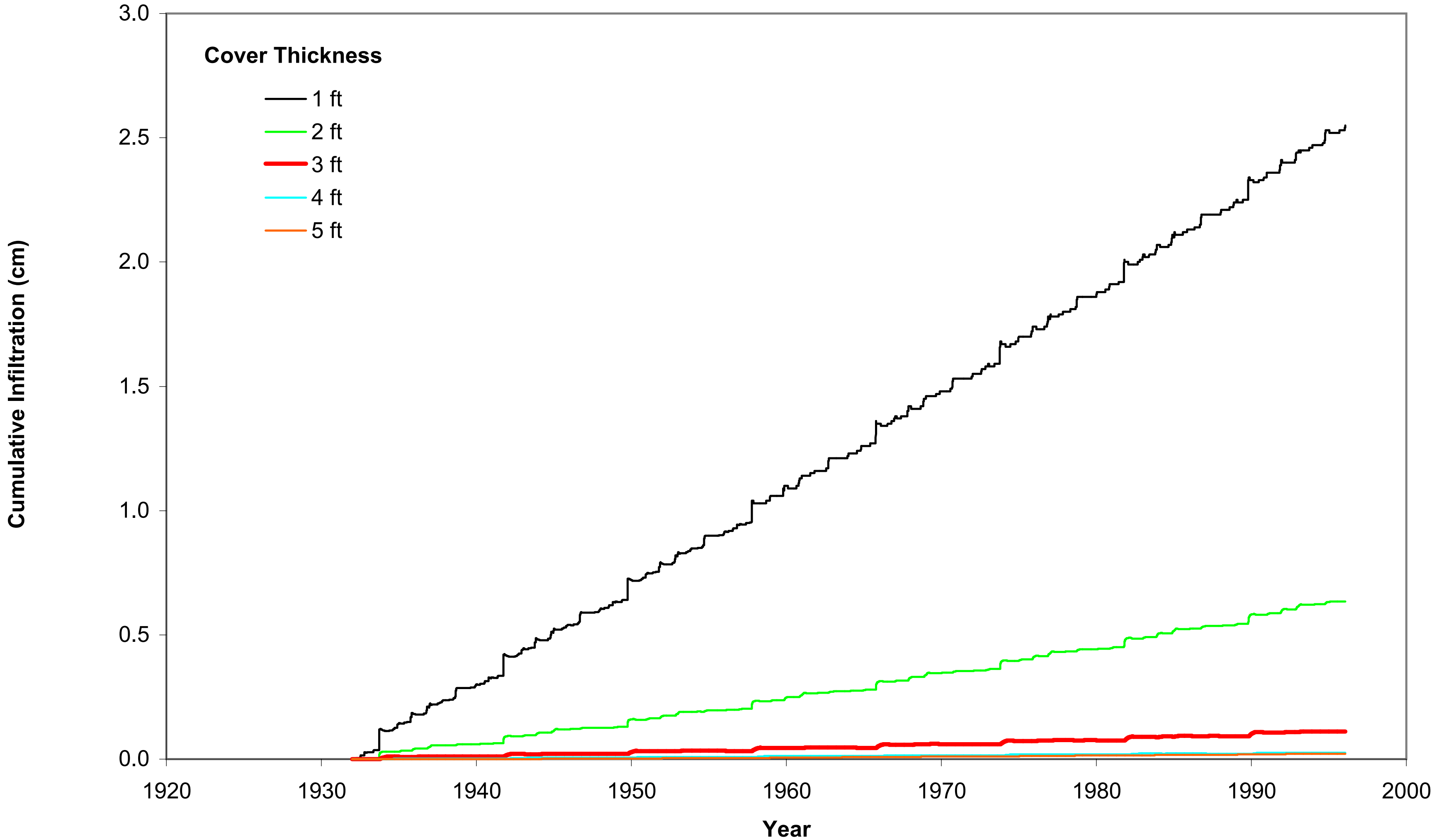

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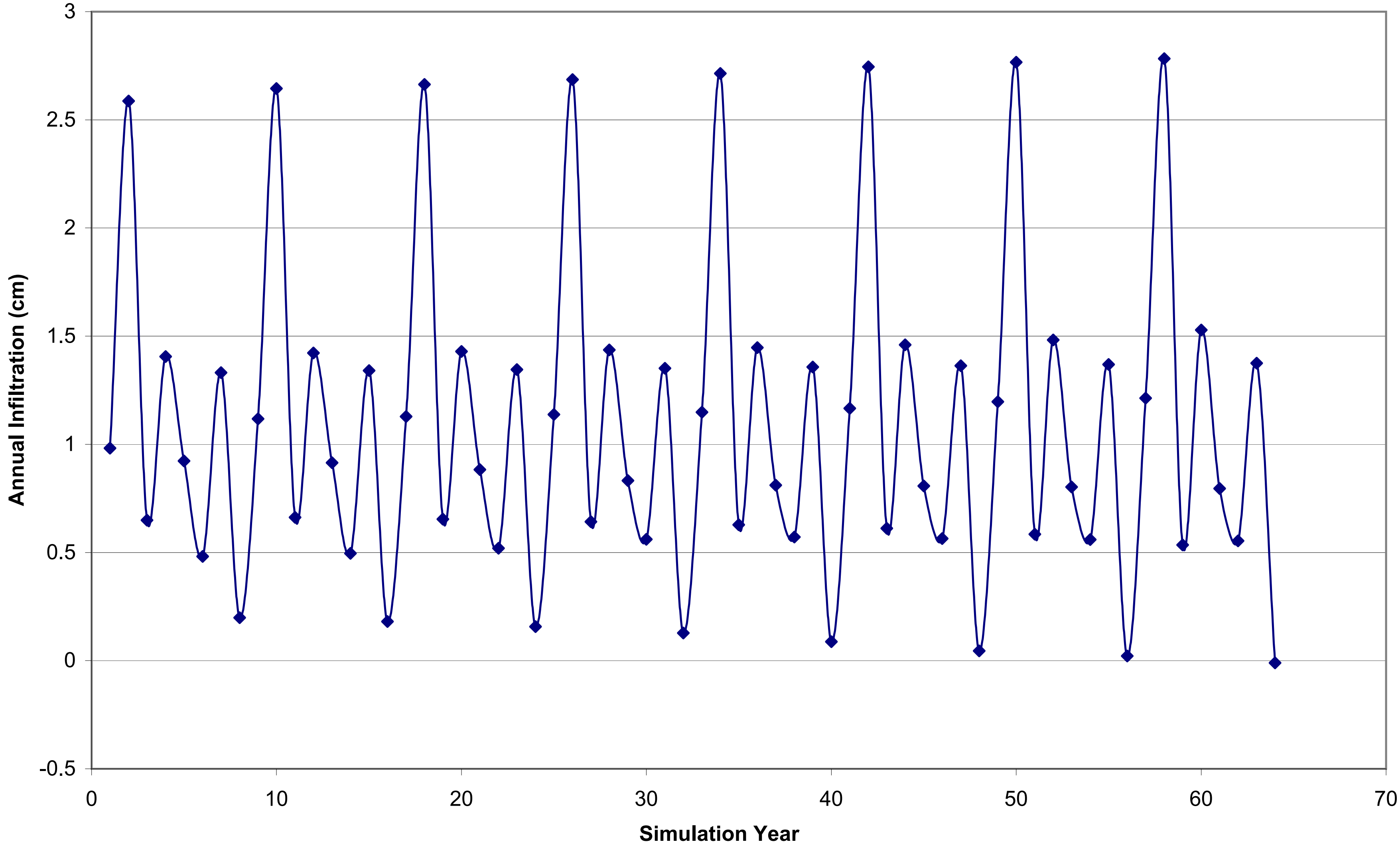
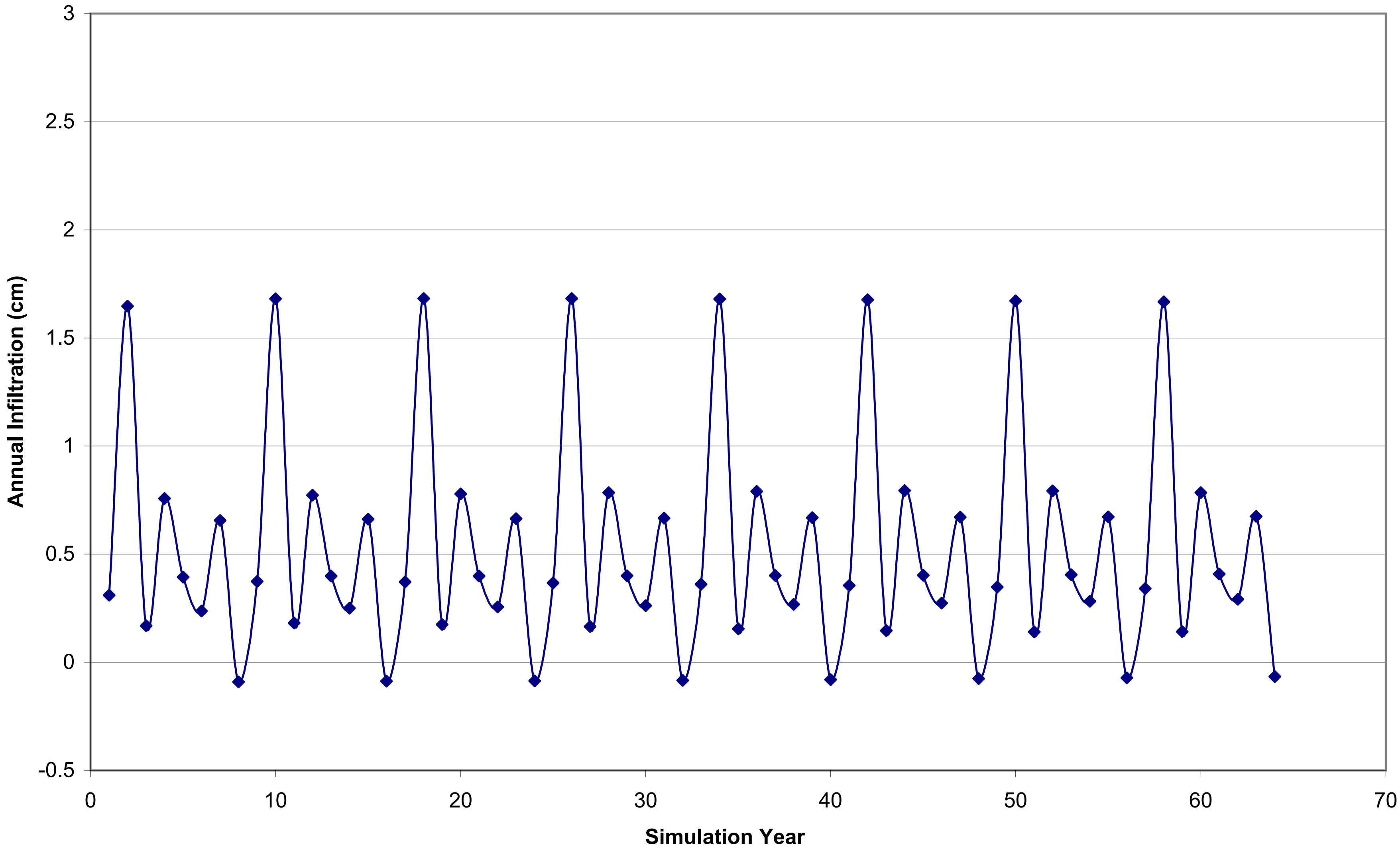


Figure 5-28 Annual Infiltration Through a 1-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data



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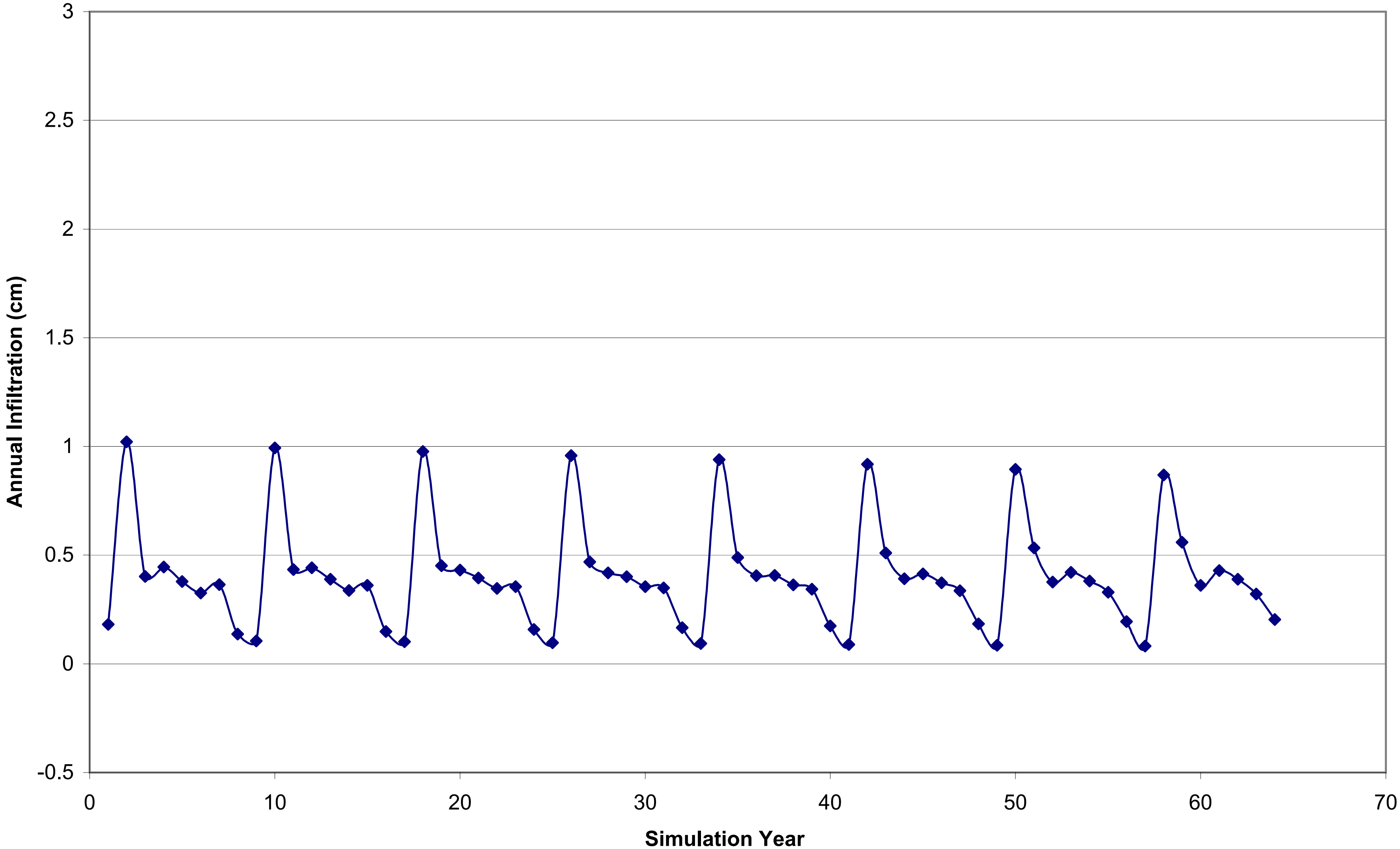

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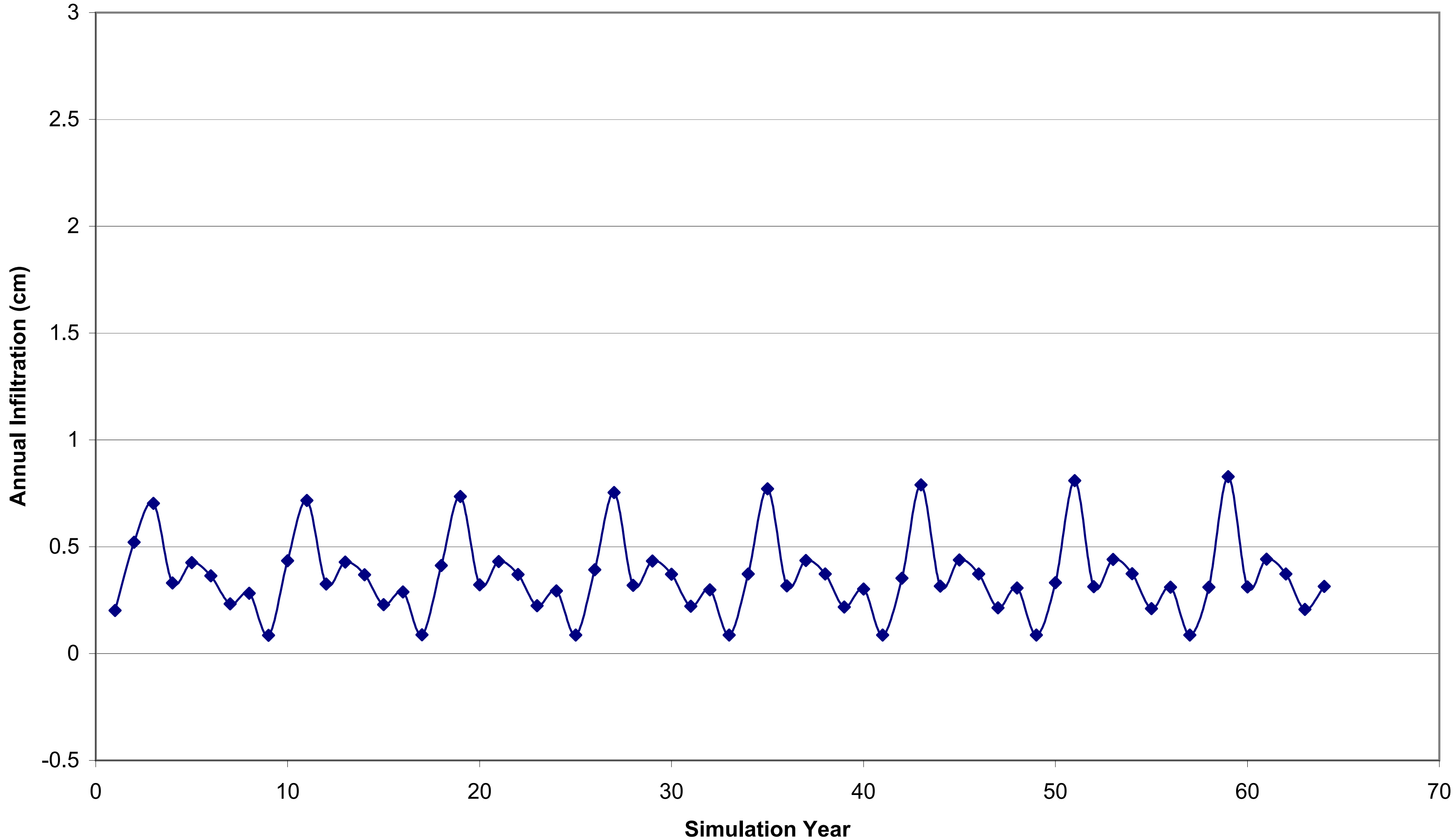

Figure 5-31 Annual Infiltration Through a 4-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

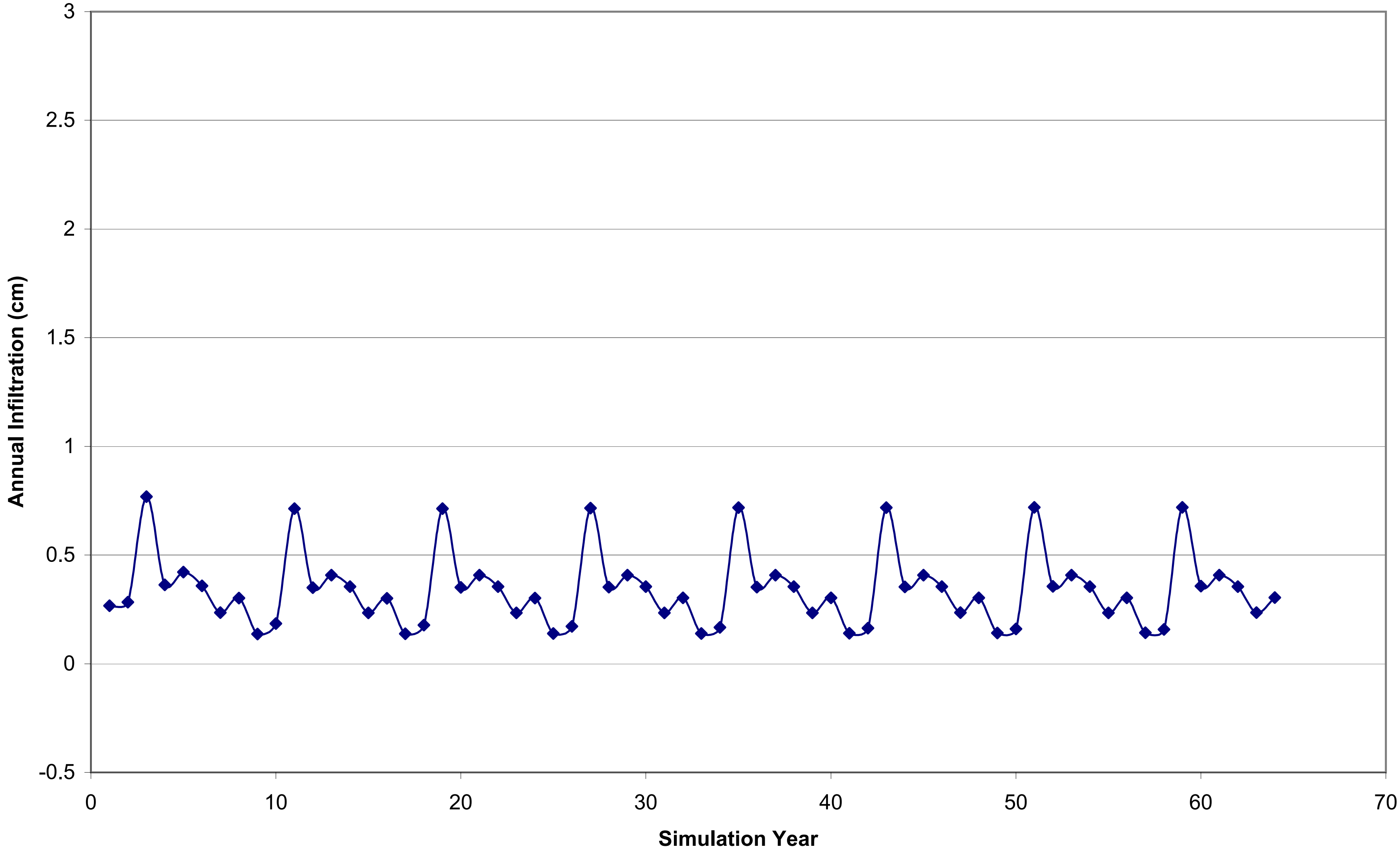

Figure 5-32 Annual Infiltration Through a 5-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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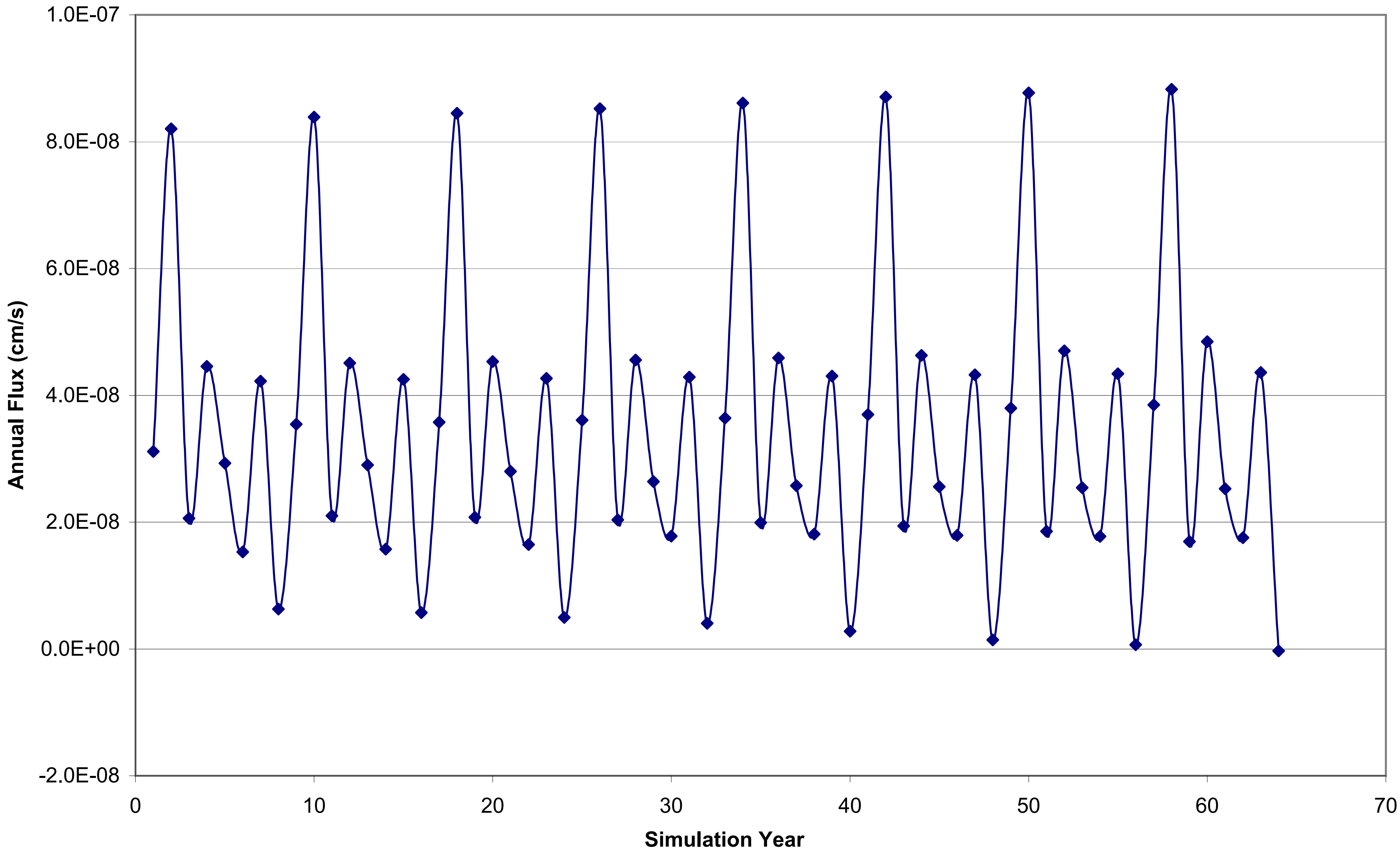

Figure 5-33 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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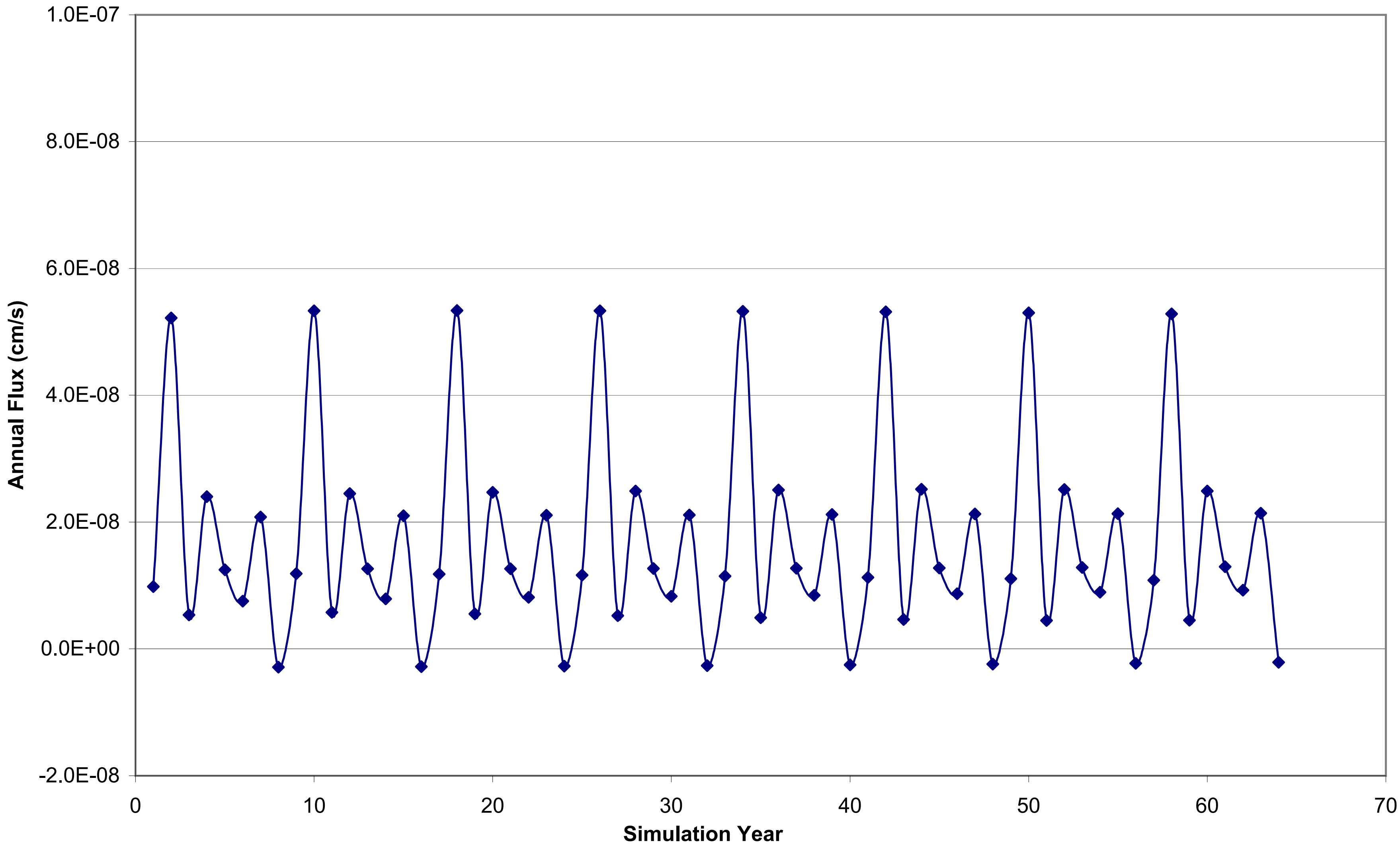

Figure 5-34 Annual Flux Through a 2-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

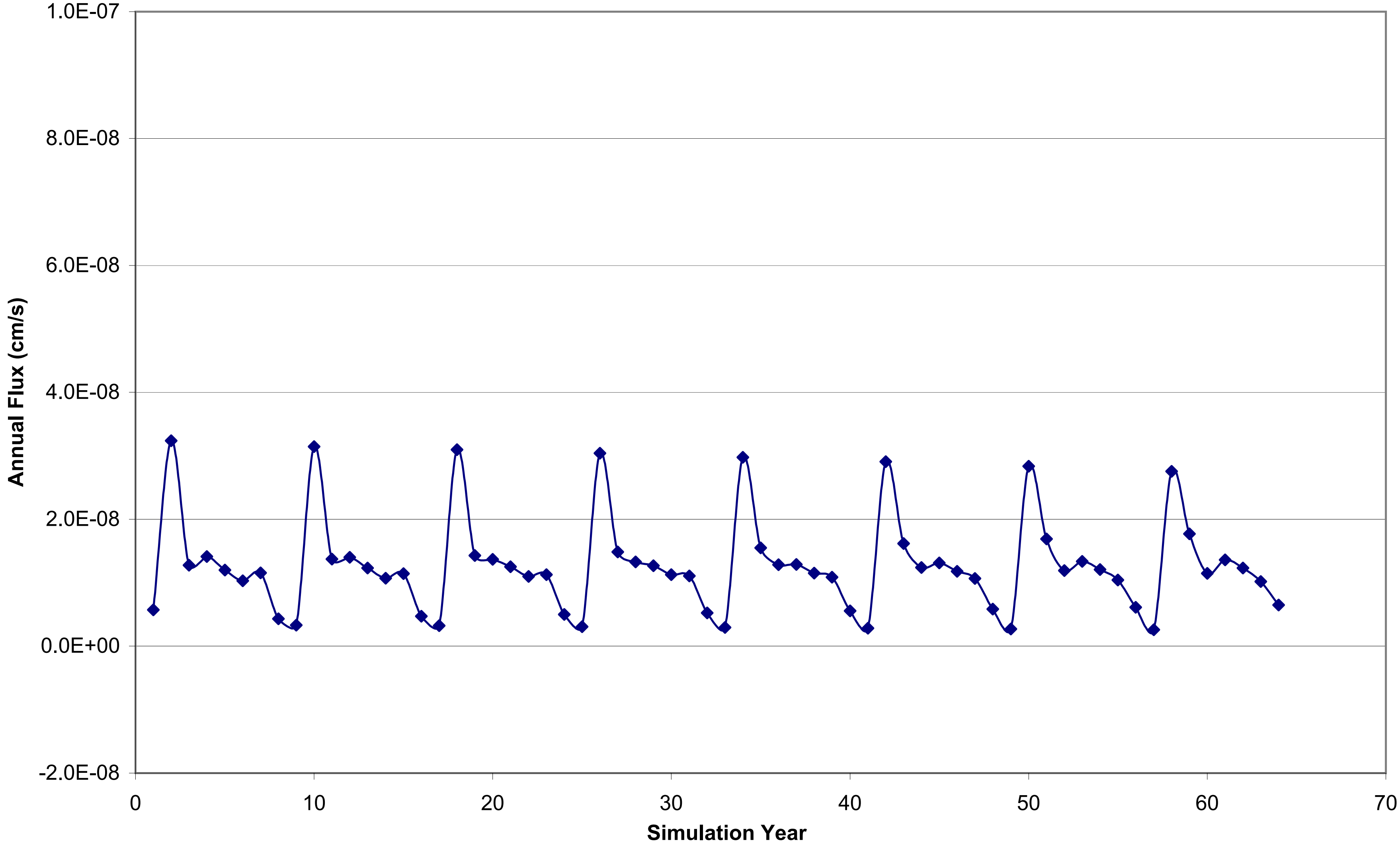

Figure 5-35 Annual Flux Through a 3-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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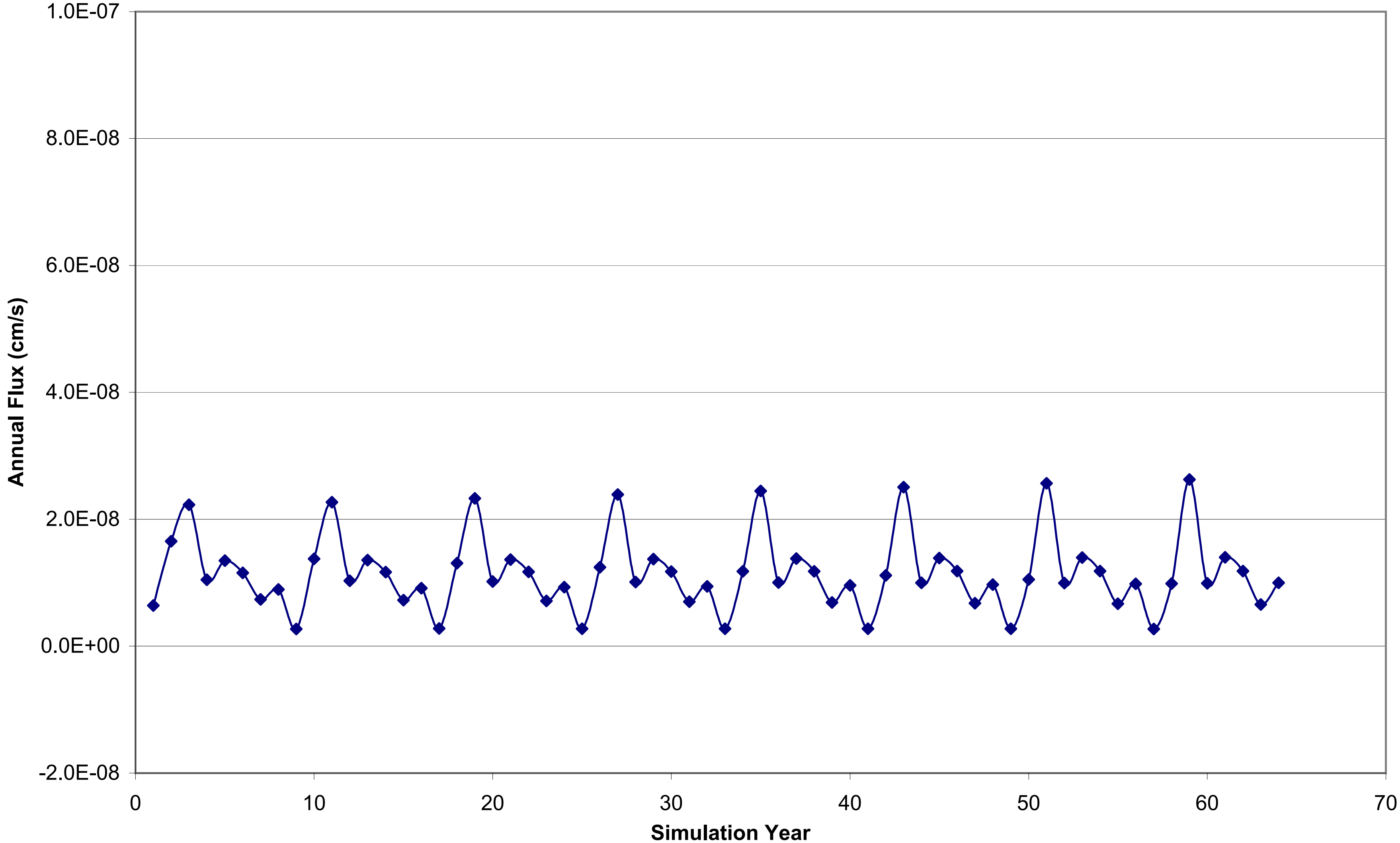

Figure 5-36 Annual Flux Through a 4-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

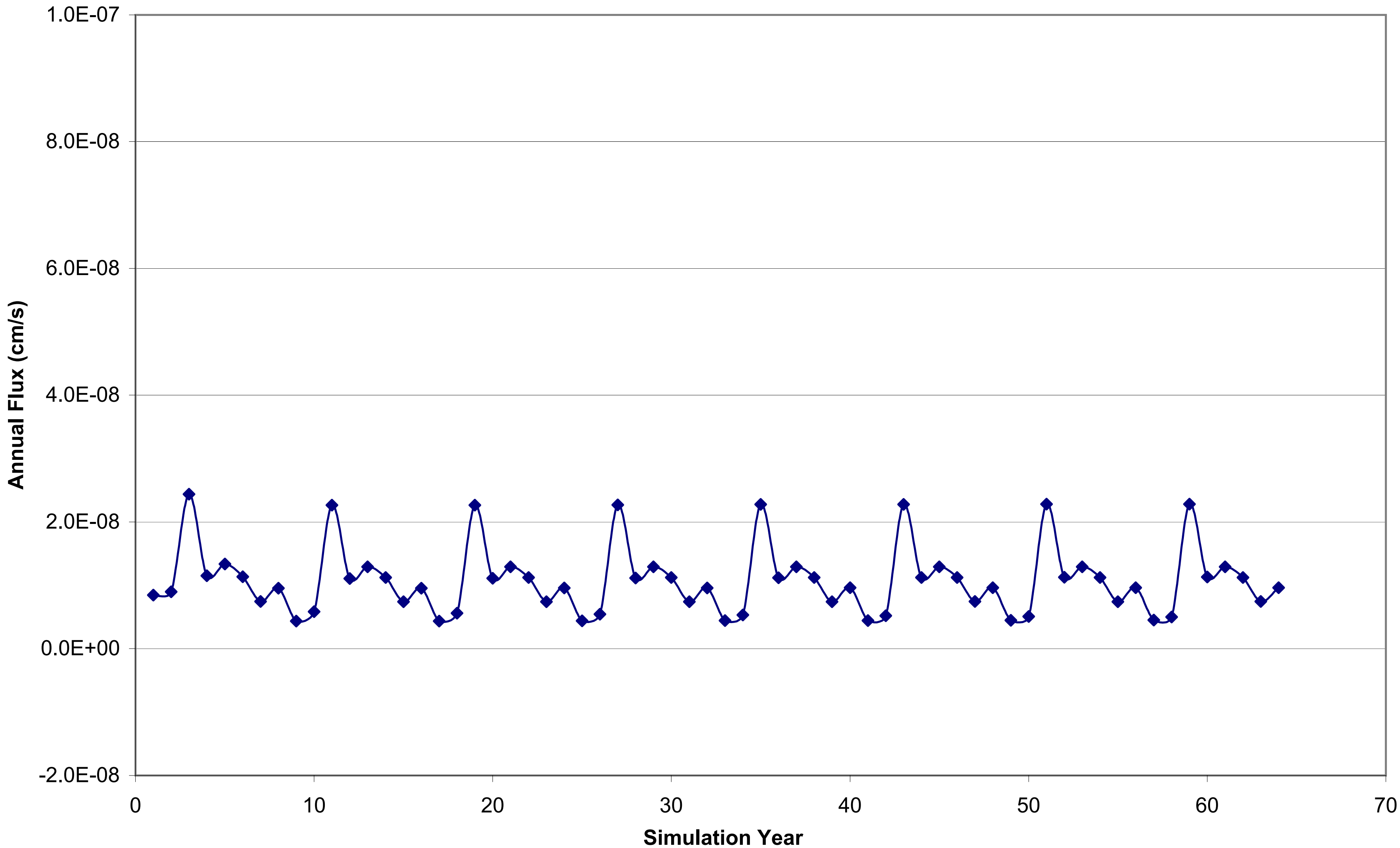

Figure 5-37 Annual Flux Through a 5-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

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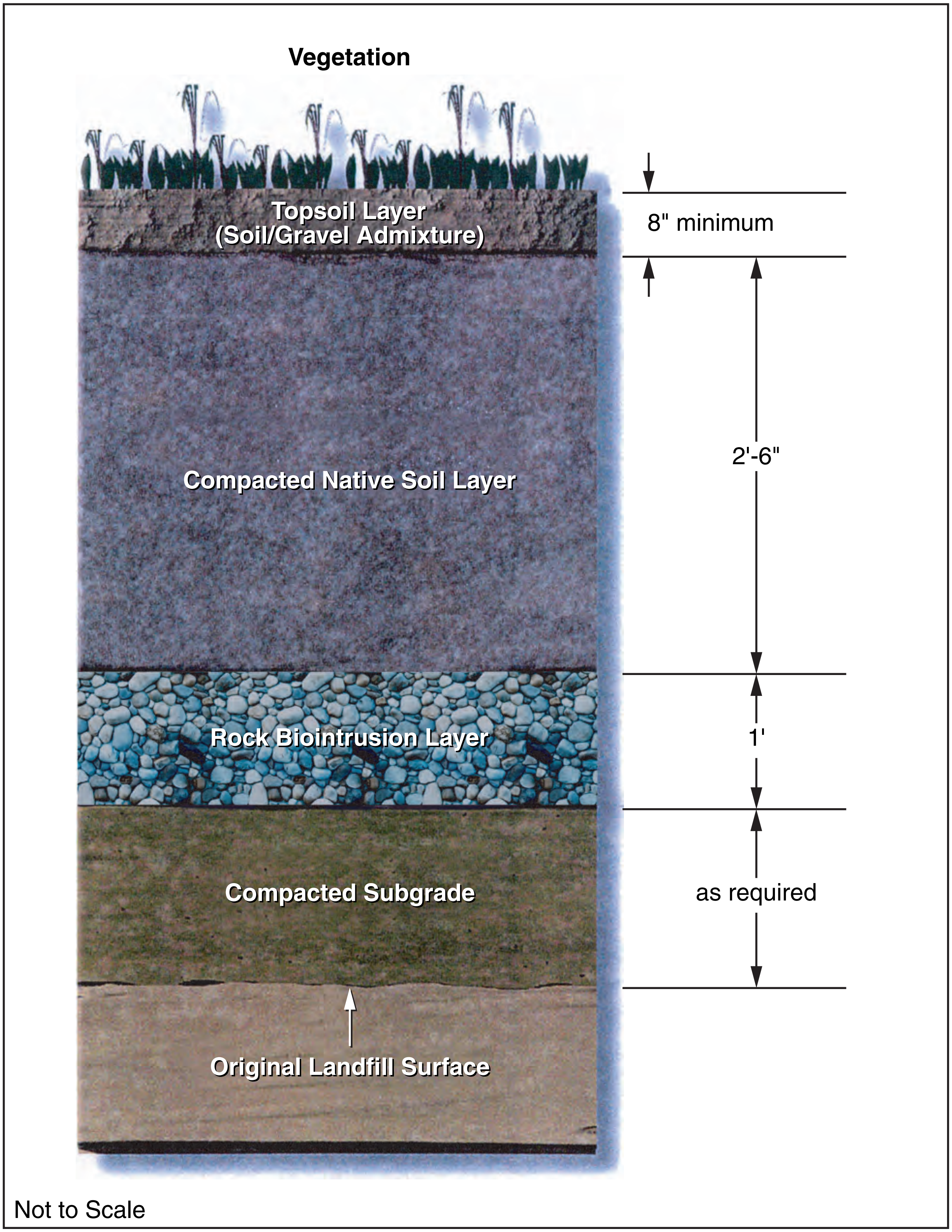

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Figure 6-1 Schematic of Mixed Waste Landfill Alternative Cover

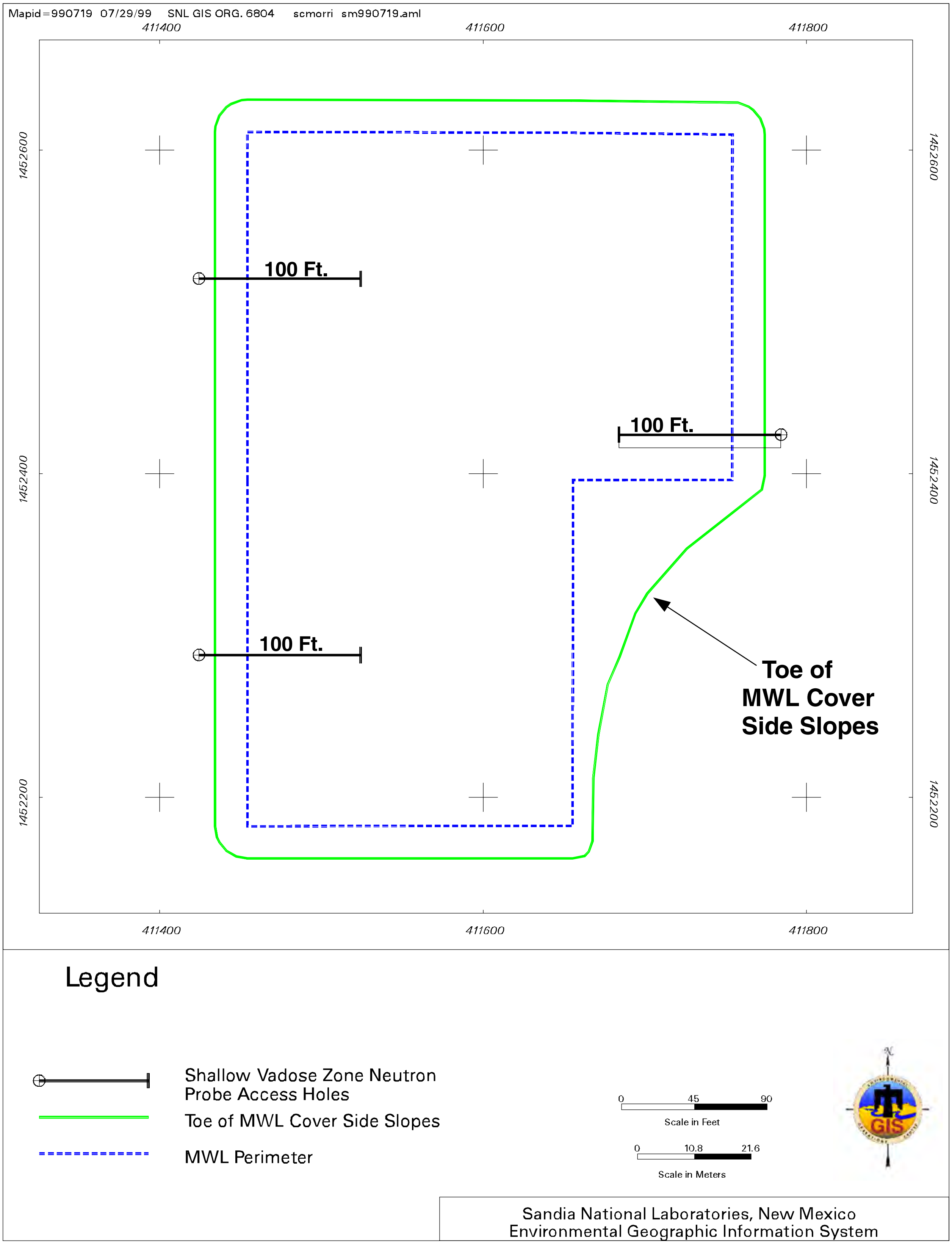

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Figure 7-1 Location of Shallow Vadose Zone Neutron Probe Access Holes

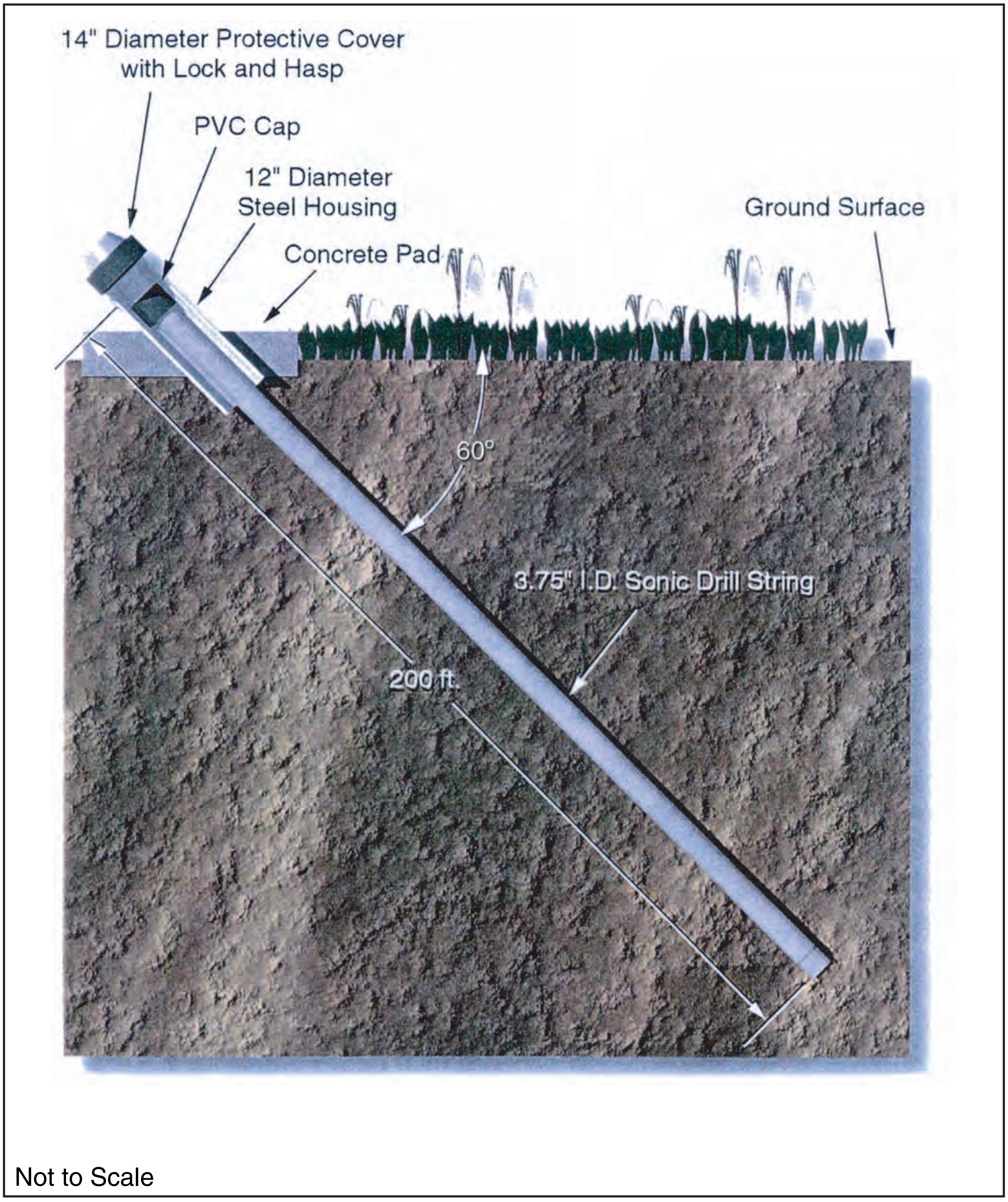

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Figure 7-2 Schematic of Vadose Zone Neutron Probe Access Holes and Casings

TABLES

Table 5-1
Hydraulic Conductivity Data for Subsurface Soil at the Mixed Waste Landfill

Sample Location	Sample/Borehole	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Laboratory
Field Measurements				
60 feet north of IP Test Site	Artificial Rainfall Test	2	5.3E-04	In Situ Field Measurement
MWL IP Test Site	IP Test	3	4.0E-04	In Situ Field Measurement
Geometric Mean of Field Measurements			**4.6E-04**	**NA**
Laboratory Measurements				
MWL Perimeter	MWL-BH-01	10	3.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	26	1.1E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	52	9.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	78	3.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	26	8.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	52	5.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	78	4.4E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-04	98	2.6E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	26	1.1E-03	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	52	1.7E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	78	7.5E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	104	9.2E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	30	2.1E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	52	8.4E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	26	6.8E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	56	1.0E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	15	4.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	36	1.6E-04	SNL Hydrology Laboratory
MWL IP Test Site	015-045	1	2.3E-05	SNL Hydrology Laboratory
MWL IP Test Site	045-075	2	2.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	075-105	3	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	105-135	4	2.0E-03	SNL Hydrology Laboratory
MWL IP Test Site	135-165	5	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	165-195	6	9.0E-04	SNL Hydrology Laboratory
MWL Test Pit Area 2	Knight Piesold 1a	0.33	3.1E-04	Knight Piesold Laboratory
MWL Test Pit Area 2	Knight Piesold 1b	1.50	2.1E-04	Knight Piesold Laboratory
Geometric Mean of Laboratory Measurements:			**1.1E-04**	**NA**

BH = Borehole.
cm/s = Centimeter(s) per second.
ft = Foot (feet).
IP = Instantaneous profile.
MWL = Mixed Waste Landfill.
NA = Not applicable.
SNL = Sandia National Laboratories.

Table 5-2
Hydraulic Conductivity Data for Mixed Waste Landfill Cover Soil at 90 Percent Compaction

Sample Location	Sample	Depth Range (ft)	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Percent Compaction	Laboratory
MWL Test Pit Area 2	Composite 2A	0–2	1	1.0E-05	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1A	0–2	1	1.1E-04	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1B	> 2	3	4.3E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas:				**3.6E-05**	**NA**	**NA**
CAMU Soil Piles	Native Soil 1 of 3	Upper 2	1	1.5E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 2 of 3	Upper 2	1	1.7E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 3 of 3	Upper 2	1	3.2E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 1 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 2 of 3	Surface to 5	3	2.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 3 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from CAMU Stockpiles:				**1.6E-05**	**NA**	**NA**
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas & CAMU Stockpiles:				**2.1E-05**	**NA**	**NA**

CAMU = Corrective Action Management Unit.
cm/s = Centimeter(s) per second.
ft = Foot (feet).
MWL = Mixed Waste Landfill.
NA = Not applicable.

Table 5-3
Summary of Input Parameters Used for HELP-3, UNSAT-H, and VS2DT Predictive Modeling

Parameter	HELP-3[a]	UNSAT-H	VS2DT
Porosity, cm^3/cm^3	0.453	0.4	0.4
Field Capacity cm^3/cm^3	0.19	NA	NA
Residual Water Content cm^3/cm^3	NA	0.08	0.08
Wilting Point cm^3/cm^3	0.085	NA	NA
Head at Wilting or Pressure Head in Roots	NA	345 ft (10508 cm)	330 ft (10,058 cm)
Air Entry Parameter Alpha	NA	0.641 ft^{-1} (0.021 cm^{-1})	0.641 ft^{-1} (α' = -1.56 ft)
Van Genuchten “n”	NA	2.00	2.00
Initial Water Content	0.085	0.0862	0.0862
Initial Head, ft	NA	80 ft (2438 cm)	80 ft (2438 cm)
Saturated Hydraulic Conductivity	2.04 ft/day	0.85 ft/day (1.08 cm/hr)	0.85 ft/day
Slope	0.02 ft/ft	0 (1-dimensional)	0 (1-dimensional)
Drainage Length	200 ft	NA	NA
Maximum Root Depth	NA	3.25 ft	3.28 ft
Evaporative Zone Depth	42 inches	NA	NA
Atmospheric Pressure Potential	NA	750 ft (22860 cm)	500 ft to 1,000 ft
Head where Transpiration Starts to Decrease	NA	165 ft (5029 cm)	NA
Temperature	Air temp varies	293°K	NA
Membrane Defects	No membrane	NA	NA

[a]HELP-3 runs used HELP-3’s default Type 6 soil because the model was very sensitive and inconsistent in its response to soil parameters.

cm = Centimeter(s).
cm^3 = Cubic centimeter(s).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
°K = Degree(s) Kelvin.
ft = Foot (feet).
hr = Hour.
NA = Not applicable.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.

Table 5-4
Summary of Mixed Waste Landfill Cover Modeling Results Using Historical Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	28.0	0.09	0.15	0.00	0.00
UNSAT-H	Cumulative Infiltration (cm)	41.5	15.00	8.44	5.79	4.15
VS2DT	Cumulative Infiltration (cm)	37.5	5.49	0.43	0.07	0.09
HELP-3	Average Flux (cm/s)	1.4E-08	4.3E-11	7.1E-11	0.0E+00	0.0E+00
UNSAT-H	Average Flux (cm/s)	2.0E-08	7.3E-09	4.1E-09	2.8E-09	2.0E-09
VS2DT	Average Flux (cm/s)	1.8E-08	2.7E-09	2.1E-10	3.6E-11	4.5E-11
HELP-3	Average Infiltration Rate (cm/yr)	0.4314	0.0014	0.0023	0.0000	0.0000
UNSAT-H	Average Infiltration Rate (cm/yr)	0.6396	0.2307	0.1299	0.0891	0.0638
VS2DT	Average Infiltration Rate (cm/yr)	0.5768	0.0844	0.0066	0.0011	0.0014
HELP-3	Maximum Volumetric Moisture Content	0.28	0.18	0.17	0.16	0.16
UNSAT-H	Maximum Volumetric Moisture Content	0.21	0.15	0.13	0.12	0.11
VS2DT	Maximum Volumetric Moisture Content	0.20	0.13	0.10	0.09	0.09

cm = Centimeter(s).
ft = Foot (feet).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
s = Second.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.
yr = Year.

Table 5-5
Summary of Mixed Waste Landfill Cover Modeling Results Using Maximum Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	35.4	0.20	0.47	0.58	0.86
UNSAT-H	Cumulative Infiltration (cm)	70.1	33.8	25.8	23.2	21.8
VS2DT	Cumulative Infiltration (cm)	77.7	19.4	3.38	0.78	0.66
HELP-3	Average Flux (cm/s)	1.8E-08	1.0E-10	2.3E-10	2.9E-10	4.3E-10
UNSAT-H	Average Flux (cm/s)	3.5E-08	1.7E-08	1.3E-08	1.1E-08	1.1E-08
VS2DT	Average Flux (cm/s)	3.8E-08	9.6E-09	1.7E-09	3.9E-10	3.3E-10
HELP-3	Average Infiltration Rate (cm/yr)	0.5539	0.0032	0.0073	0.0091	0.0135
UNSAT-H	Average Infiltration Rate (cm/yr)	1.0959	0.5277	0.4024	0.3624	0.3400
VS2DT	Average Infiltration Rate (cm/yr)	1.2144	0.3024	0.0529	0.0122	0.0104
HELP-3	Maximum Volumetric Moisture Content	0.30	0.20	0.18	0.17	0.17
UNSAT-H	Maximum Volumetric Moisture Content	0.24	0.17	0.14	0.14	0.13
VS2DT	Maximum Volumetric Moisture Content	0.22	0.15	0.12	0.10	0.10

cm = Centimeter(s).
ft = Foot (feet).
HELP-3 = Hydrologic Evaluation of Landfill Performance Model, Version 3.
s = Second.
UNSAT-H = Unsaturated Soil Water and Heat Flow Model.
VS2DT = Variably-Saturated 2-D Flow and Solute Transport Model.
yr = Year.

APPENDIX A
Construction Specifications

MIXED WASTE LANDFILL ALTERNATIVE COVER
CONSTRUCTION SPECIFICATIONS
REVISION 2
July 29, 2005

SPECIFICATION NUMBER	TITLE
01001	Definitions
01563	Temporary Diversion and Control of Water during Construction
02110	Clearing and Grubbing
02115	Biointrusion Barrier
02200	Earthwork
02210	Grades, Lines, and Levels
02221	Trenching, Backfilling, and Compaction
02445	Administrative Control Fences and Gates
02670	Monitoring Well MW-4 Extension
02930	Reclamation Seeding and Mulching

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SECTION 01001

DEFINITIONS

General Conditions	General terms and conditions for construction projects at Sandia National Laboratories, New Mexico.
Operator	Sandia National Laboratories, New Mexico
Construction Team or Contractor	Hereinafter referred to as the "Contractor." Operates separately from the Operator and the Construction Quality Assurance (CQA) Engineer. Responsible for constructing the Mixed Waste Landfill (MWL) alternative cover in strict accordance with the design criteria, specifications, design drawings, and CQA Plan using the necessary construction procedures and techniques.
Construction Quality Assurance Engineer	Hereinafter referred to as the CQA Engineer. Operates separately from the Operator and the Contractor. Responsible for activities specified in the CQA Plan (e.g., inspection, verification testing, and documentation).

END OF SECTION

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SECTION 01563

TEMPORARY DIVERSION AND CONTROL OF WATER DURING CONSTRUCTION

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment for controlling surface water and dewatering work areas prior to and throughout construction operations. Control measures implemented may include berms, swales, ditches, temporary pipes/hoses, portable pumps, silt fences, sediment traps, or any other measure approved by the Operator in accordance with this specification.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

2. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

3) Earthwork shall be in accordance with Section 02200 of these specifications.

4) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve data submittals as required by this specification.

2) Inspect work for compliance with requirements of these specifications, in addition to inspection by the Contractor and with the design drawings.

3) Review pre-placement conditions, placement of controls, and other job conditions during performance of the work.

4) Perform final inspection and acceptance of water diversion and control work.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 Equipment

1) All equipment and tools shall conform to the safety requirements of the MWL Health and Safety Plan.

2) All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and maintained in satisfactory working condition at all times.

3) The Contractor's equipment shall be adequate and capable of controlling water prior to and throughout construction as required by this specification.

2.1.2 Materials

1) All materials shall be furnished by the Contractor and shall be subject to approval by the Operator.

2) Maintenance, repairs, and replacement of materials damaged by the Contractor or his subcontractors shall be the responsibility of the Contractor.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Standing water outside the construction boundary may be allowed to infiltrate.

3.1.2 The Contractor shall manage storm water such that all construction areas shall be free of standing water. Suitable water control measures shall be constructed at all locations where construction work may be affected by surface water at the time of the work.

3.1.3 The Contractor shall divert surface water around the periphery of the construction area by constructing temporary ditches, berms, or other means of control.

3.1.4 The Contractor shall be solely responsible for the protection of work against damage, delay, or environmental impacts from water flow.

3.1.5 The Contractor shall direct and control surface water in a manner that protects adjacent structures and facilities.

3.2 WORK IN EXTREME WEATHER

3.2.1 In the event of extreme storm activity, the Contractor shall provide protective measures to prevent damage to the construction area and maintain control of runoff and run-on. During such extreme storm events, the Contractor shall protect slopes by methods approved by the Operator. The Contractor shall inspect erosion protection structures within 24 hours after extreme storm events to verify that erosion protection structures are in place and functional. To maintain the integrity of erosion prevention structures, the Contractor shall clean out, as necessary, all temporary control structures of debris and sediment buildup, and repair or replace any damaged areas either in the temporary control structures or in permanent work areas as identified by the Operator.

3.3 INSPECTIONS AND REPAIRS

3.3.1 The Contractor shall inspect temporary water control structures and materials on a regular basis and shall record inspection findings in the Daily Field Report. The inspection records shall be submitted weekly to the Operator.

3.3.2 The Contractor shall remove debris and sediment build-up from the temporary control structures as required to maintain the intended flow path.

3.3.3 Should an overflow or breach condition be encountered or any other damage observed at the temporary water control structures, repair and/or replacement of the damaged area shall be completed by the Contractor.

3.3.4 Acceptance criteria for repaired and/or replaced temporary water control structures shall be in accordance with the requirements of this section.

3.4 REMOVAL OF TEMPORARY CONTROL MEASURES

Temporary storm water control measures shall be removed once the work has been completed and as approved by the Operator. The materials removed shall be properly disposed of by the Contractor, at locations designated by the Operator. All areas where temporary control structures are removed shall be regraded and revegetated in accordance with Sections 02200 and 02930 of these specifications.

3.5 ACCEPTANCE

The Contractor shall submit a description of any repair or replacement work required to the Operator prior to implementation. Acceptance criteria for repaired or replaced water control measures shall be in accordance with the requirements of this specification.

END OF SECTION

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SECTION 02110

CLEARING AND GRUBBING

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment, and shall perform clearing and grubbing during construction activities in accordance with this specification and as shown on the design drawings.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

3) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve submittals as required for this specification.

2) Designate items that require salvage, storage, reuse, and/or relocation.

3) Perform final inspection and confirm acceptance of clearing and grubbing.

4) In addition to inspection by the Contractor, the Operator and/or the CQA Engineer may inspect work for compliance with the requirements of this specification.

1.2 SUBMITTALS

1.2.1 Procedures, Certifications, and Records

The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can review work for compliance with the requirements of this specification and make CQA decisions in real-time.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition by the Contractor at all times.

2.1.2 The Contractor's equipment shall have the capability to perform the indicated clearing and grubbing specified herein.

2.1.3 The Contractor shall ensure that all equipment used for clearing and grubbing work is fitted with appropriate safety devices that comply with all applicable Federal laws and the MWL Health and Safety Plan, and that will adequately protect equipment operators and minimize exposure of site workers and others.

2.2 ITEMS SALVAGED FOR REUSE, STORAGE, OR RELOCATION

The Operator will designate items that require reuse, storage, or relocation.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Site Inspection

The Contractor shall inspect the site to determine the nature, location, size, and extent of vegetative material, debris, and obstructions to be removed or preserved, as specified herein.

3.1.2 Traffic

The Contractor shall conduct clearing and grubbing operations to ensure minimum interference with roads, walks, and adjacent facilities. The Contractor shall not close or obstruct roads, walks, or adjacent operational facilities without written permission from the Operator.

3.1.3 Protection of Existing Structures and Facilities

The Contractor shall provide protection necessary to prevent damage to the existing structures and facilities which are to remain in place. The Contractor shall restore or replace damaged property to original condition, or to the satisfaction of the Operator.

Items damaged in removal shall be repaired and refinished, or replaced by the Contractor with new matching items as required by the Operator.

3.1.4 Salvageable Items

Items damaged in removal shall be repaired, refinished, or replaced by the Contractor with new matching items as required by the Operator. The Contractor shall save and protect from construction damage all vegetative materials (shrubs, grass, and other vegetation) beyond the limits of the required clearing and grubbing. The Contractor shall restore or replace damaged vegetative materials to the conditions as required by the Operator, in accordance with Section 02930 of these specifications.

3.1.5 Protection of Monuments and Other Permanent Surface Features

The Contractor shall locate and mark existing monuments, monitoring wells, stanchions, and markers before construction operations commence and shall protect such items during construction. The Contractor shall restore or replace damaged items to original condition as required by the Operator.

3.2 CLEARING AND GRUBBING

3.2.1 Clearing and Grubbing

The Contractor shall clear the site of shrubs, vegetation, rocks and debris as required within the limits of the landfill cover, laydown and stockpile areas south of the MWL. Roots exceeding 1 inch in dimension, as well as rocks and other debris exceeding 2 inches in dimension in the top 6 inches of the existing site grade shall be removed by hand or mechanical means. Removal methods shall minimize the disturbance of soils below 6 inches in depth. Clearing and grubbing shall conform to the Radiological Work Permit (RWP).

3.2.2 Reclamation Seeding and Mulching

The Contractor shall seed and mulch disturbed areas in accordance with Section 02930 of these specifications.

3.3 DISPOSAL OF WASTE AND DEBRIS MATERIALS

3.3.1 Organic Material

Organic materials, including grass, shrubs, stumps, roots, and other organic debris removed due to clearing activities, shall be transported by the Contractor to a stockpile/disposal site designated by the Operator. The stockpile/disposal site shall be located within ¼ mile of the project area. Organic material shall be stockpiled or disposed of as directed by the Operator.

3.3.2 Disposal

The Contractor shall remove all materials not designated for relocation, reuse, or salvage. These materials shall be disposed of or stockpiled as directed by the Operator.

3.4 DAMAGED AREAS

The Contractor shall confine clearing and grubbing operations to within those areas required for cover construction or as directed by the Operator. Any areas outside the designated areas that are damaged or disturbed by the Contractor's operations shall be reclaimed by the Contractor. Reclamation shall be in accordance with Section 02930 of these specifications.

3.5 ACCEPTANCE

Clearing and grubbing not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor at the Contractor's expense. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for approval before use. Acceptance criteria for repaired and/or replaced clearing and grubbing shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02115

BIOINTRUSION BARRIER

PART 1 GENERAL

1.1 TOPOGRAPHIC SURVEY

A topographic survey shall be performed immediately prior to and after placement of the biointrusion barrier in order to document as-built conditions and elevations. Ground elevations shall be determined to the nearest 0.1 ft using conventional ground surveying techniques.

1.2 DESCRIPTION OF WORK

This section describes the requirements for placement of crushed rock directly on the subgrade layer for use as a biointrusion barrier to discourage small and large burrowing mammals from penetrating the cover. Crushed rock for use as a biointrusion barrier will be provided by the Operator in stockpiles located south of the MWL.

PART 2 BIOINTRUSION BARRIER MATERIAL

The biointrusion barrier material shall consist of crushed rock of stone size so that 50 percent of the fragments, by weight, shall be larger than the D_{50} = 4-inch size. The graded material shall be a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the larger rock fragments. The diameter of the largest rock fragment in such a mixture shall be 6 inches (1.5 times the D_{50} = 4-inch size).

PART 3 EXECUTION

3.1 PLACEMENT

The biointrusion barrier shall be placed in a single lift directly on the subgrade layer. The completed biointrusion barrier layer shall be a minimum of 1 ft in thickness and not exceed 1.25 ft in thickness.

3.2 COMPACTION

The biointrusion barrier material shall be compacted using heavy equipment approved by the Operator prior to use. Compaction shall consist of repeated passes over all areas where biointrusion barrier material has been placed until the crushed rock fragments are firmly locked in place. The compaction equipment shall be operated at a speed that prevents displacement of the biointrusion barrier material.

END OF SECTION

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SECTION 02200

EARTHWORK

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment for all types of earthwork to be performed during the construction activities in accordance with this specification and as shown in the design drawings. Earthwork includes grading and placement of all earthen cover materials, disposal of unsuitable materials, and reclamation of areas designated by the Operator.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

5) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

6) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve submittals as required by this specification,

2) Review and approve results of quality assurance tests and surveying performed for compliance with this specification,

3) Document and monitor corrective actions,

4) Identify the acceptable borrow areas and soil stockpiles,

5) Have the option to approve all compaction equipment prior to use,

6) Have the option to inspect and approve surface conditions prior to placement of fill and crushed rock,

7) Have the option to inspect and approve all fill and crushed rock prior to placement, and

8) Have the option to perform final inspection and confirm acceptance of earthwork.

1.2 SUBMITTALS

1.2.1 Procedures, Certifications, and Records

The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can review work for compliance with the requirements of this specification and make CQA decisions in real-time.

1.3 QUALITY ASSURANCE

The Contractor shall prepare, maintain, and use a written QA/QC Manual for the work performed. The QA/QC Manual shall include requirements to ensure the application of the latest design documents and the incorporation of approved changes. As a minimum, the Contractor shall record and maintain appropriate data that verify the quality of materials, the application of approved procedures, and performance of tests and inspections. The Contractor shall maintain appropriate written approval signatures for acceptance of work performed.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIALS

2.1.1 Equipment

1) All equipment and tools shall comply with the safety requirements of the MWL Health and Safety Plan.

2) All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition at all times. All compaction

equipment shall be inspected for acceptance by the Operator prior to the start of construction.

3) The Contractor's equipment shall be adequate for and have the capability to produce the requirements specified herein. Compaction equipment shall be appropriate to compact the fill as specified by the manufacturer.

2.1.2 Fill

Fill shall be from an Operator-designated soil stockpile or borrow area and shall be free of plants, rubble, litter, insect infestation, and other deleterious matter and be free of rocks larger than 2-inches in dimension.

1) Subgrade fill shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Subgrade fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 - 100
#40	70 - 100
#200	20 - 40

2) Crushed rock for the biointrusion barrier shall be obtained from the stockpile south of the MWL. The material shall have a minimum dimension of 1 inch and be free of all fine material. The crushed rock will be free of organic material, soft and friable fragments, and other objectionable materials as determined by the Operator. The maximum fragment size of the biointrusion barrier shall be 6 inches with D_{50} = 6 inches, and each fragment shall have 100 percent fracture face.

3) Native Soil Layer fill shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Native Soil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 – 100
#40	70 – 100
#200	20 – 40

4) Topsoil Layer soil shall be obtained from the TA-3 borrow pits soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Topsoil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	90 - 100
#40	85 - 100
#200	20 - 45

The Topsoil Layer fill shall be admixed with 3/8-inch, crushed gravel 25 percent by volume, before placing and grading. The gravel is to be clean with no more than 5 percent passing the #4 sieve.

5) Pre-acceptance QC testing of fill soils shall be in accordance with Section 3.4 of this specification. Acceptance of materials with variations from this classification will be evaluated by the CQA Engineer and the Operator.

PART 3 EXECUTION

3.1 PROTECTION AND SAFETY

The Contractor shall keep all operational areas adjacent to or part of this project usable at all times. The Contractor shall provide all necessary measures for the protection of the workers and the public, as per the standards established by the Operator or the Occupational Safety and Health Administration (OSHA).

3.1.1 The Contractor shall provide protection necessary to prevent damage to existing structures indicated in the design drawings or indicated by the Operator to remain in place. The Contractor shall restore damaged property to original condition, and obtain written approval of repairs from the Operator.

3.1.2 The Contractor shall clearly mark all laydown areas.

3.1.3 The Contractor shall mark or otherwise indicate the location of existing monuments and markers, and protect these structures before construction operations commence. The Contractor shall be responsible for the marking and/or protection of all necessary objects.

3.1.4 During earthwork operations, a representative of the Contractor shall be present at all times to observe work and notify the CQA Engineer and Operator immediately upon the discovery of any deviations from this specification.

3.2 EXISTING UTILITIES

3.2.1 There may be existing utilities within the limits of the construction or borrow areas. Known utilities shall be identified by the Operator and the utilities protected by the Contractor. The Operator shall be immediately notified of utilities not shown on the design drawings.

3.3 INSTALLATION OF COVER MATERIALS

3.3.1 General Requirements

1) The Contractor shall ensure that the stockpiling and handling of fill and crushed rock is confined within the limits of the designated work area. Stockpiling of clean imported material shall be confined to the Contractor's laydown and storage area as approved by the Operator. Stockpiled materials shall have stable slopes and be evenly graded and self-draining. Materials shall be stockpiled in such a way that any storm water can be controlled to prevent escape of excessive fill from the stockpile area.

2) The Contractor shall place all materials to the lines, grades, and elevations as shown in the design drawings and as specified in Section 02210 of these specifications.

3) The Contractor shall not begin placement of fill or crushed rock until after acceptance by the CQA Engineer and the Operator of the existing landfill surface or layer and placement conditions for all underlying layers.

4) The Contractor shall not place fill or crushed rock on frozen surfaces, in standing water, or when fill contains snow or ice.

5) The Contractor shall operate compaction equipment so that structures or underlying instrumentation are not damaged or overstressed during placement operations. The Contractor shall use hand-operated mechanical tampers for compaction of fill and crushed rock adjacent to wells or instrumentation wherever rolling compaction equipment is impractical for use.

6) The Contractor shall use placement methods which ensure the integrity of the underlying fill and crushed rock.

7) The Contractor shall slope temporary grades to direct water away from the construction area to reduce the potential for ponding of water. The Contractor shall provide erosion protection as specified in Section 01563 of these specifications.

8) Previously approved compacted subgrade, lifts, or layers disturbed by subsequent construction operations by the Contractor or adverse weather shall

be reworked to the required placement conditions specified herein or to the satisfaction of the CQA Engineer and Operator.

9) Application of water for dust suppression activities shall comply with Section 01563 of these specifications. Standing water will be minimized during dust suppression operations.

10) The Contractor shall ensure that unsuitable materials shall not enter the construction area.

3.3.2 Fill

1) The Contractor shall perform field-testing of the compacted materials in accordance with Section 3.4 of this specification. The Contractor shall submit results of the testing to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

2) The Contractor shall take care to avoid disturbance of the underlying lifts, layers, and instrumentation.

3) The Contractor shall reclaim borrow areas in accordance with Section 02930 of these specifications. Borrow areas shall be regraded to minimize erosion and sustain vegetation.

3.3.3 Existing Landfill Surface

1) The existing grade shall be prepared as required in Sections 02110 of these specifications.

2) The existing grade shall be scarified to a depth not to exceed 6 inches.

3) The contractor shall remove all rock and debris greater than 2 inches in dimension in preparation for compaction.

4) The Contractor shall moisten the soil to approximate optimum moisture (-2 to +2 percentage points) and compact/proof-roll the surface utilizing 10 passes of a roller. Depressions that are formed with the proof-rolling shall be filled with moistened, clean fill, and the filled area recompacted with 10 passes of the roller. The roller shall have a minimum total ballasted weight of 25 tons and a minimum pneumatic tire pressure of 90 psi. No proof rolling shall be allowed within a 2-ft radius of any groundwater monitoring well, measuring device, or other placed surface as designated by the Operator and/or CQA Engineer.

3.3.4 Subgrade

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain fill.

2) Subgrade fill may be stockpiled at an Operator-approved location at the MWL.

3) The Contractor shall remove all rock and debris greater than 2 inches in dimension from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

7) The Contractor shall take care to minimize disturbance to underlying lifts.

8) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.5 Biointrusion Barrier

1) The biointrusion barrier stockpile, located south of the MWL, shall be used to obtain crushed rock for the biointrusion barrier.

2) The biointrusion barrier shall be constructed using a graded, crushed rock. Crushed rock shall be of stone size so that 50 percent of the fragments, by weight, shall be larger than the D_{50} = 4-inch size. The graded material shall be a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the larger rock fragments. The diameter of the largest rock fragment in such a mixture shall be 6 inches (1.5 times the D_{50} = 4-inch size).

3) The Contractor shall place the crushed rock at a minimum of 1 ft in thickness and not exceed 1.25 ft in thickness.

4) The Contractor shall compact the crushed rock layer until the crushed rock fragments are firmly locked in place. Compaction equipment shall be operated at a speed that prevents displacement of the biointrusion barrier material.

3.3.6 Native Soil Layer

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain Native Soil Layer fill.

2) Native Soil Layer fill may be stockpiled at an Operator-approved location at the MWL.

3) The contractor shall remove all rock and debris greater than 2 inches in dimension from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform hydraulic conductivity testing on samples obtained from each lift as it is constructed. Samples shall be obtained by means of a thin-walled sample tube or equivalent sampling device in a manner that minimizes disturbance to the lift and in the direction perpendicular to the plane of compaction. Samples shall be sealed and carefully stored to prevent drying during storage and transport. Hydraulic conductivity testing shall be performed in the laboratory according to ASTM specifications for rigid wall testing.

7) The hydraulic conductivity of the samples from each lift shall have a target maximum value of 4.6×10^{-4} cm/s, the estimated hydraulic conductivity of the underlying natural soils. It is expected that approximately 5 percent of the hydraulic conductivity tests will fail to meet the target value of 4.6×10^{-4} cm/s. The failing samples shall have a hydraulic conductivity no greater than one-half order of magnitude above the target value.

8) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to initiation of placement of subsequent lifts.

9) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full

depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.7 Topsoil Layer

1) The TA-3 borrow pits , located approximately 1.5 miles south of the MWL, shall be used to obtain topsoil.

2) Topsoil may be stockpiled at an Operator-approved location at the MWL.

3) The topsoil shall be admixed with 25 percent, by volume, 3/8-inch crushed gravel.

4) The Contractor shall place topsoil in a minimum 8-inch loose lift.

5) Topsoil shall be minimally compacted to facilitate root development.

6) The Contractor shall take care to minimize disturbance to the underlying layer.

3.4 TESTING

3.4.1 General

The Contractor shall be responsible for the performance of all pre-acceptance and quality control testing. The Contractor shall submit test results in accordance with the requirements of this specification and the MWL CQA Plan to the Operator and/or the CQA Engineer as soon as this information is available so that the Operator and/or the CQA Engineer can review work for compliance with the requirements of this specification and make CQA decisions in real-time. Test results shall be provided from an approved independent soils testing laboratory.

3.4.2 Fill and Borrow Area Testing

The Contractor shall submit results for the following tests conducted during construction:

1) Subgrade Layer: Standard Proctor (ASTM D698), Gradation (ASTM C136), Classification (ASTM D2487 and D4318)

2) Native Soil Layer: Standard Proctor (ASTM D698), Gradation (ASTM C136), Classification (ASTM D2487 and D4318), Saturated Hydraulic Conductivity (ASTM rigid wall testing)

3) Topsoil Layer: Gradation (ASTM C136), Classification (ASTM D2487 and D4318)

The CQA Engineer and Operator shall review and accept submittals pertaining to testing prior to the transportation and placement of fill.

3.4.3 Field Placement Testing

The Contractor shall be responsible for the performance of all field testing and for confirmation of placement conditions. The Contractor shall submit all field test data for review and approval by the CQA Engineer and Operator. Table 3.1 outlines the material type, test methods, and test frequency for field placement activities.

3.5 INSPECTION

3.5.1 The Contractor shall be responsible for pre-operation, operation, and post-operation inspection during the performance of all work.

3.5.2 The Operator reserves the right to inspect all work for compliance with this specification.

3.6 ACCEPTANCE

The Contractor shall be responsible for documenting all test results and the number of compaction passes completed per lift. Placed materials not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced materials shall be in accordance with the requirements of this specification.

Areas that do not conform to the compaction specifications will be first investigated by the Contractor for the extent of the non-conformance. Areas that are of a different material type or that have failed the specifications after efforts to recompact the fill shall undergo additional testing regardless of the testing frequency guidelines. The Operator will determine when additional testing is required. Additional testing may include Standard Proctor and Gradation tests. Results of additional testing shall be submitted to the Operator for review. Following review of the testing results, the Operator shall determine whether a new moisture-density relationship curve shall be developed or if the Contractor shall continue to rework the non-conforming areas to meet specifications. If a new moisture-density relationship curve is produced for a change in soil type, all tests outlined in Table 3.1 shall be conducted for the new material type.

Final acceptance shall be explicitly detailed by survey location, layer description, material type, and lift number. A final report shall be submitted by the Contractor within 30 calendar days after final acceptance of the cover, detailing all field survey and quality control information performed during construction operations.

TABLE 3.1

Testing Methods and Frequencies for Borrow and Fill Areas

Item	Test Method	Frequency
Existing landfill surface	No Field Testing	Not applicable
Borrow Area Testing:		
Subgrade	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487)	1/500 cubic yards
	Standard Proctor (ASTM D698)	1/500 cubic yards
Fill Area Testing:		
Subgrade	Field Density and Moisture Testing (ASTM D2922 and ASTM D3017)	5/acre/lift
Borrow Area Testing:		
Native Soil Layer	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487 and D4318)	1/500 cubic yards
	Standard Proctor (ASTM D698)	1/500 cubic yards
Fill Area Testing:		
Native Soil Layer	K_{sat} (saturated hydraulic conductivity)	1/acre/lift
	Field Density and Moisture Testing (ASTM D2922 and ASTM D3017)	5/acre/lift
Borrow Area Testing:		
Topsoil Layer	Gradation (ASTM C136)	1/500 cubic yards
	Classification (ASTM D2487 and D4318)	1/500 cubic yards
Fill Area Testing:		
Topsoil Layer	No Field Testing	

END OF SECTION

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SECTION 02210

GRADES, LINES, AND LEVELS

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment to perform surveying. The Contractor shall perform surveying to ensure that the proper grades, lines, and levels are established as set forth in these specifications and as shown in the design drawings. The Operator may procure an independent survey, provided by an independent firm registered in the State of New Mexico, to verify construction surveys. Construction surveys may be completed by the Contractor or an independent firm provided the work is completed under the supervision of a Registered Land Surveyor in the State of New Mexico.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be performed in accordance with Section 02110 of these specifications.

2) Earthwork shall be performed in accordance with Section 02200 of these specifications.

3) The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

5) Monitoring Well MW-4 Extension shall be performed in accordance with Section 02670 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required for this specification,

2) Provide Contractor with SNL/NM survey grid information,

3) Provide two benchmarks near the landfill, as shown in the design drawings,

4) Inspect work for compliance with the requirements of this specification in addition to inspection by the Contractor,

5) Verification of “as constructed” survey of the final cover closure surface,

6) Perform final inspection and confirm acceptance of surveying work.

1.2 REFERENCE DOCUMENTS

SNL/NM topographic grid and MWL design drawings.

1.3 SUBMITTALS

1.3.1 Procedures

1) The Contractor shall submit a plan for the work, including descriptions of survey equipment, procedures used to establish temporary or permanent benchmarks or measurements, field notes, calculations, reductions, closures, and documentation for any benchmarks or monuments to the Operator for approval.

2) Data shall be reduced and plotted by the Contractor in a form acceptable to the Operator. Legible notes, drawings, and reproducible documentation shall be submitted to the Operator for approval. The Contractor shall supply the following survey data to the Operator for approval:

    A) Topography map of final grade of each of the intermediate layers of the cover (Subgrade, Biointrusion Barrier, Native Soil Layer) with a contour interval of 0.5 feet and the location, as appropriate, of groundwater monitoring wells and instrumentation.

    B) Topography map of the final grade of the cover with a contour interval of 0.5 feet and the location, as appropriate, of groundwater monitoring wells and instrumentation.

3) All topography plats and all project benchmarks shall be based upon the SNL/NM grid. In addition to the above noted submittals, all plats shall also be submitted in electronic microstation or autocad format.

4) The Contractor shall not proceed with placement of an overlying layer or with subsequent work phases until the surveyor has completed the survey of the existing layer measurements and the data have been reviewed and accepted by the Operator.

1.3.2 Certifications

The Contractor shall submit a letter to the Operator after completion of the work specified herein, verifying conformance to the requirements identified in this specification. The letter shall be prepared and executed by a Professional Land Surveyor registered in the State of New Mexico.

1.3.3 Records

The Contractor shall submit to the Operator for information, all field notes from surveying and layout activities.

1.4 QUALITY ASSURANCE

The Contractor shall be responsible for protecting and maintaining all horizontal and vertical control points during construction.

1.4.1 Accuracy

Optical survey, tape measurement, and electronic measurement shall have a minimum accuracy of ± 0.1 feet in horizontal locations and ± 0.01 feet in elevations, or as superseded by criteria set forth in other sections of these specifications.

1.4.2 Tolerances

The Contractor shall survey all finished layers within the tolerances specified below:

Description	**Tolerances**
Subgrade:	-0.00 to +0.25 feet
Biointrusion Barrier	-0.00 to +0.25 feet
Native Soil Layer	-0.00 to +0.25 feet
Topsoil Layer	-0.00 to +0.25 feet

The Contractor shall ensure that no low points capable of retaining water are present in the final cover surface. If any low points are identified, the Contractor shall repair such locations.

PART 2 PRODUCTS

None.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 All surveying shall be recorded in the New Mexico State plane central zone NAD 27.

3.1.2 The Contractor shall check and verify that as-built thickness and elevations match those shown in the design drawings based on site benchmarks, and prepare as-built drawings of the cover.

3.1.3 The Contractor shall be responsible for controlling lift thickness and individual layer thickness such that overall cover thickness conforms to the specified tolerances. The Contractor shall be responsible for establishing, recording, protecting, and maintaining all permanent and temporary horizontal and vertical control benchmarks.

3.2 SURVEY MEASUREMENTS

3.2.1 Prior to commencement of construction work, the Contractor shall establish survey control at the construction area.

3.2.2 Survey control points shall be established so that any point within the construction area can be accurately re-established and elevations can be obtained to the required tolerances at any time during the course of construction. The Contractor shall verify all baselines, and horizontal and vertical control benchmarks stipulated in the information provided by the Operator.

3.3 ACCEPTANCE

3.3.1 Surveying work not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the corrective action methods to the Operator for approval before use. Acceptance criteria for corrected actions shall be in accordance with the requirements of this specification.

3.3.2 In the event of a survey discrepancy, the area in question shall be re-surveyed and verified at no cost to the Operator.

END OF SECTION

SECTION 02221

TRENCHING, BACKFILLING, AND COMPACTING

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The Contractor shall furnish all materials, labor, tools, and equipment to complete trenching, backfilling, and compacting necessary during construction activities for installing drainage swales.

1.1.2 <u>Related Work Specified Elsewhere</u>

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3. The Biointrusion Barrier shall be placed in accordance with Section 02115 of these specifications.

4) Earthwork shall be in accordance with Section 02200 of these specifications.

5) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

6) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 <u>Work to be performed by the Operator and/or CQA Engineer:</u>

1) Review and approve data submittals required by this specification,

2) Have the option to perform final inspection and acceptance of trenching, backfilling, and compacting.

PART 2 <u>GENERAL REQUIREMENTS</u>

2.1 The Contractor shall be responsible for trenching, backfilling, and compacting.

2.2 The Contractor shall contain trenching, backfilling, and compacting operations within the designated areas, layers, and lifts as indicated in the design drawings. If conditions encountered warrant modification to the designated limits, the Operator shall be notified prior to proceeding.

2.3 The Contractor shall perform trenching, backfilling, and compacting operations in a manner that maintains drainage and control of water at all times, in accordance with Section 01563, Temporary Diversion and Control of Water during Construction.

PART 3 DRAINAGE SWALE EXCAVATION

3.1 The Contractor shall excavate the drainage swale to the required cross-section and grade shown in the design drawings.

3.2 The Contractor shall take care to avoid excavating the drainage swale below the grade indicated except where unsuitable materials are encountered as defined by the Operator. Areas where existing grade is less than that required in the design drawings shall be backfilled to grade.

3.3 The Contractor shall ensure positive drainage of the drainage swale.

3.4 The drainage swale shall be revegetated in accordance with Section 02930.

3.5 The drainage swale shall be maintained by the Contractor until final acceptance of the work.

PART 4 INSPECTION

4.1 The Contractor shall be responsible for in-process inspection during performance of all work.

4.2 In addition to inspection by the Contractor, the CQA Engineer and/or Operator shall inspect all work for compliance with the requirements of this specification.

PART 5 ACCEPTANCE

Trenching, backfilling, and compacting not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced trenching, backfilling, and compacting shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02445

ADMINISTRATIVE CONTROL FENCES AND GATES

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment to construct administrative control fences and gates in accordance with this specification and as shown in the design drawings. Fence material shall be produced and installed by methods recognized as good commercial practices.

1.1.2 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve data submittals required by this specification;

2) Have the option to inspect work for compliance with the requirements of this specification, in addition to inspection by the Contractor;

3) Have the option to review pre-installation conditions, installation, and other job conditions during performance of the work, and;

4) Have the option to perform final inspection and confirm acceptance of administrative control fences and gates.

1.2 REFERENCE DOCUMENTS

None.

1.3 SUBMITTALS

1.3.1 Data

The Contractor shall submit the proposed administrative control fence, gate, and sign materials to the Operator for written approval prior to procurement.

1.3.2 Test Reports

None.

1.3.3 Procedures

The Contractor shall submit a description of methods for repair and/or replacement of administrative control fences and gates that are not in accordance with the requirements of this specification to the Operator for written approval before use.

1.3.4 Certifications

The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification and as shown in the design drawings.

1.3.5 Records

1) The Contractor shall submit records of inspection to the Operator after completion of the inspection. Inspection records shall include on-site inspection records of the administrative control fences and gates.

2) The Contractor shall submit to the Operator for information all field notes from surveying and layout activities after completion of these activities.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 General

1) Administrative control fences shall be strand barbed wire with tee posts driven into the ground and steel corner posts set in concrete.

2) All fence materials shall be galvanized in accordance with ASTM A123, A384, and A385.

3) All fence items shall be the product of an established fence manufacturer.

2.2.2 Barbed Wire

1) Barbed wire shall conform to ASTM A121 with a Class 1 coating.

2) Fence shall consist of 3 horizontal runs of barbed wire spaced as shown in the design drawings.

3) Barbed wire shall be No. 12-1/2 gauge, 2-strand, copper-bearing, hot-galvanized steel wire with large, four-point-pattern, hard-tempered, round barbs spaced 5 inches apart.

4) Tie wires for fastening barbed wire to steel posts shall be No. 12 gauge copper-bearing steel wire. Tie wires shall be heavily galvanized by the hot-dip process.

5) Stays shall be No. 9 gauge copper-bearing steel wire conforming to the requirements of ASTM A116. Stays shall be 42 inches long.

2.2.3 Posts

1) End and corner posts shall be nominal 2-1/2-inch diameter standard galvanized pipe per ASTM A53, Type S, Grade B, or Operator approved equivalent.

2) Tee posts shall be fabricated from rail, billet, or commercial grade steel which conforms to the requirements of ASTM A702.

2.2.4 Gates

1) All gates, hardware, and accessories for installation of the gates shall be furnished and installed by the Contractor.

2) Hinges shall be pivot-type, galvanized and industry standard size to suit gate size as shown in the design drawings. Hinges shall be non-lift-off type and offset to permit 180-degree gate opening. Each gate leaf shall be provided with 2 hinges.

3) Gates shall be galvanized high carbon-welded, 2-inch diameter, tubular steel 40 inches high, or Operator approved equal, with internal bracing. Gate fabric shall be No. 14 gauge copper-bearing open-hearth steel wire, woven in a 2-inch by 4-inch mesh, and heavily galvanized by the hot-dip process after weaving.

4) Gate posts shall be nominal 2-1/2-inch diameter standard galvanized steel pipe.

2.2.5 Bracing

All end and corner posts shall be braced by means of diagonal trusses. Trusses shall be hot-galvanized 3/8-inch steel rod complete with turnbuckles.

PART 3 EXECUTION

3.1 FOOTINGS

3.1.1 General

1) All corner and end posts shall be set and centered in a concrete encasement to the diameters and depths shown in the design drawings.

2) Concrete footings shall be neatly domed off at the finish grade line to shed water from the posts.

3) Concrete shall have a minimum 28-day strength of 3000 psi.

3.2 ERECTION OF FENCING

3.2.1 General

1) The Contractor shall assemble and erect fences and gates as specified herein and in the design drawings, and in accordance with detailed instructions furnished by the fence manufacturer.

2) Where necessary, the Contractor shall adjust the grade of the fence to fit the contour of the ground. The Operator shall be notified prior to any grading of surface soils.

3.3 ACCEPTANCE

Installation of fences and gates not in accordance with the materials and method requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired fences and gates shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02670

MONITORING WELL MW-4 EXTENSION

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all labor, tools, and equipment necessary to extend groundwater monitoring well MW-4 in accordance with this specification and as shown in the design drawings. The Operator shall provide the Contractor with the materials necessary for extension of monitoring well MW-4.

1.1.2 Related Work Specified Elsewhere

Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required by this specification,

2) Inspect and approve existing conditions prior to extension of monitoring well MW-4.

3) Perform final inspection and confirm acceptance of monitoring well MW-4 extension.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 General

The components, materials, and configuration required for monitoring well extension are shown in the design drawings.

PART 3 EXECUTION

3.1 Monitoring Well MW-4 Extension

1) The Contractor shall remove the existing MW-4 concrete pad, stanchions, protective casing, and locking top cap prior to initiation of construction activities.

2) The Contractor shall complete the well extension utilizing acceptable PVC construction techniques before or during cover construction, whichever is most convenient and practical.

3) Existing MW-4 Schedule 80 PVC well casing shall be extended such that the top of the PVC well casing is located a minimum of 2' - 6" above the final grade of the constructed cover.

4) Only hand-operated compaction equipment shall be used to compact soils around the extended well casing as each lift is placed during cover construction.

5) The concrete pad, protective casing, and locking top cap shall be refitted to its original configuration, consisting of steel cover, locking top cap, and concrete pad.

6) The final location and elevation of the top of the new PVC well casing and four corners of the concrete pad shall be surveyed. The results of the survey shall be retained for future use to prepare as-built drawings.

3.2 INSPECTION

3.2.1 The CQA Engineer and Operator shall be responsible for in-process inspection during performance of all work.

3.2.2 Monitoring well extension not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced monitoring well extension shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02930

RECLAMATION SEEDING AND MULCHING

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all labor, materials, tools and equipment, and shall place seed and mulch in accordance with this specification and as indicated in the design drawings. This section describes the Contractor's requirements to provide a final vegetated surface in those areas designated herein. These designated areas shall be seeded and mulched as set forth in this section.

1.1.2 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required by this specification,

2) Have the option to inspect equipment, work, and materials for compliance with the requirements of this specification, in addition to inspection by the Contractor,

3) Have the option to review pre-seeding conditions and other related job conditions during performance of the work, and,

4) Have the option to perform inspection and acceptance of the final vegetated surfaces.

1.2 REFERENCE DOCUMENTS

City of Albuquerque, Specification 1012, Native Grass Seeding

Biological Assessment for the Sandia National Laboratories Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico, July 1992

Vegetation Study in Support of the Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico, SAND2004-6144.

1.3 SUBMITTALS

1.3.1 Procedures

The Contractor shall submit a Seeding and Mulching Plan to the Operator for written approval after notice to proceed. The plan shall describe the methods of placement and the equipment to be used during operations.

1.3.2 Certification

1) The Contractor shall submit the seed vendor's certified statement for the seed mixture required, stating scientific and common names, percentages by weight, and percentages by purity and germination.

2) The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification after completion of the work specified herein.

1.3.3 Records

The Contractor shall submit records of inspection to the Operator after completion of the inspection.

PART 2 PRODUCTS

2.1 GENERAL

Seed, fertilizer, mulch, and equipment shall be inspected upon arrival at the job site by the Operator and/or CQA Engineer for the conformity to type and quality in accordance with these requirements. Unacceptable materials shall be removed from the job site by the Contractor.

2.2 EQUIPMENT AND MATERIAL REQUIREMENTS

2.2.1 Seed Mix for Cover and Reclaimed Areas

Seed shall be labeled in accordance with USDA rules and regulations under the Federal Seed Act. Seed shall be furnished in sealed bags or containers clearly labeled to show the name and address of the supplier, the seed name, the lot number, net weight, origin, the percentage of weed seed content, the guaranteed percentage of purity and germination, pounds of live seed of each seed species, the total pounds of pure live seed in the container, and the date of the last germination test which shall be within a period of 6 months prior to commencement of planting operations. Seed shall be from a current or previous year's crop.

The following seed mixture shall be used:

Species	(lb/acre pure live seed)
Galleta grass	8.0
Black grama	6.0
Spike dropseed	3.0
Ring muhly	3.0
Total rate:	20 lb/acre

2.2.2 Fertilizer

A starter fertilizer containing nitrogen, phosphorous, potassium, and sulfur shall be used. A 20-20-0-22 shall be acceptable.

2.2.3 Mulch

The Contractor shall furnish all labor, materials, tools and equipment to place a grain straw (wheat, oats, or barley) mulch on the reclaimed areas. The straw mulch shall be applied at the rate of 2 tons/acre. The straw mulch shall be clean, free of seed, and free of noxious weeds.

2.2.4 Equipment

The Contractor shall provide appropriate types of equipment for the performance of drill seeding and mulch spreading. Seeding of the grass species shall be performed with a rangeland grass drill equipped with multiple seed bins, depth bands, and press wheels. Drills shall have agitators to prevent the seed from segregating and lodging in the seed box. The depth bands should be suitable for placing the seed at a depth that does not exceed 1/2 inch.

Mulch crimping equipment shall properly crimp the straw without cutting the straw. Discing equipment shall not be used.

2.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

2.3.1 Delivery

The Contractor shall deliver seed to the site in the original, unopened containers bearing the container labels or tags stating the producer's guaranteed statement of analysis.

2.3.2 Storage

Materials shall be stored in areas designated by the Operator. Seed shall be stored in cool, dry locations away from contaminants and in accordance with manufacturer's recommendations. Storage times shall not exceed manufacturer's recommendations.

2.3.3 Handling

Except for bulk deliveries, the Contractor shall not drop or dump materials from vehicles.

PART 3 EXECUTION

3.1 APPLICATION PROCEDURES

3.1.1 Topsoil Preparation

Prior to seeding, the Contractor shall till the top 3 inches of the surface into an even and loose seed bed, free of clods in excess of 4 inches in dimension, and bring the tilled surface to the desired line and grade. The area to be seeded shall be free of erosion rills and gullies.

3.1.2 Seeding

1) The Contractor shall seed the constructed cover, laydown and stockpile areas, drainage swale, and other locations impacted by construction activities. The TA-3 borrow pits shall not be seeded.

2) The Contractor shall apply the seed mix uniformly to the prepared surface by means of drill seeding at not less than the minimum rate specified in Part 2.2.1 of this specification.

3) Seed shall be uniformly drilled to a maximum depth of 1/2 inch using equipment specified in Part 2.2.4 of this specification.

4) The Contractor shall seed in a pattern perpendicular to the slope, working from the top of the slope down and using row markers to indicate seeded areas.

5) The Contractor shall seed the grass mixture in either the spring or fall. Spring seeding shall be performed after the chances of freezing temperatures have passed. Fall seeding shall be performed before the ground is frozen and covered with snow and after the time temperatures would cause germination.

6) The stand of grass resulting from the seeding shall not be considered satisfactory until accepted by the Operator. The Contractor shall provide a one-year warranty to assure the stand of grass from the seeding. If areas are

determined to be unacceptable, the unacceptable areas shall be reseeded in accordance with these specifications.

3.1.3 Fertilizer

Fertilizer shall be placed at a spreading volume of 10 lb/acre unless otherwise specified by the Operator.

3.1.4 Mulch

Mulch shall be straw spread uniformly at a rate of 2 tons/acre immediately following seeding. Mulch shall be anchored into the soil to a depth of at least 2 inches with no more than one pass of the crimping equipment. The crimping operation shall proceed perpendicular to the slope so as not to encourage the formation of rivulets down slope. Mulching shall not be performed when wind interferes with placement.

3.2 MAINTENANCE

3.2.1 General

1) Maintenance of the constructed cover, laydown and borrow areas, drainage swale, and other locations impacted by construction activities during seeding shall be provided by the Contractor.

2) Areas damaged by the Contractor during seeding shall be repaired and reseeded by the Contractor at the Contractor's expense.

3.3 ACCEPTANCE

Seeding and mulching not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced seeding or mulching shall be in accordance with the requirements of this specification.

END OF SECTION

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APPENDIX B
Construction Quality Assurance Plan

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
CQA	construction quality assurance
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
MWL	Mixed Waste Landfill
NMED	New Mexico Environment Department
QC	quality control
Sandia	Sandia Corporation
SCA	Soils Contamination Area
SCR	Sandia Construction Representative
SNL	Sandia National Laboratories/New Mexico

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1.0 INTRODUCTION

A construction quality assurance (CQA) Plan is essential for determining, with a reasonable degree of certainty, whether a completed final cover meets or exceeds all design criteria, plans, and specifications. This document presents the various controls established by the CQA Plan for construction of the Mixed Waste Landfill (MWL) alternative cover at Sandia National Laboratories/New Mexico (SNL). It should be recognized that the management of construction quality involves using scientific and engineering principles and practices to verify that the alternative cover to be constructed meets or exceeds design criteria, plans, and specifications. This management activity begins prior to construction, continues throughout construction, and ends when the alternative cover is accepted by the New Mexico Environment Department (NMED).

1.1 Concept and Objectives of the CQA Plan

The governing purpose for the CQA Plan is to verify that the MWL alternative cover is constructed as specified in the design. To verify proper construction, the following objectives must be met:

- Guidelines and requirements in design drawings and construction specifications are followed
- Inspection and verification testing throughout construction to verify that design features are implemented as intended
- Evaluation of variances to the design and their effects upon system performance
- Complete documentation demonstrating that the design has been implemented and that performance requirements have been met.

In meeting these objectives, the following are defined as part of the CQA Plan:

- Quality-related qualifications, responsibilities, and authorities of personnel
- Controls for the procurement of services and materials
- Direction for necessary inspections and verification testing during construction so that execution of the design documents can be confirmed. Acceptance criteria for the inspections and testing are also included
- Provision for team communication throughout construction so that the work progresses as an organized, planned sequence of events which allows revision and change
- Direction for the preparation and maintenance of records so that it can be demonstrated that the construction was performed in accordance with design requirements.

An audit system will be established to provide evaluation of the implementation of the design drawings and construction specifications, the CQA program, and work areas and activities including materials and workmanship.

1.2 Basis of the CQA Plan

The following sources have been used as guidance in the preparation of the CQA Plan:

- U.S. Environmental Protection Agency (EPA), Technical Guidance Document, "Quality Assurance and Quality Control for Waste Containment Facilities," Report No. EPA/600/R-93/182, September 1993

- EPA, Design and Construction of RCRA/CERCLA Final Covers, EPA/625/4-91/025, May 1991

- New Mexico Administrative Code Title 20, Chapter 4, Part 1, Subpart V

- SNL, Mixed Waste Landfill Voluntary Corrective Measures Plan, July 2005

1.3 Presentation of the CQA Plan

The CQA Plan contains general direction for the control of construction activities, such as the definition of organizational responsibilities and authorities, CQA personnel qualifications, and specific technical information, such as execution guidance and verification tests to be performed throughout construction.

Inspection checklists have been developed for use by CQA personnel to document the inspection and verification requirements in the CQA Plan. These checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of these checklists are included in Attachment B1 of this Plan.

Whenever possible, nationally recognized test methods such as those published by the American Society for Testing and Materials (ASTM) will be utilized. In general, recognized standards will be cited only by reference and not included verbatim. If a test method is not a nationally recognized standard, the test method will be defined, including criteria for acceptability.

2.0 RESPONSIBILITY AND AUTHORITY

The principal organizations involved in construction of the SNL MWL alternative cover include:

- NMED (Lead Regulatory Agency)
- U.S. Department of Energy (DOE) (Owner/Operator)
- Sandia Corporation (Sandia) (Designer and Operator)

- CQA Contractor
- Construction Team or Contractor
- Testing Laboratory

The areas of responsibility and lines of authority are delineated in the following sections such that the lines of communication are established to effectively implement the CQA Plan. An organizational chart for the project during cover construction is shown in Figure B-1.

2.1 Review/Permitting Agency

The NMED, the lead regulatory agency, has the authority to review the MWL alternative cover design and approve construction of the cover. It is the responsibility of the NMED to review the Operator's site-specific CQA Plan for compliance with the agency's regulatory requirements, and to review all CQA documentation during and/or after construction of the cover to confirm that the CQA Plan was followed and that the cover was constructed as specified.

2.2 DOE (Owner/Operator)

The DOE and Sandia have responsibility for compliance with the regulatory requirements of the NMED in order to obtain approval of the MWL alternative cover design and assure the NMED, by the submission of CQA documentation, that the cover was constructed as specified in the approved design. The DOE also has the authority to accept or reject design drawings and construction specifications, the CQA Plan, reports and recommendations of the CQA Engineer, and the materials and workmanship of the Construction Contractor (see Table 3.1 of Construction Specification 02200).

2.3 Sandia (Designer and Operator)

Sandia's primary responsibility is to design and specify an alternative cover that fulfills the closure needs of the Owner and the regulatory requirements of the NMED. Design activities may not end until the cover is completed. Revisions to the design may be required if unexpected site conditions are encountered or changes in construction methodology occur that could adversely affect cover performance. The CQA program provides assurance that these unexpected changes or conditions will be detected, documented, and addressed during construction.

Sandia has the authority to select and dismiss the organizations responsible for the CQA and construction activities. Responsibilities and authority of Sandia include formulating and implementing the CQA Plan, periodic review of CQA documentation, modifying construction site activity, and specifying corrective measures in cases where deviation from the approved design or failure to meet design criteria, plans, and specifications is identified by CQA personnel. Sandia will have a Construction Representative (Sandia Construction Representative [SCR]) on site to coordinate and oversee all construction-related activities.

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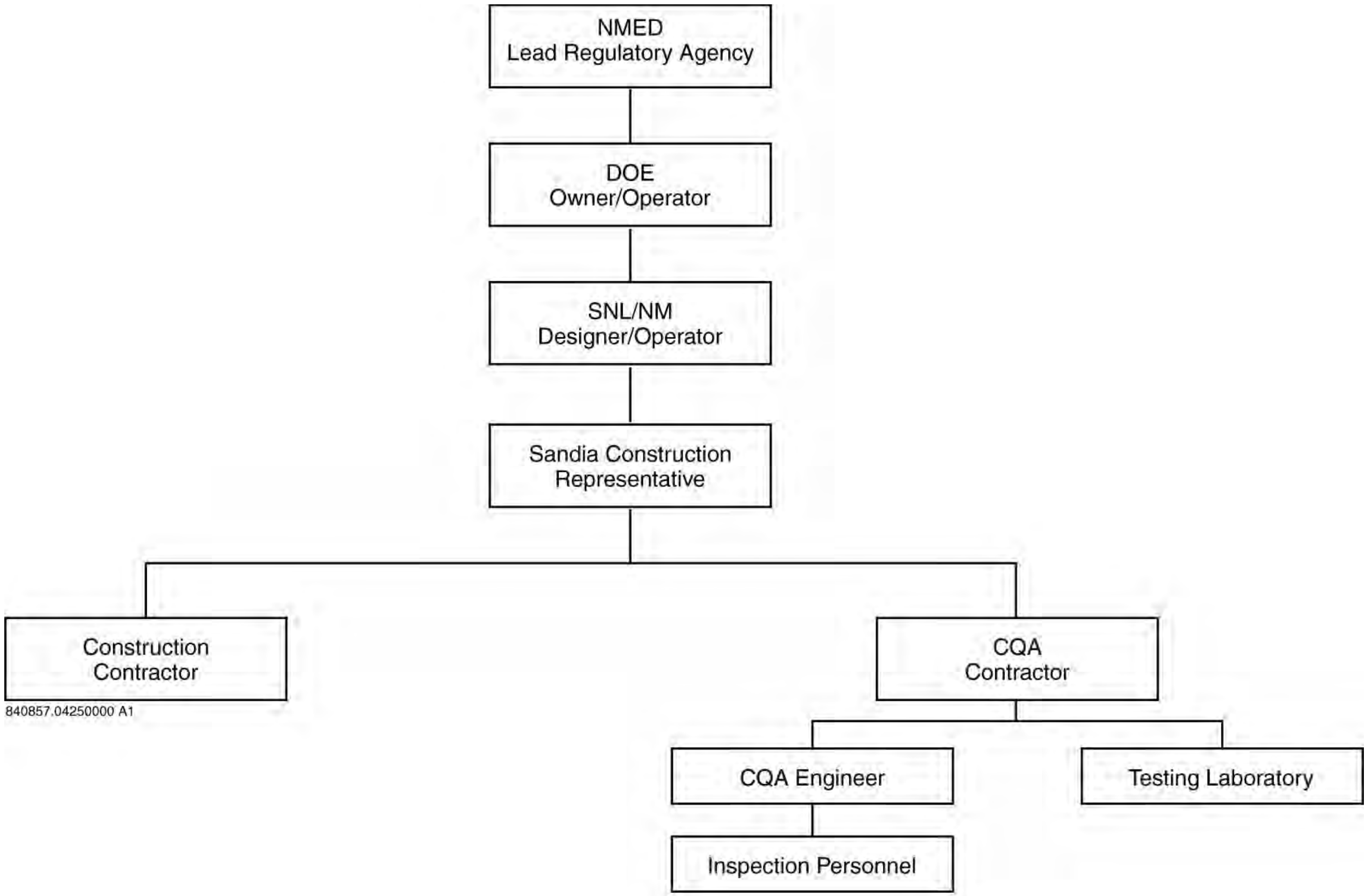

Figure B-1 Organizational Chart, SNL Mixed Waste Landfill Alternative Cover Construction

2.4 Sandia Construction Representative (Owner's Representative)

The Sandia Construction Representative (SCR) will report directly to Sandia and has the following responsibilities:

- Overall coordination of construction activities
- Oversee implementation of the CQA Plan
- Notify the CQA Contractor, and the Construction Contractor of any nonconformances observed
- Approve changes and notify other personnel, as appropriate, of the changes
- Ensure that inspections and verification tests performed by the CQA Contractor are conducted at required intervals and in accordance with the CQA Plan
- Review as-built drawings, results of inspections, and field and laboratory data from verification testing
- Stop work if conditions adverse to quality are persistent, and ensure that conditions are corrected before proceeding
- Maintain construction documents and records after transfer from the CQA Contractor.

2.5 Construction Team or Contractor

It is the responsibility of the Construction Team or Contractor, hereinafter referred to as the "Contractor," to construct the MWL alternative cover in strict accordance with the design criteria and drawings, construction specifications, and CQA Plan using the necessary construction procedures and techniques.

2.6 CQA Contractor

The overall responsibility of the CQA Contractor is to perform those activities specified in the CQA Plan (e.g., inspection, sampling, and documentation). At a minimum, the CQA Contractor will include a CQA Engineer and the necessary supporting CQA inspection personnel. Specific responsibilities and authority of the CQA Contractor's personnel are defined clearly below and in the associated contractual agreements with the Owner.

2.6.1 CQA Engineer

Specific responsibilities of the CQA Engineer include, but are not limited to, the following:

- Review of design criteria and drawings, and construction specifications for clarity and completeness so that the CQA Plan can be implemented

- Educate CQA inspection personnel on CQA requirements and procedures

- Schedule and coordinate CQA inspection activities

- Direct and support the CQA Inspectors in performing observations and tests by:

  — Confirming that regular calibration of testing equipment is properly conducted and recorded

  — Confirming that the testing equipment (e.g., nuclear density gauge), personnel, and procedures do not change over time or making sure that changes do not adversely impact the inspection process

  — Confirming that the test data are accurately recorded and maintained (this may involve selecting reported results and backtracking them to the original observation and test data sheets)

  — Verifying that the raw data are properly recorded, validated, reduced, summarized, and interpreted

  — Ensuring that construction CQA testing is conducted at the proper frequency.

- Maintain CQA-related documents, including but not limited to the CQA Plan, field notes, meeting notes, test results, and miscellaneous reports

- Provide the SCR with recommendations and reports on the inspection results including:

  — Review and interpretation of data sheets, as-built drawings, and reports

  — Identification of work that will be accepted, rejected, or uncovered for observation, or that may require special testing, inspection, or approval

  — Verification that corrective measures are implemented.

- Report nonconformances to the SCR

- Report to the SCR activities that are adverse to overall quality

- Document nonconformances

- Work with the SCR and the Construction Contractor to resolve problems prior to and during cover construction phases.

2.6.2 CQA Inspection Personnel

The CQA Inspectors will provide day-to-day inspections and field verification tests. Their role is critical to successful demonstration of construction procedures and required documentation. Their major responsibilities include:

- Performing independent on-site inspection of the work in progress to assess compliance with cover design criteria and drawings, and construction specifications

- Inspect delivery tickets and manufacturers quality control (QC) reports to verify that materials meet construction specifications

- Verifying that the equipment used in testing meets the test requirements and that the tests are conducted in accordance with standardized procedures defined by the CQA Plan

- Collecting samples in the field for subsequent verification testing by off-site laboratories. CQA testing will be conducted at a frequency of at least 5% of that done by the Construction Contractor

- Reporting to the CQA Engineer results of all inspections including work that is not of acceptable quality or that fails to meet the specified design criteria

- Reporting of nonconformances, as appropriate, to the construction foremen, superintendents, or manager if correction can be made during the normal course of work

- Reporting of nonconformances to the CQA Engineer if correction cannot be readily achieved to the satisfaction of the CQA Inspector, so that resolution can be accomplished by the CQA Engineer

- Reporting to the CQA Engineer any activities which are adverse to overall quality and any nonconformances which are recurring

- Documenting nonconformances

- Reporting to the CQA Engineer any changes in the design drawings and/or construction specifications

- Documenting inspection and verification testing activities through the completion of specified forms and daily logs.

2.6.3 CQA Certifying Engineer

The CQA Certifying Engineer is responsible for certifying to the Owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications, and certifying the CQA document has been approved by the NMED. The certification statement is normally accompanied by a final CQA report that contains all the appropriate documentation, including daily observation reports, sampling locations, test results, drawings of record or sketches, and other relevant data. The CQA Certifying Engineer may be the CQA Engineer or someone else in the CQA Engineer's organization that is a registered professional engineer with experience and competency in certifying like installations.

2.7 Testing Laboratory

The testing laboratory will have its own internal QC plan to verify that the laboratory procedures conform to the appropriate ASTM standards or other applicable testing standards. The testing laboratory is responsible for ensuring that tests are performed in accordance with applicable methods and standards, internal QC procedures are followed, sample chain-of-custody records are maintained, and data are effectively and accurately reported. The testing laboratory must be willing to allow the Operator, CQA Engineer, or the NMED to observe the sample preparation, testing procedures, or record-keeping procedures, if they so desire. The Operator, CQA Engineer, or the NMED may request that they be allowed to observe some or all tests on a particular job at any time, either announced or unannounced. The testing laboratory personnel must be willing to accommodate such a request, but the observer will not interfere with the testing or slow the testing process.

3.0 PERSONNEL QUALIFICATIONS

The key individuals involved in CQA and their minimum recommended qualifications are listed in Table B-1.

Table B-1
Recommended Personnel Qualifications

Individual	Minimum Recommended Qualifications
Sandia Construction Representative	The specific individual designated by the Owner with knowledge of the project, its plans, specifications, and Quality Assurance/Quality Control documents.
CQA Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer.
CQA Inspectors	Employed by an organization that operates separately from the Construction Contractor and the Owner/Operator; experienced in performing the appropriate field tests and making observations during construction activities.
CQA Certifying Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer in the State of New Mexico.

4.0 PROJECT COMMUNICATIONS

Communication between CQA program participants is crucial. Required reporting to program participants is necessary so that activities can be reviewed and work can proceed. Communications in the form of construction documents, inspection reports, audit reports, verification test results, and daily logs must be timely so that reviews and evaluations can take place.

Throughout this Plan, required report preparation and the individuals responsible for distribution, review, and approval are cited.

4.1 Meetings

Meetings will be held throughout the course of construction. Following are discussions of three specific meeting formats.

4.1.1 Preconstruction Meeting

Prior to the start of construction of the MWL alternative cover, a Preconstruction Meeting will be held to review and acquaint personnel with the requirements of the CQA Program, design drawings, and construction specifications. The Preconstruction Meeting will include a tour of the MWL, borrow areas, and access routes. The meeting will be led by the SCR and the CQA Engineer. Attendance at the meeting is required of all key personnel involved in the project. Meeting notes will be prepared by the CQA personnel and will be maintained in the on-site records system. If any subcontractors arrive on site after construction begins and the preconstruction meeting has been held, the SCR and CQA Engineer will meet with those subcontractors to review appropriate activities of their work. These meetings will be documented as well.

The preconstruction meeting should present the following:

- Organization
- Schedule
- Review requirements of the design drawings and construction specifications
- MWL Health & Safety Plan
- Review requirements of the CQA Program including:
  - Responsibilities and authority of specific personnel such as the CQA Inspectors and the SCR
  - Inspection and verification testing methods, frequencies, and acceptance criteria

- A review of required documentation and operation of the on-site records system

- A discussion of potential nonconformances, the resolution of any such nonconformances, and the responsibility of all personnel to bring nonconformances to the CQA Engineer

- A discussion of the procedure for changes to design drawings and construction specifications and the means for review and approval.

4.1.2 Progress Meetings

Progress meetings will be held at the request of the SCR and should include, as appropriate, members of the Construction Contractor personnel, and the CQA personnel. Progress meetings will be documented in the form of meeting notes prepared by the CQA personnel. These notes will be maintained in the on-site construction and/or CQA records system.

The purpose of the progress meeting is to:

- Review activities and accomplishments
- Review the work location and activities
- Identify the Construction Contractor's personnel and equipment assignments
- Discuss any potential construction problems.

4.1.3 Quality Resolution Meetings

Special meetings may be called by Owner, the Operator, the SCR, or the CQA Engineer to discuss activities adverse to construction quality and to define resolution. It is intended that these meetings be called to discuss quality problems that cannot be readily resolved, or those that continue to be ongoing or recurring.

The purpose of this meeting is to:

- Define and discuss the quality-related problems
- Review appropriate solutions
- Implement a plan to resolve any quality-related problems that have been defined.

Resolution of quality-related problems will be approved by the Operator and/or the SCR, as appropriate. A member of the CQA personnel will prepare meeting notes.

5.0 ALTERNATIVE COVER—OBSERVATIONS, INSPECTION ACTIVITIES, AND TESTS

The alternative cover design for the MWL includes up to 40 inches of compacted subgrade; a 1.0-foot biointrusion barrier; 2.5 feet of compacted native soil fill; and a maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel. The final cover will be seeded with native grasses, mulched and crimped. The layers of the cover in descending order are as follows:

- A maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel
- 2.5 feet of compacted native soil
- A 1.0-foot, compacted biointrusion barrier containing 1.0-in. to 6.0-in. crushed rock
- Up to 40 inches of compacted subgrade.

5.1 Earthwork

This section specifies the observations, inspections and tests necessary to control, verify, and document that the earthwork for the MWL alternative cover conforms to the design drawings and construction specifications.

Earthwork activities include:

- Clearing, grubbing, and compaction of existing MWL surface and perimeter
- Placement and compaction of subgrade fill
- Placement and compaction of biointrusion barrier
- Placement and compaction of native soil layer fill
- Placement and minimal compaction of topsoil layer.

In order to verify proper CQA, inspection checklists have been developed for use by CQA personnel. The checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer to ensure that construction of the cover was according to design drawings and construction specifications. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of the inspection checklists for each phase of cover construction are included in Attachment B1 of this Plan. Attachment B1 inspection sheets may be modified as needed to enhance CQA.

5.1.1 Existing Landfill Surface

The alternative cover will extend beyond the MWL fenced perimeter as shown in the design drawing plates. Appropriately, the existing surface and perimeter of the MWL will be cleared, grubbed, and compacted to provide a stable surface for the final cover and side slopes.

5.1.1.1 Observations and Inspections

CQA personnel will perform the following observations and inspections during the preparation of the MWL surface and perimeter:

- Ensure that the MWL surface and perimeter has been cleared of all vegetation, organic matter, rubble, trash, and deleterious material. Rocks larger than 2 inches in dimension will be removed
- Ensure that any loose or soft zones have been appropriately compacted.
- Observe coverage and number of passes by compaction equipment.

5.1.1.2 Laboratory Tests

The Operator will provide archived laboratory data for use in preparation of the existing MWL surface and perimeter. The MWL is designated as a Soils Contamination Area (SCA). Soil samples from the existing landfill surface shall not be taken off-site.

5.1.1.3 Field Tests

In addition to performing the required observations and inspections, CQA personnel will perform the following field tests as required by the earthwork specifications:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor (see Table 3.1 of Construction Specification 02200). Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.2 Subgrade Fill

Subgrade fill will be obtained from the TA-3 borrow pits. Subgrade fill will bring the entire landfill surface to a central crown and a uniform 2% grade. Subgrade fill will be placed in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing). The subgrade will tie to the existing landscape to achieve a stable and functional slope.

5.1.2.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction of the subgrade:

- Inspect the fill to be used for construction of the subgrade. Fill will be obtained from the TA-3 borrow pits. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in dimension will be removed from subgrade fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect individual and final lift thickness

- Verify lines and grades of the completed subgrade.

5.1.2.2 Laboratory Tests

Laboratory tests of subgrade fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D698 for each 500 cubic yards of fill, or more often if there is a change of material

- Gradation as determined by ASTM C136 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

5.1.2.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the subgrade fill will be performed. Fill placed at densities and/or moisture contents not conforming to the construction specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.3 Biointrusion Barrier

A biointrusion barrier composed of 1.0-in. to 6.0-in. and D_{50} = 4 in. crushed rock will be placed between the subgrade fill and the native soil layer. The crushed rock will be placed in a 1-ft minimum, 1.25-ft maximum thickness layer. The crushed rock shall be compacted using heavy equipment. Compaction shall consist of repeated passes over all areas where crushed rock has been placed until the crushed rock fragments are firmly locked in place.

5.1.3.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the crushed rock to be used for construction of the biointrusion barrier. Crushed rock will be obtained from the stockpile south of the MWL. Visual inspections of crushed rock will be made by CQA personnel to verify that the material conforms to the construction specification and to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction.

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect final lift thickness

- Verify lines and grades of the completed biointrusion barrier.

5.1.3.2 Laboratory Tests

No laboratory tests of the biointrusion barrier will be performed.

5.1.3.3 Field Tests

No field tests of the biointrusion barrier will be performed.

5.1.4 Native Soil Layer

A 30-inch layer of native fill will be placed and compacted between the biointrusion barrier and the topsoil layer. Native fill will be placed in successive 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of the maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

5.1.4.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the fill to be used for construction of the native soil layer. Fill will be obtained from TA-3 borrow pits. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in dimension shall be removed from native soil layer fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Inspect individual and final lift thickness

- Verify lines and grades of the completed native soil layer.

5.1.4.2 Laboratory Tests

Laboratory tests of the compacted native soil fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D698 for each 500 cubic yards of fill, or more often if there is a change of material

- Gradation as determined by ASTM C136 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

- Hydraulic conductivity testing on each sample as determined by ASTM rigid wall methods (one per acre per lift), or when CQA personnel notice a change in material.

5.1.4.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the compacted native soil fill will be performed. Fill placed at densities and/or moisture contents not conforming to the constructions specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D2922 and ASTM D3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled with like material and hand-tamped.

5.1.5 Topsoil Layer

A minimum 8-inch topsoil layer containing 25% by volume 3/8-inch crushed gravel will be placed on top of the native soil layer. Topsoil will be minimally compacted to provide a uniform, prepared surface for seeding and to facilitate root development.

5.1.5.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the topsoil to be used for construction of the topsoil layer. Topsoil will be obtained from the TA-3 borrow pits. Visual inspections of topsoil will be made by CQA personnel to detect the presence of rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. Organic matter is desirable in the topsoil and, therefore, only gross organic matter, such as Russian thistle will be removed.

- Verify that only hand-operated compaction equipment is used around monitoring wells

- Verify topsoil is free of rocks greater than 2 inches in dimension

- Inspect final thickness

- Verify lines and grades of the completed topsoil layer.

- Verify gravel size and volume admixture with topsoil

5.1.5.2 Laboratory Tests

Laboratory tests of the topsoil layer will be performed to document the engineering properties and to verify the acceptability of the topsoil for use in construction.

The laboratory tests will include the following:

- Gradation as determined by ASTM C136 (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D2487 and D4318 (one per 500 cubic yards), or when CQA personnel notice a change in material.

5.1.5.3 Field Tests

No field tests of the topsoil layer will be performed.

5.1.6 Reclamation Seeding and Mulching

The topsoil layer will be seeded with native grasses in accordance with the construction specifications.

5.1.6.1 Acceptance of Seed

Following the delivery of the seed mix, the CQA Engineer will inspect the delivery ticket to verify that the quantity and type of seed supplied by the manufacturer is consistent with construction specifications.

5.1.6.2 Storage and Handling

CQA personnel will verify that the seed will be stored in a cool area, free of moisture and standing water.

5.1.6.3 Observations and Inspections

CQA personnel will perform the following observations and inspections during seeding of the topsoil layer:

- Inspect the seed to ensure that it has been stored appropriately and has not rotted

- Verify that seeding takes place during favorable weather conditions (i.e., low winds)

- Verify that the appropriate application method is used
- Observe and verify that the application rate of soil additives and seed are in accordance with the construction specifications
- Survey lines and grades of the final cover
- Verify mulching and crimping.

6.0 MONITORING WELL MW-4 EXTENSION

Groundwater monitoring well MW-4 will be extended such that the top of the PVC casing is located a minimum of 30 inches above the final grade of the completed cover. MW-4 will be refitted to its original configuration, consisting of steel protective cover, locking top cap, and concrete pad. Protective stanchions will not be required.

6.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Ensure that the existing concrete pad, protective steel stanchions, protective steel well casing cover and locking top cap are removed prior to cover construction
- Observe extension of the existing MW-4 PVC well casing. The well casing will be extended before or during cover construction
- Ensure that only hand-operated compaction equipment is used to recompact fill around the extended well casing as each lift is placed during cover construction
- Observe completion of the new concrete pad, protective steel well casing cover and locking top cap to ensure that construction is performed in accordance with construction specifications
- Observe that the final location and elevation of the top of the new PVC well casing and four corners of the concrete pad are surveyed. The results of the survey will be retained for future use to prepare as-built drawings.

6.2 Laboratory Tests

No laboratory tests will be performed during the extension and reconstruction of monitoring well MW-4.

6.3 Field Tests

No field tests will be performed during the extension and reconstruction of monitoring well MW-4.

7.0 NONCONFORMANCE

7.1 Laboratory and Field Nonconformances

Nonconforming items and activities are those that do not meet the design drawings, construction specifications, procurement document criteria, approved work procedures, or the CQA program.

Nonconformances may be detected and identified by any site workers including:

- CQA personnel—during construction operations by observation, field inspections, and/or verification testing
- Laboratory personnel—during the preparation for and performance of laboratory testing and/or during calibration of equipment
- SCR—during the performance of audits, surveillances, and/or other CQA-related activities
- Construction Contractor—during construction operations by field inspections.

Each nonconformance affecting quality will be documented by the personnel identifying or originating nonconformance. For this purpose, the results of calibration and laboratory analysis quality control tests, audit reports, inspection reports, or an internal memorandum or letter can be used as appropriate. This documentation will be compiled by the CQA Engineer and documented in a Nonconformance and Corrective Action Report and submitted to the SCR.

This report will, when necessary, include:

- Description of nonconformance
- Identification of individual(s) identifying or originating the nonconformance
- Method(s) for completing corrective action and corrective action taken
- Schedule for completing corrective action and corrective action taken
- Responsible individuals for correcting the nonconformance and verifying satisfactory resolution.

Documentation will be available to the Owner, SCR, Construction Contractor, CQA Contractor, and/or subcontractor(s), as necessary. It is the responsibility of everyone working at the project site to inform CQA personnel of potential nonconformances. The CQA personnel will discuss the potential nonconformance and, if necessary, stop work to address the potential nonconformance. In addition, the SCR will be notified by the CQA Engineer as soon as possible of all nonconformances that could impact the results of the work. Corrective action, if warranted, will be determined and implemented.

CQA personnel, as part of future activities, should verify completion of corrective actions for nonconformances.

Any recurring nonconformance should be evaluated by the SCR, CQA Contractor, and/or testing laboratory to determine its cause and the appropriate changes instituted to prevent future recurrence. When such an evaluation is performed, the results will be documented.

8.0 DOCUMENTATION

Compliance with the requirements of the construction specifications for the MWL alternative cover will be documented throughout all phases of construction. Documentation will consist of records prepared by CQA personnel, the independent testing laboratory, the Construction Contractor, and any subcontractors.

8.1 Daily Summary Report

Whenever there is any construction activity, a Daily Summary Report will be prepared. Other records required will depend on the specific work being performed that day.

The Daily Summary Report will be prepared by the CQA Inspector and reviewed by the CQA Engineer. It will contain the following:

- The date
- A summary of the weather conditions
- A summary of locations where construction is occurring
- A list of personnel on the project
- A summary of any meetings held and attendees
- A description of all materials used and references or results of testing and documentation
- The certificates for calibration and recalibration of test equipment
- The inspection checklists.

8.2 Inspection Checklists

Inspection checklists (Attachment B1) will be reviewed by the CQA Engineer, and submitted to the SCR. The purpose of the checklists is to document all inspections performed by CQA personnel during construction activities.

At a minimum, each inspection checklist will contain the following information:

- The date and time of inspection
- The location
- Weather conditions
- The type of inspection
- The procedure used (e.g., ASTM method)
- Test data
- The results of the activity
- Personnel involved in the inspection and sampling activities
- The signature of the inspector.

8.3 Nonconformance and Corrective Action Reports

Whenever any material or workmanship does not meet the requirements of the construction specifications or has an obvious defect, the appropriate personnel will be notified and a Nonconformance and Corrective Action Report will be completed by the CQA Engineer. Additional information on nonconformance, corrective action, and the documentation thereof is presented in Section 8.0 of this Plan.

8.4 Field and Laboratory Test Reporting

Reports of all field and laboratory tests will be submitted to the CQA Engineer and SCR.

8.4.1 Field Test Data

The soil testing technicians will submit reports of all field tests and retests to the CQA Engineer and SCR as soon as possible upon completion of the required tests.

The reports may include, but are not limited to, the following:

- Date of the test and date submitted

- Location of test
- Weather
- Test method (ASTM or approved)
- Wet weight, moisture content, and dry weight of field sample (if required)
- Description of soil
- Ratio of field dry density to maximum lab dry density expressed as a percent (if required)
- Comments concerning the field density passing or failing the specified compaction
- Comments about results.

CQA Inspectors will record field test data on the appropriate inspection checklists or approved forms.

8.4.2 Laboratory Test Data

The independent testing laboratory will submit data reports of all laboratory tests to the CQA Engineer as soon as possible upon completion of the tests. The reports will include, but not be limited to, the following:

- Date of the test and date submitted
- Identification and description of sample tested
- Test method (ASTM or approved)
- Results of test.

8.5 Photographic Reporting

Any photographs used to document the progress and acceptability of cover construction may be incorporated into the daily summary report and the acceptance report.

Each photo will be identified individually as well as in a photograph log that contains the following information:

- The date, time, location, and direction of the photograph
- The name of the photographer
- Brief description of the activity photographed.

8.6 As-Built Drawings

Final as-built drawings will be prepared by the CQA Contractor and will be retained by the Owner as a permanent record of the final configuration and dimensions of the cover features (e.g., subgrade, biointrusion barrier, and final cover). As-built drawings must be reviewed and approved by the CQA Engineer and the SCR.

8.7 Final Documentation

When construction of the MWL alternative cover has been completed and the final inspection/punch list shows that all items have been resolved, a final report will be prepared for submittal to the Operator.

The final report will be certified as correct by the CQA Engineer and will contain the following:

- Daily summary reports
- Inspection checklists
- Nonconformance and corrective action reports
- Field test results
- Laboratory test results
- Photographs and photograph logbook
- As-built drawings
- Internal CQA memoranda or reports with data interpretation or analyses
- Design changes.

8.8 Document Control and Storage of Records

During construction of the MWL alternative cover, the CQA Engineer will be responsible for storage of all CQA documents. All records prepared by the CQA Contractor will remain on-site during the project to provide documentation of the cover construction. The CQA documents will include:

- Design drawings
- Construction specifications
- CQA Plan
- Inspection checklists
- Field test data reports
- Laboratory test data reports
- Nonconformance and corrective action reports

- Meeting notes
- Daily summary reports.

Duplicate copies will be kept at another location as a safeguard in case the originals are damaged or lost. Once construction is complete, the originals will be transferred to the SCR.

ATTACHMENT B1
Inspection Checklists

The inspection checklists contained in this attachment are provided for use by CQA personnel during construction of the MWL alternative cover. The format of the inspection checklists may be modified by the CQA Engineer; however, the revised inspection checklist must include all checks and information contained in the original form and meet the approval of the Operator. The inspection checklists will be completed and signed by CQA Inspectors and reviewed by the CQA Engineer. These checklists will become part of the final cover construction report documenting the CQA process throughout construction.

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LIST OF FORMS

Title **Form No.**

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RI-01
RECEIVING INSPECTION FORM
SEED/FERTILIZER/MULCH

Project Name ___________________________________

Material Name ___________________________________
Transporter/Supplier ______________________________
Number of Bags/Bales _____________________________

Date ______________ Time___________
Received by ______________________
Inspected by ______________________
Delivery Shipment No. ______________
Storage Location __________________

	SPECIFICATION	MATERIAL RECEIVED	NOTE NO.
Supplier	________________	___________	__________
Supplier designation	________________	___________	__________
Material	________________	___________	__________

(Provide explanatory notes if the answers to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Checks before unloading:		
Have delivery tickets and QC certificates been provided for seed/fertilizer/mulch received?	_______	__________
Does the material description match the construction specifications?	_______	__________
Is the material free of damage?	_______	__________
Is the material acceptable for use?	_______	__________
Checks after unloading:		
Is the material free of damage?	_______	__________
Is the material properly stored?	_______	__________
Is the storage area free of water and/or moisture?	_______	__________

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TI-01
TESTING INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER FIELD TEST FORM

Project Name ________________________________ Date ______________ Time______________

Inspected by ________________________________ Weather ______________________________

Compaction Equipment ____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has soil been moistened to approximate optimum moisture content?	_______	________
Has surface been compacted/proof-rolled utilizing 10 passes of a roller?	_______	________
Have depressions been filled with moistened, clean fill, and recompacted with 10 passes of a roller?	_______	________
Did roller have a minimum ballasted weight of 25 tons?	_______	________
Did roller have a minimum pneumatic tire pressure of 90 psi?	_______	________
Was any proof rolling conducted within a 2-ft radius of any groundwater monitoring well?	_______	________

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TI-02
TESTING INSPECTION FORM
SUBGRADE FILL FIELD TEST FORM

Project Name ________________________________ Date ________________ Time____________

Lift Number ________________________________ Inspected by __________________________

Borrow Area ________________________________ Weather ______________________________

Compaction Equipment ____

Soil Description ____
____
____

Volume and location of soil placed during shift ____________________________________
____
____

Surface area and location covered during shift ____________________________________
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed at the frequency required?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the in situ density and moisture content tests been performed in accordance with ASTM D2922 and ASTM D3017, and recorded on Form TI-07 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________

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TI-03
TESTING INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD TEST FORM

Project Name ______________________________ Date ______________ Time______________

Lift Number ______________________________ Inspected by ________________________

Borrow Area ______________________________ Weather ____________________________

Compaction Equipment ____

Soil Description ____

____

____

Volume and location of soil placed during shift ____________________________________

____

____

Surface area and location covered during shift ____________________________________

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed at the frequency required?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the in situ density and moisture content tests been performed in accordance with ASTM D2922 and ASTM D3017, and recorded on Form TI-07 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________
Have the laboratory hydraulic conductivity tests been performed at the specified frequency and the locations plotted?	_______	_________

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TI-04
TESTING INSPECTION FORM
<u>SUBGRADE FILL LABORATORY TEST VERIFICATION FORM</u>

Project Name ____________________________ Date _____________ Time____________

Inspected by ______________________

Weather __________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

NOTES:

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TI-05
TESTING INSPECTION FORM
NATIVE SOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ________________________ Date ____________ Time__________

Inspected by ____________________

Weather ________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Has hydraulic conductivity testing been performed in accordance with ASTM rigid wall testing procedures?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

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TI-06
TESTING INSPECTION FORM
TOPSOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ________________________________ Date ________________ Time_____________

Inspected by ___________________________

Weather _______________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has gradation been performed in accordance with ASTM C136?	_______	_________
Has classification been performed in accordance with ASTM D2487 and D4318?	_______	_________
Do laboratory tests meet the construction specification?	_______	_________

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TI-07
TESTING INSPECTION FORM
MOISTURE/DENSITY FIELD TEST RESULTS FORM

LOCATION SKETCH

Project Name:
Stockpile Area:
Borrow Area:
Type of Construction:
(landfill surface and perimeter, subgrade, native soil layer, topsoil layer)
Maximum Dry Density (pcf):
Optimum Moisture:
Date:
Time:
Weather:

Test Number	Approximate Location			In Situ Dry Density (pcf)	Percent Compaction	In Situ Water Content (WC %)	Percent Water Content Variation	Soil Description
	North	East	Elevation					

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CI-01
CONSTRUCTION INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER CLEAR AND GRUB FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date ______________ Time___________

Weather ____ Inspected by ______________________

Compaction Equipment ____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have all shrubs, grass, roots, and other vegetation been completely cleared and grubbed from the landfill surface and perimeter?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that all loose or soft zones have been properly compacted?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-02
CONSTRUCTION INSPECTION FORM
SUBGRADE FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date ______________ Time___________

Inspected by ______________________

Borrow Area ____ Max Dry Density (pcf) _______________

Weather ____ Optimum Moisture (%) ______________

Compaction Equipment ____

Fill Description

____

____

____

Volume and location of soil placed during shift ____

____

____

Surface area and location covered during shift ____

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has all organic matter, rubble, trash, and deleterious material been removed from subgrade fill prior to use?	_______	_________
Has the prepared subgrade been surveyed for final grades to verify that it conforms to the construction drawings?	_______	_________
Have TA-3 borrow soils been determined to be suitable for subgrade fill?	_______	_________
Has approved fill been used during subgrade construction?	_______	_________
Has the subgrade been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-03
CONSTRUCTION INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date ______________ Time___________
Lift Number ____ Inspected by ______________________
Borrow Area ____ Max Dry Density (pcf) _______________
Weather ____ Optimum Moisture (%) ______________

Compaction Equipment ____

Fill Description
____
____
____

Volume and location of soil placed during shift ____
____
____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grades to verify that it conforms to the construction specifications?	_______	_________
Have TA-3 borrow soils been determined to be suitable for native soil lifts?	_______	_________
Has approved fill been used during lift construction?	_______	_________
Has the lift been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-04
CONSTRUCTION INSPECTION FORM
TOPSOIL LAYER FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____ Date _____________ Time__________
Inspected by ______________________

Borrow Area ____
Weather ____

Topsoil Description
____
____
____

Volume and location of topsoil placed during shift ______________________________________
____
____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grade to verify that it conforms to the construction specifications?	_______	_________
Has the topsoil been admixed with 25% by volume 3/8-inch crushed gravel?	_______	_________
Has approved topsoil been used for topsoil layer?	_______	_________
Has the topsoil layer been inspected to ensure that it is free of all rocks greater than 2 inches in dimension?	_______	_________

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CI-05
CONSTRUCTION INSPECTION FORM
RECLAMATION SEEDING AND MULCHING FIELD FORM
(Complete One Form Per Shift When This Work Is Being Done)

Project Name ________________________________ Date ____________ Time__________

Weather ________________________________ Inspected by ____________________

Surface area and location covered during shift ________________________________

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the cover surface been surveyed for final grade prior to placement of seed?	_______	_________
Has approved seed been used for seeding?	_______	_________
Has the cover surface been mulched and crimped after seeding?	_______	_________
Did seeding take place during favorable weather conditions?	_______	_________
Did application rate of seed mix meet the construction specifications?	_______	_________

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APPENDIX C
Qualifications of Persons Implementing the CMI Plan

Mary Creech

Qualifications

Ms. Creech has seven years experience, six of which have been in the environmental field. She is the assistant task leader for Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration Chemical Waste Landfill (CWL), Solid Waste Management Unit (SWMU) 91 (Lead Firing Site), and SWMU 68 (Old Burn Site) projects. She provides regulatory reporting, strategic planning, and waste management coordination services.

At the CWL, Ms. Creech is responsible for managing and documenting the effort to close the associated site operational boundary. She is also responsible for regulatory compliance and documenting removal of waste from the CWL, including writing the final waste management report and detailing the removed waste its final disposition. She heads efforts to prepare the final Toxic Substance Control Act report required by the U.S. Environmental Protection Agency. She has also provided project management for waste management, site closure activities, and personnel as well as client interface for scheduling site closure, budgetary issues, project reporting, and support for contract closure. She has completed disposal packages for project-generated, chemical and bulk wastes generated from the remediation of the CWL and managed the disposition of over 200 waste parcels, including the quality control and assurance for all data.

Ms. Creech has provided strategic planning for the lead-contaminated soil removal and radiological investigation at SWMU 68. She leads in negotiating the waste management and radiological protection aspects of the project with both SNL/NM waste management facilities. She is the primary author for the radiological sampling, analysis, and waste management plan for SWMU 68 (required to comply with both the Nevada Test Site and Envirocare of Utah's waste acceptance criteria) as well as the final report and request for closure.

Ms. Creech is one of the ATLs working on the closure of SWMU 91. She is currently providing waste management coordination and peer review services for the project, which has involved the removal of 18.6 tons elemental lead from an inactive firing range. She provided waste management planning and oversight services as well as strategic planning support for the field implementation aspect of the project.

Training/Education

B.S., Biology, New Mexico Institute of Mining & Technology

Joseph E. Fritts, P.G.

Qualifications

Mr. Fritts is a senior geologist with 19 years of technical and management experience in the environmental field. His experience in hydrogeology and waste management includes investigations of soil and groundwater contamination, site characterization, site remediation, waste management, groundwater protection, and Resource Conservation and Recovery Act (RCRA) Remedial Investigation/Feasibility Studies. Mr. Fritts has Environmental Restoration (ER) experience at Sandia National Laboratories/New Mexico (SNL/NM), Los Alamos National Laboratory, and the U.S. Department of Energy (DOE) Mound Plant. Has worked on hydrogeological investigations at the Naval Air Weapons Station in China Lake, California, and at Project Shoal near Fallon, Nevada.

He has participated in all aspects of a classified landfill remediation project including managing all waste characterization, waste disposal, and waste minimization activities. He has worked to remediate environmental sites including the excavation of contaminated soil and materials, and has worked on earthen covers installed over closed landfill sites. Mr. Fritts has performed extensive fieldwork involving hydrogeologic site investigations at twenty-two mine tailings sites located throughout the western United States.

Mr. Fritts has extensive regulatory compliance experience including RCRA, National Environmental Policy Act, and Uranium Mill Tailings Remedial Action regulations. He has worked with regulators in the New Mexico Environment Department, the DOE, and the U.S. Environmental Protection Agency in order to resolve environmental issues. He has extensive experience supervising drilling programs supervising rotosonic, air rotary, mud rotary, air rotary casing hammer, ODEX, Stratex, and auger drilling methods. He also has experience drilling and installing soil vapor monitoring systems.

He currently provides technical support for various sites that are part of the ER Project at SNL/NM. He is working on a project to install an earthen cover over recently excavated and remediated chemical waste landfill. He oversaw writing and implementation of the quality assurance plan, scheduling, and daily oversees cover installation operations.

Training/Education

B.S., Geology, University of New Mexico

A.A., Humanities, Orange County Community College

Timothy J. Goering

Qualifications

Mr. Goering has more than 22 years of technical experience in the environmental field, including 18 years experience as a groundwater hydrologist working on various U.S. Department of Energy (DOE) projects, including Remedial Action and Environmental Restoration Programs. His expertise includes groundwater hydrology, vadose zone characterization, aquifer characterization, corrective measures studies, Resource Conservation and Recovery Act (RCRA) facility investigations (RFI), and Superfund investigations as well as waste management and compliance with state and federal regulations including RCRA, Comprehensive Environmental Response, Compensation, and Liability Act, National Environmental Policy Act, Uranium Mill Tailing Remedial Action, Toxic Substances Control Act, and DOE orders pertaining to radioactive, mixed, and hazardous wastes. He works with regulators in the New Mexico Environment Department (NMED), the Nuclear Regulatory Commission (NRC), and the U.S. Environmental Protection Agency to resolve issues on environmental problems and provides expert testimony for public hearings and private litigation.

Mr. Goering supports Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration Project on a variety of groundwater-related issues. His responsibilities at the Mixed Waste Landfill (MWL) include overseeing groundwater characterization and monitoring activities, including vadose zone characterization activities, and preparation of RCRA documents such the recently completed MWL Corrective Measures Study (CMS) and the Corrective Measures Implementation Plan. The CMS included evaluating technologies and potential remedial alternatives for the MWL, and developing their cost estimates. In addition, he provided expert testimony on the CMS in support of the DOE and SNL/NM in a public hearing held by the NMED in December 2004.

For the MWL, Mr. Goering assisted with development of an alternative cover, a thick layer of soil and native vegetation that uses evapotranspiration to minimize infiltration. He helped to develop and conduct the Phase 2 RFI Work Plan for the MWL, which included performing surface geophysics to delineate waste trench boundaries at the site, sampling volatile organic compounds in soil vapor and tritium in soils, designing and installing groundwater monitoring wells, conducting aquifer pump-and-recovery tests, overseeing groundwater sampling activities, and drilling angled boreholes beneath pits and trenches to assess subsurface contamination.

Training/Education

M.S., Hydrology and Water Resources, University of Arizona

B.A., Environmental Science, University of Virginia

J. Ben Martinez

Qualifications

Mr. Martinez serves as environmental scientist, engineer, and project manager specializing in construction/remediation, removal/installation of above- and underground storage tanks (ASTs and USTs) and field service activities. He has ten years of experience in project supervision/management on numerous Sandia National Laboratories/New Mexico (SNL/NM) and U.S. Department of Defense environmental construction projects. He prepares budgets and implements workplans, technical reports, final assessment reports, environmental impact statements, environmental assessments, quality assurance project plans, and health and safety plans. He is also an experienced heavy equipment operator.

Mr. Martinez has participated in numerous field operations at SNL/NM since 1997. His duties include project/site management, health and safety oversight, operation of heavy machinery, and soil, water, and radiological sampling and screening. He is currently the project/site manager of four Environmental Restoration Project sites, the TA-II Classified/Radiological Landfill Backfill Projects, the TA-III Chemical Waste Landfill Backfill Project, Solid Waste Management Unit (SWMU) 91 (Lead Firing Site), and SWMU 68 (Old Burn Site).

Mr. Martinez was contractor-oversight manager for the U.S. Postal Service (USPS) UST Removal, Replacement, and Upgrade Project, in New Mexico and Colorado. He was involved in the decommissioning and retrofitting and modifications (upgrading) of the UST systems to comply with 1998 USPS U.S. Environmental Protection Agency regulations.

Mr. Martinez investigated several SWMUs at Kirtland Air Force Base (KAFB) to characterize the nature and extent of hazardous and radioactive material releases from each unit. All sites were part of a Resource Conservation and Recovery Act facility investigation and involved sampling with direct push technology for the collection of subsurface soil samples.

As assistant project manager/field operations manager for the U.S. Army Corps of Engineers (USACE) Program at KAFB, Mr. Martinez was responsible for implementation of the work plan by subcontracted personnel performing UST removal/replacement construction activities in adherence with USACE military specifications. The scope of work required removal of 102 USTs, some of which were compromised and leaking. He sampled for contaminants in excavations, logged, and coordinated with laboratories in compliance with applicable regulatory protocols. Other technical tasks included coordination with basewide network personnel including water, sewer, gas, communication, and other associated utilities. He ensured that all Occupational Safety and Health Administration and Brown & Root safety procedures were followed. To replace some tanks that were removed, 20 ASTs and 10 vaulted below storage tanks were constructed.

Training/Education

B.S., Environmental Science, New Mexico Highlands University

Anthony R. Martinez

Qualifications

Mr. Martinez has worked in the environmental field for more than five years as a site safety officer, field technician, heavy equipment operator, and waste management specialist. He has been part of the Chemical Waste Landfill (CWL) and Corrective Action Management Unit project teams at Sandia National Laboratories/New Mexico (SNL/NM) since 2000. His experience includes the operation of heavy equipment, environmental sampling/ characterization, hazardous/mixed/solid waste management, and the development, writing, and field implementation of Health and Safety (H&S) plans and task-specific hazard analyses. He was the site safety officer for three major SNL/NM Environmental Restoration remediation/construction projects.

Mr. Martinez's responsibilities include conducting and documenting daily safety meetings, coordinating with adjacent facility safety personnel, interacting with other SNL/NM safety professionals, and tracking H&S training records. He has also been a key member of the management team for CWL Solid Waste Management Unit (SWMU) 91 (Lead Firing Site) and SWMU 68 (Old Burn Site) and is actively involved with problem solving and process improvement. He is currently the site safety officer for the CWL cover installation field project and is responsible for implementing the Integrated Safety Management System approach, which involves ensuring that all related project hazards are identified and addressed on a continual basis. The combination of his field and H&S experience has resulted in an excellent project safety record while maintaining operational efficiency.

Mr. Martinez has provided site H&S oversight on three major projects since 2004, including the CWL backfilling and final cover installation and SWMU 68 and SWMU 91 Voluntary Corrective Actions (VCAs). He was the site safety officer responsible for these VCAs, which included significant excavation of lead-contaminated soil and various debris. Because simultaneous activities were needed, careful advance planning, communication, organization, coordination, and oversight were necessary. The SWMU 91 VCA involved the excavation of approximately 18,000 cubic yards of soil and debris, from which approximately 18 tons of lead were removed for recycling using a three-stage mechanical screen plant as part of a waste/debris segregation process. Approximately 500 cubic yards of soil and solid waste were disposed of off site. SWMU 68 also involved the excavation and disposal of over 500 cubic yards of soil and solid waste, as well as the disassembly of a burn pan test structure and surrounding earthen berm. He led the effort to remove the pan structure and berm, which included scanning the soil for radiological contamination. Using an approach to minimize waste, under his direction the team safely decommissioned the burn pan and earthen berm, generating less than a cubic yard of depleted uranium and thorium soil waste.

Training/Education

Occupational Safety and Health Administration Hazardous Waste Operations and Emergency Response Supervisor Certification

Site Safety Officer Training, IT Corporation

Michael M. Mitchell

Qualifications

Mr. Mitchell has more than 16 years of technical and management experience in environmental consulting, covering all phases of project work driven by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA). His experience includes preparing major reports under RCRA, including Final Voluntary Corrective Measure, Corrective Measures Study (CMS), Final Closure, and Post-Closure Care Plans and Reports as well as a Permit Application for an interim status landfill closing under both 40CFR264 and 40CFR265 requirements.

Mr. Mitchell prepares hydrogeological investigations for RCRA and CERCLA sites, including definition of vadose zone and aquifer characteristics, groundwater flow patterns, geologic and exposure pathways, and the nature and extent of contamination in soil and groundwater. He develops health and safety plans, work plans, waste management plans, and environmental sampling procedures. He designs and implements remediation plans at U.S. Department of Defense and U.S. Department of Energy sites contaminated with hazardous and radioactive materials and manages remediation projects involving heavy equipment and excavation, waste screening and segregation, and waste management. He coordinates and supervises drilling, sampling, analytical laboratory services, heavy equipment operation, and waste management and disposal.

Mr. Mitchell is assistant task leader for the Chemical Waste Landfill (CWL) and Solid Waste Management Unit 91 (Lead Firing Site) for Sandia National Laboratories/New Mexico Environmental Restoration Project. He negotiates final resolution of CMS Report and Post-Closure Care Permitting issues with the New Mexico Environmental Department, coordinates and documents technical aspects of the CWL vegetative soil cover construction project, and oversees final closure reporting to meet RCRA and Toxic Substance Control Act requirements. He is the primary author of regulatory deliverables that set the foundation for final CWL closure.

Mr. Mitchell ensures compliance with state and federal RCRA, National Environmental Policy Act, and Occupational Safety and Health Administration requirements associated with characterization and remediation projects as well as providing public and regulatory presentations support.

Training/Education

M.S., Geology, University of Tennessee

B.A., Geology, Trinity University

Jerry L. Peace

Qualifications

Mr. Peace is a geologist, geophysicist, and civil engineer for Sandia National Laboratories/New Mexico (SNL/NM). His diverse background includes environmental, geoscience, civil engineering, applied geophysics, drilling engineering, soil physics and mechanics, geology, vadose zone hydrology, predictive modeling, groundwater monitoring, remote sensing, environmental sensors, public relations, and environmental regulations experience. He heads all activities at the Mixed Waste Landfill.

Mr. Peace is the project manager and technical leader of a multidisciplinary team of experienced, hands-on professionals who investigate the geologic, hydrologic, and engineering properties of SNL/NM cold-war-legacy waste sites. His team develops documentation, implements noninvasive and invasive technologies, reduces and interprets data, reports findings, and implements the best available remedial measures.

He is also the project manager and technical leader of environmental restoration project geophysics at SNL/NM, which includes airborne and ground magnetic and electromagnetic surveys to delineate subsurface legacy waste burials and the Rio Grande basement structure to determine regional geology, structure, and groundwater transport mechanisms.

He is also the project manager and technical leader of environmental restoration project drilling engineering at SNL/NM, which includes air/rotary casing hammer, resonant sonic, Stratex, reverse circulation drilling technologies to delineate subsurface structure, lithology, geohydrology to determine vadose zone and groundwater transport mechanisms.

Training/Education

Ph.D., Geophysical Engineering, New Mexico State University

M.S., Civil Engineering, New Mexico State University

M.S., Geophysics, University of Alaska

B.S., Geology, New Mexico State University

Donald P. Schofield

Qualifications

Mr. Schofield has worked at Sandia National Laboratories/New Mexico (SNL/NM) for more than 20 years, the last 11 of which have been with the Environmental Restoration (ER) Project. He has overseen the successful deployment of both large and small cleanup operations. He has served as field technician, assistant task leader, and task leader. He managed the ER Field Office that provided personnel and equipment to support Solid Waste Management Unit (SWMU) characterization and remediation. He has extensive experience in contract placement and oversight, as well as project management (schedule, scope, and cost). He has played key roles in the selection, procurement, and implementation of remediation technologies in the field.

From 1998 through 2002, Mr. Schofield was the Assistant Task Leader for the Chemical Waste Landfill, Landfill Excavation Voluntary Corrective Measure, which involved the complete excavation and removal of the original landfill contents. His focus on this four-year, multimillion dollar remediation project (the largest ER Project at SNL/NM) was on contract management and field problem solving. The contents of the former CWL, approximately 52,000 cubic yards of contaminated soil and waste, were removed, segregated, and characterized for final disposal. He established a multidisciplinary team of environmental professionals that backfilled the CWL in two distinct phases from 2002 to 2004. The CWL excavation met all risk-based cleanup goals. The final report was approved by the New Mexico Environment Department in December 2004.

Mr. Schofield is the Task Leader for the CWL cover installation project completed in July 2005. He also serves as the Task Leader of the SWMU 68 (Old Burn Site) and SWMU 91 (Lead Firing Site) Voluntary Corrective Action (VCA) projects that were completed in 2004 and 2005 (final reporting pending). He is responsible for project management, including field construction activities. The SWMU 91 VCA included the excavation of soil and debris, from which lead and metal were removed for recycling. Confirmatory sampling and geophysical surveys were used to demonstrate that corrective action objectives had been met. SWMU 68 was also remediated to maximize operational efficiencies using the same field personnel. The remediation at SWMU 68 included the removal of soil and solid waste for disposal, man-made structures, and radiological soil contamination. Confirmatory sampling demonstrated project goals had been met, as well as site grading, re-vegetation, and related reporting tasks. Projects were safely completed on time and within budget

He was also the assistant task leader for the treatment and disposal of soil at SNL/NM's Corrective Action Management Unit from 2002 to 2003, providing technical input and oversight for the construction of the aboveground, mounded cover. During 2003 he managed the backfilling operations for two excavated landfills at TA-II.

Training/Education

B.S., University of Minnesota, College of Forest Engineering

APPENDIX D
Health and Safety Plan

Site or Activity Name: Mixed Waste Landfill Vegetative Cover Installation

Job Site Location: Technical Area 3

Technical Task Leader: Jerry Peace, SNL/NM, 6116

Alternate: Don Schofield, SNL/NM, 6134

Site Safety Officer: To Be Determined

Alternate: Various personnel

Amendment No.: NA

( ) Amendment to Existing Approved HASP

( ) Date Existing Approved HASP

HASP prepared by:

Tim Goering, SNL/NM 6147
Assistant Task Leader

7/7/05
Date

HASP approved by:

Jerry Peace, SNL/NM 6116
Task Leader - MWL

7/7/05
Date

Michael Oborny, SNL/NM 6328
Industrial Hygienist

5 Jul 2005
Date

Dick Fate, SNL/NM 6147
Department Manager

7/29/05
Date

1.0 INTRODUCTION

1.1 Objective

This Health and Safety Plan (HASP) for the Mixed Waste Landfill addresses installation of the vegetative cover and bio-intrusion barrier at Sandia National Laboratories' Mixed Waste Landfill (MWL). The vegetative cover design and additional details for cover installation are presented in the MWL Voluntary Corrective Measures Work Plan. A detailed history of the MWL and additional background information are presented in the Mixed Waste Landfill Phase 2 RFI Report (Peace et al. September 2002).

The Mixed Waste Landfill (MWL) is located approximately 5 miles southeast of Albuquerque International Sunport and 4 miles south of Sandia National Laboratories/New Mexico (SNL/NM) Technical Area (TA)-1. The landfill occupies 2.6 acres in the north-central portion of TA-3. The MWL accepted containerized and uncontainerized low-level radioactive waste and minor amounts of mixed waste from SNL/NM research facilities and off-site generators from March 1959 to December 1988. Approximately 100,000 cubic feet of low-level radioactive waste (excluding packaging, containers, demolition and construction debris, and contaminated soil) containing 6300 curies (Ci) of activity (at the time of disposal) were disposed of at the MWL.

1.2 Project Organization

The MWL project is managed by SNL/NM Environmental Restoration (ER) Project Task Leaders (TLs). Jerry Peace is the TL responsible for the MWL Project. Don Schofield will be the primary Sandia interface with other SNL/NM Departments, such as Compliance and Generator Interface, Hazardous Waste Management, Radioactive and Mixed Waste Management, Security, and Radiation Protection Operations. Daily coordination of activities involving other SNL/NM Departments will be routinely performed by Assistant Task Leaders (ATLs) and/or task-specific SSOs, as appropriate. Mike Mitchell will be Project Manager, and Tim Goering and Joseph Fritts will be responsible for QA/QC and hydrologic testing of the cover.

1.3 Health and Safety Goals and Objectives

The goal of the Health and Safety program is to deploy the MWL vegetative cover with zero occupational injuries or illnesses for site workers. This HASP integrates the information and experience gained from 15 years of characterization, sampling activities, and waste management conducted at the MWL to anticipate and recognize potential hazards associated with the remaining MWL activities, evaluate those hazards in a systematic fashion, and describe the engineering and administrative methods that will be used to control the hazards. This approach, along with the commitment of MWL ER staff and management to continuous process improvement, is consistent with the principles of the Integrated Safety Management System (ISMS). If new information about site hazards is obtained, this HASP will be amended and the changes communicated to all affected parties as appropriate based upon the identified hazards.

2.0 Project Health and Safety Roles and Responsibilities

Section 1.3 presents the general project-level organization. The following sections provide additional information relative to the task-specific implementation of this HASP and related task work. According to SNL/NM policy, any site worker has the authority to stop work if unsafe conditions exist at the site.

2.1 ER Task Leaders (TLs)

The ER TLs have the primary responsibility for project completion and are the focal point of communication and direction between SNL/NM support organizations and contractor personnel. The TLs are responsible for all task work at the MWL, including administering contracted project activities and contractor personnel technical work. The TLs report directly to the SNL/NM ER Department 6147 Manager and work with the SNL/NM Contract Representative to administer contracts. The TLs will coordinate all interactions and activities with SNL/NM, DOE, the public, and other organizations, except those interactions or responsibilities they specifically delegate.

2.2 Assistant Task Leaders (ATLs)

The ER ATLs will assist the TLs and will interact with other contractor personnel and SNL/NM support organizations to ensure safe task completion. ATLs will typically coordinate day-to-day work the task-specific contractors are performing, under the direction of the TL(s). ATLs will be responsible for maintaining appropriate training and serve as the focal point of communication between support organizations and task-specific contractor personnel. ATLs will also coordinate with the Hazardous Waste Management Office (HWM), the Radioactive and Mixed Waste Management Facility (RMMF), and the Radiation Protection Office (RPO).

2.3 Task-Specific Contractor Personnel

The TLs will staff specific task work with appropriate, qualified contractor personnel. Task-specific contractors will be responsible for maintaining appropriate training and performing site work safely, as specified in their contracts.

2.4 Site Safety Officer (SSO)

The SSO may vary based upon the task work being performed. For each task, at least one SSO will be designated by the TL. The SSO role may be filled by a TL, ATL, or task-specific contractor. The SSO will be responsible for the following specific activities:

- Conduct and document daily tailgate safety briefings for all task-specific personnel and identify who will be responsible for carrying the two-way radio or cell phone and/or pager;
- Verify appropriate training documentation is maintained on site for each task-specific site worker;
- Review Task Hazard Analysis (THA) information with site workers, including PPE requirements;
- Coordinate health and safety issues and emergency response actions with site personnel and others, as appropriate.

- Monitor weather conditions;
- Maintain site safety field logs that include the following information: weather conditions, employees on-site, safety issues and any corrective actions implemented;
- Coordinate with SNL/NM industrial hygiene, safety, and radiation protection personnel as necessary and appropriate; and
- Enforce compliance with all requirements of this HASP and stop work if an unsafe condition is identified.

2.5 Site Visitors

All visitors most obtain permission prior to visiting the site from the SNL/ER Department Manager or the ER TL on site. Site visitors will be required to receive a task-specific site safety briefing and comply with health and safety requirements as specified by the SSO if they are present in an area of the site where work is being performed. The TL or ATL on site can then appropriately respond to the visitor and notify available on-site personnel of the visitor's purpose and request appropriate support.

3.0 Identified Work Tasks and Task Hazard Analyses

Identified work tasks and the Task Hazard Analysis (THA) process are described in this section. The THA process is the tool that will be used to evaluate and control hazards associated with identified work tasks. If new tasks are added to the MWL work scope, THAs will be prepared and reviewed with all involved site workers prior to starting the new task.

Identified work tasks at the MWL are summarized below.

Task Scope	Comments
<u>Cover Installation</u> ▪ Remove perimeter fences, and install temporary area boundary using T-posts and rope. ▪ Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. ▪ Compact landfill surface to prepare for subgrade fill. ▪ Place and compact subgrade fill (from TA-3 soil stockpiles). ▪ Place rock bio-intrusion barrier. ▪ Place and compact native soil layer fill (from TA-3 soil stockpiles). ▪ Place and minimally-compact topsoil layer.	Grubbed material will be stockpiled and used as mulch or rip-rap as needed in the design specifications. The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA, and will follow the RWP during cover construction activities. However, once the subgrade fill has been applied, the only applicable radiological control to be applied will be no intrusive work.

▪ Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix, as needed. Additional tasks to be conducted include: ▪ Soil screening ▪ Surveying ▪ Equipment decontamination, if needed (see Section 7.0). ▪ Clearing, grubbing, shallow excavation (at the TA-3 borrow area), minor cut and fill, contouring, scarifying, and harrow work. ▪ Road maintenance and dust control ▪ QA/QC sampling ▪ Nuclear gauge moisture and density verification measurements	Mechanical screening, grading, shallow excavation for surface water drainage features, and other closure activities are covered under this THA. Shallow excavation to generate additional clean fill from a borrow pit area is also covered under this THA. Soil screening will be conducted on clean soils near the TA-3 borrow area west of the CAMU. During screening, personnel at the nearby RWMMF will be notified regarding heavy equipment traffic. A dust permit and digging permit will be required.
Task Scope	**Comments**
<u>Waste Management Activities</u> ▪ Miscellaneous waste management tasks, including waste characterization, packaging, labeling, inspections, and movement.	No wastes are anticipated other than PPE, miscellaneous operational wastes, and decon water. The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA. However, once the subgrade has been applied, the only applicable radiological control to be applied will be no intrusive work.
<u>Mobilization, Demobilization and Site Closure</u> ▪ Fence removal and installation ▪ Addition or removal of temporary structures including site trailers ▪ Miscellaneous site clean-up activities ▪ Loading, unloading, and moving equipment and supplies. ▪ Geophysical surveys and other surveys	Much of this work will be performed between other task work as the schedule and personnel availability permit.

3.1 Task Hazard Analyses

The Task Hazard Analysis (THA) tool is the approach used to identify hazards and establish hazard controls prior to the execution of work. This approach is an integral part of implementing SNL/NM's Integrated Safety Management System initiative at the MWL.

Preliminary THA summaries have been prepared for each identified task and are provided in Attachment D1. Each task is described, the required equipment listed, and the anticipated level of PPE specified. Hazards are sorted into four categories: chemical, physical, radiological, and biological, and then rated based upon the probability of occurrence and the severity of the consequences. Anticipated control measures are then described. The hierarchy of controls is elimination, substitution, engineering, administration, and PPE. Potential offsite impacts are considered and control measures described, although for most of the remaining task work there is very low probability of any off-site impacts. These THAs will be modified and/or new ones generated as new information becomes available and/or new tasks are added to the work scope. THAs for non-routine tasks will be performed and reviewed with site workers prior to conducting the specific task. The results of these THAs will be incorporated in the daily, task-specific tailgate safety briefings. The TL will maintain the most current version of THAs, distribute them to personnel as appropriate, and attach them to the site HASP.

3.2 Underground Utilities

All soil disturbance, regardless of depth, will require a dig permit so the location of buried utilities can be identified prior to the start of field work. A comprehensive excavation permit has been submitted to cover all activities described in this HASP, and to comply with the SNL/NM Excavation and Penetration Activities Procedure AP-004 Revision 8. In the past, if the activity did not penetrate below 1 foot, an excavation permit was not required and the hazard of encountering underground utilities was not, as a rule, considered. Now all surface-disturbing activities will follow the procedures below. Surface disturbing activities include:

Digging	Sampling
Scraping	Fence construction
Grading	Posting & signage installation

- Before any excavation is performed, submit a request for an Excavation Permit to Facilities.
- Have any underground utilities identified, spotted and marked by Facilities before start of the activity.
- When submitting a request for an excavation permit describe the work area and note the exact location on a drawing of the site.
- Designate a sufficient size work area to allow the opportunity to locate work away from marked utilities.
- Pre-inspect the area after spotting has been completed to see if there are buried utility issues that need to be resolved.
- Do not mechanically dig closer than 5 feet to any marked or mapped buried utilities.
- If hand digging within the 5-foot exclusion area is not possible, call the Excavation Permit organization in Facilities Management for other options.

- No intrusive digging activities are planned at the Mixed Waste Landfill. However, clean soils will be excavated to a depth of up to 3 ft from the TA-3 borrow area, located approximately ¾ mile south of the MWL.
- Alert authorities if any underground utilities are encountered. Call 311, the non-emergency hotline (24/7) for guidance. For emergencies call 911. Notify your line management.
- Report even known utilities that are uncovered so that Facilities can determine their exact location with GPS equipment and correct their drawings, if needed.
- Report any site-installed utilities to Facilities so they may add them to the drawings of the area.

3.4 Hot Work

Various activities at the MWL may require welding, cutting metal with a cutting torch, or other forms of hot work. The SNL/NM Hot Work Administrative Procedure AP-032 Revision 1 will be followed for all applicable hot work at the MWL, including obtaining a hot work permit prior to conducting the related work. The permit process identifies hazards associated with hot work and identifies appropriate controls for those hazards. The hot work permit will be maintained on site. Any hot work being conducted by outside contractors will be performed under the MWL hot work permit, and Sandia will provide oversight and fire watch support during the hot work. The SSO will also ensure that any person performing hot work will be provided with and will wear proper protection specific to the particular task.

3.5 Weather

Weather-related hazards include heat stress, sunburn, cold stress, rain, wind, hail, snow, and lightning. The task-specific SSO is responsible for briefing workers on weather-related hazards, warning signs, and appropriate hazard control measures. All site personnel are responsible for monitoring weather conditions while performing activities outside, and stopping work if weather conditions create an unsafe work environment. If lightning occurs within 1 mile of the work area (5 to 7 second count between the lightning flash and the sound of thunder), work will be stopped until the lightning moves further away or the storm dissipates.

3.6 Borrow Area Excavation

The TA-3 borrow area is located west of the CAMU in the southern part of TA-3. The excavation at the borrow area will extend no deeper than 3 ft bgs, and therefore, does not constitute a significant hazard.

4.0 Personal Protective Equipment

Due to the nature of the hazards at the MWL, this work will be performed in Level D PPE, as described below.

Level D Protection

- Cotton coveralls
- Climate appropriate underclothes
- Hard Hat*
- Safety shoes/boots
- Safety glasses w/sideshields or goggles
- Work Gloves (leather or cotton)*

*Task-specific PPE requirements will be determined by the SSO and communicated to workers at the tailgate safety briefing.

The SSO is responsible for evaluating the PPE requirements and can make appropriate changes based upon actual site conditions and/or information obtained during task work. The SSO for each task will determine if hard hats are necessary based upon whether or not an overhead hazard exists. Equipment operators working in closed cabs for all tasks do not need to wear safety glasses or hardhats. No buried MWL wastes are likely to be encountered during cover construction activities, as wastes are buried several feet or more below ground surface. For this reason, Tyvek or other disposable coveralls are not required, and Level D PPE will be adequate for all activities on site.

Tritium is present in surface soils at the MWL. Most of the tritium occurs in soils primarily in the northern half of the MWL, with the greatest concentration occurring in the Classified Area. Figure D-1 shows the distribution of tritium in surface soil at the MWL, based on sampling activities conducted in the early 1990's. Tritium activities in surface soil are relatively low and do not pose a threat to human health or the environment (Peace et al, 2002).

Plutonium-238 has been detected at concentrations of up to 0.103 pCi/g in localized surface soils in the unclassified area of the MWL (Figure D-2). Risk assessment shows the plutonium (at the concentrations detected) does not pose a threat to human health or the environment (SNL/NM 2002).

Standard dust suppression techniques will be used to minimize the generation of windblown dust. These techniques include the limited spraying of soils with water or the use of soil fixatives to minimize dust generation. Fixatives used for dust control shall be reviewed prior to application for potential effects on landfill leachate and landfill surface runoff. Over-application of water resulting in free liquids will not be allowed because of waste minimization controls.

If required and specified, fixatives may be used to mitigate dust. Dust control will be in accordance with the New Mexico Environment Department's Ambient Air Quality Standards (NMAC Title 20 Chapter 2 Part 3) and all applicable DOE and SNL standards. Work will be restricted or suspended if unacceptable amounts of dust are being generated as determined by the SSO and/or radiological control technician. Work areas that have the potential for generating dust will require dust suppression techniques.

PPE requirements by task are summarized below and in the task-specific THAs provided in Attachment D1.

Task Activities	PPE Requirements and Comments
<u>Cover Installation</u> ▪ Remove perimeter fences, and install temporary area boundary using T-posts and rope. ▪ Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. ▪ Compact landfill surface to prepare for subgrade fill. ▪ Place and compact subgrade fill (from TA-3 soil stockpiles). ▪ Place gravel/cobble bio-intrusion barrier. ▪ Place and compact native soil layer fill (from TA-3 soil stockpiles). ▪ Place and minimally-compact topsoil layer. ▪ Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix, as needed. Additional tasks to be conducted include: ▪ Soil screening ▪ Surveying ▪ Equipment decontamination, if needed ▪ Clearing, grubbing, shallow excavation (at the TA-3 soil borrow area), minor cut and fill, contouring, scarifying, and harrow work ▪ Road maintenance and dust control ▪ QA/QC sampling ▪ Nuclear gauge moisture and density verification measurements	All activities can be performed in Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO, or by the Rad Technician in accordance with the RWP # 2562 .

<u>Waste Management Activities</u> ▪ Miscellaneous waste management tasks, including waste characterization, packaging, labeling, inspections, and movement.	All waste management tasks are adequately covered by Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO.
<u>Mobilization, Demobilization and Site Closure</u> ▪ Fence removal and installation ▪ Addition or removal of temporary structures including site trailers ▪ Miscellaneous site clean-up activities ▪ Loading, unloading, and moving equipment and supplies ▪ Geophysical surveys and other surveys	All activities can be performed in Level D PPE (Section 4.0). Task-specific PPE requirements will be determined and communicated to site workers by the SSO.

5.0 Personnel Training and Medical Monitoring Requirements

All on-site workers must sign the HASP compliance agreement in Section 10.0 and attend the daily, task-specific tailgate safety meetings. All site visitors entering active work areas, regardless of employer, must receive a site-specific safety briefing delivered by the SSO or designee for that work area.

The task-specific SSOs are responsible for verifying training compliance for site workers involved in the specific tasks they are assigned to. The TLs, with support from the task-specific SSOs, ATLs and administrative staff are responsible for tracking and notifying personnel when training updates are needed. Copies of training records will be maintained at the MWL site. Unless otherwise noted, all training must be documented by a certificate of completion, by signing a training log, or an SNL/NM TEDS printout. Site workers are responsible for providing the SSO or designee with training documentation prior to starting work, and attending scheduled training. All site workers must comply with medical surveillance requirements outlined in 29 CFR 1910.120(f).

Site Safety Officers will be required to have RAD Worker II training. Because construction activities will be noninvasive, heavy equipment operators in closed cabs are required to have Rad Worker 1 training. For any work requiring use of a respirator, site workers must have medical approval, respiratory protection training, and a respiratory fit test. At least one person on site must have CPR, First Aid, and Fire Extinguisher training. Site workers that operate a forklift must have the appropriate SNL/NM training (FKL153G) or equivalent training from another source.

Training requirements for site personnel are summarized in the Table below.

Responsibility	Required Training*
Task-Specific Site Safety Officers (SSOs)	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 8 Hr. HAZWOPER Supervisor Training, 24-Hr. Supervised OJT, ESH100, Rad Worker II
Task Leaders and Assistant Task Leaders	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 8 Hr. HAZWOPER Supervisor Training, 24-Hr. Supervised OJT, ESH100, Rad Worker II
Site Workers (including Task Specific Contractors)	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 24-Hr. Supervised OJT, ESH100, Rad Worker 1
Heavy Equipment Operators	40-hour OSHA HAZWOPER, 8 Hr. Annual Refresher, 24-Hr. Supervised OJT, ESH100, Rad Worker 1, Drivers License [CDL not required, as operators will not be on public roads]

*SNL/NM security training requirements applicable to the level of clearance for each worker will be completed and documented.

6.0 Monitoring

Dust monitoring may be required during the initial phase of the construction project. If it is requested by a task-specific SSO, dust monitoring will be coordinated with the MWL TL(s).

Because the MWL is an SCA, work in radiologically-controlled areas is addressed under RWP # 2562 and subsequent revisions. Screening and sampling for radiological contamination will be conducted as per the RWP and project waste characterization criteria. Radiation monitoring may be required by the RWP. The radiation monitoring instruments will be calibrated and maintained by SNL/NM Radiation Protection. The criteria for stopping work and notifying the SNL/NM Radiological Control Technician are specified in the RWP.

7.0 Work Zones and Decontamination

Chemical decontamination for personnel and equipment will not be required, as no wastes will be excavated from the site. Radiological decontamination of equipment may be required during the subgrade preparation phase of the project, when heavy equipment may encounter contaminated soils. Radiological decontamination is addressed in RWP # 2562 and subsequent revisions. Once clean subgrade have been placed over the contaminated soils, radiological decontamination will no longer be necessary

7.1 Work Zones

An exclusion zone (EZ) will be established to protect personnel during heavy equipment operations on the cover. A contamination reduction zone (CRZ) will not be necessary, as no excavation into contaminated materials is anticipated, and personnel decontamination should not be required. The SSO will be responsible for setting up appropriate task-specific EZs within the MWL site operational boundary. The necessity for a radiological buffer and decontamination area will addressed in RWP # 2562 and subsequent revisions.

7.2 Personnel Decontamination

Personnel decontamination should not be necessary during the MWL cover construction project, as contamination levels in MWL soils are relatively low. Once soils are covered by the subgrade layer, there will be no potential for contamination of personnel during the remaining cover construction activities. RWP # 2562 and associated revisions discuss radiological requirements for decontamination when exiting a radiologically-controlled area.

7.3 Equipment Decontamination

Equipment that comes into contact with contaminated MWL soil during the initial phase of the project may require decontamination, in accordance with the MWL RWP # 2562. The approved MWL decontamination procedure involves either a dry decon or washing equipment with a high-pressure spray or a low-pressure wash/brush, using a surfactant such as Alconox mixed with water.

If necessary (and if required by the RWP), a decontamination pad may be set up alongside the landfill and used for heavy equipment decontamination. Smaller equipment may also be decontaminated in this location or in leak-proof containers. All decontamination fluids will be collected and sampled for disposal following established waste management procedures.

After the subgrade material has been placed, heavy equipment will no longer require decontamination for the remainder of site work, and radiological control procedures will be eliminated because there will be no further potential for contamination. The only radiological control remaining in place will be the requirement for no intrusive activities at the site.

8.0 Emergency Response Plan

This section provides information regarding the action(s) to be taken by site personnel in the event of an emergency situation. Based on the current activities at the MWL, the potential for a project emergency, such as encountering buried unexploded ordnance, is extremely unlikely. The potential for other TA 3 operations to affect work at the MWL is possible, but also limited. This section provides important emergency information, including lines of communication, to ensure site personnel are prepared to deal with an on-site emergency or off-site evacuation.

8.1 Communication and Muster Points

Direct voice communication and/or two-way radios will be the primary means for communication on-site. Because more than one crew may be working on site at the same time, each crew will carry a site radio or cell phone if crews are not working in the same general area. A designated member of the work crew (typically the SSO, site supervisor, or designee) will carry and monitor the radio or cell phone. More than one work crew may be covered by one radio or cell phone if they are all working in the same general area and have coordinated ahead of time to notify each other in case of an emergency situation. This will be documented through the tailgate safety briefing in the morning before the field work begins.

Site emergencies will be communicated either directly (person to person) or through the site radios or cell phones. An off-site emergency within TA 3/5 that requires the notification and/or evacuation of MWL site personnel will be communicated via two-way radios from the SNL/NM Incident Command (two-way IC radios) and/or Sandia alpha-numeric pagers. Because MWL personnel may not be in the site trailers at all times during the day, the two-way IC radio or cell phone/Sandia pager will provide a back-up means to ensure MWL personnel are notified of a TA 3/5 emergency situation (off-site emergency). At least one, on-site, MWL representative will carry and monitor the two-way IC radio or wear the Sandia pager and carry a cell phone. The person(s) carrying the two-way IC radio or cell phone/Sandia pager will be identified in the daily tailgate safety briefings and be responsible for notifying the other MWL site personnel in the event of an off-site emergency.

In the event of an off-site or on-site emergency situation, the MWL TL(s) will be notified immediately. The MWL TLs, if available, or designee, will be responsible for communicating with other SNL/NM organizations/personnel. In the event of an emergency that requires the evacuation of the immediate area, personnel will muster at the MWL muster points (Figure D-3).

If an evacuation of TA 3 is required, all MWL site personnel will proceed directly to the Kirtland Air Force Base Golf Course parking lot and wait there until further information is available, or as directed by the SSO, TL(s), or designee.

Specific roles and responsibilities to be carried out by site personnel will depend on the nature of the incident. Site workers will carry out the various initial response actions, including notifying everyone in the immediate vicinity of the emergency situation and associated hazards.

Communications during site emergencies will occur in the following sequence:

1. On-site personnel will be notified first via direct voice communication, supplemented if necessary by two-way radio or cell phone communication, to ensure all on-site MWL personnel are aware of the situation. If more practical given the circumstances, two blasts on a vehicle or hand-held horn will be repeated to sound the initial warning. If someone is injured, site workers will check scene for hazards and notify the closest, properly-trained First Aid/CPR responder. If imminent danger exists, proceed directly to step 4 and then proceed with the following steps.

2. If possible based upon the situation, notify the MWL TL(s) immediately, who in turn will notify the 6147 Department Manager. The TL(s) and/or SSO(s) will determine appropriate initial responses, including selecting a muster point if appropriate (Figure D-3). As per Section 3.2, if a buried utility is encountered, notify the non-emergency hotline immediately and stop intrusive work in the area.
3. Activate the SNL/NM Incident Command by phone, two-way IC radio, or cellular phone.
4. Use tailgate safety briefing forms or site entry logs and the buddy system at the muster point to account for all site workers.

MEDICAL EMERGENCY

In case of a medical emergency/injury, the SSO (or nearest site worker) will survey the scene and ensure that it is safe to enter and render assistance. If emergency medical attention is needed the SSO will immediately activate or have someone else activate the SNL/NM Emergency Response by calling 911 on a land line or 844-0911 by cell phone, or by using the two-way IC radio. The SSO or the nearest trained site worker will then provide CPR and/or emergency first aid as necessary. If the situation is not a medical emergency, the injured individual(s) should be transported to the Sandia Medical Clinic or Lovelace Medical Center for non-business hours, as appropriate. Lovelace Medical Center will typically be used by contractors for minor injuries and non-emergency medical conditions. The evacuation routes to Sandia Medical Clinic and the Lovelace Medical Center are shown in Figure D-4.

Medical Clinic Information	
SNL Medical Clinic Address: Building 831, corner of F & 7th Streets, KAFB, NM Route to SNL Medical Clinic: Exit east from TA-3 to Pennsylvania (Lovelace Rd.), then left (northwest) to Wyoming, then right (north) to F Street, east on F Street to 7th Street *[Used during normal business hours of 0700-1700]*	**SNL Medical Clinic: 845-8692 (reception)** **845-8159 (Dr. McCarthy)**
Lovelace Hospital Address: 5400 Gibson Blvd. SE. Route to Lovelace Hospital: Exit east from TA 3 to Pennsylvania Ave, go left (northwest) to Wyoming, go right (north) to Gibson, go left (west) to Emergency Entrance, 5400 Gibson Blvd. See Figure D-4 for map to Lovelace. *[Used only during non-regular business hours]*	**Lovelace Phone:** **262-7000 (main switchboard)** **262-7222 Emergency Room**

8.2 Emergency Contact Information

Emergency contact information provided below for the MWL Project.

EMERGENCY CONTACTS	NAME/ORGANIZATION NUMBER	PHONE
24-Hour Emergency Line	Incident Command System/3137	911 (base) / 844-0911 (cell)
Non-Emergency Hotline	Incident Command System/3137	311 (base) / 844-6515 (cell or base)
Sandia Medical Clinic	Staff	911 (base) / 844-0911 or 844-0081 (cell or base)
Lovelace Medical (Gibson)	Staff	Emergency Room: 262-7222 (cell) or 7-262-7222 (base)
Department Manager	Dick Fate / 6147	284-2568 (office)
Project Task Leaders	Jerry Peace / 6116 Don Schofield / 6141	284-2472 (office) 844-4088 (office) / 259-7098 (cell)
Assistant Task Leaders	Mike Mitchell / 6141 Tim Goering / 6147 Joe Fritts / 6146	284-6757 (office) 250-7224 (cell) 284-2563 (office) 845-8703 (office) / 681-8016 (cell)
Fire Department	KAFB	911 (base) / 844-0911 (cell)
KAFB EOD	Staff	846-2229
Radiation Protection Operations	To Be Determined	To Be Determined
Industrial Hygiene	Michael Oborny / 6328	845-8040
Safety Engineering	Michael Oborny / 6328	845-8040
6100 ES&H Coordinator	Johnny Ethridge / 6140	845-9295

9.0 References for Key MWL Project Documents

The following project documents contain information that is relevant to the task work described and covered by this HASP.

Peace, J.L. and T.J. Goering, January 2005. "Calculation Set for Design and Optimization of Vegetative Soil Covers, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2005-0480.

Peace, J.L. and T.J. Goering, March 2004. "Mixed Waste Landfill Corrective Measures Study Final Report, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2004-0627.

Peace, J.L, T.J. Goering, M.D. McVey, and D.J. Borns, May 2003. "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico," SAND Report SAND2003-0836.

Peace, J.L., Goering, T.J. and M.D. McVey, September 2002. "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico", Sandia National Laboratories Report SAND2002-2997.

Sandia National Laboratories/New Mexico (SNL/NM), July 2005. "Mixed Waste Landfill Voluntary Corrective Measures Work Plan, Sandia National Laboratories/New Mexico", prepared at Sandia National Laboratories by J. Peace and T. Goering for the US Department of Energy, Albuquerque, New Mexico.

10.0 Compliance Agreement

All site workers will be required to review and comply with the information contained in this HASP. This will be documented by the site workers signing the compliance agreement form on the following pages. The signed agreement will be maintained on site.

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT:
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT (continued):
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

HEALTH AND SAFETY PLAN ACKNOWLEDGMENT (continued):
I have read, understand, and agree to abide by the provisions detailed in this Site Health and Safety Plan. Failure to comply with these provisions may lead to disciplinary action and my dismissal from the site.

Printed Name	Signature	Organization/Company	Date

Attachment D1

Task Hazard Analyses

For:

Vegetative Cover Installation Activities

Waste Management Activities

Mobilization, Demobilization and Site Closure Activities

TASK HAZARD ANALYSIS
Task — MWL Vegetative Cover Installation

Description —
A vegetative cover with a rock bio-intrusion barrier will be installed on the Mixed Waste Landfill (MWL). The cover will be placed over the original 2.6-acre landfill surface and will consist of three feet of compacted native soil, overlying a rock bio-intrusion layer. A vegetated topsoil layer admixed with 25 percent 3/8-in. crushed gravel will be applied to maintain water balance and mitigate water and wind erosion.

Tasks associated with MWL Vegetative Cover Installation activities include:

- Remove perimeter fences and install temporary operational boundary using T-posts and rope.
- Clear and grub existing landfill surface. Grubbing is not to exceed 6 in. in depth. Grubbed materials will be stockpiled onsite and used as mulch or rip-rap where needed.
- Compact landfill surface to prepare for subgrade fill.
- Place and compact subgrade fill (from TA-3 soil stockpiles).
- Place rock bio-intrusion barrier.
- Place and compact native soil layer fill (from TA-3 soil stockpiles).
- Place and minimally-compact topsoil layer.
- Seed the cover, lay-down area, borrow areas, and other disturbed areas with a native seed mix. The surface will be drill-seeded, mulched and crimped.

Additional tasks to be conducted include:

- Mechanical screening of fill material
- Surveying
- Equipment decontamination (if required by the RWP) and cleaning
- Clearing, grubbing, minor cut and fill, contouring, scarifying, and harrow work. Shallow excavation (≤3 feet) will be conducted at the TA-3 borrow area west of the CAMU.
- Road maintenance and dust control

- QA/QC sampling
- Moisture and density verification measurements using a CPN MC-3 Portaprobe

Equipment Required:

- Heavy Equipment- excavator, four yard loader, dozer (D-6 or equivalent), dozer (JD 650 or equivalent) grader, soil compactor, 60-ft boom lift, high reach fork lift
- Mechanical screen (ScreenAll)
- Vehicles-14-yard dump truck, water truck (2000 and 4000 gallon), water wagon, pick-ups
- Hand Tools-shovels, picks, etc.
- GPS and survey equipment
- CPN MC-3 Portaprobe
- Safety Equipment

Level of Protection: Level D PPE will be appropriate for all cover installation activities (see Section 4.0 for discussion of PPE). The task-specific SSO is responsible for evaluating the PPE requirements and can make appropriate changes based upon actual site conditions and/or information obtained during task work. The SSO for the cover installation tasks will determine if hard hats are necessary based upon whether or not an overhead hazard exists. Equipment operators working in closed cabs do not need to wear safety glasses or hardhats.

MWL Vegetative Cover Installation - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical • Direct contact with chemically-contaminated soil and debris	Not Applicable	Chemical contamination of MWL surface soils is not significant, and will not be an issue. Only clean soil and rock will be used for MWL cover construction.
Physical • Cover construction • Heavy Equipment • Excavation Activities-Utilities • Mechanical screening • Tools • Worker fatigue • Heat and Cold stress • Slip, Trip and Fall • Heavy Lifting	Medium	The construction area will be controlled, and these controls will be maintained until cover installation are completed. Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. Heavy equipment will be inspected daily when used. The number of workers in the work area will be minimized when heavy equipment is operating. Any excavation activities will follow OSHA requirements for sloping, as appropriate. An SNL/NM excavation permit will be required for the TA-3 borrow area. The permit requirements and reporting protocol will be reviewed with workers. The mechanical screen will be located downwind of personnel and water will be used for dust control. If dust control measures are not adequate, screening will be stopped. All tools will be inspected prior to use. A work/rest plan will be implemented as appropriate by the SSO. Workers will dress appropriately for the weather conditions and heat/cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible) slip, trip and fall hazards. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible.

Potential Hazard	Hazard Rating	Control
Radiological • Ingestion or inhalation of radiologically-contaminated soil and dust	Low	The MWL is a Soil Contamination Area (SCA). Site workers will be required to read and sign the RWP prior to performing work in the SCA. Dust suppression techniques will be used to minimize the generation of dust during construction. These include limited spraying of soils with water or the use of soil fixatives. Work areas that have the potential for generating dust will require dust suppression.
Explosive	Not Applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, Insects	Low	Work areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

TASK HAZARD ANALYSIS
Task — MWL Vegetative Cover Installation (Concluded)

Potential Off-Site Impacts:

1. Increased traffic – Considerable vehicle and heavy equipment traffic related to cover construction will occur within the site operational boundary. However, subgrade and native soil layer fill from the TA-3 soil stockpiles will be trucked to the MWL from the soil stockpiles and borrow area, located approximately 1 mile south of the MWL. Increased localized traffic in TA-3 is anticipated during the four month construction period for the cover. Suggested truck routes from the soil stockpiles to the MWL are shown in Figure D-5. Additional traffic will also be generated during the trucking of rock from an offsite source to the MWL for the bio-intrusion layer. Traffic impacts on KAFB as a whole are expected to be minimal, however. If necessary, local traffic near the MWL will be re-directed.
2. Increased noise – no significant off-site impact anticipated.
3. Utility outages - no off-site impact anticipated.
4. Dust - suppress dust with limited water as necessary, or with soil fixatives, if appropriate. Use magnesium chloride/water mixture as appropriate to maintain soil stockpiles and local road surfaces. The decision to apply magnesium chloride will be made by the site

manager or the SSO. Mechanical screening will be terminated at the request of the SSO if dust suppression techniques are not adequate to prevent offsite dust releases due to wind that adversely impacts on-site or off-site personnel.

5. Fire - Task Leader, SSO, or designee will communicate with local facility Points of Contact and initiate emergency response plan if necessary.

TASK HAZARD ANALYSIS
Task — Waste Management

Description —
Minimal waste will be generated by the MWL cover construction project. Waste generated will likely be limited to small quantities of miscellaneous operational wastes. Although the MWL is an SCA, the generation of radiological waste should be minimal. Organic debris removed during clearing and grubbing the landfill surface will be utilized onsite as mulch during the seeding operation. Similarly, rocks removed during clearing and grubbing and concrete waste generated during fence removal will be utilized onsite in the rock bio-intrusion barrier, or as rip rap for the cover.

Waste management tasks include

- Waste characterization sampling
- Waste packaging, labeling, inspections, and other miscellaneous waste management tasks

Heavy equipment and light vehicles may be used when necessary to move waste containers and waste materials. Radiological release surveys may be required for items, equipment, containers, etc. before leaving the SCA. RWP # 2562 and subsequent revisions will be followed for all work in the SCA. The task-specific SSO for any waste management activities conducted in the SCA will be responsible for reviewing the RWP with site workers and coordinating with Radiation Protection, as appropriate, to ensure compliance with the RWP and this HASP.

Equipment Required:
- Heavy Equipment-backhoe, forklift, front loader
- Vehicles- pick-ups.

- Hand Tools-shovels, picks, hammers, screwdrivers, etc…
- Power Tools-drill, saws, air-tools, etc…
- Rigging-slings, chokers, barrel lifters, chains, shackles, hooks
- Safety Equipment- radiation monitors as per RWP
- Polyethylene sheeting

Level of Protection: Level D is required for waste management tasks. See Section 4.0 for discussion of PPE.

Waste Management - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical • No hazards anticipated	Not Applicable	No contact with chemical contamination is anticipated during MWL cover construction.

Potential Hazard	Hazard Rating	Control
Physical • Heavy Equipment • Motor vehicle use for transport • Tools • Worker fatigue • Heavy lifting • Heat and Cold Stress • Slip, Trip and Fall	Medium	Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. Heavy equipment will be inspected daily when used. The number of workers in the work area will be minimized when heavy equipment is operating. Site workers using motor vehicles will have a current driver's licenses and obey all traffic laws. All tools will be inspected prior to use. A work/rest plan will be implemented as appropriate by the task-specific SSO. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible for heavy lifting. Workers will dress appropriately for the weather conditions and heat and cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible) slip, trip and fall hazards.
Radiological • Handling potentially contaminated soil/debris	Low	The MWL is a soil contamination area (SCA). MWL soils are contaminated with tritium and plutonium. SCA controls will be maintained within the MWL perimeter until the subgrade layer has been placed. Waste management tasks have a low potential radiological hazard rating, and will be conducted in accordance with the RWP.
Explosive	Not applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, Insects	Low	Areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

Potential Off-Site Impacts:
No offsite impacts anticipated.

TASK HAZARD ANALYSIS
Task — Mobilization, Demobilization, and Site Closure Activities

Description — This task covers numerous activities that are related to mobilization, demobilization, and site closure activities. Site closure activities include permanently closing down site restoration operations at the MWL and the associated temporary infrastructure. The following list summarizes the main types of activities covered under this task.

- Fence removal and installation
- Removal of temporary structures, including site trailers
- Removal of temporary utilities (if applicable)
- Redistribution of SNL/NM owned equipment and material
- Miscellaneous site clean up activities
- Loading and unloading, movement of equipment, supplies, and waste materials
- Preparing equipment and supplies for transport off-site
- Surveys

These activities will be conducted in a phased manner, as personnel and resources allow. Also covered under this task will be any welding or hot work required as part of remaining MWL task work (see Section 3.4). A final survey is planned after completion of cover installation. After completion of the site closure activities the site will be in its end-state condition.

Equipment Required:
- Heavy Equipment – forklift, front-end loader, track-hoe, backhoe, small front-end loader
- Hand Tools – hammers, shovels, sledge hammer, etc.
- Power Tools – electric drill, circular saw, etc.
- Rigging-slings, chokers, barrel lifters, chains, shackles, hooks
- Welding/hot work equipment (Section 3.4)
- Vehicles – pick-up trucks, dump truck, semi-trucks
- Safety Equipment

Level of Protection: Level D PPE should cover all demobilization activities (see Section 4.0 for discussion of PPE). The task-specific SSO and the assigned rad technician are responsible for evaluating the PPE requirements and can make appropriate changes based on the specific demobilization task work being performed. Hot work may require additional PPE, which will be determined by the task-specific SSO and consistent with the SNL/NM Hot Work Permit (Section 3.4).

Mobilization, Demobilization, and Site Closure Activities - Potential Hazards and Controls

Potential Hazard	Hazard Rating	Control
General Approach to Work Hazards	Not Applicable	Maintain worker awareness and coordinate task-specific work regime through tailgate safety briefings. Use buddy system and team approach to keep workers watching out for each other.
Chemical	Not Applicable	No intrusive work in contaminated areas.
Physical • Heavy equipment • Motor vehicle use for transport • Electrical • Tools • Hot work • Heat and cold stress • Slips, trips, and falls • Heavy lifting	Medium	Heavy equipment will be inspected daily when used. Only qualified operators will operate heavy equipment, which will be equipped with backup alarms. The number of workers in the work area will be minimized when heavy equipment is operating. If a crane is needed it will be obtained, along with a SNL/NM qualified operator, through SNL/NM Facilities. Site workers using motor vehicles will have a current drivers license and obey all traffic laws. Qualified electricians perform electrical work. Lock out tag out procedures will be followed where applicable. An SNL/NM excavation permit covering the entire MWL area has been obtained. The permit requirements and reporting protocol will be reviewed with workers who are involved with any type of intrusive activities. All tools will be inspected prior to use. A hot work permit will be obtained from SNL/NM Facilities prior to conducting hot work. Proper precautions, including fire prevention, will be followed as per the permit. Workers will dress appropriately for the weather conditions and heat/cold stress warning signs and hazards will be reviewed. Shaded rest areas and sheltered, heated rest areas will be provided. Frequent water/hydration breaks will be implemented. Workers will watch for and eliminate (where possible)

Potential Hazard	Hazard Rating	Control
		slip, trip and fall hazards, as part of a "good house-keeping" approach. Safe lifting procedures will be reviewed with workers and mechanical aids used whenever feasible for heavy lifting.
Radiological	Low	The MWL is an SCA. Soils are contaminated with tritium and localized plutonium. SCA controls will be maintained within the MWL perimeter until the subgrade layer has been placed. Mobilization, demobilization, and site closure tasks have a low potential radiological hazard rating, and will be conducted in accordance with the RWP.
Explosive	Not Applicable	No explosive hazards anticipated.
Biological • Snakes, Rodents, and Insects	Low	Areas will be kept clean and places of refuge for biological hazards eliminated where possible. Worker awareness will be maintained through tailgate safety briefings.

Potential Off-Site Impacts:
No off-site impacts anticipated.

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Figures

Figure D-1
1993 Tritium Surface Soil Sampling Results

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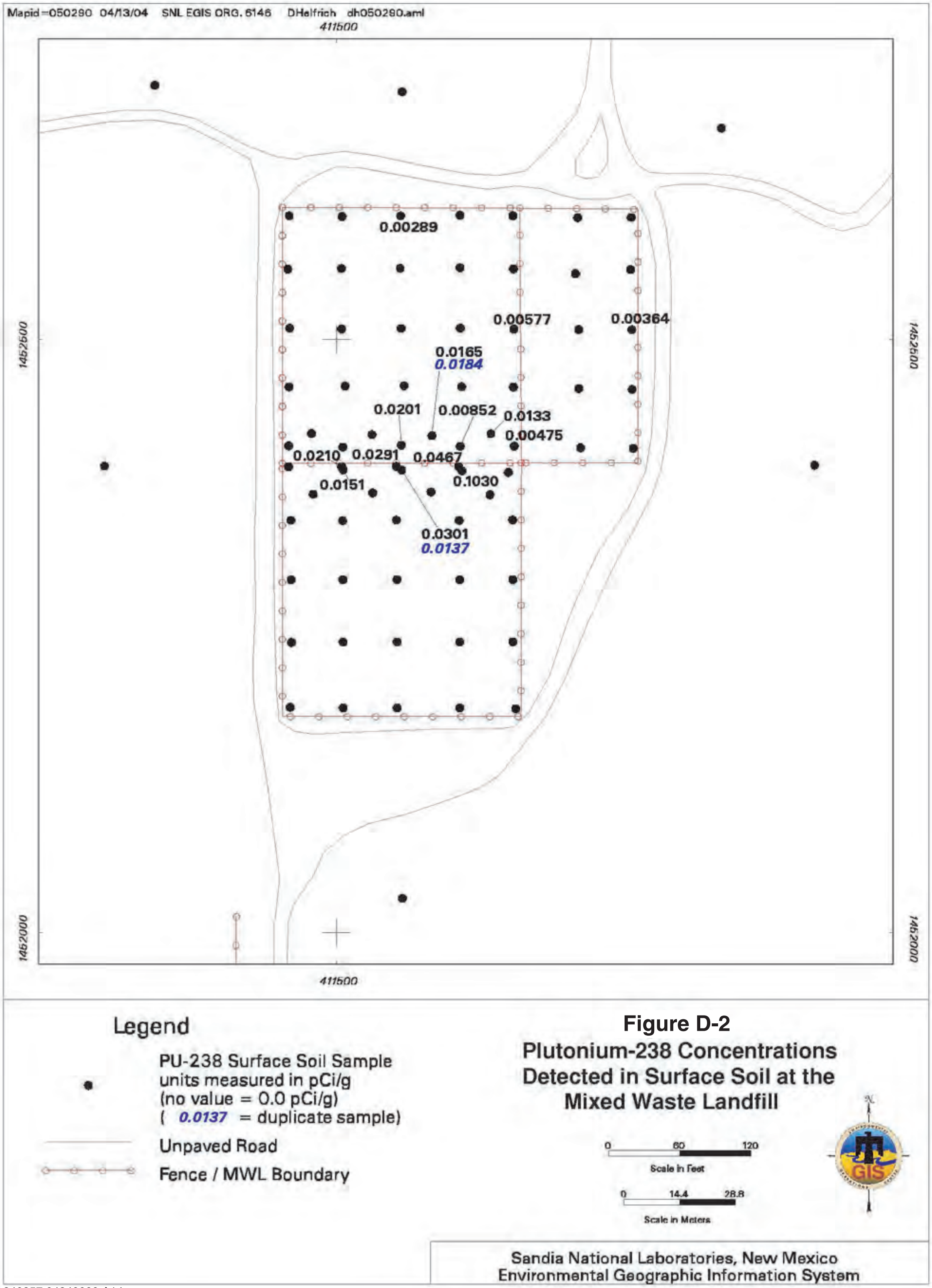

Figure D-2
Plutonium-238 Concentrations Detected in Surface Soil at the Mixed Waste Landfill

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

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Figure D-3
Mixed Waste Landfill
Muster Points

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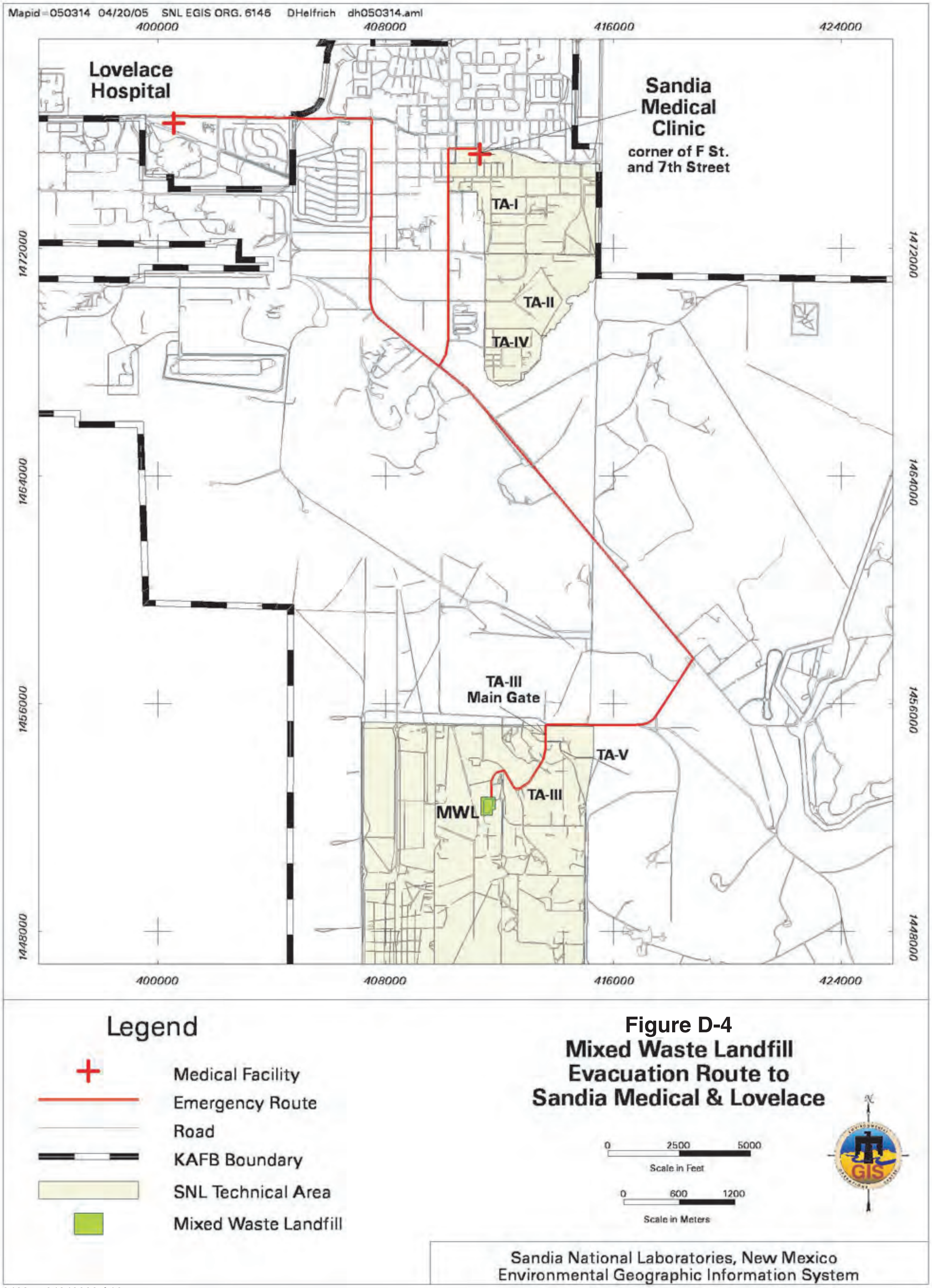

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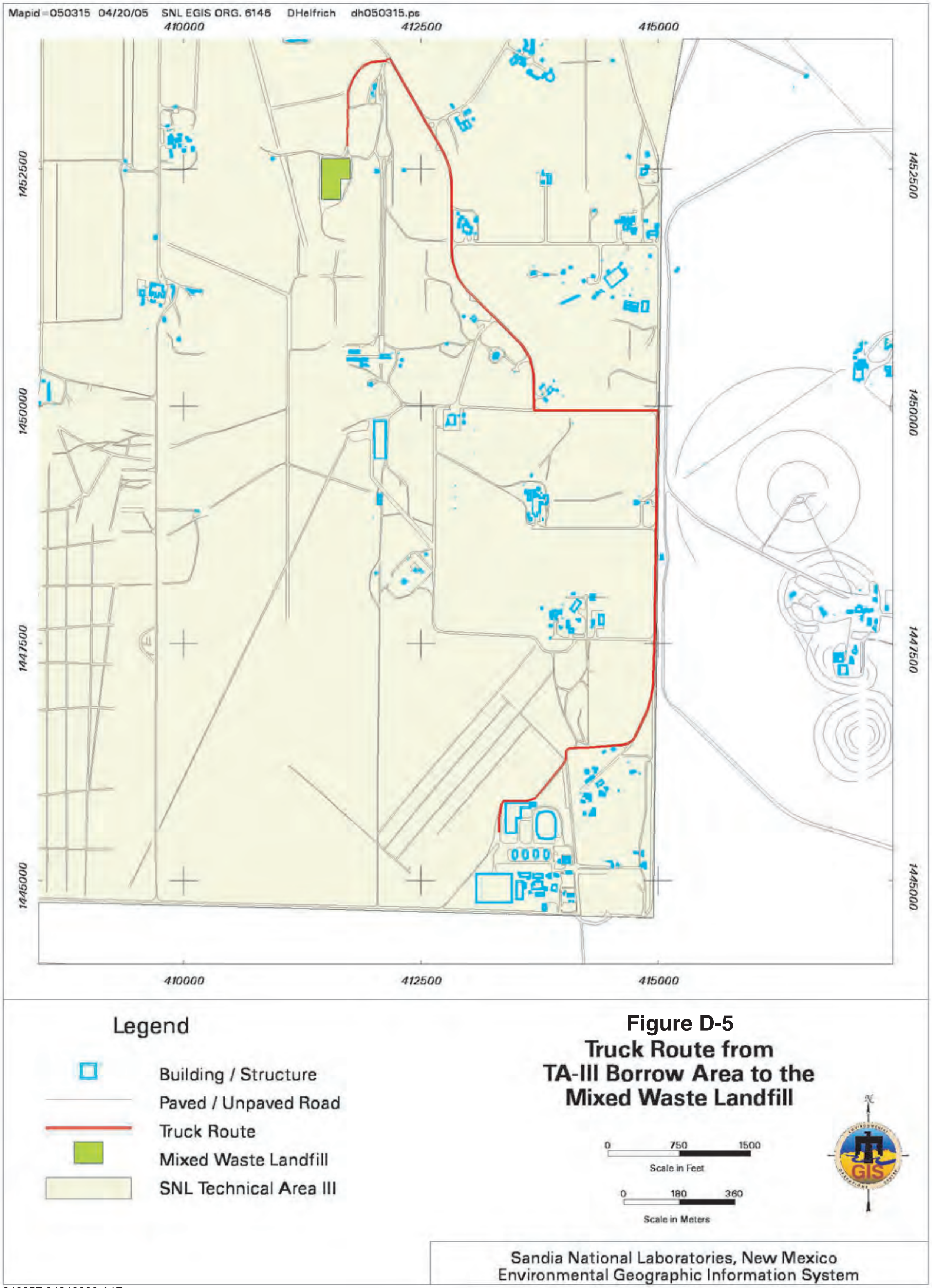

Figure D-5
Truck Route from TA-III Borrow Area to the Mixed Waste Landfill

Sandia National Laboratories, New Mexico
Environmental Geographic Information System

APPENDIX E
Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories

Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories

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Abstract

A probabilistic performance assessment has been conducted to evaluate the fate and transport of radionuclides (amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, radon-222, strontium-90, thorium-232, tritium, uranium-238), heavy metals (lead and cadmium), and volatile organic compounds (VOCs) at the Mixed Waste Landfill (MWL). Probabilistic analyses were performed to quantify uncertainties inherent in the system and models for a 1,000-year period, and sensitivity analyses were performed to identify parameters and processes that were most important to the simulated performance metrics. Comparisons between simulated results and measured values at the MWL were made to gain confidence in the models and perform calibrations when data were available. In addition, long-term monitoring requirements and triggers were recommended based on the results of the quantified uncertainty and sensitivity analyses.

At least one-hundred realizations were simulated for each scenario defined in the performance assessment. Conservative values and assumptions were used to define values and distributions of uncertain input parameters when site data were not available. Results showed that exposure to

tritium via the air pathway exceeded the regulatory metric of 10 millirem/year in about 2 percent of the simulated realizations when the receptor was located at the MWL (continuously exposed to the air directly above the MWL). Simulations showed that peak radon gas fluxes exceeded the design standard of 20 picocuries/square meter/second in about 3 percent of the realizations if up to 1 percent of the containers of sealed radium-226 sources were assumed to completely degrade in the future. If up to 100 percent of the containers of radium-226 sources were assumed to completely degrade, 30 percent of the realizations yielded radon surface fluxes that exceeded the design standard. For the groundwater pathway, none of the radionuclides or heavy metals (lead and cadmium) were simulated to reach the groundwater during the 1,000-year evaluation period. Tetrachloroethene (PCE) was used as a proxy for other VOCs because of its mobility and potential to exceed maximum contaminant levels in the groundwater relative to other VOCs. Simulations showed that PCE reached the groundwater, but only 1 percent of the realizations yielded aquifer concentrations that exceeded the regulatory metric of 5 micrograms/liter.

Based on these results, monitoring triggers have been proposed for the air, surface soil, vadose zone, and groundwater at the MWL. Specific triggers include numerical thresholds for radon concentrations in the air, tritium concentrations in surface soil, infiltration through the vadose zone, and uranium and select VOC concentrations in groundwater. The proposed triggers are based on U.S. Environmental Protection Agency and Department of Energy regulatory standards. If a trigger is exceeded, then a trigger evaluation process will be initiated which will allow sufficient data to be collected to assess trends and recommend corrective actions, if necessary.

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Acronyms and Abbreviations

ANL	Argonne National Laboratory
bgs	below ground surface
BOSS	Borehole Optimization Support System
Ci	curie(s)
cm	centimeter(s)
CMI	Corrective Measures Implementation
CWL	Chemical Waste Landfill
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	foot (feet)
g	gram(s)
in.	inch(es)
kg	kilogram(s)
L	liter(s)
MCL	maximum contaminant level
m	meter(s)
μg	microgram(s)
mg	milligram(s)
mm	millimeter(s)
MWL	Mixed Waste Landfill
NMED	New Mexico Environment Department
PCE	tetrachloroethene
ppb	part(s) per billion
pCi	picocurie(s)
$pCi/m^2/s$	picocurie(s) per square meter per second
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
SNL/NM	Sandia National Laboratories/New Mexico
TA	Technical Area
TCE	trichloroethene
USGS	U.S. Geological Survey
VOC	volatile organic compound
yr	year

Acknowledgments

The authors would like to thank Amy Blumberg, M.J. Davis, Joe Estrada, Dick Fate, Ray Finley, John Gould, Mike Nagy, and Fran Nimick for their reviews of this report. We also thank Mitch Pelton and Randal Taira at Pacific Northwest National Laboratory for their assistance with FRAMES/MEPAS.

1. Introduction

1.1 Background and Objectives

The Corrective Measures Implementation (CMI) Plan for the Mixed Waste Landfill (MWL) at Sandia National Laboratories/New Mexico (SNL/NM), is being submitted to the New Mexico Environment Department (NMED). As part of the final order selecting a remedy for the MWL (NMED May 2005), the NMED required that the CMI Plan include a comprehensive fate and transport model to determine if contaminants will move from the MWL down through the vadose zone to groundwater. In addition, the NMED required that the CMI Plan include triggers for future action that identify and detail specific monitoring results that will require additional testing or implementation of an additional or different remedy.

This report presents the probabilistic fate and transport models that were used to assess the performance of the MWL. Relevant contaminants of concern at the site were included, and site-specific models and parameters were used in a probabilistic analysis. Results of the analysis were compared to regulatory performance metrics, and sensitivity analyses were performed to determine the most important parameters and processes that impacted the variability of the simulated performance metrics. Based on these simulations and results, appropriate triggers were identified and defined to address long-term monitoring requirements at the site.

A period of 1,000 years was selected for the probabilistic analysis to be consistent with U.S. Department of Energy (DOE) Order 435.1. DOE Order 435.1 requires that performance assessments be conducted for low-level radioactive waste disposed after September 26, 1988, and that performance objectives be evaluated for a 1,000-year period to determine potential risk impacts to the public and environment. Although most of the MWL wastes were disposed of prior to September 26, 1988, a 1,000-year period was nonetheless determined to be appropriate for assessment of regulatory performance metrics.

1.2 Overview of the Mixed Waste Landfill

The MWL is located approximately 5 miles southeast of Albuquerque International Sunport and 4 miles south of SNL/NM's central facilities (Figure E-1). The landfill is a fenced, 2.6-acre area in the north-central portion of Technical Area (TA)-3 . The mean elevation at the MWL is 5381 feet (ft).

The MWL was established in 1959 as a disposal area for low-level radioactive and mixed waste that was generated at SNL/NM research facilities. Originally, the landfill was opened as the "Area 3 Low-level Radioactive Dump," when the low-level radioactive disposal area in TA-2 was closed in March 1959. The MWL accepted low-level radioactive waste and minor amounts of mixed waste from March 1959 through December 1988. Approximately 100,000 cubic ft of low-level radioactive waste containing approximately 6,300 curies (Ci) of activity was disposed of at the landfill.

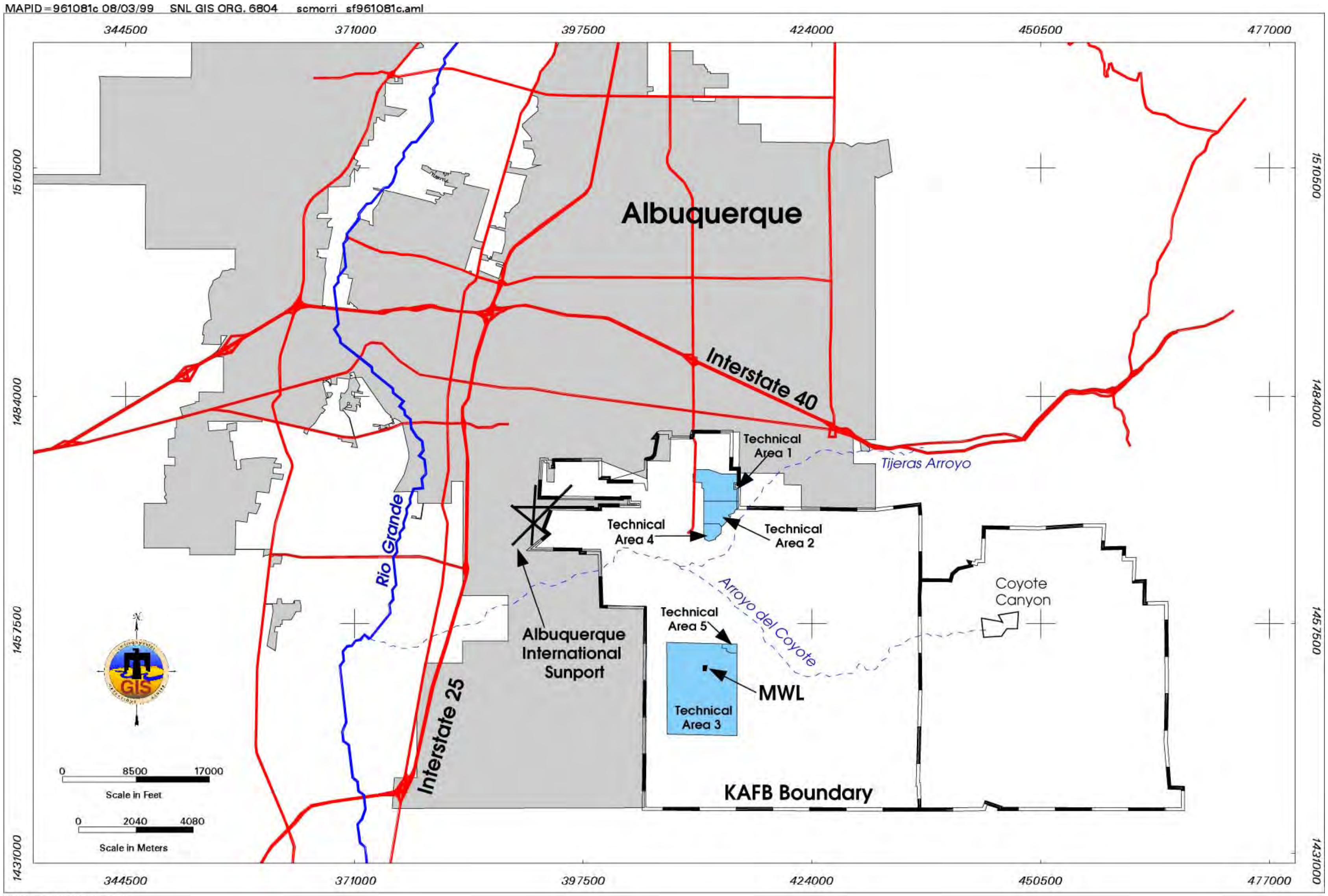


Figure E-1 Location of the Mixed Waste Landfill Relative to Albuquerque, New Mexico, and Kirtland Air Force Base

1.2.1 Site Description

The MWL consists of two distinct disposal areas: the classified area, occupying 0.6 acres, and the unclassified area, occupying 2.0 acres (Figure E-2). Low-level radioactive and mixed waste has been disposed of in each area. Wastes in the classified area were buried in unlined, vertical pits. Wastes in the unclassified area were buried in unlined, shallow trenches.

A Phase 1 Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL and to begin characterizing the nature and extent of any such release. The Phase 1 facility investigation indicated that tritium was the primary contaminant of concern. No organic contaminants were identified. A Phase 2 RFI was initiated in 1992 to determine contaminant source, define the nature and extent of contamination, identify potential contaminant transport pathways, evaluate potential risks posed by the levels of contamination identified, and recommend remedial action, if warranted, for the landfill.

The Phase 2 RFI incorporated the streamlining approach, combining data quality objectives and the observational approach. Nonintrusive field activities were conducted first to facilitate the efficiency and cost-effectiveness of intrusive field activities. Data collected during the Phase 2 RFI were evaluated using U.S. Environmental Protection Agency (EPA)-approved methods. Initially, a constituent population was statistically compared to natural background. Any constituent failing the statistical comparison was further analyzed for spatial distribution. Constituents that failed the statistical comparison to background and showed a strong spatial correlation were identified as potential contaminants of concern.

The Phase 2 RFI was completed in 1995. This investigation included surface radiological surveys; ambient air sampling; soil sampling for background metals and radionuclides; soil sampling for volatile organic compounds (VOCs), semivolatile organic compounds, target analyte list metals, and radionuclides; nonintrusive geophysical surveys; passive and active soil gas sampling; borehole drilling; installation of groundwater monitoring wells; groundwater sampling; vadose zone tests; aquifer tests; and risk assessment. The Phase 2 RFI confirmed the findings of the Phase 1 RFI.

1.2.2 Contaminants of Concern

Based on the results of the Phase 1 and Phase 2 RFIs, tritium was found to be the primary contaminant of concern that has been released from the MWL. An estimated 2400 Ci of tritium were disposed of in the MWL. Tritium is extremely mobile when incorporated in water in liquid and vapor form, moving easily through the vadose zone and into the atmosphere.

Tritium levels range from 1100 picocuries (pCi)/gram (g) in surface soils to 206 pCi/g in subsurface soils in the classified area of the landfill. The highest tritium levels are found within 30 ft of the surface in soils adjacent to and directly below classified area disposal pits. At depths greater than 30 ft below ground surface (bgs), tritium levels fall off rapidly to a few picocuries/gram of soil.

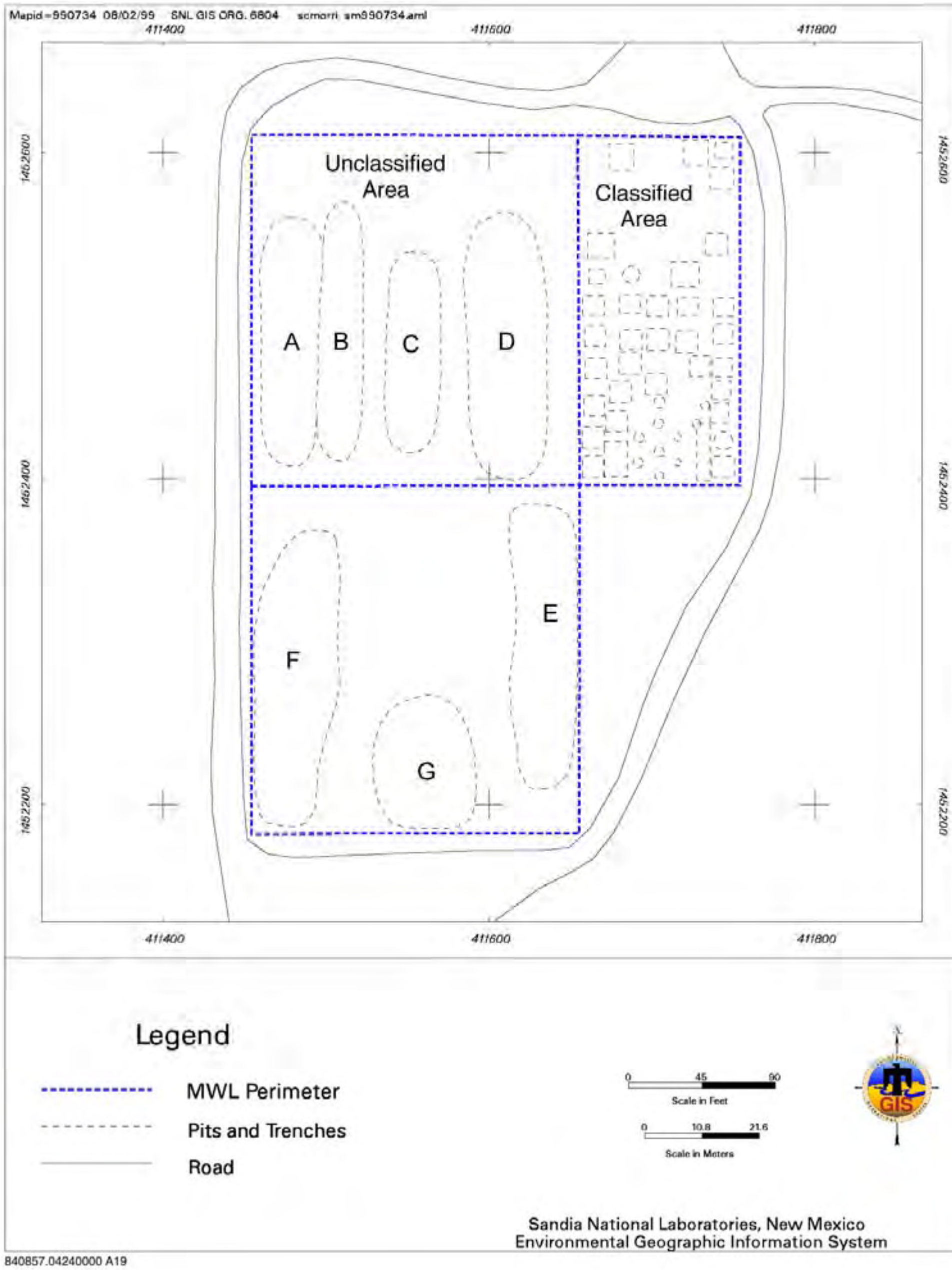


Figure E-2 Map of the Mixed Waste Landfill

Tritium also occurs as a diffuse air emission from the landfill. Tritium emissions from the MWL are diminishing with time due to its half-life of 12.3 years. Total tritium emissions to the atmosphere were measured at 0.294 Ci/year (yr) in 1993 and at 0.090 Ci/yr in 2003 (Peace et al. 2002; Anderson February 2004).

An estimated 27,900 kilograms (kg) (9.3 Ci) of uranium-238 (depleted uranium) are present in the MWL inventory. Based on the results from the Phase 1 and Phase 2 RFIs, there is no indication that uranium has been released from the MWL. However, because of the large quantity of depleted uranium disposed of in the MWL, the fate and transport of uranium was modeled in this study.

Other radionuclides present in the MWL inventory include cobalt-60, strontium-90, cesium-137, plutonium-238 and -239, americium-241, radium-226, and thorium-232. The fate and transport of these radionuclides was modeled, although there is no evidence that these radionuclides have been released from the MWL.

There is an estimated 128,000 kg of lead disposed of within various pits and trenches in the landfill. Most of the lead is in the form of shielding (i.e., lead bricks, casks, pigs, and shipping canisters). Smaller lead items include containers commonly used to dispose of radioactive sources. The lead containers were typically placed in concrete-filled A/N cans or 55-gallon drums. Larger lead items include five massive stainless steel and lead casks disposed of in Trench F, each weighing up to 40 tons. The fate and transport of lead was modeled, although there is no evidence that lead has been released from the MWL.

Cadmium is not specifically listed in the MWL inventory. However, slightly-elevated cadmium has been detected in five boreholes along the west side of the MWL to depths of up to at least 104 ft bgs. The cadmium concentrations in MWL soils range from nondetect to 1.97 milligrams (mg)/kg, approximately two times the NMED maximum background value of 0.9 mg/kg. The source of cadmium in MWL soils is unknown.

Cadmium has occasionally been detected in MWL groundwater at concentrations above the EPA maximum contaminant level (MCL), although these detections are sporadic and unpredictable. Because the cadmium detections above the MCL are inconsistent, it is believed that these detections do not indicate contamination from the MWL. Nevertheless, cadmium is considered a contaminant of concern, and the fate and transport of cadmium was modeled.

During the Phase 2 RFIs, low levels of VOCs were detected in soil gas samples obtained from the landfill. The primary VOCs detected in soil gas at the MWL include tetrachloroethene (PCE), trichloroethene (TCE), dichloro-difluoromethane, 1,1,1-trichloroethane, trichlorofluoromethane, and 1,1,2-trichloro,1,2,2-trifluoroethane. Of these VOCs, PCE was determined to have the highest potential to reach groundwater at concentrations near its MCL (Klavetter 1995a). Other VOCs were either not as mobile or did not have sufficiently high initial soil gas concentrations. For this reason, PCE is a contaminant of concern, and the fate and transport of PCE was modeled. However, because the remaining VOCs still have some potential to contaminate groundwater, PCE was modeled in this study as a proxy for all of the VOCs.

Radon gas generation from the landfill is based on the estimated 6 Ci of radium-226 in the MWL inventory. Most of the radium-226 in the MWL is in the form of sealed sources. Emission of radon gas from the MWL was investigated in 1997. No significant difference between the MWL and the background measurements in terms of median, mean, and standard deviation was observed (Haaker 1998). However, at the request of the NMED, radon was included in the MWL fate and transport model.

In summary, the following list of actual and potential contaminants was included in the MWL fate and transport model: tritium, americium-241, cesium-137, cobalt-60, plutonium-238 plutonium-239, radium-226, radon-222, strontium-90, thorium-232, uranium-238, lead, cadmium, and PCE.

2. Modeling Approach

2.1 Previous Modeling Studies

This section summarizes previous modeling studies conducted for the MWL. These studies include fate and transport modeling studies conducted by Argonne National Laboratory (ANL), Sandia, and WERC (Consortium for Environmental Education & Technology Development). Cover performance modeling studies were conducted by Sandia in support of the MWL cover design, and are summarized in this section as well.

2.1.1 Fate and Transport Modeling Studies

Previous fate and transport modeling studies conducted for the MWL include a study by ANL in 1995 as part of a preliminary human health risk assessment for the MWL; a subsequent study conducted by Sandia in 1995 regarding the potential migration of radionuclides and organic compounds from the MWL; a 1997 study to model the infiltration of reactor coolant water discharged into an MWL trench in 1967; and a study conducted in 2001 by WERC of tritium migration through the vadose zone beneath the MWL.

2.1.1.1 Argonne National Laboratory Modeling Study

One of the earlier modeling studies on the MWL was conducted by Johnson et al. (1995) at ANL. The ANL study used a “worst case” scenario approach in which they took conservative values of parameters at different levels of model complexity to ascertain the probable fate and transport of, as well as risk from, the contaminants. The study used a tiered approach for modeling the fate and transport of contaminants, with increasing model complexity and more justifiable simplifying assumptions.

The first-tier screen was a geometric approach in which tritium from the MWL was distributed evenly throughout the vadose zone. This first-tier screening suggested that tritiated water from the MWL could potentially reach groundwater, although the likelihood was considered small.

The second-tier analysis utilized a one-dimensional analytical solution for flow and transport in the vadose zone, but did not include lateral dispersion, which would reduce concentrations of tritium and the distance traveled by tritium from the landfill. This analysis showed that tritium concentrations could exceed the EPA drinking water guideline of 20,000 pCi/liter (L) after 57 years if the underlying soils were fully saturated. However, because of the uncertainty of the input parameters (particularly velocity, which was considered too high), the analysis over-predicted tritium concentrations in subsurface soils.

The final tier utilized a three-dimensional numerical code, TRACR3D, which still is extensively used for flow and transport calculations. This code is relatively complex, utilizing finite-element solutions for both the saturated and unsaturated zones. Tritium was the primary contaminant modeled because of its assumed higher mobility compared to other radionuclides and organic contaminants. Conservative assumptions were used in the model, boundary conditions, and hydrologic parameters to bound the probable extent and concentration of tritium. The model predicted that 27 years after disposal, the maximum tritium contamination reaches 184 ft bgs with a maximum concentration of 2.8 x 10^{+6} pCi/L, significantly higher than measured field values. After an additional 100 years, the tritium was predicted to have traveled to a depth of 230 ft bgs, with a maximum tritium concentration of 5,400 pCi/L. The ANL study concluded that no detectable tritium concentrations would be likely to reach groundwater at the MWL.

The study also included screening calculations for aqueous-phase transport of PCE and TCE, and predicted that these VOCs could reach the water table approximately 250 years from time of disposal. No calculations were conducted for vapor-phase transport, which has proven to be the most significant transport mechanism for organic compounds in the vadose zone at nearby SNL/NM Environmental Restoration sites, including the Chemical Waste Landfill (CWL) (SNL/NM December 2004).

2.1.1.2 Sandia Modeling of Radionuclide and Organic Compound Transport

A subsequent study was conducted by Sandia in August 1995 to simulate potential contaminant flow and transport from the MWL. The study was conducted using the code Borehole Optimization Support System (BOSS), originally developed to determine the optimum number and location of boreholes and monitoring wells necessary to define the nature and extent of contamination. Monte Carlo uncertainty analysis of flow and transport was used to simulate the migration of radionuclides and organic compounds from the MWL. (Klavetter 1995a; Klavetter 1995b).

BOSS was first used to simulate the migration of radionuclides, including tritium, cesium-137, and strontium-90 from the MWL, using more representative hydrologic property values than were applied in the ANL study. The modeling study predicted that no detectable tritium would reach groundwater at the MWL, and that detectable tritium would not migrate below a depth of 40 meters (m) (131 ft). These results are consistent with the actual tritium distribution data for subsurface soils collected during the Phase 2 RFI. The model also predicted that no detectable activity of cesium-137 and strontium-90 would migrate even 10 m below the MWL pits and trenches.

The code BOSS was also used to simulate the vapor-phase and aqueous-phase transport of the six VOCs detected in MWL soil gas (Section 1.2.2). The modeling results demonstrated that aqueous-phase transport of organic contaminants from the MWL was not a significant transport mechanism. The modeling results also demonstrated that vapor-phase transport of five of the six organic compounds was not significant, due to the low concentrations of these contaminants detected in the soil gas.

Concentrations of PCE detected in soil gas near the MWL surface were calculated to be high enough to result in concentrations of sub-parts per billion (ppb) to a few ppb in groundwater within 50 years. The model predicted that the lateral extent of PCE in the groundwater would be limited, with PCE at concentrations greater than 1 ppb extending less than 130 m (426 ft) downgradient of the MWL. The study recommended that further evaluation of the fate and transport of PCE be considered, including a review of PCE concentrations in borehole soil samples collected during the Phase 2 RFI. PCE was detected at low concentrations in soil samples from 2 of the 16 boreholes drilled during the Phase 2 RFI. PCE was detected in BH-3 at a maximum concentration of 2.45 J micrograms (μg)/kg, and in MW-4 at a maximum concentration of 5.4 μg/kg (Peace et al. 2002).

2.1.1.3 Modeling Study of Reactor Coolant Water Infiltration

In 1997, a modeling study was conducted to simulate the infiltration of 271,500 gallons of reactor coolant water from a trench at the MWL (Wolford 1997). The objective of the study was to evaluate the potential migration of coolant water discharged into Trench D of the MWL in May and June, 1967. The water originated from the Sandia Engineering Reactor Facility in TA-5, and contained approximately 1 Ci of total radioactivity, primarily short-lived fission products. Trench D was an active disposal trench at the time, and was believed to be the most likely source for contaminant release and migration from the MWL.

The modeling study used the code VS2DT (Healy 1990), a finite difference unsaturated flow and transport model developed by the U.S. Geological Survey (USGS). The modeling results indicated that the reactor coolant water, and any tritium mobilized by the water, would not have migrated beyond a depth of approximately 120 ft, based on a 30-year simulation. The modeling results were consistent with Phase 2 RFI field measurements of tritium activities in subsurface soils, which showed tritium detected to a maximum depth of 120 ft bgs.

The study also simulated the fate and transport of the coolant water and tritium for a period of 90 years into the future. The study predicted that the coolant water and any tritium in the water would not migrate more than 5 to 10 ft below its current predicted depth of 120 ft. Due to radioactive decay, tritium concentrations in the water were predicted to decrease at a faster rate than the downward movement of the wetting front.

2.1.1.4 WERC Modeling of Tritium Migration through the Vadose Zone

In January 2001, WERC was requested by the U.S. Congress to perform an independent peer review of the performance of the MWL. The results of the study are presented in WERC (2001).

As part of this study, members of the WERC review team developed a fate and transport model of tritium migration in the vadose zone beneath the MWL. The code GoldSim, a generalized object-oriented probabilistic spreadsheet, was used to model tritium contaminant concentrations and fluxes at various depths beneath the MWL over time. The model incorporated mass transport from a source (inventory), various release mechanisms, transport processes, migration pathways, and radionuclide decay.

The WERC team concluded that based on their model results, the spatial and temporal distribution of tritium activities measured in the vadose zone appear to be consistent with those expected, given the inventory, regional meteorology, subsurface soil conditions, and hydrologic parameters. Their modeling results showed good agreement with the Phase 2 RFI data regarding tritium distributions in subsurface soils beneath the MWL. The WERC team also concluded that future concentrations of tritium in subsurface soils at the MWL should decrease over the next 10 years, based on diffusion and natural decay of tritium.

2.1.2 Cover Performance Modeling

In addition to the fate and transport models discussed above, Sandia has conducted extensive cover performance modeling to predict infiltration through various thicknesses of alternative covers. The results from these studies were used to develop the MWL alternative cover design.

2.1.2.1 Early Cover Performance Modeling

Sandia's early cover performance modeling studies utilized multiple codes to assess infiltration through various thicknesses of alternative covers. The codes used included the water balance model, HELP-3 (Schroeder et al. 1994), and two unsaturated flow models, UNSAT-H (Fayer and Jones 1990) and VS2DT (Healy 1990).

The earlier modeling studies are documented in Wolford (1998); SNL/NM (April 1999); and culminate with the modeling results presented in the original MWL design document, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico" (SNL/NM September 1999). This report was submitted to the NMED in September 1999 for technical review and comment, and was later published as a SAND report by Peace et al. in 2003. The cover performance modeling results from the report are also presented in Section 5.3 of the main text of the MWL CMI Plan.

In order to demonstrate that the MWL alternative cover design complies with regulatory guidance, the hydrologic performance of the cover was modeled using HELP-3, UNSAT-H and VS2DT. These codes were used to predict infiltration through soil covers ranging in thickness from 1 to 5 ft. All three models demonstrated that deployment of a vegetated soil cover for final closure of the MWL would reduce infiltration into the landfill to a small percentage of the total precipitation. The models also demonstrated that a 3-ft-thick vegetated soil cover meets the intent of RCRA Subtitle C regulations. Additional cover thicknesses did not lead to significantly better performance. Additional details on the cover performance modeling using HELP-3, UNSAT-H and VS2DT are presented in Section 5.3 of the MWL CMI Plan.

2.1.2.2 Recent Cover Performance Modeling

The most recent cover performance modeling was conducted in 2003 and 2004 using site-specific climate, hydrologic, and vegetation input parameters. The modeling simulated infiltration of water through the MWL soil cover using the one-dimensional, numerical code UNSAT-H. UNSAT-H is a Richards' equation-based model that simulates infiltration, unsaturated flow, redistribution, evaporation, plant transpiration, and deep infiltration of water. The modeling results corroborated the results from earlier modeling studies. The recent modeling results are published in the SAND report entitled, "Calculation Set for Design and Optimization of Vegetative Soil Covers" (Peace and Goering 2005). The modeling results were used to determine infiltration input parameters for the MWL probabilistic performance-assessment model.

One of the objectives of the modeling was to assess whether a 3-ft soil cover would meet the EPA-prescribed technical equivalency criteria. The EPA performance-based, technical equivalency criteria used are 31.5 millimeter (mm)/yr, or less, for net annual infiltration and 1×10^{-7} centimeter (cm)/second (s) average infiltration rate, based on a hydraulic conductivity of 1×10^{-7} cm/s and the assumption of unit-gradient conditions. The modeling results verified that the 3-ft MWL cover will meet the EPA-prescribed technical equivalency criteria for RCRA landfills under both present and future conditions.

Present conditions were simulated by modeling infiltration through various thicknesses of an engineered cover, while future conditions were simulated by modeling infiltration through various thicknesses of soil under natural conditions (i.e., the "natural analog"). The recent cover modeling results are discussed further in Section 3.4 below. Complete modeling input parameters, boundary conditions, and results are presented in Peace and Goering (2005).

2.2 Probabilistic Performance-Assessment Modeling Approach

This section summarizes the approach used in this study to provide a comprehensive performance assessment of the MWL. Previous studies have looked at individual components of the landfill performance, and nearly all of the studies relied on deterministic evaluations. This study describes a probabilistic performance-assessment approach that captures the inherent uncertainties in the system while honoring site-specific features, processes, and parameters. Sensitivity analyses are also introduced that utilize the probabilistic results to identify the parameters and processes that are most important to the simulated performance metrics.

A performance assessment is defined in DOE M 435.1-1 as "an analysis of a radioactive waste disposal facility conducted to demonstrate there is a reasonable expectation that performance objectives established for the long-term protection of the public and the environment will not be exceeded following closure of the facility." In addition, DOE M 435.1-1 states that the method used for the performance assessment must include uncertainty analyses. A method that addresses these requirements has been used for the Waste Isolation Pilot Plant (DOE 1996), the Yucca Mountain Project (DOE 1998), and the intermediate-depth Greater Confinement Disposal Boreholes (Cochran et al. 2001) to assess the long-term performance of nuclear waste repositories. Probabilistic performance assessments have also been used for sites with uranium mill tailings (Ho et al., 2004). A similar systematic approach has been used here to conduct a performance assessment of the MWL. The approach is outlined as follows:

- Develop and screen scenarios based on regulatory requirements (performance objectives) and relevant features, events, and processes
- Develop models of relevant features, events, and processes
- Develop values and/or uncertainty distributions for input parameters
- Perform calculations and sensitivity/uncertainty analyses
- Compare results to performance objectives, identify important parameters and processes, and provide feedback to improve calculations, as needed

In Step 1, a scenario is identified as a well-defined sequence of features, events and processes that describes possible future conditions at the disposal site. An example of a scenario is the release of radionuclides from a landfill via the vadose zone to the aquifer, where water is pumped from a well and ingested by an individual. The decision to evaluate various scenarios depends, in part, on relevant performance objectives set forth by regulatory requirements. In addition, scenarios should be chosen that represent features, events, and processes that are relevant to the specific site being evaluated.

Step 2 develops the models that are necessary to simulate the chosen scenarios in the performance assessment. The models that are used vary in complexity, and a hierarchy of models can exist. A conceptual model of each scenario is developed to guide the development of more detailed mechanistic models of individual features, events, and processes that comprise the scenario. These detailed models are then integrated into a total-system model of the entire scenario. The integration of the more detailed models may include the models themselves or a simplified abstraction of the model results.

In Step 3, values are assigned to the parameters to populate the models. If the parameter is well-characterized, a single deterministic value may be assigned. However, uncertainty and/or variability in the parameter may require the use of distributions (e.g., log-normal, uniform) to define the values. Experimental data, literature sources, and professional judgment are often used to determine these distributions. The development of uncertainty distributions for parameters used in this study is described in Section 3.3.

In Step 4, calculations are performed using the integrated models. Because stochastic parameters are used, a Monte Carlo approach is taken to create an ensemble of simulations that use different combinations of the input parameters. For each run (realization), a value for each input parameter is sampled from the uncertainty distribution, and the simulation is performed. The results of each realization are equally probable, and the collection of simulation results yields an uncertainty distribution that can be compared to performance objectives to assess the risk of exceeding those performance objectives or metrics. Sensitivity analyses can also be performed to determine which parameters the performance metrics are most sensitive to (Section 2.2.1).

The last step (Step 5) is to analyze and compare the results with relevant performance objectives. The findings are typically documented as cumulative distribution functions that present the probability of exceeding a performance objective. Important parameters and processes are also identified through sensitivity analyses. Together, these results may be used to assess the overall performance, prioritize site characterization, evaluate alternative designs, or identify triggers for future actions to address long-term monitoring requirements for regulatory compliance. In this study, the primary purpose of the performance assessment is to determine which contaminants and performance objectives are at risk based on the simulated performance of the MWL. This information will then provide a basis for the triggers that are identified and recommended for the site.

2.2.1 Sensitivity Analyses

A probabilistic performance assessment provides not only a quantification of uncertainties in the simulated performance metrics, it also allows for a quantified sensitivity analysis to be performed. A sensitivity analysis of the probabilistic assessment results can provide valuable information regarding the processes and parameters that are most important to the simulated performance metric(s). This information provides understanding about the relationship between uncertainty in individual input parameters and the uncertainty in the performance of the system.

In addition, knowledge of the parameters having the greatest influence on future performance can be used to help prioritize site characterization activities, to help optimize landfill cover design, and to assist in the design of monitoring systems and triggers. Using a sensitivity analysis provides the quantitative information necessary to ensure that resources are directed to those aspects of the cover system that "drive" performance and not on those aspects of cover design that have little significance.

The sensitivity of the performance-assessment model can be determined from the Monte Carlo probabilistic realizations using regression analysis. Multiple regression analysis involves construction of a linear regression model of the simulated output (the dependent variable) and the stochastic input variables (independent variables) using a least-squares procedure. Stepwise linear regression is a modified version of multiple regression that selectively adds input parameters to the regression model in successive steps (Helton and Davis 2000). In this method, a sequence of regression models is constructed that successively adds the most important input parameters to the regression to improve the overall correlation. In the end, the sensitivity analysis identifies those parameters that are significantly correlated to the performance metric, and omits those parameters that are not. This study uses a stepwise linear rank regression to perform sensitivity analyses on simulated performance metrics that are at risk of being exceeded.

3. Performance-Assessment Modeling of the Mixed Waste Landfill

3.1 Scenarios and Performance Objectives

In this study, relevant contaminants of concern were grouped into the following categories: (1) radionuclides, (2) heavy metals, and (3) VOCs. Table E-1 summarizes the specific contaminants, scenarios, and performance objectives that were considered in this study. In general, the two pathways of concern include transport of volatile or gas-phase contaminants from the MWL to the atmosphere, and migration of aqueous-phase or vapor-phase contaminants through the vadose zone to the groundwater. For each of these primary pathways, relevant performance objectives and metrics were identified for each of the contaminants of concern. The chosen scenarios represent the most likely releases of contaminants from the MWL based on estimated inventories, contaminant properties, and previous studies.

3.2 Performance-Assessment Models

The following sections describe the models that were developed and used to simulate the fate and transport of the different contaminants in the various scenarios summarized in Table E-1.

3.2.1 FRAMES/MEPAS

The transport of heavy metals (lead and cadmium) and the radionuclides (except for radon) were simulated using the probabilistic simulation tools FRAMES[1] (Framework for Risk Analysis in Multimedia Environmental Systems, Whelan et al. 1997) and MEPAS[2] (Multimedia Environmental Pollutant Assessment System, Whelan et al. 1992), developed by Pacific Northwest National Laboratory. The FRAMES system, which integrates the fate and transport models comprising MEPAS, allows for a holistic approach to modeling in which models of different type (i.e., source, fate and transport, exposure, health impact), resolution (i.e., analytical, semi-analytical, and numerical), and operating platforms can be combined as part of the overall assessment of contaminant fate and transport in the environment. The FRAMES system employs a graphical user interface for integrating computer models, an extensive contaminant database, a probabilistic sensitivity/uncertainty module, and textual and graphical viewers for presenting modeling outputs.

Existing models in FRAMES include those derived from MEPAS (Whelan et al. 1992). MEPAS is a physics-based environmental analysis code that integrates source-term, transport, and exposure models for endpoints such as concentration, dose, or risk. MEPAS is capable of computing contaminant fluxes for multiple routes, which include leaching to groundwater, overland runoff, volatilization, suspension, radioactive decay, constituent degradation, and source/sink terms. In this study, only the source-term and vadose-zone models were implemented. The source-term model conservatively simulates leaching from the waste zone (assuming no containment) based on either the solubility or the inventory-limited concentration

[1] http://mepas.pnl.gov/FRAMESV1

[2] http://mepas.pnl.gov/earth/mepasmain.html

Table E-1
Summary of Scenarios and Performance Objectives Used in the Performance Assessment of the MWL

Scenario	Description	Performance Objectives[a]
1	Water percolates through the cover to the waste	• Infiltration through the cover shall be less than 10^{-7} cm/s (a unit-gradient flow is assumed to equate infiltration to hydraulic conductivity) (EPA 40 CFR 264.301)
2	Tritium diffuses to the atmosphere and migrates via gas and aqueous phases through the vadose zone to the groundwater	• Dose to the public via the air pathway shall be less than 10 mrem/yr (excludes radon) (EPA 40 CFR 61.92) • Dose from beta particles and photon emitters shall be less than 4 mrem/yr (EPA 40 CFR 141.66, EPA 2003) • Tritium concentrations in groundwater shall not exceed 20,000 pCi/L (40 CFR 141.66 Table A; tied to 4 mrem/yr)
3	Radon steadily diffuses to the atmosphere and migrates via gas and aqueous phases through the vadose zone to the groundwater	• The average flux of radon-222 gas shall be less than 20 pCi/m^2/s at the surface of the landfill (EPA 40 CFR 192) • Radon concentrations in groundwater shall not exceed 300 pCi/L (proposed EPA rules, Federal Register: November 2, 1999 (Volume 64, Number 211) Pages 59345–59378)
4	One or more radionuclides migrate via the aqueous phase through the vadose zone to the groundwater	• Maximum concentrations in groundwater of gross alpha particle activity (including radium-226 but excluding radon and uranium) is 15 pCi/L (EPA 40 CFR 141.66, EPA 2003) • Uranium concentrations in groundwater shall not exceed EPA MCL of 30 µg/L (EPA 40 CFR 141.66, EPA 2003) • Dose from beta particles and photon emitters shall be less than 4 mrem/yr (EPA 40 CFR 141.66, EPA 2003)
5	Lead and cadmium migrate via the aqueous phase through the vadose zone to the groundwater	• Lead concentrations in groundwater shall not exceed the EPA action level of 15 µg/L (EPA 2003) • Cadmium concentrations in groundwater shall not exceed the EPA MCL of 5 µg/L (EPA 2003)
6	PCE migrates through the vadose zone to the groundwater	• PCE concentrations in groundwater shall not exceed the EPA MCL of 5 µg/L (EPA 40 CFR 141.61, EPA 2003)

[a]The point of compliance is taken at the boundary of the waste site. The period of performance was specified as 1,000 years in the regulations for some of the performance metrics, but for many of the performance metrics, the period of performance was not specified. In this study, a 1,000-year period was simulated.

CFR = Code of Federal Regulations.
cm/s = Centimeter(s) per second.
EPA = U.S. Environmental Protection Agency.
MCL = Maximum Contaminant Level.
µg/L = Microgram(s) per liter.
mrem/yr = Millirem per year.
MWL = Mixed Waste Landfill.
PCE = Tetrachloroethene.
pCi/L = Picocurie(s) per liter.
pCi/m^2/s = Picocurie(s) per square meter per second.

(Streile et al. 1996). The transport of the contaminant through the vadose-zone is then simulated assuming liquid-phase advection, dispersion, adsorption, and decay of the contaminant (Whelan et al. 1996). In this study, the aquifer concentration and subsequent dose, if applicable, were conservatively estimated based on the simulated concentration of the constituent in the groundwater at the interface of the vadose-zone and the water table (e.g., dilution caused by transport in the saturated zone was ignored). Section 3.3 presents the input parameters that were used in the radionuclide-transport models.

Uncertainty analyses are performed in FRAMES using the sensitivity module. The sensitivity module can be attached to any model that has been integrated into FRAMES and allows the user to stochastically vary any input parameter that is identified in the process models. Input parameters can be stochastically varied by a distribution, correlation coefficient, an equation, or any combination of these three options. Four distributions are currently available: (1) uniform, (2) log uniform, (3) normal, and (4) log normal. The sensitivity module utilizes the Latin Hypercube Sampling (Wyss and Jorgensen 1998) technique to minimize the number of modeling runs that must be performed to accurately represent distributions selected by the user. In this study, 100 realizations were simulated for each scenario (a sensitivity analysis was performed using 100 versus 200 realizations in Section 3.5.2.2, and results showed that 100 realizations were sufficient to adequately represent the distribution of the simulated output).

3.2.2 Transient Gas- and Liquid-Phase Transport

A separate model was used to model the transient transport of tritium at the MWL. Tritium, in the form of tritiated water, is volatile and can be transported via both the gas and liquid phases. Regulatory metrics exist for dose caused by exposure to tritium (a beta particle emitter) in both the air and groundwater pathways (Table E-1). Also, because the half-life of tritium is relatively short (12.3 years), a transient analysis was required. Therefore, the transport of tritium was modeled using a transient model that accounts for advective liquid-phase transport, diffusive gas-phase transport, decay, and adsorption (if applicable) in the vadose zone (Jury et al. 1983; Jury et al. 1990). This same model was also used to model the transport of PCE. In this model, a contaminated zone is assumed to initially exist with a defined thickness and concentration. Over time, the contaminant migrates and decays (if applicable) assuming a flux boundary condition at the surface, defined by an atmospheric boundary layer thickness (Jury et al. 1983) and a zero concentration boundary beneath the waste zone at a location infinitely far away from the source. Superposition is used to account for a clean overburden (cover) above the waste zone (Jury et al. 1990). The analytical solution to this model was implemented in Mathcad®, and a Monte Carlo analysis was implemented with the uncertain variables using 100 realizations. Section 3.3 presents the input parameters and distributions that were used in the tritium- and PCE-transport models.

3.2.3 Steady-State Gas- and Liquid-Phase Transport

Radon-222 is generated from the decay of radium-226, which is a decay product of uranium-238. Because these parent constituents have long half lives, the source of radon-222 production is assumed to last indefinitely. Therefore, the transient model described in the previous section that accounts for a finite source of contaminant is not appropriate. Instead, a steady-state model of radon transport was developed to account for steady generation of radon-222, advective liquid-phase transport, diffusive gas-phase transport, and decay (Attachment E1). Mathcad® was used to provide a Monte Carlo analysis of the analytical solution using 100 realizations. Section 3.3 presents the input parameters and distributions that were used in the radon-transport model.

3.3 Input Parameters and Distributions

The constituents that were included in the performance assessment of the MWL are summarized in Table E-2. The parameter values and distributions that were used are also summarized in the table. The adsorption coefficient (K_d) was assumed to be an uncertain parameter, so a range of values was obtained from the literature for the constituent and soil type (sandy loam) at the MWL. A log-uniform distribution was used to emphasize the lower values in the distribution. The inventory of each constituent was also assumed to be an uncertain variable. The estimated inventory from previous reports and studies was used as the lower bound in a uniform distribution for each constituent. The lower bound was multiplied by two to obtain the upper bound for the assumed uniform distribution. The maximum solubility obtained from the literature for each constituent was used. All other parameters were obtained from site-specific reports, scientific literature, or EPA recommendations.

Table E-3 summarizes the parameters and distributions used to define the contaminated waste zone (source term) in the models. The waste-zone length, width, and thickness is based on the size of the pits, trenches, and dimensions of the MWL. The maximum thickness of the cover is based on the design specifications given in Peace et al. (2005). The minimum thickness of the cover is set equal to zero as a bounding value to account for the possibility that complete erosion of the cover may occur in the future. This is a conservative bounding assumption since the intent is to maintain the integrity of the cover at the MWL.

Table E-4 summarizes the parameters and distributions used to describe the vadose-zone in the models. Uncertainty was included for a number of variables including thickness of the vadose zone, infiltration rate, hydraulic conductivity, and site-specific transport parameters. The distributions used for the various vadose-zone parameters were derived from site-specific data or literature pertaining to the constituents and scenarios evaluated in this study. The liquid- and gas-phase tortuosity coefficients are used to calculate effective diffusion coefficients in porous media. The tortuosity coefficient accounts for the increased tortuosity and reduced area available for diffusion in porous media. The minimum value is based on formulation by Millington (1959), and the maximum value is assumed to be equal to one (the upper bound), which yields the maximum diffusion. Studies of enhanced vapor diffusion have shown that large values of the tortuosity coefficient (yielding diffusion rates equivalent to those in free space) are possible in unsaturated porous media because of evaporation and condensation mechanisms across liquid islands in pores (Ho and Webb 1998).

Finally, Table E-5 summarizes the parameters and distributions used to estimate dose due to exposure via the atmospheric (e.g., inhalation) or groundwater pathway. Dose via inhalation and dermal adsorption of gas-phase tritium was calculated based on the surface flux ($pCi/m^2/s$) of tritium determined in the models. The length and width of the waste zone was used to determine the flux rate of tritium at the surface (pCi/s), and the average wind speed and vertical mixing height was used to determine the average concentration above the landfill. The inhalation rate was then used to estimate the human intake of gas-phase tritium, and the dose-

Table E-2
Summary of Input Parameters and Distributions for Constituents Used in the Models

Constituent and Molecular Weight	Inventory[a]	Half-Life[b]	Specific Activity (Ci/g)[c]	Adsorption Coefficient, K_d (mL/g)[d]	Max Solubility (mg/L)[e]	Liquid-Phase Diffusion Coefficient (m^2/s)[f]	Gas-Phase Diffusion Coefficient (m^2/s)[f]	Henry's Constant (C_g/C_l)[g]	Dose Conversion Factor (rem/pCi)[h]
Americium-241[α]	Uniform: 0.04–0.08 Ci	433 yr	3.43	Log-Uniform: 1900–9600	2.4×10^{4}	6×10^{-10}	N/A	N/A	3.64×10^{-6}
Cesium-137[β]	Uniform: 410–820 Ci	30.2 yr	86.4	Log-Uniform: 30–4600	137,000	6×10^{-10}	N/A	N/A	5.0×10^{-8}
Cobalt-60[β]	Uniform: 3500–7000 Ci	5.27 yr	1130	Log-Uniform: 60–1300	600	6×10^{-10}	N/A	N/A	2.69×10^{-8}
Plutonium-238[α]	Uniform: 0.0012–0.0024 Ci	87.7 yr	17.1	Log-Uniform: 80–520	0.24	6×10^{-10}	N/A	N/A	3.2×10^{-6}
Plutonium-239[α]	Uniform: 0.0012–0.0024 Ci	2.41×10^{4} yr	0.0621	Log-Uniform: 80–470	0.24	6×10^{-10}	N/A	N/A	3.54×10^{-6}
Radium-226[α]	Uniform: 6-12 Ci	1,600 yr	0.989	Log-Uniform: 500–36,000	0.45	6×10^{-10}	N/A	N/A	1.32×10^{-6}
Radon-222[α]	Constant generation from radium-226	3.82 days	1.54×10^{5}	0	N/A	$0.07\exp[-4(S - S\phi^2 + S^5)]$ where S = liquid saturation, ϕ = porosity		0.26^{-1}	1.44×10^{-8} (inhalation)
Strontium-90[β]	Uniform: 410–820 Ci	29.1 yr	137	Log-Uniform: 15–20	90,000	6×10^{-10}	N/A	N/A	1.42×10^{-7}
Thorium-232[α]	Uniform: 1–2 Ci	1.4×10^{10} yr	1.10×10^{-7}	Log-Uniform: 20–2000	23	6×10^{-10}	N/A	N/A	2.73×10^{-6}
Tritium[β] H-3	Uniform: 2400–4800 Ci	12.3 yr	9690	0	N/A	2.3×10^{-9}	2.6×10^{-5}	1.7×10^{-5}	6.4×10^{-11} (inhalation; x1.5 to include dermal absorption)
Uranium-238[α]	Uniform: 9.3–18.6 Ci	4.47×10^{9} yr	3.35×10^{-7}	Log-Uniform: 0.4–15	24	6×10^{-10}	N/A	N/A	2.55×10^{-7}
Cadmium 112.41	Uniform: 1350–2700 kg	stable	N/A	Log-Uniform: 8–80	1.4×10^{6}	6×10^{-10}	N/A	N/A	N/A
Lead 207.2	Uniform: 128,000–256,000 kg	stable	N/A	Log-Uniform: 270–4360	4.43×10^{5}	6×10^{-10}	N/A	N/A	N/A

Refer to footnotes at end of table.

Table E-2 (Continued)
Summary of Input Parameters and Distributions for Constituents Used in the Models

Constituent and Molecular Weight	Inventory[a]	Half-Life[b]	Specific Activity (Ci/g)[c]	Adsorption Coefficient, K_d (mL/g)[d]	Max Solubility (mg/L)[e]	Liquid-Phase Diffusion Coefficient (m^2/s)[f]	Gas-Phase Diffusion Coefficient (m^2/s)[f]	Henry's Constant (C_g/C_l)[g]	Dose Conversion Factor (rem/pCi)[h]
PCE 165.83	Uniform: 5–70 kg	Log-Uniform: 9 months–10^{10} yr	N/A	Log-Uniform: 0.038–2	N/A	9.2×10^{-10}	9.5×10^{-6}	0.42	N/A

[α]Alpha particle; [β]Beta particle.

[a]Minimum inventory of all constituents except cadmium and PCE was estimated from values in SNL/NM (1993); maximum value was assumed to be twice the minimum value. Cadmium inventory was estimated from measured soil concentrations (Peace et al. 2002) and maximum simulated penetration depth (120 ft) of coolant water potentially carrying the cadmium (Wolford 1997). PCE inventory is estimated from measured soil-gas concentrations (Peace et al. 2002); the maximum measured gas concentration (5,900 ppb) was used as a minimum value in a uniform distribution increasing to ten times this value (calibrated to available data). The maximum areal extent of the MWL was used (430 x 300 ft) along with an uncertain thickness ranging from 10 to 27 ft (see Table E-3 for waste-zone description).

[b]Lide (2005); half-life of PCE is assumed to range from 9 months (EPA fact sheet: www.epa.gov/WGWDW/dwh/t-voc/tetrachl.html) to 10^{10} yr (no degradation).

[c]Specific activity is calculated as 3.575×10^5/(half-life (yr) x molecular weight).

[d]EPA (1999), Sheppard and Thibault (1990), Looney et al. (1987), EPA fact sheet: www.epa.gov/WGWDW/dwh/t-voc/tetrachl.html.

[e]Looney et al. (1987), Chen et al. (2002), Ohe et al. (2002), Elless and Lee (1998), BSC (2005), and EPA Online Fact Sheets (www.epa.gov/safewater/dwh/t-ioc). Based on the maximum inventory and minimum waste volume possible, the solubility may potentially limit the maximum aqueous source concentration for radium-226, thorium-232, uranium-238, and lead; all other constituents are not limited by the solubility.

[f]Whelan et al. (1996), Smiles et al. (1995), Rogers et al. (1984), U.S. NRC (1989), Reid et al. (1987).

[g]Rogers et al. (1984), U.S. NRC (1989), Smiles et al. (1995), steam tables, and EPA's online Henry's Constant calculator (www.epa.gov/athens/learn2model/part-two/onsite/esthenry.htm).

[h]EPA (1988).

BSC = Bechtel SAIC Company.
Ci = Curie(s).
EPA = U.S. Environmental Protection Agency.
ft = Foot (feet).
kg = Kilogram(s).
m^2/s = Square meter(s) per second.
mg/L = Milligram(s) per liter.
mL/g = Milliliter(s) per gram.
MWL = Mixed Waste Landfill.
N/A = Not applicable or not used in the model; for solubility, this indicates that the value is not limiting.
NRC = Nuclear Regulatory Commission.
PCE = Tetrachloroethene.
pCi = Picocurie(s).
ppb = Part(s) per billion.
SNL/NM = Sandia National Laboratories/New Mexico.
yr = Year(s).

Table E-3
Summary of Input Parameters and Distributions for the Waste Zone

Input Parameter	Value or Distribution	Basis and Comments
Waste-Zone Length [m]	Uniform 3.05–131	Minimum value determined by size of individual pit (10 ft). Maximum value determined by extent of MWL.
Waste-Zone Width [m]	Uniform 3.05–91.4	Minimum value determined by size of individual pit (10 ft). Maximum value determined by extent of MWL.
Waste-Zone Thickness [m]	Uniform 3.05–8.23	The thickness of the waste zone for all constituents except for cadmium is based on the depth of the trenches and pits, which range from 3–8 m (10–27 ft). The thickness of the cadmium contamination zone is assumed to be equal to 36.6 m (120 ft), which is the maximum simulated penetration depth of the coolant water that may have carried the cadmium (Wolford 1997).
Thickness of Cover and Clean Overburden [m]	Uniform 0–4.88	Minimum value is assumed to be zero due to erosion.[a] Maximum value is based on maximum thickness of the cover at various locations (Peace et al. 2005).

[a]The intent is to maintain the integrity of the cover at the MWL. Complete erosion of the cover is a conservative bounding assumption for modeling purposes.
ft = Foot (feet).
m = Meter(s).
MWL = Mixed Waste Landfill.

Table E-4
Summary of Input Parameters and Distributions for the Vadose Zone

Input Parameter	Value or Distribution	Basis and Comments
Thickness of Vadose Zone[a] [m]	Uniform 133–148	Thickness of the vadose zone for all constituents except for cadmium is based on measured depths to the water table. The depth to the water table from the surface ranges from 141–151 m (461–495 ft) (Goering et al. 2002). The range of vadose-zone thicknesses accounts for the waste-zone thickness. For cadmium, the thickness is assumed to be 104 m (461–120 = 341 ft).
Infiltration Rate [m/s]	Uniform 1.18×10^{-11}– 6.12×10^{-11}	Minimum value based on infiltration through 2 ft of engineered cover under current climate (Peace and Goering 2005); maximum value based on two times the current maximum precipitation in a natural analog vegetative cover to account for future climates (Waugh 1997, Menking et al. 2004).
Saturated Hydraulic Conductivity [cm/day]	Log-Normal Mean log: 1.039 S.D. log: 0.705 Upper bound: 173 Lower bound: 0.38	Peace et al. (2003)
Porosity [-]	Uniform 0.302–0.445	Peace and Goering (2005)
Volumetric Moisture Content [-]	Uniform 0.053–0.225	Peace and Goering (2005)
Longitudinal dispersivity [m]	0.1 times the travel distance (vadose-zone thickness)	Based on field data reported in Gelhar et al. (1992). This is used in the FRAMES/MEPAS models for liquid transport to the groundwater.
Liquid-Phase Tortuosity Factor [-]	Uniform 0.001–1	Lower bound based on formulation of Millington (1959); upper bound is physical limit. This is used in the tritium and PCE models.
Gas-Phase Tortuosity Factor [-]	Uniform 0.1–1	Lower bound based on formulation of Millington (1959); upper bound is physical limit. This is used in the tritium and PCE models.

[a]Used only in FRAMES/MEPAS. For all other models, the depth to the water table (141 to 151 m) is used.
cm = Centimeter(s).
ft = Foot (feet).
m = Meter(s).
PCE = Tetrachloroethene.
s = Second(s).

Table E-5
Summary of Input Parameters and Distributions for the Biosphere

Input Parameter	Value or Distribution	Basis and Comments
Atmospheric Boundary Layer Thickness [m]	Uniform 0.001–1	Minimum is based on values reported by Jury et al. (1983). Maximum is a conservative upper value.
Vertical Atmospheric Mixing Length [m]	2	Conservative value to encompass volume occupied by a human (Yu et al. 1993).
Average Wind Speed [m/s]	3.63	Average value based on seven years of site data (SNL/NM Site Environmental Monitoring Reports 1990–1996).
Inhalation Rate [m^3/day]	20	EPA (1991)
Water Intake [L/day]	10	Conservative estimate to account for drinking water and indirect ingestion or absorption via plants, animals, showering, etc. Recommended value for drinking water is 2 L/day (EPA 2000).
Distance to Receptor [m]	0	The point of compliance for groundwater concentrations is assumed to be at the boundary of the landfill. Receptor is assumed to be located adjacent to landfill for inhalation, and water used for drinking, irrigation, etc., is assumed to be drawn from the aquifer directly beneath the MWL.

EPA = U.S. Environmental Protection Agency.
L = Liter(s).
m = Meter(s).
m^3 = Cubic meter(s).
MWL = Mixed Waste Landfill.
s = Second(s).
SNL/NM = Sandia National Laboratories/New Mexico.

conversion factor (Table E-2) was used to determine the dose. For groundwater exposure, a conservative estimate for water ingestion (10 L/day) was used together with the simulated groundwater concentrations to determine intake. The assumed water ingestion rate of 10 L/day is five times greater than the EPA drinking-water standard of 2 L/day and is intended to account for indirect sources of water ingestion and absorption such as consumption of vegetables and fruits irrigated by contaminated water. The dose-conversion factor was then used to estimate dose via the groundwater pathway.

Key Assumptions:

The key assumptions regarding the models and input parameters used in the performance assessment of the MWL are summarized below:

- Receptor located adjacent to MWL.
    - Tritium dose caused by continuous inhalation and exposure of tritium flux directly above MWL.
    - Groundwater dose calculated based on concentrations in aquifer directly beneath MWL. Water intake assumed to be 10 L/day (five times the EPA standard of 2 L/day for drinking water).

- Maximum waste inventory set equal to twice estimated values based on historical records.

- Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor for radon-222 allowed to increase).

- Cover allowed to completely erode in 1,000 years.

- 1-D model: yields maximum transport to surface and groundwater.

- Bounding tortuosity coefficients: yields maximum diffusion rates.

3.4 Water Infiltration through the Cover

Infiltration of water through a proposed soil cover for the MWL was modeled using the one-dimensional, numerical code UNSAT-H (Peace and Goering 2005). UNSAT-H is a Richards' equation-based model that simulates infiltration, unsaturated flow, redistribution, evaporation, plant transpiration, and deep infiltration of water. The modeling was conducted in 2003 and 2004 using site-specific climate, hydrologic, and vegetation input parameters. The modeling results corroborated the results from earlier modeling studies presented in Section 5.3 of the MWL CMI Plan. Complete modeling input parameters, boundary conditions, and results are discussed in Peace and Goering (2005).

One of the objectives of the modeling was to assess whether the proposed 3-ft cover will meet the EPA-prescribed technical equivalency criteria. The EPA performance-based, technical equivalency criteria used in this study are 31.5 mm/yr, or less, for net annual infiltration and 1×10^{-7} cm/s average infiltration rate, based on a hydraulic conductivity of 1×10^{-7} cm/s and the assumption of constant unit gradient conditions. The modeling results demonstrate that the proposed 3-ft MWL cover will meet the EPA-prescribed technical equivalency criteria for RCRA landfills under both present and future conditions.

3.4.1 Model Description

The modeling study was formulated in one dimension, vertically, and was discretized by placing computational nodes at predetermined vertical spacing in a conceptual soil profile to evaluate the performance of a cover 3 ft in thickness. Figure E-3 shows a cross-section of the conceptual soil profile and its numerical discretization. A total of 30 nodes were used to discretize a conceptual soil profile 6 ft in thickness. A thickness of 6 ft is used so that the overlying nodes of interest are not adversely impacted by the lowermost boundary conditions.

The conceptual soil profile was simulated as a lithologic monolayer. A soil profile with uniform soil and hydrologic properties translates into a significant conservative estimate of liquid water flow. If multiple layers are simulated, the water potential in the underlying layer must equal the water potential in the overlying layer before flow into the lower layer occurs. Multiple layering in performance modeling as well as multiple layers in nature attenuate the downward flow of liquid water (e.g., multiple capillary barriers). UNSAT-H input parameters for the cover are

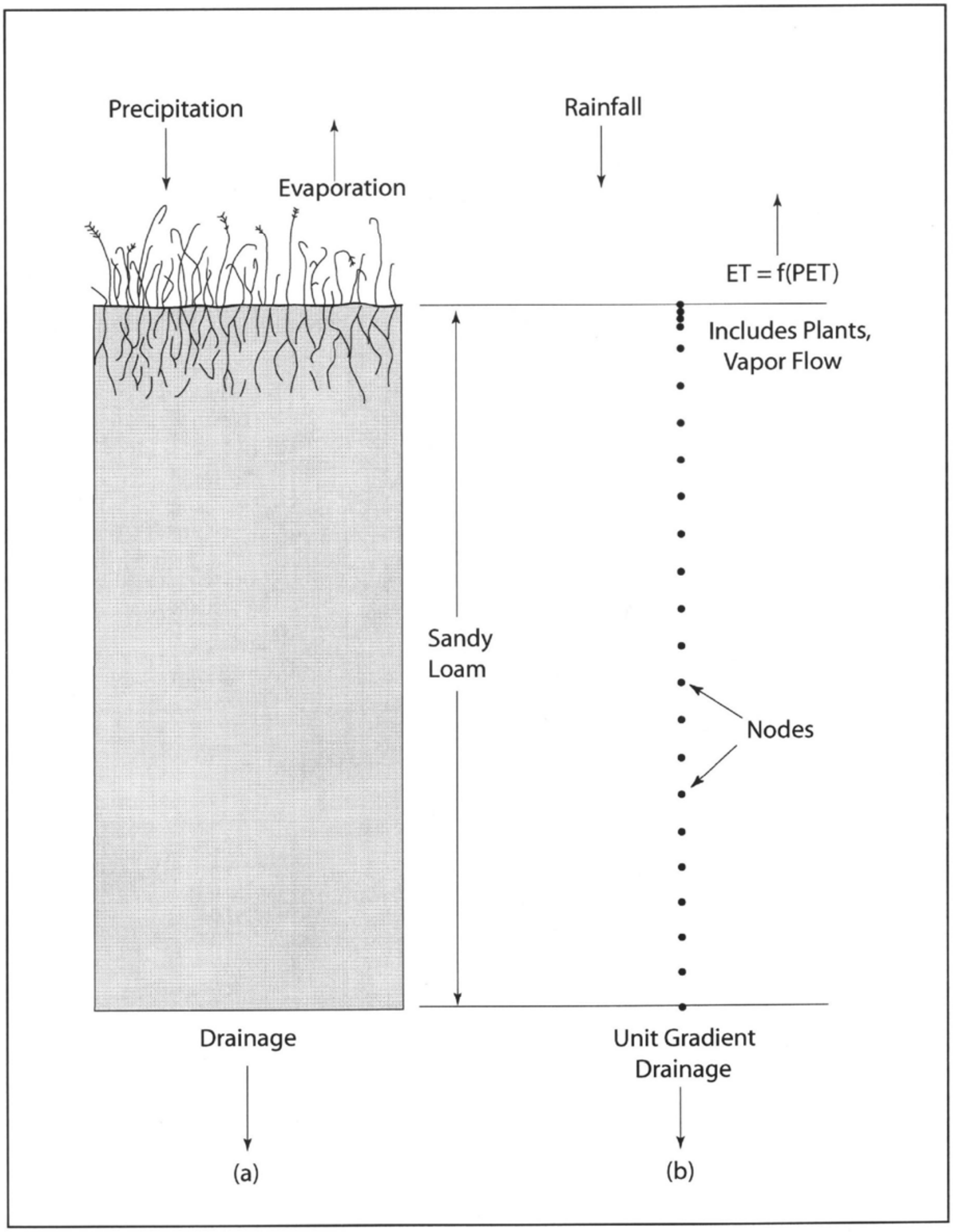


Figure E-3 (a) Conceptual Model for Infiltration Model (b) Nodal Discretization in UNSAT-H

summarized in Table 6-1 in Peace and Goering (2005). All parameters are site-specific and were carefully measured to obtain the most accurate estimate of infiltration possible.

Climatic data represent the site-specific conditions to the maximum extent possible. The historical rainfall record from Albuquerque International Sunport, dating from 1919 to 1996, was used to input precipitation and simulate infiltration through the cover. Two discrete sets of precipitation data were compiled from the historical record. The first data set, the "historical precipitation data," included 65 years of daily rainfall recorded from 1932 to 1996. The second data set, the "maximum precipitation data," included the 8 heaviest years' rainfall recorded between 1919 and 1996, repeated 8 times for a total of 64 years. The heaviest rainfall years were 1919, 1929, 1940, 1941, 1982, 1986, 1988, and 1992. These maximum precipitation data represent a climate change of 50 percent more precipitation overall (1.5 times the current level). Precipitation during these years ranged from 12 inches (in.) to over 15 in. The current average annual precipitation for the Albuquerque area is 8.65 in./yr.

Literature evidence suggests that wetter conditions probably occurred during the last glacial episodes in the Southwest. Studies of paleoclimate during the Last Glacial Maximum suggest that precipitation in the Estancia basin, located west of the Manzano Mountains, nearly doubled relative to modern levels during brief, decade- to century-long episodes of colder and wetter climate (Menking et al. 2004). Farther west, studies of floral assemblages in late Pleistocene packrat middens near Yucca Mountain, Nevada, indicate that precipitation was an estimated 2.4 times modern levels during the Last Glacial Maximum (Menking et al. 2004).

Because precipitation in the southwest may have been significantly higher in the past, a precipitation multiplier of 2X was used to estimate maximum infiltration levels in the future through the MWL cover. A polynomial extrapolation of infiltration was developed using the results from modeling the "historical precipitation data" and the "maximum precipitation data," and assuming that hydrologic properties of the cover are at equilibrium with the natural system.

Plant transpiration is the primary mechanism in removing water from a cover. Without plants, covers would only depend on evaporation to remove water from the soil profile. Vegetative input for the UNSAT-H code included root depth, root length density, leaf area index, growing season, and percent bare area. Root depth, root length density, leaf area index, growing season, and percent bare area for a climax community were measured in the field (Peace and Goering 2005).

3.4.2 Model Results

The UNSAT-H code simulated infiltration through a soil cover with a climax community of native vegetation. The range of average infiltration rates for the MWL was predicted under current and future climate conditions. For both the current and future scenarios, the estimated infiltration rates through a 2-ft cover rather than a 3-ft cover were used to be conservative, as the model predicted infiltration through a 3 ft cover to be slightly negative, i.e., a net upward flux (Peace and Goering 2005).

Under present climate conditions, the model predicted the average infiltration rate through the proposed MWL cover to be 1.18 x 10^{-9} cm/s for the historical precipitation scenario and 5.34 x 10^{-9} cm/s for the maximum precipitation scenario.

Under future climate conditions, the properties of the MWL cover soils will gradually revert towards those of the natural soils around the landfill, as the bulk density and porosity of the soil equilibrate with natural conditions. Under these conditions, the model predicted the average infiltration rates to be 2.44 x 10^{-10} cm/s for the historical precipitation scenario and 1.04 x 10^{-9} cm/s for the maximum precipitation scenario.

Since the maximum precipitation scenario represents a 50 percent increase in precipitation over the historical precipitation scenario, a polynomial regression for infiltration as a function of precipitation can be determined (assuming that zero infiltration occurs with zero precipitation). We assign a normalized precipitation value of one to the historical precipitation scenario and a value of 1.5 to the maximum precipitation scenario. The quadratic regression then allows extrapolation to future climates where the precipitation is expected to be twice as high as present values. If the future precipitation is twice as high as current precipitation, the precipitation multipliers will increase to 2X for the historical scenario and 3X for the maximum scenario. Applying these multipliers to the quadratic regression yields estimated future infiltration rates of 2.29 x 10^{-9} cm/s for the historical precipitation scenario and 6.12 x 10^{-9} cm/s for the maximum precipitation scenario (Figure E-4). We use 6.12 x 10^{-9} cm/s as an upper bound for the infiltration distribution to represent maximum precipitation conditions in the future, and we use 1.18 x 10^{-9} cm/s as a lower bound for the infiltration distribution to represent current precipitation conditions with the engineered cover design.

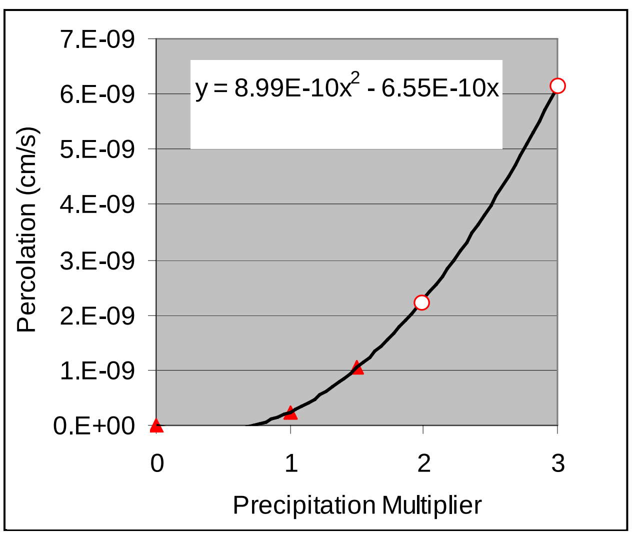


Figure E-4 Polynomial Regression Used to Estimate Future Infiltration Values as a Function of Precipitation Multipliers. Triangles Denote Simulated Values; Circles Denote Extrapolated Values

In summary, the modeling results demonstrate that the proposed 3-ft soil cover will meet the EPA-prescribed technical equivalency criteria for both present and future climate conditions, even if precipitation is significantly higher. The EPA performance-based, technical equivalency criteria are 31.5 mm/yr or less for net annual infiltration and 1 x 10^{-7} cm/s average infiltration rate, based on a hydraulic conductivity of 1 x 10^{-7} cm/s and the assumption of constant unit gradient conditions. Predicted average infiltration rates through the MWL cover are expected to range from 1.18 x 10^{-9} cm/s for present conditions to 6.12 x 10^{-9} cm/s for future conditions, under the assumption of significantly higher precipitation. These infiltration rates are considerably lower than the EPA performance-based, technical equivalency criterion of 1 x 10^{-7} cm/s.

3.4.3 Summary of Key Results and Assumptions

- Simulations of infiltration through the engineered cover at the MWL show that the net annual infiltration will be less than the regulatory metric of 10^{-7} cm/s.

- Predicted average infiltration rates through the MWL cover are expected to range from 1.18 x 10^{-9} cm/s for present conditions to 6.12 x 10^{-9} cm/s for future conditions.

Key Assumption:

- Predicted range of infiltration rates was based on simulated infiltration averaged over 64 years of data (as opposed to selected annual or daily averages).

3.5 Fate and Transport of Tritium

3.5.1 Model Description

As described in Section 3.2.2, the fate and transport of tritium was simulated using a model that accounts for transient liquid advection, gas diffusion, and decay (Jury et al. 1983, Jury et al. 1990). The upper boundary condition at the surface allowed for gas-phase transport of tritium to the atmosphere across a prescribed (uncertain) boundary-layer thickness. The concentration at the bottom of the model was specified as zero infinitely far away from the source.

The initial inventory of tritium was estimated from past records (SNL/NM 1993), and the extent of the contaminated waste zone was allowed to vary from the size of an individual pit to the entire size of the MWL. The inventory was allowed to vary between the estimated value (as a lower bound) and an upper bound equal to twice the estimated value. The simulations were run until tritium concentrations decreased to negligible values in the system. One hundred realizations were used in the simulations.

3.5.2 Model Results

3.5.2.1 Comparison to Field Data

In 1990 and 1993, measurements of tritium at the surface and at locations in the subsurface were measured at the MWL (Johnson et al. 1995). These measurements were used as a reference to check the simulated results of the model. Figure E-5 shows the simulated tritium surface flux as a function of time for 100 realizations. The minimum and maximum measured tritium surface

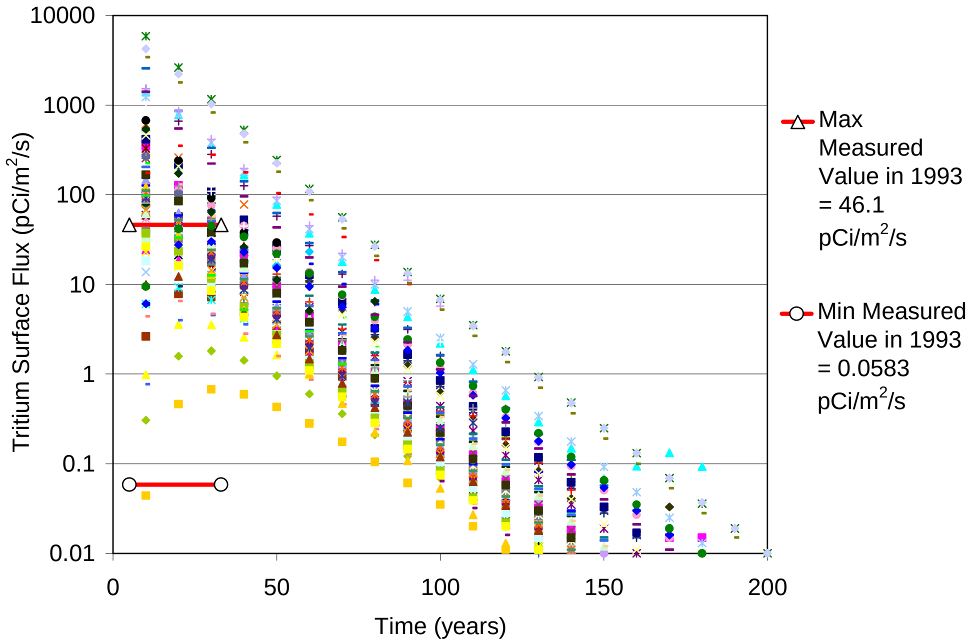


Figure E-5 Comparison of Simulated Tritium Surface Flux as a Function of Time for 100 Realizations with Range of Measured Values in 1993

flux values taken in 1993 are also shown in the figure. The measured values are shown spanning 5 to 33 years because the actual time elapsed since the tritium was emplaced is uncertain.

Emplacement of waste at the MWL began in 1960 and ended in 1988; therefore, the measured values sampled in 1993 could have occurred between 5 and 33 years after emplacement. Results show that the simulated results during this span of time are either within or above the measured bounding values. Figure E-6, Figure E-7, and Figure E-8 show similar plots and results for different locations in the subsurface. In most cases, the simulated fluxes and concentrations are higher than the measured values. These results and comparisons provide evidence that the models can provide realistic values for the simulated outputs. In addition, the comparisons confirm that the model is producing conservatively high results for surface fluxes and subsurface concentration because of the conservative values and distributions used for the model parameters.

3.5.2.2 Comparison to Performance Objectives

The simulated tritium concentrations reaching the groundwater are shown in Figure E-9 for all 100 realizations as a function of time. The peak tritium groundwater concentrations are all small, and Figure E-10 shows the cumulative probability of the peak concentrations for 100 realizations and 200 realizations. The results show that the simulated tritium groundwater concentrations are all well below 20,000 pCi/L. In addition, the distribution resulting from 100 realizations is nearly the same as the distribution resulting from 200 realizations (therefore, all subsequent analyses only use 100 realizations).

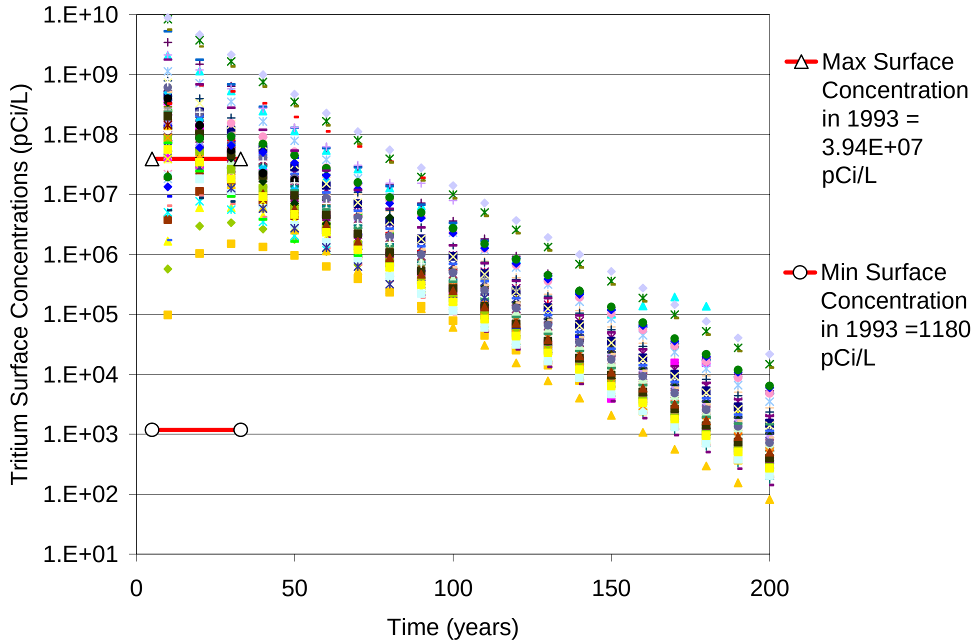


Figure E-6 Comparison of Simulated Tritium Surface Concentration as a Function of Time for 100 Realizations with Range of Measured Values in 1993

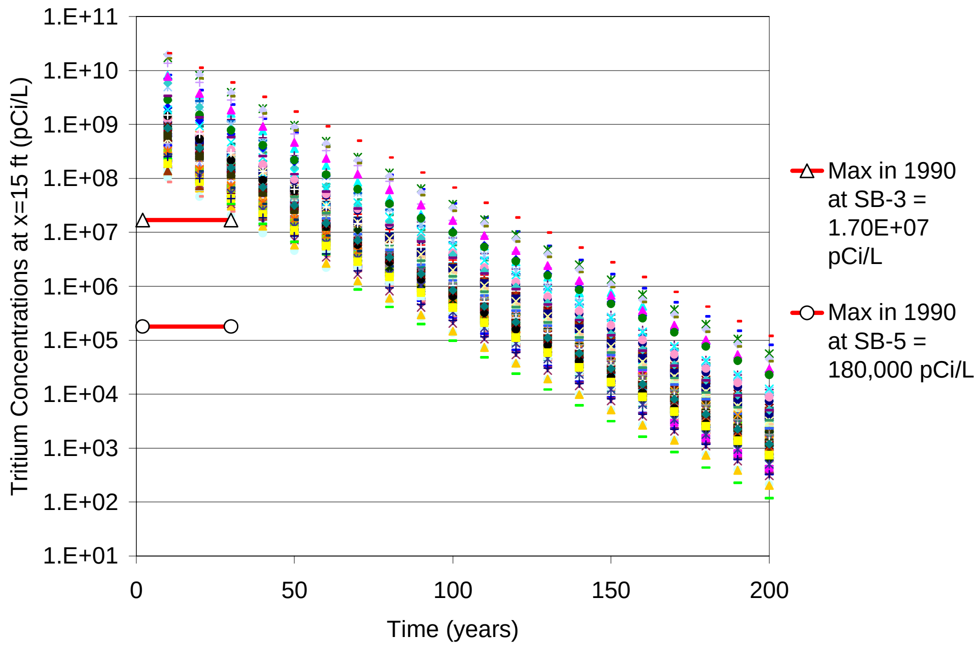


Figure E-7 Comparison of Simulated Tritium Concentration at a Depth of 15 ft as a Function of Time for 100 Realizations with Measured Maximum Values in 1990

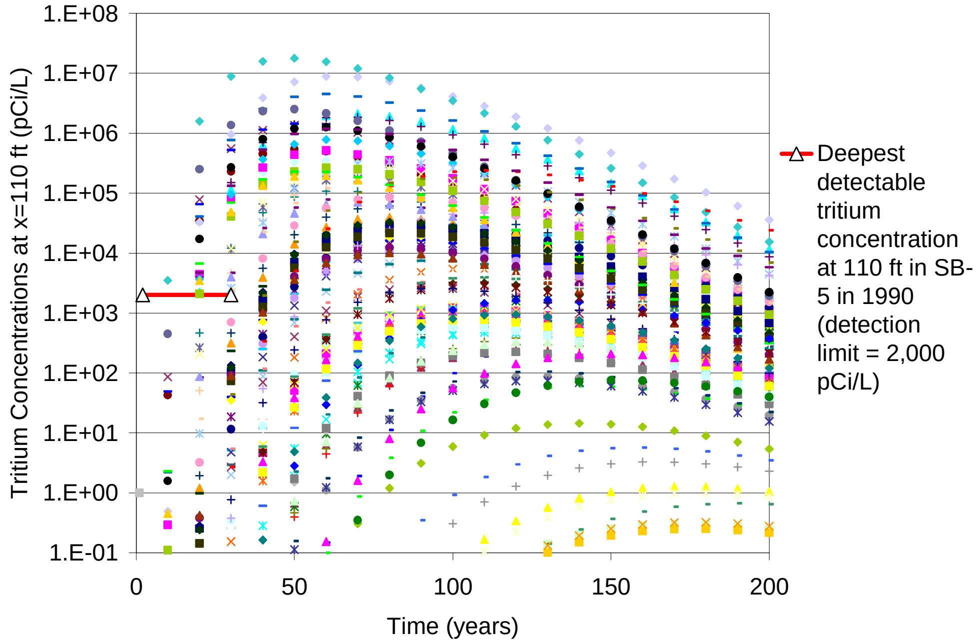


Figure E-8 Comparison of Simulated Tritium Concentration at a Depth of 110 ft as a Function of Time for 100 Realizations with Measured Value in 1990

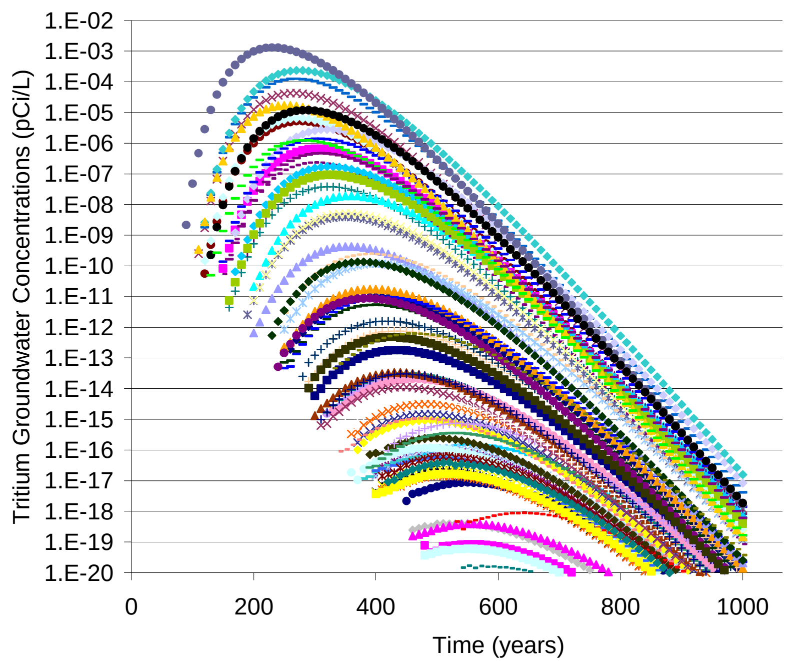


Figure E-9 Simulated Tritium Concentrations in the Aquifer as a Function of Time for 100 Realizations

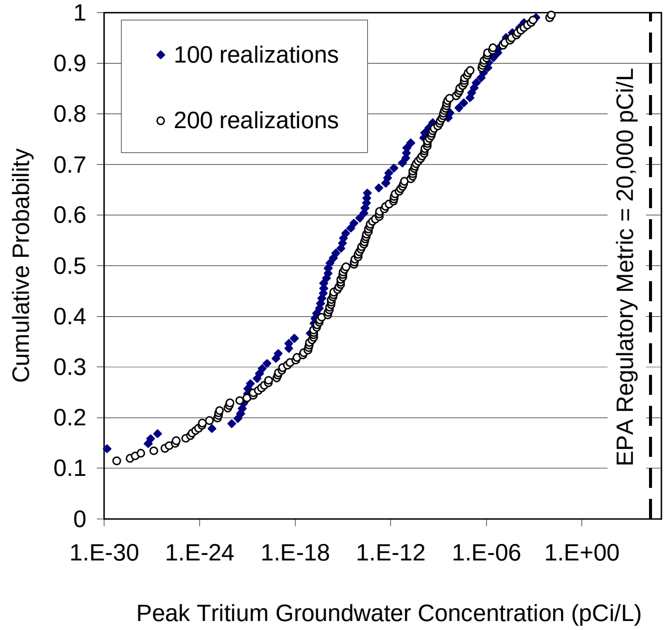


Figure E-10 Cumulative Probability for Simulated Peak Tritium Groundwater Concentrations Using 100 and 200 Realizations

Figure E-11 shows the cumulative probability for the simulated peak tritium dose via groundwater, which is calculated based on the simulated aquifer concentrations and a conservative water intake of 10 L/day (accounts for drinking water, indirect ingestion via plants and animals, absorption and inhalation via showering, etc.). The results show that all realizations are well below the EPA metric of 4 mrem/yr.

Figure E-12 shows the cumulative probability for the simulated peak tritium dose via the air pathway for 100 realizations. The simulated dose due to inhalation (and skin absorption) is based on the concentration of gas-phase tritium immediately above the MWL. The average wind velocity, vertical mixing length, and surface flux of tritium are used to calculate the air concentration above the MWL, and the inhalation rate is used to calculate the intake (Table E-5). The dose conversion factor (Table E-1) is then used to calculate the dose rate. Because the simulated surface flux of tritium for several realizations was quite high (Figure E-5), a small percentage (approximately 2 percent) of the realizations yield a dose via the air pathway that exceeds the EPA metric of 10 mrem/yr.

It should be noted, however, that Figure E-5 shows the peak tritium surface fluxes occurring before 50 years due to the natural decay of tritium. The simulated maximum surface concentrations of tritium that yielded the peak fluxes are on the order of 10^{10} pCi/L. If measured values of tritium vapor concentrations at the surface over the next few decades are not shown to increase from previously measured values, which are several orders of magnitude less than maximum simulated values, the dose due to tritium via the air pathway is not likely to be exceeded.

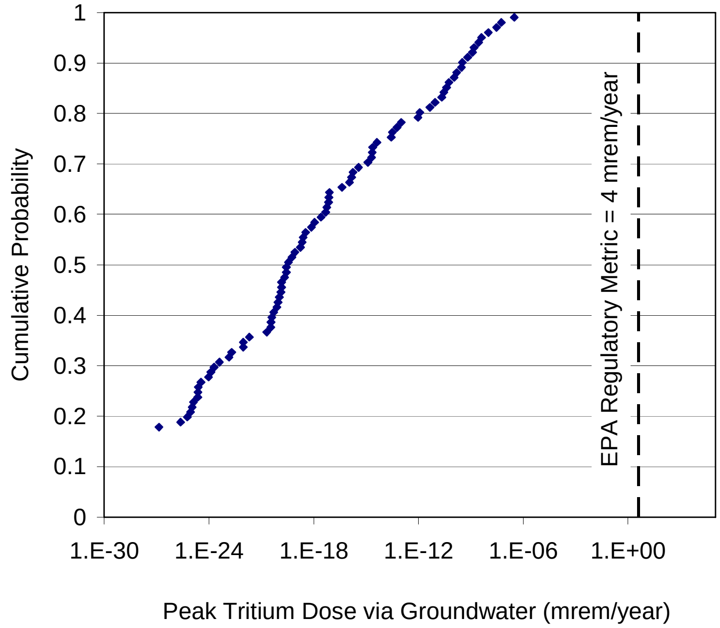


Figure E-11 Cumulative Probability for Simulated Peak Tritium Dose via the Groundwater Pathway Using 100 Realizations

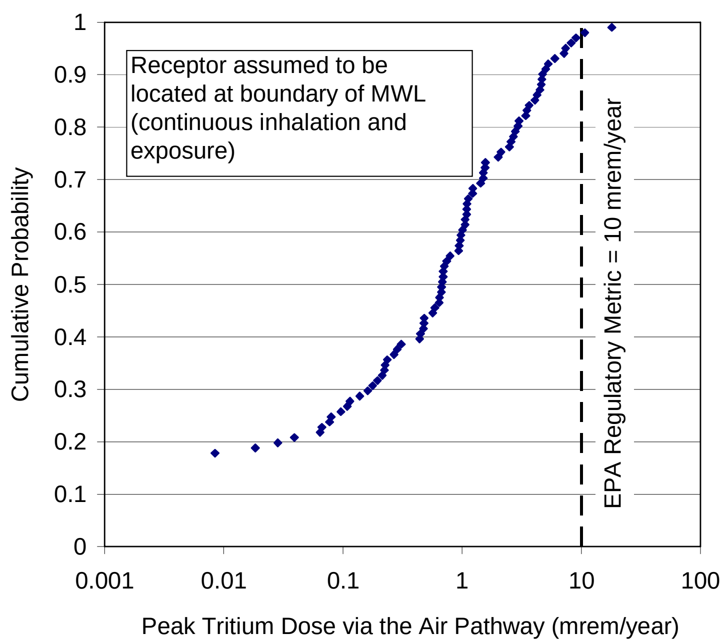


Figure E-12 Cumulative Probability for Simulated Peak Tritium Dose via the Air Pathway for 100 Realizations

3.5.2.3 Sensitivity Analysis

A sensitivity analysis (as described in Section 2.2.1) was performed to determine the parameters that were most important to the simulated performance metrics of aquifer concentration and inhalation dose. Figure E-13 presents a chart that summarizes the results of the stepwise linear rank regression analysis.

The sensitivity of the inhalation dose to liquid-phase tortuosity and moisture content indicates that the transport of tritium is dependent on upward diffusion through the liquid phase as well as the gas phase. A conservative upper bound for the liquid- and gas-phase tortuosity coefficients was implemented in this study (Table E-4) to account for the possible effects of enhanced vapor diffusion (Ho and Webb 1998). The dependence on cover thickness and atmospheric boundary-layer thickness indicates that the inhalation dose is also dependent on the upper boundary conditions of the landfill. Therefore, the thickness and integrity of the cover should be monitored and maintained to mitigate tritium migration to the surface. Finally, although not included as an uncertain parameter, the location and disposition of the receptor played an important role in the simulated inhalation dose. In this study, the receptor was assumed to be located adjacent to the MWL, continuously inhaling air directly above the MWL (24 hours a day, 365 days a year). If the receptor were located further away from the site, or if the exposure were not continuous, the simulated dose via the air pathway would be considerably less.

The variability of the tritium aquifer concentration is shown to be dependent on the liquid-phase mobility parameters, indicating that diffusion of liquid-phase tritium is important. A separate ("one-off") sensitivity analysis of infiltration revealed that the infiltration would have to be increased by several orders of magnitude (close to the saturated hydraulic conductivity of the vadose zone) in order for the tritium to reach substantial concentrations in the groundwater.

3.5.3 Summary of Key Results and Assumptions

- All simulated realizations of tritium aquifer concentration and dose via the groundwater pathway were well below the regulatory metrics of 20,000 pCi/L and 4 mrem/yr, respectively.

- A small percentage (2 percent) of the simulated dose due to tritium via the air pathway exceeded the regulatory metric of 10 mrem/yr.

- Parameters impacting tritium diffusion through both the liquid and gas phases (e.g., tortuosity coefficient, moisture content, cover thickness, atmospheric boundary-layer thickness) were found to be important to the simulated inhalation dose.

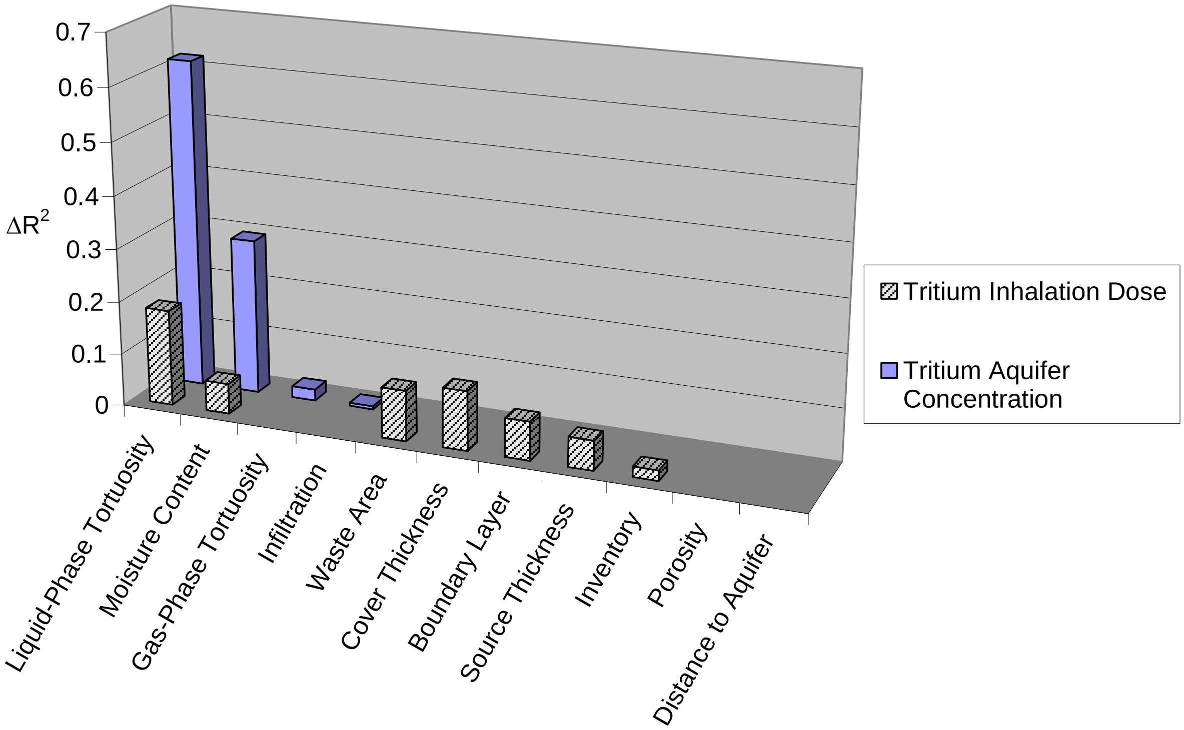


Figure E-13 Analysis of Sensitivity of Simulated Tritium Inhalation Dose and Aquifer Concentration to Uncertain Input Parameters

Key Assumptions:

- Receptor located at MWL; continuous inhalation and exposure of tritium flux from subsurface
- Cover allowed to erode completely
- 1-D model: maximum transport to surface
- Bounding tortuosity coefficients: maximum diffusion rate
- Maximum waste inventory set equal to twice estimated value of 2,400 Ci

3.6 Fate and Transport of Radon

3.6.1 Model Description

Section 3.2.3 and Attachment E1 describe the steady-state radon transport model that was developed for this study. Diffusion, advection, and decay of radon is included in the model. A constant generation of radon is assumed to occur in the prescribed waste zone, which can vary in size. A significant difference between the current model and previous models of radon transport in geological media (see, for example, Rogers et al. 1984) is the nature of the radium-226 source.

In previous studies, the radium-226 originated from ore deposits containing uranium. At the MWL, pure radium-226 was disposed of in sealed containers. Therefore, the overall concentration of radium-226 can be much higher in the current analysis, but the emanation factor, *E*, which governs how much radon-222 gas can be released from the radium-226, can be significantly lower because of the containment. Generally speaking, the integrity of radioactive sealed sources is very robust. The radium-226 sealed sources disposed of in the MWL were most likely fabricated according to design standards that required tests to evaluate the integrity of the sources subject to extreme temperature, impact, pressure, and vibration (see, for example, 10 CFR 39.41).

3.6.2 Model Results

3.6.2.1 Comparison to Field Data

Radon surface fluxes at the MWL were measured in 1997 (Haaker 1998). A total of 89 four-in.-diameter activated charcoal radon canisters were used to evaluate the radon surface fluxes in the vicinity of the MWL, as well as background values. Results showed that the measured radon fluxes above the MWL were not significantly different than the background values. The median flux in the vicinity of the MWL was 0.33 $pCi/m^2/s$ while the median background flux was 0.35 $pCi/m^2/s$. The maximum measured fluxes for the MWL and background were 1.02 and 0.664 $pCi/m^2/s$, respectively. This difference in maximum values was used to calibrate the emanation factor in the radon transport model. The emanation factor governs how much radon is released to the immediate surroundings from the radium-226 source. A factor of zero represents no emission (complete containment), and a factor of one represents total emission (no containment).

The potential sources of radon-222 (radium-226) were sealed and contained, and the sealed sources were likely tested for integrity before disposal in the MWL. Therefore, the containment is assumed to be generally intact at present, but defects or breaks may still be present. The minimum emanation factor, which accounts for present-day emissions, was adjusted to yield a radon flux between 0.1 and 1 $pCi/m^2/s$ (equivalent to the difference in maximum measured and background fluxes). The resulting minimum emanation factor used in the probabilistic simulations was 10^{-6}. The maximum emanation factor was estimated based on the possibility that the sealed containers may degrade in the future. The integrity of the containers is expected to last well beyond 1,000 years, but an upper value of the emanation factor was set equal to 0.01 to represent the possibility that 1 percent of the containers will completely degrade within 1,000 years. An evaluation was also performed assuming that the maximum emanation factor was equal to one, which is equivalent to complete degradation of the containment of all the radon sources within 1,000 years. A log-uniform distribution between 10^{-6} and the maximum value was used for the emanation factor.

3.6.2.2 Comparison to Performance Objectives

Figure E-14 shows the cumulative probability for the simulated peak radon-222 surface flux for 100 realizations. For the scenario with a maximum emanation factor of 0.01 (1 percent of the radon-source containers degrades completely), the results show that 97 percent of the simulated radon surface fluxes are below the design standard of 20 $pCi/m^2/s$ (3 percent of the realizations

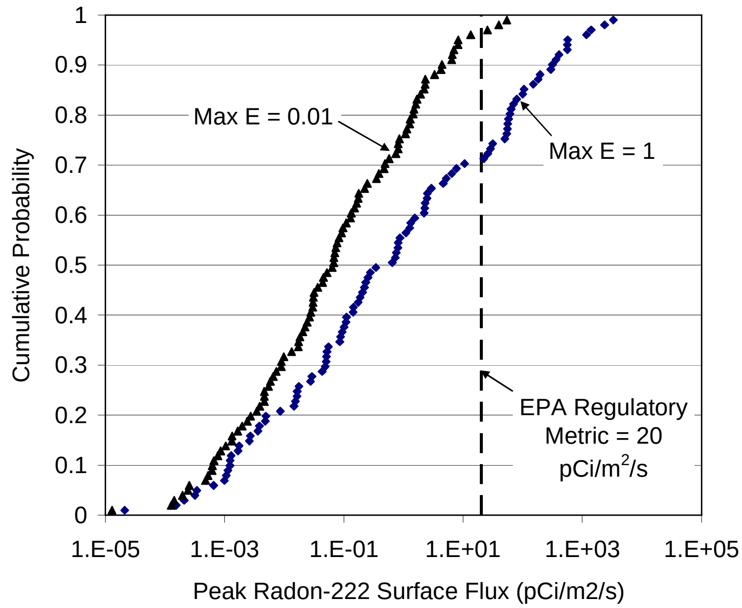


Figure E-14 Cumulative Probability for Simulated Peak Radon-222 Surface Flux for 100 Realizations Using Two Different Maximum Values for the Emanation Factor, E

yield radon surface fluxes that exceed the design standard). In the bounding scenario, where we allow all of the containment of the sealed sources to completely degrade, nearly 30 percent of the realizations exceed the design standard of 20 pCi/m2/s. As shown in the sensitivity analysis in the next section, the large uncertainty in the emanation factor allowed significant variations in the simulated radon surface flux. It is unlikely that the sealed sources and containers for radium-226 will degrade significantly over the next few hundred years, but because the half-life of radium-226 and uranium-238 is extremely long, radon-222 will continue to be generated from these parent products indefinitely. Therefore, degradation of the containers may eventually cause the emanation factor for radon-222 to increase at some point in the future. For a 1,000-year evaluation period, however, the probability of exceeding the radon surface-flux design standard is very small if the sealed sources and containers do not degrade significantly and the emanation factor remains below 0.01.

Simulated radon concentrations in groundwater were negligible (less than 10 to 20 pCi/L). The short half-life of radon (3.8 days) and the large thickness of the vadose zone prohibit radon from migrating significant distances to the water table when the source originates from the landfill. However, in Section 3.7, small amounts of radon are shown to reach the groundwater after 10,000 years when radon is included as progeny of uranium-238, which is fairly mobile (relative to the other nonvolatile radionuclides). This effectively mobilizes the source of radon toward the groundwater. However, the decay chain for uranium-238 to radium-226 to radon-222 is an extremely long process (billions of years). Therefore, the amount of radon-222 produced from uranium-238 in 1,000 years is extremely small; no radon-222 is simulated to reach the groundwater in 1,000 years, even when it is included as progeny of uranium-238.

3.6.2.3 Sensitivity Analysis

A sensitivity analysis (as described in Section 2.2.1) was performed to determine the stochastic input parameters that were most important to the simulated radon surface flux. Figure E-15 presents a chart that summarizes the results of the stepwise linear rank regression analysis. The emanation factor was by far the most significant variable that influenced the variability in the simulated radon surface flux. The waste volume, cover thickness, and effective diffusion coefficient were also shown to be statistically correlated to the simulated radon surface flux, but to a much lower degree.

3.6.3 Summary of Key Results and Assumptions

- Sensitivity studies show that the emanation factor, which depends on the integrity of the radium-226 containment, is important to the performance of the landfill with regard to surface radon fluxes.

- For a maximum radon emanation factor of 0.01 (1 percent of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard of 20 $pCi/m^2/s$ in about 3 percent of the realizations. For a maximum radon emanation factor of 1 (100 percent of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard in about 30 percent of the realizations.

- Simulated radon concentrations in the groundwater were negligible.

Key Assumptions:

- Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor allowed to increase)

- Cover allowed to erode completely

- 1-D model: maximum transport to surface

3.7 Fate and Transport of Other Radionuclides

3.7.1 Model Description

The FRAMES/MEPAS source-term and vadose-zone models (Section 3.2.1) were used to evaluate the aqueous-phase transport of the following radionuclides to the groundwater: amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, strontium-90, thorium-232, tritium, and uranium-238. Although tritium was simulated separately using the model of Jury et al. (1983, 1990), it was also included in the FRAMES/MEPAS model. Decay products of plutonium-238 (e.g., uranium-234), radium-226 (e.g., radon-222), and uranium-238 (e.g., uranium-234, radium-226) are also simulated in the FRAMES/MEPAS model (Whelan et al. 1996).

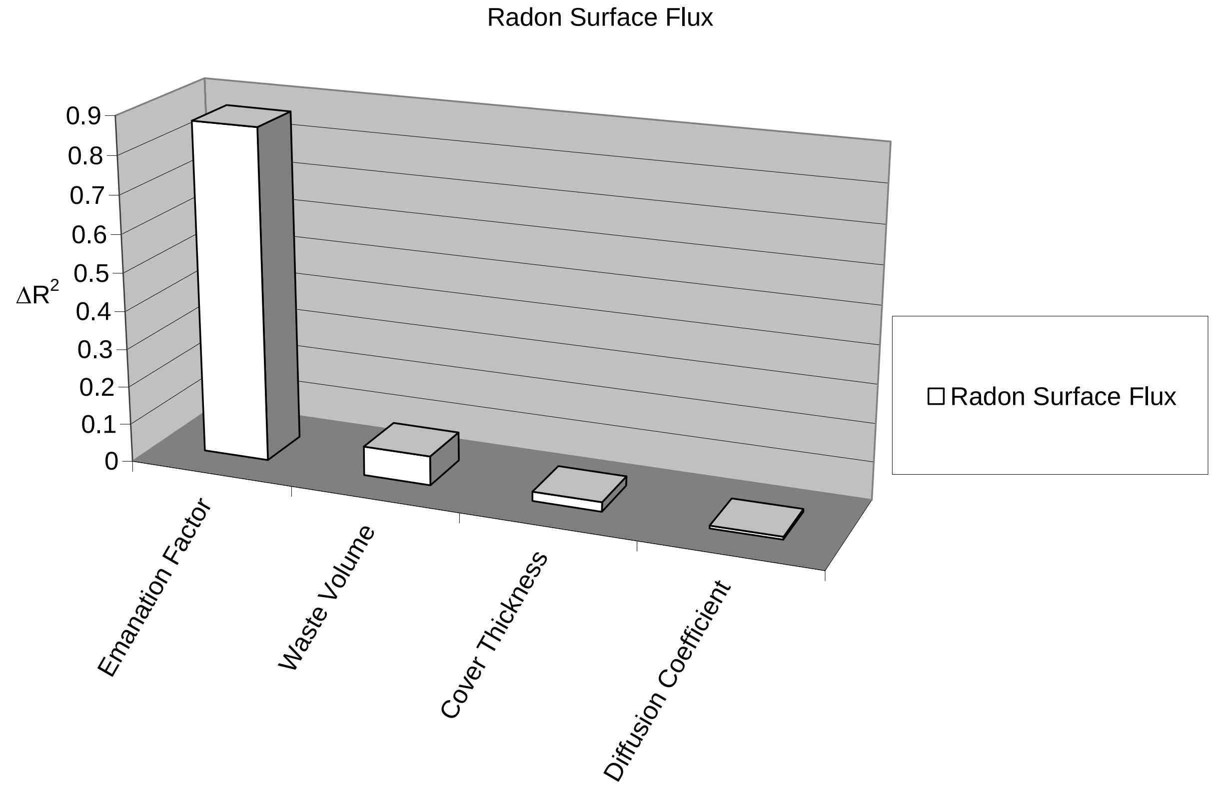


Figure E-15 Analysis of Sensitivity of Simulated Radon Surface Flux to Uncertain Input Parameters

3.7.2 Model Results

3.7.2.1 Comparison to Field Data

Other than the detection of tritium and radon in the atmosphere and subsurface as discussed in previous sections, no other radionuclides have been detected at the surface or in the subsurface beyond the extent of the landfill. The inventory for each of the radionuclides shown in Table E-2 was estimated based on past records regarding the content of the MWL (SNL/NM 1993). The upper value for the inventory distribution of each radionuclide was conservatively assumed to be equal to twice the estimated value from past records.

3.7.2.2 Comparison to Performance Objectives

In all realizations, none of the radionuclides were simulated to reach the groundwater in 1,000 years.[3] All of the radionuclides were retarded sufficiently by adsorption to prevent significant migration in 1,000 years, even with the realistically conservative distributions used for model inputs (Table E-2). In order to assess potential failure mechanisms, additional scenarios were performed.

[3] Tritium was simulated to reach the groundwater when vapor-phase transport was included in Section 3.5, but simulated tritium groundwater concentrations and dose were well below the regulatory metrics.

Alternative Scenario: Increased Infiltration

First, the infiltration was increased while holding all other input parameters at fixed, conservative values. After 1,000 years, uranium (uranium-238, uranium-234) reached the groundwater when the Darcy infiltration through the vadose-zone was increased by an order of magnitude over its maximum stochastic value (6.12×10^{-11} m/s) to 6.12×10^{-10} m/s, but the groundwater concentrations were still less than the regulatory metric of 30 μg/L. Groundwater concentrations of uranium exceeded the regulatory metric when the simulated Darcy infiltration increased by two orders of magnitude over the maximum stochastic value to 6.12×10^{-9} m/s.

Alternative Scenario: Increased Simulation Period

FRAMES/MEPAS was allowed to run past 1,000 years to assess the potential travel times of the different radionuclides to the groundwater using the original distributions and parameter values (Table E-2). Only uranium-238 and its decay products (uranium-234, radon-222) were simulated to reach the groundwater after approximately 10,000 years. The other radionuclides were retarded by their relatively large adsorption coefficients. The radon-222 that reached the groundwater was a decay product of uranium-238. As shown in previous simulations of radon originating from the waste zone (Section 3.6), radon originating from the MWL was not simulated to reach the water table because of its short half-life (3.8 days). However, since uranium-238 has a small distribution coefficient (K_d) and long half-life, a number of realizations showed that uranium-238 and some of its daughter products (uranium-234 and radon-222) could reach the water table after approximately 10,000 years. Although the decay of uranium-238 to radon-222 is extremely slow, some small but finite amount of radon-222 is generated from uranium-238 as it moves toward the water table. In MEPAS, the Bateman equation (Bateman 1910) is used to estimate the relative concentrations of the daughter products as a function of the concentration of the parent, the half lives of the parent and daughter products, and the time elapsed.

Figure E-16 shows the cumulative probability for simulated peak radon-222 (progeny from uranium-238) aquifer concentrations for 100 realizations after a simulated period greater than 10,000 years. Although the radon-222 reached the water table as a result of the transport of its parent product, uranium-238, the concentration of radon-222 in the groundwater is still well below the proposed limit of 300 pCi/L.

Figure E-17 shows the cumulative probability for the simulated peak uranium concentration in the groundwater for 100 realizations after a simulated time period greater than 10,000 years. The total uranium concentration is comprised of both uranium-234 (decay product of plutonium-238 and uranium-238) and uranium-238. All realizations yielded peak uranium aquifer concentrations that were less than the EPA regulatory metric of 30 μg/L.

The total groundwater dose for extended periods of time (past 10,000 years) is calculated from the peak aquifer concentrations of uranium (uranium-234 and uranium-238) and radon. The groundwater consumption is assumed to be a conservative 10 L/day to account for drinking water, indirect ingestion through irrigation of vegetables and intake by food-producing animals, and absorption via showering. Figure E-18 shows the cumulative probability for the simulated

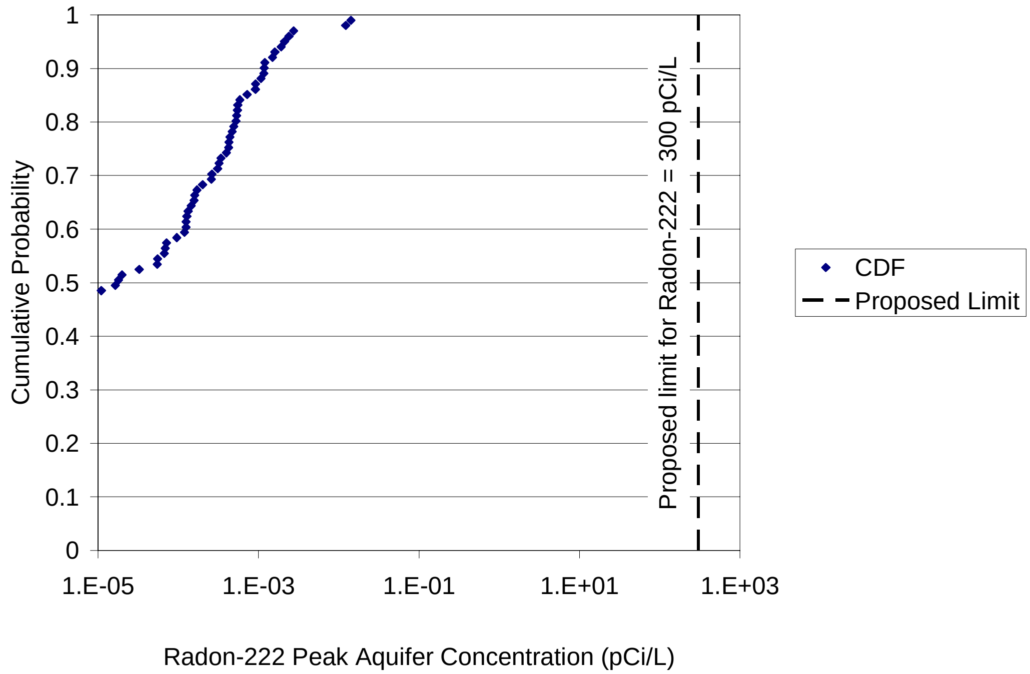


Figure E-16 Cumulative Probability for Simulated Peak Radon-222 (Progeny from U-238) Aquifer Concentrations for 100 Realizations for a time Period Extending Beyond 10,000 years

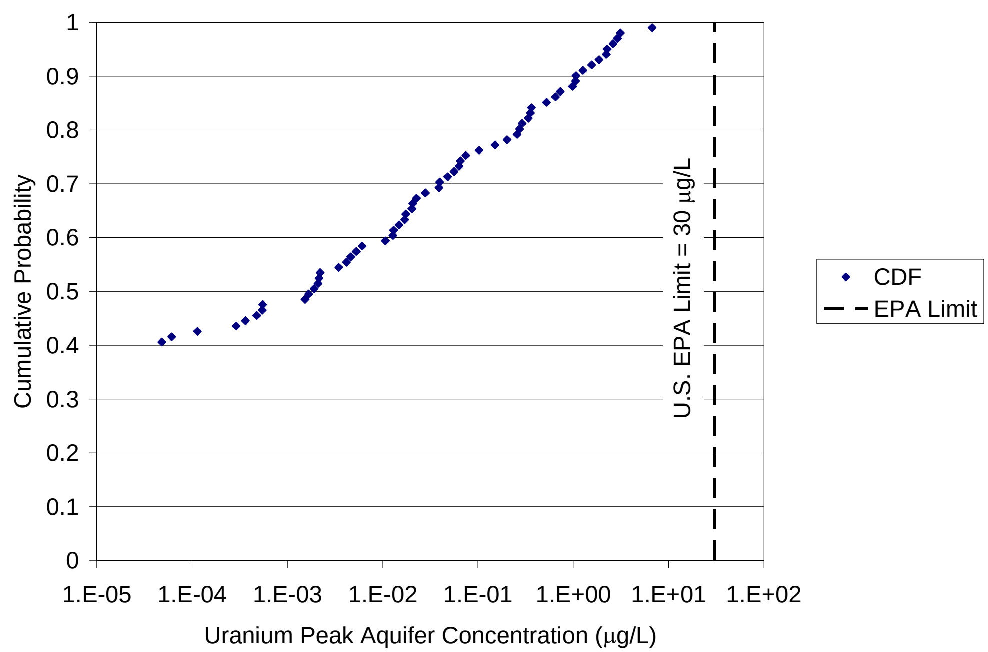


Figure E-17 Cumulative Probability for Simulated Peak Uranium Aquifer Concentrations for 100 Realizations for a Time Period Extending Beyond 10,000 Years

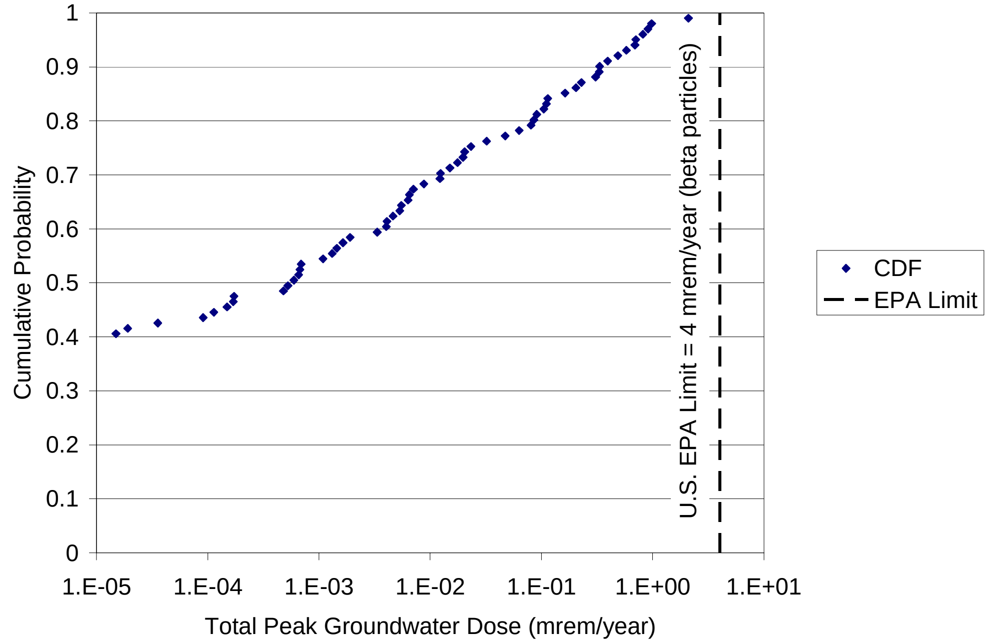


Figure E-18 Cumulative Probability for Simulated Peak Groundwater Dose for all Radionuclides for 100 Realizations for Time Periods Extending Beyond 10,000 Years

total peak groundwater dose for 100 realizations after a simulated period greater than 10,000 years. The EPA regulatory metric of 4 mrem/yr (for beta particles) is shown for reference, but it does not actually apply to the primary constituents contributing to the dose, uranium-234 and uranium-238, which are alpha particles.

3.7.2.3 Sensitivity Analysis

Although no radionuclides were simulated to reach the groundwater within 1,000 years, sensitivity analyses were performed on the extended simulations (greater than 10,000 years) to identify important parameters and processes (Figure E-19). Sensitivity analyses show that the infiltration is the primary parameter impacting the variability in the simulated aquifer concentrations for uranium-238, its decay products (uranium-234, radon-222), and the simulated dose via groundwater. A "one-off" sensitivity analysis showed that the infiltration would have to be increased by two orders of magnitude to increase the uranium concentrations above the regulatory metric of 30 μg/L within 1,000 years. Other parameters that were found to be statistically correlated to the variability in the simulated performance metrics were waste length and width, uranium-238 K_d, and the bulk density (which, together with the K_d value, impacts the retardation).

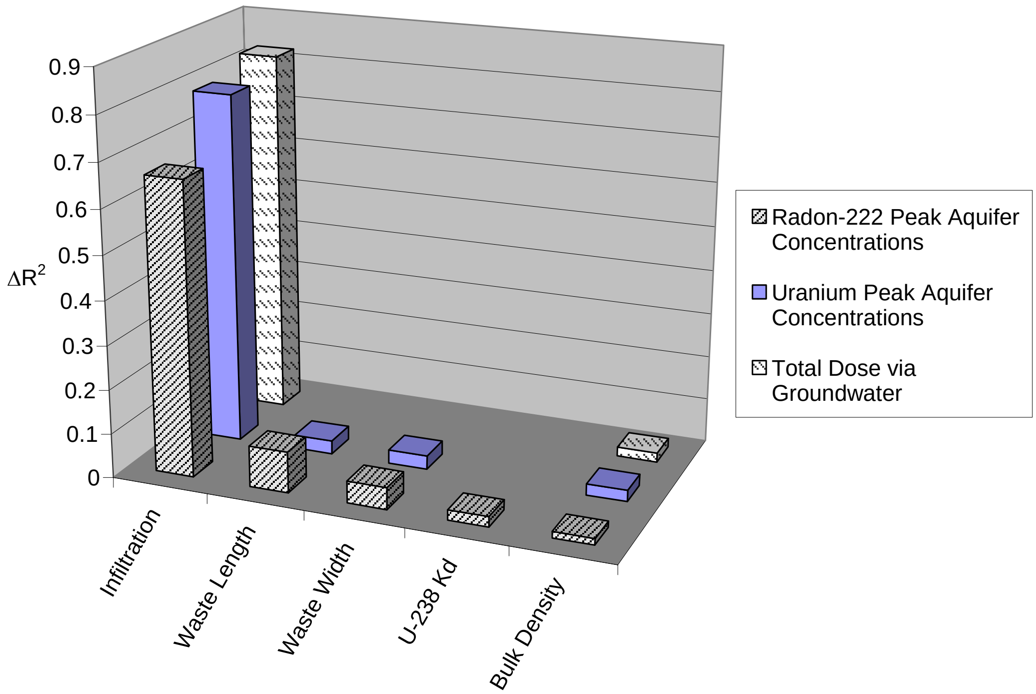


Figure E-19 Analysis of Sensitivity of Simulated Peak Radon Aquifer Concentrations, Peak Uranium Aquifer Concentrations, and Total Dose via Groundwater to Uncertain Input Parameters for a Time Period Extending Beyond 10,000 Years

3.7.3 Summary of Key Results and Assumptions

- None of the radionuclides were simulated to reach the groundwater within 1,000 years for all realizations.

- Only uranium-238 (and some of its decay products) were simulated to reach the water table for extended periods (greater than 10,000 years). All peak aquifer concentrations were still less than the EPA regulatory metric of 30 μg/L.

- Infiltration rate was found to be the most significant parameter impacting the variability in the simulated groundwater concentrations and dose via groundwater. Uranium groundwater concentrations were simulated to exceed the regulatory metric of 30 μg/L if the infiltration increased two orders of magnitude above the maximum stochastic value to 6.12×10^{-9} m/s.

Key Assumptions:

- 1-D model: maximum transport to groundwater

- Receptor assumed to be located at MWL. Water intake assumed to be 10 L/day (5 times greater than EPA standards)

3.8 Fate and Transport of Heavy Metals

3.8.1 Model Description

The fate and transport of two heavy metals, lead and cadmium, were simulated using FRAMES/MEPAS (Section 3.2.1). The inventory of lead was estimated from previous records (SNL/NM 1993), and uncertainty in the inventory was captured by using a uniform distribution with the estimated value as a lower bound (Table E-2). There were no records of cadmium being disposed of at the MWL, but soil samples revealed concentrations of cadmium in the subsurface (Peace et al. 2002). The maximum soil concentrations of cadmium were used with the bulk density of the soil and maximum simulated penetration of coolant water (Wolford 1997) to estimate the mass of cadmium in the MWL. This value was then used as a lower bound in a uniform distribution (Table E-3).

3.8.2 Model Results

Neither lead nor cadmium were simulated to reach the groundwater in any of 100 realizations for 1,000 years. Extended simulation periods (greater than 10,000 years) also did not yield any breakthrough of lead or cadmium to the water table. Therefore, comparisons to the regulatory metrics of 15 μg/L and 5 μg/L for lead and cadmium, respectively, are not plotted. Both lead and cadmium have relatively large adsorption coefficients (Table E-2), which retard their transport through the thick vadose zone.

3.8.2.1 Sensitivity Analysis

A "one-off" sensitivity analysis was performed to determine the impact of infiltration on the transport of lead and cadmium while holding all other parameters at constant conservative values. Results showed that cadmium could reach the groundwater in 1,000 years and exceed its regulatory metric if the Darcy infiltration were increased by three orders of magnitude over the maximum expected infiltration, which is based on future climate scenarios (i.e., from 6×10^{-11} m/s to 6×10^{-8} m/s). Lead was simulated to reach the water table in 1,000 years if the infiltration were increased by four orders of magnitude over the maximum expected infiltration. Although this additional increase in infiltration is not expected to occur based on detailed infiltration simulations (Section 3.4), the infiltration at the MWL should be monitored in the future. Significant increases (by several orders of magnitude or more) may lead to increased potential for migration of heavy metals and other contaminants to the groundwater.

3.8.3 Summary of Key Results and Assumptions

- Neither lead nor cadmium were simulated to reach the groundwater in 1,000 years (or extended periods past 10,000 years)

- Additional increases in infiltration would (3 to 4 orders of magnitude over expected maximum infiltration rates) allow cadmium and lead to reach the groundwater in 1,000 years.

Key Assumptions:

- 1-D model: maximum transport to groundwater

3.9 Fate and Transport of Volatile Organic Compounds

3.9.1 Model Description

VOCs were used as cleaners and solvents for machining and other industrial processes at Sandia National Laboratories. Rags, residual containers, and other wastes contaminated with these contaminants were disposed of at the MWL. Although no quantitative estimates of the volumes of these contaminants disposed of in the MWL exists, soil samples provide an estimate of the extent and concentration of the region contaminated with VOCs at the MWL. Previous studies have shown that VOCs such as TCE and PCE can migrate long distances in the vapor phase. Klavetter (1995a) showed that among the VOCs of concern at the MWL, PCE was the only VOC that posed a threat to exceeding regulatory metrics in the groundwater (PCE has a greater Henry's constant and, hence, greater gas-phase transport rate than TCE for the same aqueous source concentration). However, because there is still a potential for other VOCs from the MWL to migrate to groundwater due to their mobility, PCE was modeled in this study as a proxy for other VOCs detected in soil gas and in soils beneath the MWL.

In this study, PCE is simulated using the transient model of Jury et al. (1983, 1990), which accounts for aqueous-phase advection, gas-phase diffusion, adsorption, and decay (Section 3.2.2). Table E-2 summarizes the uncertainty distributions that were used in the model. The inventory was calculated based on the maximum measured soil gas concentration (5,900 ppb) at 30 ft (Peace et al. 2002). We assumed that the PCE vapor was in equilibrium with its aqueous phase (using Henry's constant). The maximum measured gas concentration (5,900 ppb) was used as a minimum value in a uniform distribution increasing to ten times this value to develop a range of equilibrium aqueous concentrations. The maximum value was based on calibrations with measured data (see next section). The total mass of PCE was then calculated using the moisture content, maximum areal extent of the MWL (430 x 300 ft), and an uncertain thickness ranging from 10 to 27 ft. Other values in Table E-2 were taken from conservative values and ranges found in the literature for PCE.

3.9.2 Model Results

3.9.2.1 Comparison to Field Data

Samples of PCE soil-gas concentrations were taken at the MWL in 1993 (Johnson et al. 1995). The ranges of measured values at two different depths (10 and 30 ft) were compared to simulated soil-gas concentrations using the transient PCE transport model described in the previous section. Figure E-20 and Figure E-21 show the comparisons for all 100 simulated realizations. As discussed in previous sections, the measured values in 1993 are shown spanning a time period between 5 and 33 years, which accounts for the uncertainty in the time of emplacement. Results show the majority of simulated soil-gas concentrations during this time period at the two depths are between the maximum and minimum values measured in 1993.

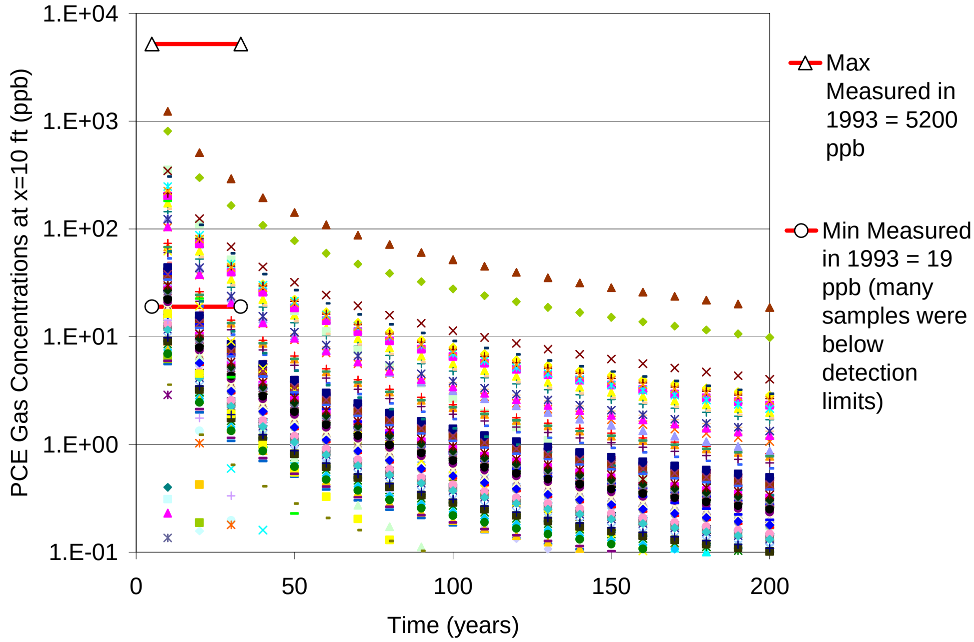


Figure E-20 Simulated PCE Gas Concentration at a Depth of 10 ft as a Function of Time for 100 Realizations with a Range of Measured Values in 1993

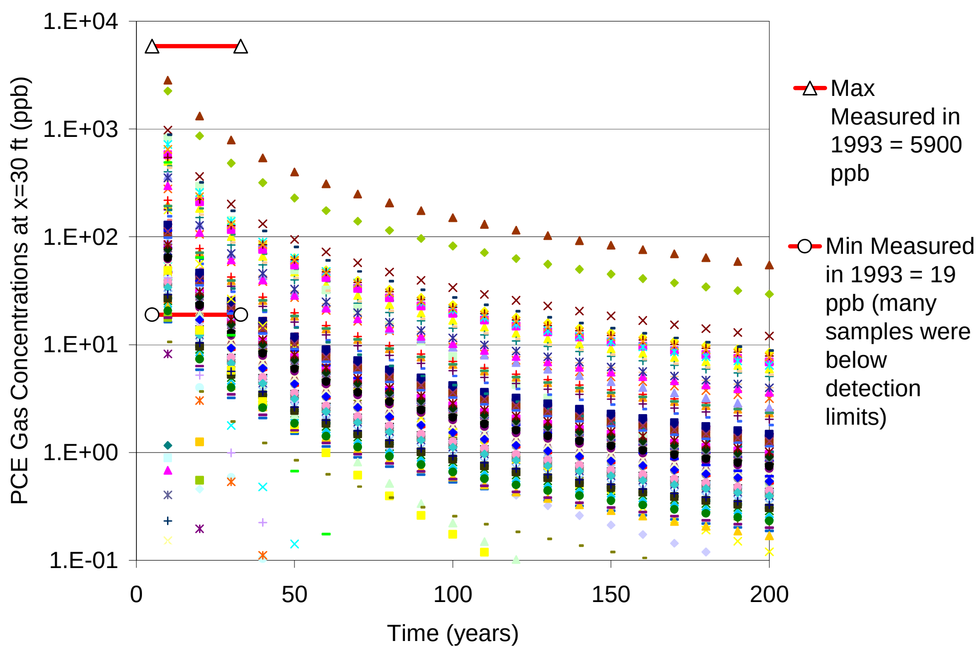


Figure E-21 Simulated PCE Gas Concentration at a Depth of 30 ft as a Function of Time for 100 Realizations with a Range of Measured Values in 1993

3.9.2.2 Comparison to Performance Objectives

Figure E-22 shows the simulated PCE concentrations in the groundwater as a function of time for all 100 realizations. The majority of the realizations show the aquifer concentrations peaking before 50 years. Depending on the time of disposal, this corresponds to peak concentrations occurring by 2010 to 2040. So far, no detectable amounts of PCE have been found in the groundwater at the MWL. This is still consistent with the simulations, which show a large amount of variability in the simulated concentrations resulting from uncertainty included in the input parameters (see next section).

The cumulative probability of the peak PCE groundwater concentration for all 100 realizations is shown in Figure E-23. The results show that approximately 99 percent of the realizations yield groundwater concentrations less than the regulatory metric of 5 μg/L. Only 1 percent of the realizations yielded groundwater concentrations that exceeded the regulatory metric.

3.9.2.3 Sensitivity Analysis

The uncertainty in the PCE K_d, half-life (degradation), inventory concentration, source thickness, and cover thickness values were found to be the most statistically significant parameters that impacted the variability in the simulated PCE aquifer concentrations (Figure E-24). As stated in previous sections, the adsorption coefficient, K_d, plays an important role in the retardation and mobility of the constituent. The half-life and inventory both govern the persistence and availability of the PCE during migration to the groundwater. The source thickness also contributes to the overall inventory of PCE since the inventory concentration is applied to the entire source volume.

3.9.3 Summary of Key Results and Assumptions

- 99 percent of the realizations yielded peak PCE concentrations in the groundwater that were less than the regulatory metric of 5 μg/L. The majority of the realizations showed that the peak PCE groundwater concentration occurred within 100 years.

- Uncertainty in the PCE adsorption coefficient, half-life, inventory concentration, source thickness, and cover thickness were found to be significantly correlated to the simulated groundwater concentrations.

Key Assumptions:

- 1-D model: maximum transport to groundwater

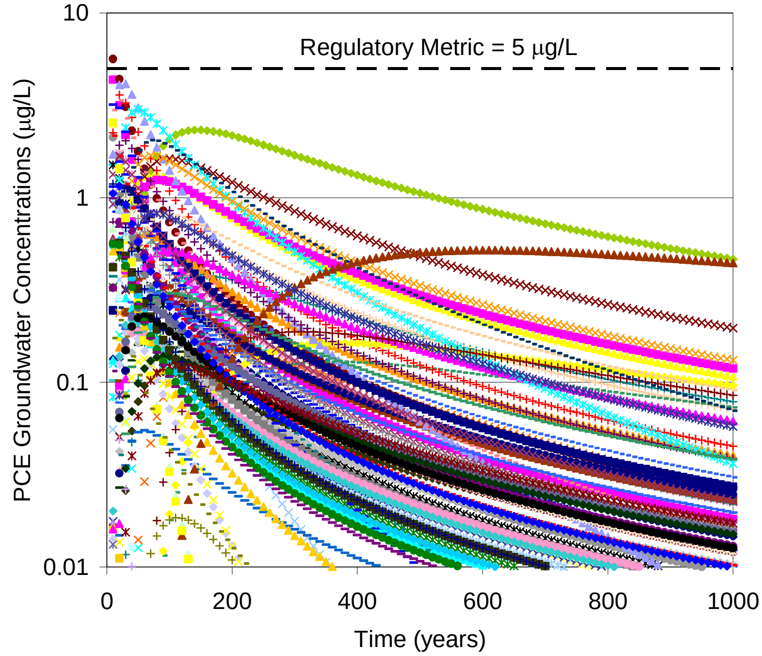


Figure E-22 Simulated PCE Groundwater Concentrations for 100 Realizations

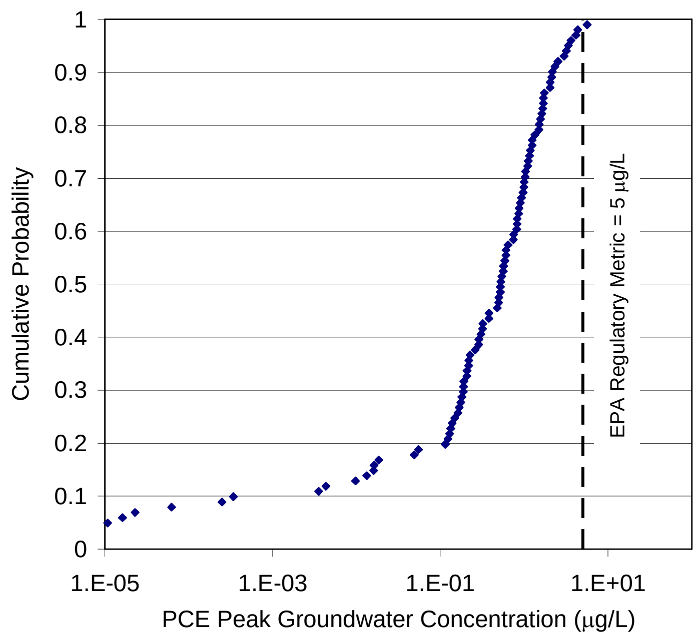


Figure E-23 Cumulative Probability for Simulated PCE Peak Groundwater Concentrations for 100 Realizations

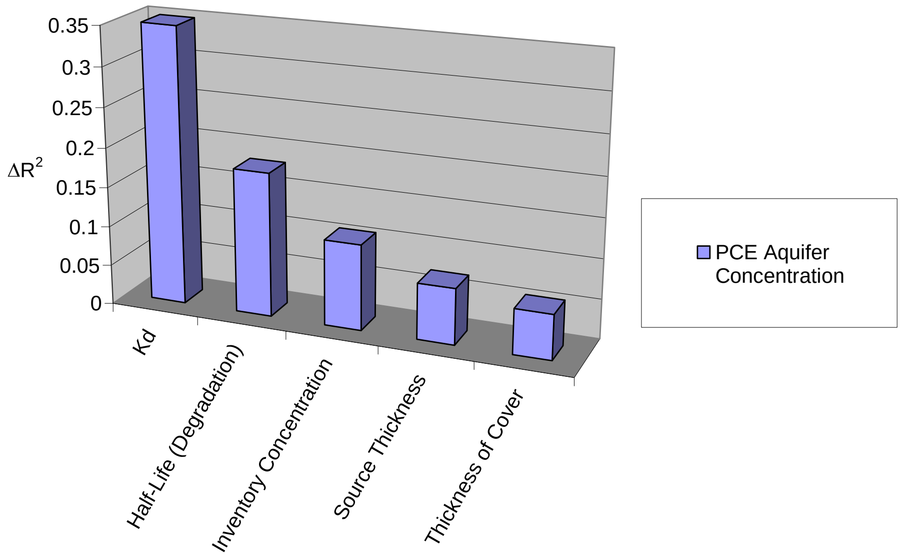


Figure E-24 Analysis of Sensitivity of simulated PCE Peak Aquifer Concentrations to Uncertain Input Parameters

4. Recommended Triggers for Long-Term Monitoring

The NMED's Class 3 permit modification (NMED, May 2005) requires that the MWL CMI Plan include triggers for future action that identify and detail specific monitoring results that will require additional testing or the implementation of an additional or different remedy. Based on the results of the probabilistic performance-assessment modeling for the MWL, the following parameters were identified as important for meeting the performance metrics:

- Surface emissions of tritium and radon
- Infiltration through the MWL cover
- Concentrations of uranium in groundwater
- Concentrations of VOCs in groundwater

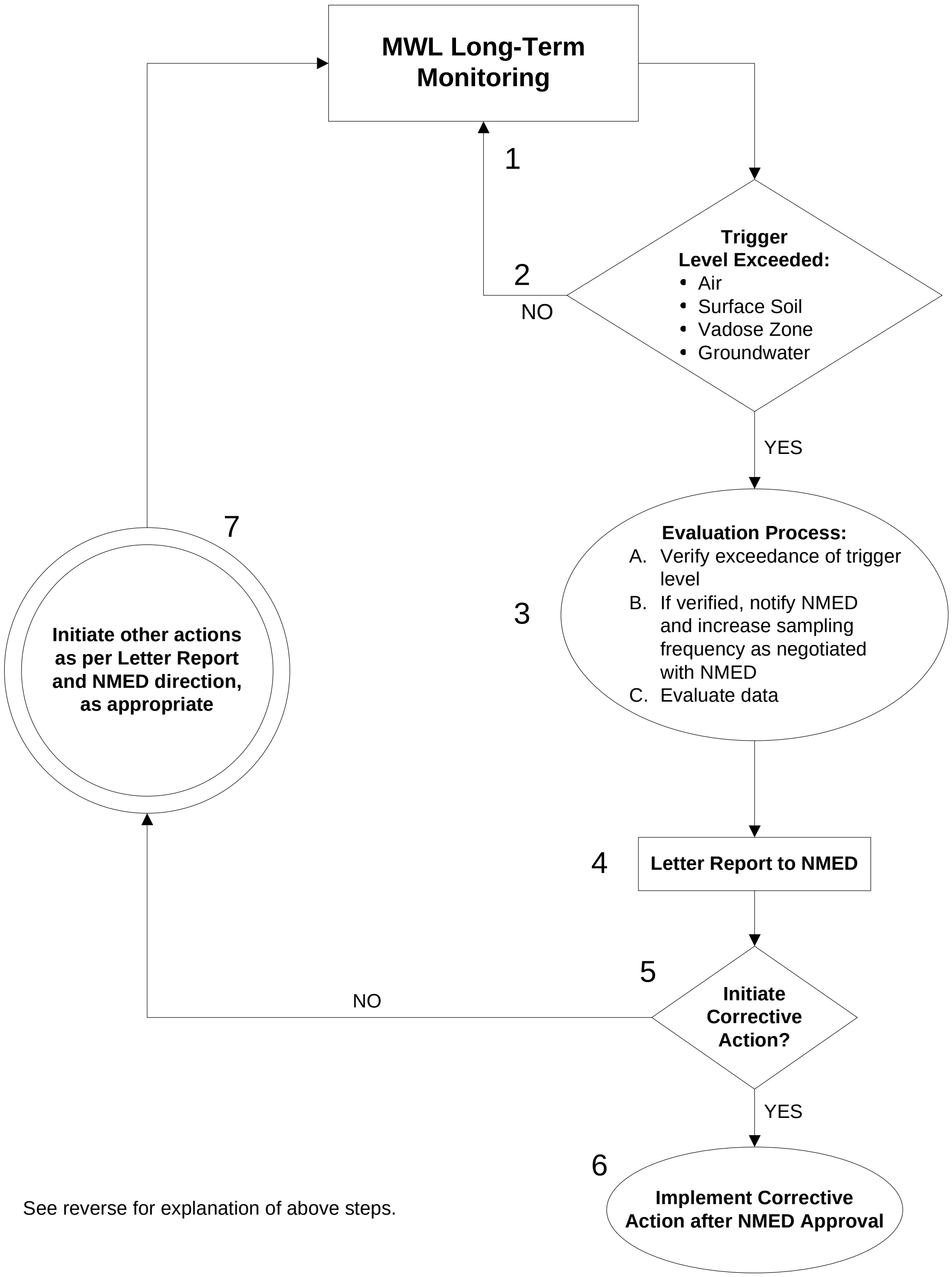
Monitoring triggers are proposed for these parameters to ensure that the MWL performance metrics and corrective action objectives are met. The proposed triggers are based on EPA and DOE regulatory standards, and are discussed in Section 4.2. A trigger evaluation process is proposed in Section 4.1. This process will be initiated if a trigger is exceeded during long-term monitoring at the MWL. The logic and rationale behind specific triggers are presented in Section 4.2.

Additional details regarding long-term monitoring at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan. This plan will be submitted within 180 days after the NMED's approval of the MWL CMI Report. The plan will include all necessary physical and institutional controls to be implemented in the future, and will also include contingency procedures to be implemented if the MWL remedy fails to be protective of human health and the environment.

4.1 Trigger Evaluation Process

A trigger evaluation process is recommended for the MWL during long-term monitoring activities at the site. The process will be a phased approach designed to ensure the protection of human health and the environment, while allowing adequate data collection to evaluate whether corrective action is warranted. This process is based upon the "Conceptual Corrective Measure Evaluation Process" proposed in the Post-Closure Care Plan for the CWL (SNL/NM September 2005).

In the event that a trigger level is exceeded, the process shown in Figure E-25 will be used to ensure that adequate data are collected to determine whether additional corrective action is warranted. The increased frequency of data collection proposed in the trigger evaluation process (see Step 3 in Figure E-25 and the corresponding explanation on the reverse side of the figure) will ensure that adequate data are collected to eliminate field sampling error, laboratory error, or short-term exceedances that do not reflect long-term trends. Thus, any recommendations for corrective action because of trigger exceedances will be based upon data trends rather than upon single detection values above the trigger level. If data trends in the monitored parameters indicate an established trend above the proposed trigger value, the process requires that a technical letter report be submitted to the NMED recommending whether or not corrective action should be implemented.



See reverse for explanation of above steps.

Figure E-25 Trigger Evaluation Process for the Mixed Waste Landfill

The steps outlined in Figure E-25 are explained below:

1. Long-term monitoring of the air, surface soil, vadose zone, and groundwater at the MWL.

2. Exceedance of one or more trigger levels initiates the specific actions described below.

3. Step A of the evaluation process initiates resampling to verify the result(s) that exceeded the trigger level. Step B is based upon the conceptual model for the MWL. If the trigger exceedance is verified, the NMED will be notified and the frequency of subsequent sampling will be negotiated with the NMED. Because infiltration through the MWL cover is expected to be very low, and contaminant transport times in the vadose zone and groundwater are anticipated to be relatively slow, a longer period for data collection at an increased sampling frequency is recommended to determine trends. The length of this period and the increased sampling frequency will be negotiated with the NMED. Once the increased sampling data have been collected, the data and any resulting trends will be evaluated to determine the significance of the exceedance (Step C).

4. After the resulting trends have been evaluated, a brief technical letter report will be prepared and submitted to the NMED within three months of receiving the final data set that summarizes the trigger exceedance(s), presents the results of the increased monitoring, and provides recommendations regarding corrective action.

5. NMED Decision Point: after the technical letter report is submitted to the NMED, a meeting will be held to discuss the data evaluation and the recommendations regarding corrective action.

6. If the data trend is increasing and higher than the proposed trigger value, corrective action may be necessary. The technical letter report will address appropriate options and form the basis for further discussion with NMED to determine the final corrective action.

7. If the data trend is not clear or is decreasing, corrective action may not be necessary, but other actions may be required as proposed in the technical letter report or requested by the NMED.

4.2 Proposed Triggers

Based on the results of the probabilistic performance-assessment modeling conducted for the MWL, monitoring triggers are proposed for the air, surface soil, vadose zone, and groundwater at the MWL. These triggers are presented in Table E-6, and are discussed below.

4.2.1 Surface Soil and Air Monitoring Triggers

Proposed surface soil and air monitoring triggers include a trigger for tritium concentrations in soil collected at select locations along the MWL perimeter, and a trigger for radon emissions from the MWL.

4.2.1.1 Tritium

Tritium is the most mobile radionuclide disposed of at the MWL, and the performance-assessment modeling indicates that there is a possibility that tritium emitted from the MWL may exceed the performance objective of 10 mrem/yr dose to the public via the air pathway. For this reason, a trigger is proposed for tritium emitted from the MWL. Figure E-12 shows that the simulated peak tritium dose via air exceeded the performance objective in only 2 percent of the realizations. Figure E-6 reveals that the maximum simulated surface concentration of tritium for the realizations that yielded the peak doses via air are on the order of 10^9 to 10^{10} pCi/L. Therefore, we propose a conservative trigger value of 20,000 pCi/L in surface soils at the MWL perimeter.

The proposed tritium trigger would apply to surface soil samples currently collected annually at select locations along the MWL perimeter by Sandia's Environmental Monitoring group. Soil samples have been collected from these locations and analyzed for tritium on an annual basis since 1985. Soil moisture is extracted from these samples, and tritium concentrations in the soil moisture are determined using liquid scintillation. Any increase in tritium emissions from the MWL would be indicated by elevated tritium concentrations in these soil samples.

Figure E-26 shows a comparison between historical tritium concentrations measured in samples from the four perimeter locations, and the proposed trigger value of 20,000 pCi/L. All exceedances of the trigger value occurred prior to 1998, and exceedances are not anticipated in the future due to radioactive decay and the relatively short (12.3-year) half-life of tritium. If measured concentrations of tritium at the surface exceed 20,000 pCi/L, this would indicate a significant increase relative to present-day values, and the trigger evaluation process (Figure E-25) would be followed. Because the proposed trigger value is 4 to 5 orders of magnitude less than simulated concentrations that yielded exceedances in the dose via air, the proposed trigger value serves as a conservative early-warning indicator for potential exceedances of tritium dose via air.

Table E-6
Proposed Monitoring Triggers for the MWL

Trigger Parameter	Medium	Proposed Trigger Value	Point of Compliance	Performance Objective	Applicable Regulation
Tritium	Soil	20,000 pCi/L tritium in soil moisture at Environmental Monitoring locations along MWL perimeter	MWL Perimeter	Dose to the public via the air pathway shall be less than 10 mrem/yr	DOE Order 5400.5, 10 CFR 61 Subpart H, 40 CFR 141.66
Radon	Air	4 pCi/L (measured by Track-Etch radon detectors)	MWL Perimeter	Average flux of radon-222 gas shall be less than 20 $pCi/m^2/s$ at the landfill surface (design standard)	EPA Action Threshold for radon in air (EPA 2005)
Infiltration	Vadose Zone	25 percent volumetric moisture content in vadose zone beneath the MWL (measured by neutron probe)	Linear depths of 10 ft to 100 ft along neutron probe access holes beneath the MWL	Infiltration through the cover shall be less than the EPA-prescribed technical equivalence criterion of 31.5 mm/yr [10E-7 cm/s]	RCRA 40 CFR Part 264.301
Uranium	Ground water	15 μg/L	Downgradient monitoring well locations	Uranium concentrations in groundwater shall not exceed the EPA MCL of 30 μg/L	EPA Primary Drinking Water Standard
1,1,1-Trichloroethane (1,1,1-TCA)	Ground water	100 μg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
1,1-Dichloroethene	Ground water	3.5 μg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Benzene	Ground water	2.5 μg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Ethyl benzene	Ground water	350 μg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Methylene chloride	Ground water	2.5 μg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

Refer to footnotes at end of table.

Table E-6 (Continued)
Proposed Monitoring Triggers for the MWL

Trigger Parameter	Medium	Proposed Trigger Value	Point of Compliance	Performance Objective	Applicable Regulation
Styrene	Ground water	50 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Tetrachloroethene (PCE)	Ground water	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Toluene	Ground water	500 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Trichloroethene (TCE)	Ground water	2.5 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard
Xylenes (Total)	Ground water	5,000 µg/L	Downgradient monitoring well locations	VOC concentrations in groundwater shall not exceed EPA MCLs	EPA Primary Drinking Water Standard

CFR = Code of Federal Regulations.
cm = Centimeter(s).
DOE = U.S. Department of Energy.
EPA = U.S. Environmental Protection Agency.
ft = Foot (feet).
L = Liter(s).
m = Meter(s).
m^2 = Square meter(s).
µg = Microgram(s).
MCL = Maximum contaminant level.
mm = Millimeter(s).
mrem = Millirem.
MWL = Mixed Waste Landfill.
pCi = Picocurie(s).
RCRA = Resource Conservation and Recovery Act.
s = Second(s).
TCA = Trichloroethane.
VOC = Volatile organic compound.
yr = Year(s).

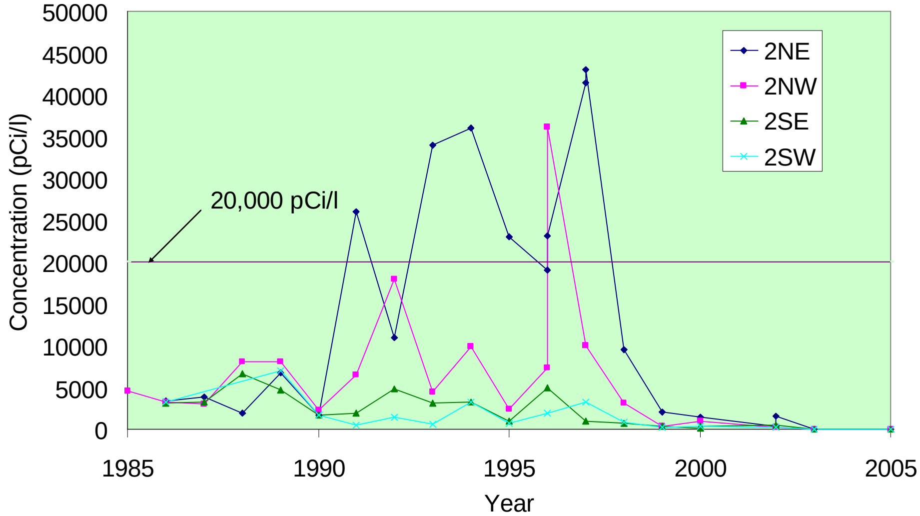


Figure E-26 Comparison Between Historical Tritium Concentrations Measured in Samples from the Four Perimeter Locations, and the Proposed Trigger Value of 20,000 pCi/L

4.2.1.2 Radon

A trigger for radon is also recommended based on the results of the probabilistic performance-assessment modeling. The modeling indicates that there is a possibility that the radon-222 flux from the MWL to the atmosphere will exceed the design standard of 20 pCi/m^2/s at the landfill surface. Commercially-available Track-Etch radon detectors are recommended to measure the radon concentration in air along the MWL perimeter. These detectors provide an integrated average concentration of radon in air over long exposure periods, on the order of 3 to 6 months. The alternative monitoring detectors, charcoal canisters, are useful only for short exposure periods, on the order of a few days.

The proposed trigger for radon in air is 4 pCi/L, and the proposed point of compliance is the MWL perimeter. The 4 pCi/L value is the EPA "action threshold" for radon in household air (EPA 2005). This proposed value is much lower than the simulated radon-gas concentrations (greater than 10,000 pCi/L) at the surface of the MWL that yielded fluxes that exceeded the design standard of 20 pCi/m^2/s. Should the radon trigger of 4 pCi/L be exceeded in air at the MWL point of compliance, then the trigger evaluation process shown in Figure E-25 will be implemented. Additional details regarding long-term monitoring of radon at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.2 Vadose Zone Monitoring Triggers

Vadose zone monitoring is planned for the MWL to provide early evidence of potential threats to groundwater, and to allow corrective action to be initiated before groundwater contamination occurs. The vadose zone beneath the MWL extends nearly 500 ft from ground surface to groundwater, and long-term vadose zone monitoring should ensure that the MWL remedy remains protective of human health and the environment.

The proposed MWL remedy will include a shallow vadose-zone monitoring system deployed directly beneath the landfill. The system consists of three neutron probe access holes drilled to a linear depth of 200 ft at a 30 degree angle directly below the waste disposal cells. The shallow vadose zone monitoring system will function as an "early warning system." Early detection of a potential threat to groundwater will allow corrective action to be initiated before significant contaminant migration occurs.

The shallow vadose-zone monitoring system will be monitored regularly after deployment of the MWL cover. The frequency and duration of long-term monitoring will be established in consultation with the NMED and documented in the MWL Long-Term Monitoring and Maintenance Plan.

4.2.2.1 Moisture Content

Infiltration through the MWL disposal cell cover is an important parameter for determining whether or not MWL performance objectives are met. Infiltration through the MWL cover will be indirectly monitored through long-term monitoring of moisture content in the vadose zone beneath the MWL. A significant increase in moisture content beneath the landfill may indicate that the disposal cell cover may not be performing as originally designed, and that infiltration through the cover is greater than originally predicted.

Moisture contents will be measured using neutron logging, and data will be compared to baseline moisture content data collected prior to deployment of the MWL cover. A significant increase in moisture content within the vadose zone may indicate that corrective action is warranted in order to prevent the downward movement of liquid water through the disposal cell. Moisture content data will be evaluated to ensure that the performance objective of infiltration through the MWL cover is less than the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr), as detailed below.

Infiltration may be estimated indirectly using Darcy's Law. The method is based on soil-physics and the relationship between unsaturated hydraulic conductivity and volumetric moisture content of subsurface soils. The method is described in detail in the MWL Phase 2 RFI SAND Report (Peace et al. 2002). Assumptions required for this method include one-dimensional, steady-state flow, a vertical hydraulic gradient of unity, and the assumption that the downward flux of water beneath the root zone will eventually reach groundwater.

If one applies these assumptions, then the downward flux at a particular depth is equivalent to the unsaturated hydraulic conductivity as a function of the moisture content at that depth. Thus, by monitoring the moisture content of the vadose zone beneath the MWL, one can also indirectly monitor the downward flux through the vadose zone. If infiltration through the cover increases significantly, than the downward flux through the vadose zone would increase as well, resulting in higher moisture content in the vadose zone beneath the landfill. Hence, by monitoring moisture content in the vadose zone, one can indirectly monitor the performance of the MWL cover. A significant increase in moisture content beneath the MWL may indicate that the cover is not performing as designed.

Figure 5-19 in Peace and Goering (2005) shows the calculated soil moisture characteristic and unsaturated hydraulic conductivity curves for 18 subsurface soil samples collected from the Instantaneous Profile Test site, located approximately 500 ft west of the MWL. Based on this figure, and assuming a unit gradient in the vadose zone, if infiltration through the MWL cover exceeds the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr), then volumetric moisture content in the underlying soils will exceed approximately 23 percent.

The recommended trigger level is the moisture content which corresponds to an unsaturated hydraulic conductivity equal to the EPA-prescribed technical equivalence criteria of 10^{-7} cm/s (31.5 mm/yr). The moisture content at which this occurs is 23 percent by volume. However, because the accuracy of the neutron logging tool is plus or minus 2 percent volumetric moisture content, this value will be added to the 23 percent value to ensure that readings at this level are not false positive interpretations. The proposed trigger level for moisture content in the vadose zone is, therefore, 25 percent by volume. This value is based arbitrarily on the EPA-prescribed technical equivalence criteria, and does not necessarily indicate that hazardous constituents or radionuclides are migrating from the landfill.

The 25-percent trigger is proposed for linear depths of 10 ft to 100 ft (vertical depths of 8.7 ft to 86.6 ft) along the neutron probe access holes in the vadose zone beneath the MWL. This interval is proposed as the "regulated interval" because it lies beneath the root zone, and yet is shallow enough that a response would be detected fairly rapidly if there is a significant increase in infiltration through the cover. Should this 25-percent trigger level be exceeded in the regulated interval, then the process shown in Figure E-25 will be implemented. Additional details regarding vadose zone monitoring at the MWL will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.3 Groundwater Monitoring Triggers

Based on the results of the probabilistic performance-assessment modeling, monitoring triggers are proposed for uranium and select VOCs in groundwater at the MWL. These proposed triggers are discussed below.

4.2.3.1 Uranium

Uranium occurs naturally in MWL groundwater at concentrations ranging from 1.34 to 9.23 μg/L, and averaging 5.97 μg/L. Total uranium concentrations in groundwater beneath the MWL are well within the total uranium ranges established by the USGS for the Middle Rio Grande Basin (USGS 2002). Isotopic analyses of uranium have demonstrated that it is of natural origin (Goering et al. 2002).

The probabilistic performance-assessment modeling for the MWL indicates that there is a possibility that uranium will reach the groundwater (although none of the simulations showed the uranium concentrations exceeding the regulatory metric of 30 μg/L). For this reason, a monitoring trigger of 15 μg/L (one-half of the EPA MCL) is proposed for uranium in MWL groundwater at the point of compliance. The proposed point of compliance is at the downgradient monitoring wells. Should the uranium trigger value be exceeded in MWL groundwater at the point of compliance, then the trigger evaluation process shown in Figure E-25 will be implemented. Additional details regarding long-term monitoring of uranium in groundwater will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.2.3.2 VOC Triggers for Groundwater

VOCs are the most mobile of the hazardous constituents detected in soils beneath the MWL. Two passive and three active soil-gas surveys at the MWL have shown the presence of low concentrations of VOCs in soil gas (Phase 2 RFI SAND Report). In addition, low concentrations of VOCs were detected in a 1993 study of VOC and tritium fluxes to the atmosphere from MWL soils (Radian Corp. 1994). Low concentrations of VOCs were also detected in subsurface soil samples collected from boreholes drilled during the MWL Phase 2 RFI.

The potential downward vertical transport of six organic compounds to groundwater by both aqueous-phase transport and vapor-phase transport was evaluated in 1995 (Klavetter 1995). The study showed that PCE could eventually migrate to groundwater through vapor-phase transport. Although the modeling predicted that the most likely PCE concentrations in groundwater would be considerably lower than the detection limit of 0.5 ppb, sensitivity analyses suggested that PCE concentrations could potentially reach 1 to 5 ppb within 50 years (Klavetter 1995a).

The current probabilistic performance-assessment modeling also simulated the migration of PCE to groundwater and arrived at similar conclusions regarding the potential contamination of groundwater by PCE through vapor-phase transport. Because PCE was modeled in this study as a proxy for other VOCs detected in soil gas and in soils beneath the MWL, there is a potential for other VOCs from the MWL to also migrate to groundwater in the future. For this reason, continued groundwater monitoring for VOCs at the MWL is recommended.

Groundwater trigger levels are proposed for all Target Compound List VOCs for which there are primary EPA MCLs, and for which detections occurred in either soil gas samples or in borehole soil samples during the Phase 2 RFI. Table E-7 lists VOCs with primary EPA MCLs, and the media in which they were detected during the Phase 2 RFI. The proposed groundwater trigger levels for VOCs detected during the Phase 2 RFI are equal to one-half of the EPA MCLs. The proposed point of compliance is the downgradient monitoring wells. Should any VOC trigger values be exceeded in MWL groundwater at the point of compliance, then the trigger evaluation process shown in Figure E-25 will be implemented. Additional details regarding long-term monitoring of VOCs in groundwater will be presented in the MWL Long Term Monitoring and Maintenance Plan.

4.3 Summary of Recommended Triggers

Based on the results of the probabilistic performance-assessment modeling conducted for the MWL, monitoring triggers have been proposed for the air, surface soil, vadose zone, and groundwater at the MWL. Specific triggers include numerical values for radon concentrations in the air, tritium concentrations in surface soil, moisture content in the vadose zone, and uranium and select VOC concentrations in groundwater (Table E-6). The proposed triggers are based on EPA and DOE regulatory standards. If a trigger is exceeded, then Sandia Corporation/DOE will initiate a trigger evaluation process which will allow sufficient data to be collected to assess trends and recommend corrective action, if necessary.

Table E-7
List of Target VOCs and Their Detections in Soil Gas and Borehole Soil Samples During the Phase 2 RFI

VOC	EPA MCL (μg/L)	Detected in Passive Soil Gas Samples?	Detected in Active Soil Gas Samples?	Detected in Radian[a] Flux Survey?	Detected in Borehole Soil Samples?	Trigger Proposed for Groundwater?
Trichloroethane (1,1,1-TCA)	200	X	X	X		Yes
1,1,2-Trichloroethane	5.0					No
1,1-Dichloroethene	7.0	X				Yes
1,2-Dichloroethane	5.0					No
1,2-Dichloropropane	5.0					No
Benzene	5.0			X		Yes
Carbon tetrachloride	5.0					No
Chlorobenzene	100					No
Ethyl benzene	700	X				Yes
Methylene chloride	5.0			X	X	Yes
Styrene	100	X				Yes
Tetrachloroethene (PCE)	5.0	X	X	X	X	Yes
Toluene	1,000	X		X	X	Yes
Trichloroethene (TCE)	5.0	X	X	X	X	Yes
Vinyl chloride	2.0					No
Xylenes (Total)	10,000	X			X	Yes
cis-1,2-Dichloroethene	70					No
trans-1,2-Dichloroethene	100					No

[a]October 1993 Survey (Radian Corp. 1993).
EPA = U.S. Environmental Protection Agency.
MCL = Maximum contaminant level.
μg/L = Microgram(s) per liter.
RCRA = Resource Conservation and Recovery Act.
RFI = RCRA Facility Investigation.
VOC = Volatile organic compound.

By utilizing these triggers during long-term monitoring at the MWL, Sandia Corporation/DOE will ensure that the MWL remedy continues to protect human health and the environment, while meeting the performance objectives for the cover and the corrective action objectives established in the MWL Corrective Measures Study (SNL/NM May 2003).

5. Summary and Conclusions

A probabilistic performance assessment has been conducted to evaluate the fate and transport of contaminants of concern at the MWL. The contaminants that were simulated include radionuclides (amercium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239, radium-226, radon-222, strontium-90, thorium-232, tritium, and uranium-238), heavy metals (lead and cadmium), and a VOC (PCE). The current analysis differs from previous analyses in several ways: (1) probabilistic analyses[4] were performed to quantify uncertainties inherent in the system and models; (2) a comprehensive analysis of the performance of the MWL was evaluated and compared against relevant regulatory metrics; (3) sensitivity analyses were performed to identify parameters and processes that were most important to the simulated performance metrics; and (4) long-term monitoring requirements and triggers were recommended based on the results of the quantified uncertainty and sensitivity analyses. The key results of this study are summarized below:

5.1 Infiltration through the Cover:

- Net infiltration through the engineered cover at the MWL was simulated to be less than the regulatory metric of 10^{-7} cm/s for all conditions and scenarios.

- Predicted average infiltration rates through the MWL cover are expected to range from 1.18×10^{-9} cm/s for present conditions to 6.12×10^{-9} cm/s for future conditions. These values were used in a uniform distribution for the performance-assessment simulations.

- To ensure that future infiltration rates will not exceed the regulatory metric of 10^{-7} cm/s, the moisture content of the vadose zone will be monitored. Based on the site-specific two-phase characteristic curves of the soil, a moisture content of 25 percent will be used as a trigger to indicate if the infiltration metric is exceeded.

5.2 Release of Radionuclides to the Atmosphere:

- A small percentage (2 percent) of the simulated dose due to exposure to tritium via the air pathway exceeded the regulatory metric of 10 mrem/yr.

- Parameters impacting tritium diffusion through both the liquid and gas phases (e.g., tortuosity coefficient, moisture content, cover thickness, atmospheric boundary-layer thickness) were found to be important to the simulated inhalation dose.

- Sensitivity studies show that the emanation factor, which depends on the integrity of the radium-226 containment, is important to the performance of the landfill with regard to surface radon fluxes.

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[4] One hundred realizations were used in the probabilistic analyses. A preliminary comparison between the results of 100 versus 200 realizations revealed that the output distribution was adequately represented by 100 realizations.

- For a maximum radon emanation factor of 0.01 (1 percent of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard of 20 pCi/m2/s in about 3 percent of the realizations. For a maximum radon emanation factor of 1 (100 percent of the radium-226 containers fail), the simulated radon surface fluxes exceed the design standard in about 30 percent of the realizations.

- Based on these results, both radon and tritium concentrations are recommended to be monitored at the surface of the MWL in the future. Specific triggers are identified in Table E-6.

5.3 Release of Radionuclides to the Groundwater:

- None of the radionuclides were simulated to reach the groundwater within 1,000 years for all realizations.

- Only uranium-238 (and some of its decay products) were simulated to reach the water table for extended periods (greater than 10,000 years). All peak aquifer concentrations were still less than the EPA regulatory metric of 30 μg/L.

- Infiltration rate was found to be the most significant parameter impacting the variability in the simulated groundwater concentrations and dose via groundwater. Uranium groundwater concentrations were simulated to exceed the regulatory metric of 30 μg/L if the infiltration increased two orders of magnitude above the maximum stochastic value to 6.12×10^{-9} m/s.

- Uranium in the groundwater will be monitored in the future and a trigger value of 15 μg/L, equal to one-half of the EPA MCL in drinking water, will be implemented.

5.4 Release of Heavy Metals to the Groundwater:

- Neither lead nor cadmium were simulated to reach the groundwater in 1,000 years (or extended periods past 10,000 years)

- Additional increases in infiltration (3 to 4 orders of magnitude over expected maximum infiltration rates) allowed cadmium and lead to reach the groundwater in 1,000 years.

- No triggers are recommended for lead or cadmium in groundwater at this time.

5.5 Release of VOCs to the Groundwater:

- Only 1 percent of the realizations yielded peak PCE concentrations in the groundwater that exceeded the regulatory metric of 5 μg/L. The majority of the realizations showed that the peak PCE groundwater concentration occurred within 100 years.

- Uncertainty in the PCE adsorption coefficient, half-life (degradation), inventory concentration, source thickness, and cover thickness were found to be significantly correlated to the simulated groundwater concentrations.

- Based on these results, PCE and other VOCs are recommended to be monitored in the groundwater at the MWL in the future (Table E-6). Trigger values will be based on values equal to one-half of the EPA MCLs in drinking water.

Key Assumptions:

- Receptor located adjacent to MWL
    - Tritium dose caused by continuous inhalation and exposure of tritium flux directly above MWL.
    - Groundwater dose calculated based on concentrations in aquifer directly beneath MWL. Water intake assumed to be 10 L/day (five times EPA standard of 2 L/day for drinking water).
- Maximum waste inventory set equal to twice estimated values based on historical records.
- Sealed sources of radium-226 allowed to degrade in 1,000 years (emanation factor for radon-222 allowed to increase).
- Cover allowed to completely erode in 1,000 years.
- 1-D model: yields maximum transport to surface and groundwater.
- Bounding tortuosity coefficients: yields maximum diffusion rates.

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ATTACHMENT E1
Derivation of a Steady-State Gas and Liquid-Phase Radon Transport Model

ATTACHMENT E1
DERIVATION OF A STEADY-STATE GAS AND LIQUID-PHASE RADON TRANSPORT MODEL

A steady-state radon transport model is derived here to account for advection in the liquid phase, diffusion in both the liquid and gas phases, and decay of radon-222. Because radium-226, which is the source of radon-222, has a half-life of 1,600 years, we assume steady-state conditions (e.g., the source of radon-222 is constant and the resulting long-term radon-222 concentration profile does not change with time). Assuming steady-state conditions is conservative because the radon-222 concentration profile is assumed to develop instantaneously.

We define three regions in the model: (1) a clean overburden (or cover) free of radium-226 that extends to a depth, L_1, beneath the surface; (2) a contaminated source zone of radium-226 that extends to a depth, L_2, from the surface; and (3) a vadose zone free of radium-226 that extends a distance, L_3, to the water table (Figure E-3). The radon-222 generated by the radium-226 is free to diffuse and advect upward to the atmosphere and downward toward the water table. Downward liquid advection also carries aqueous-phase radon toward the water table. Partitioning of radon between the gas and liquid phases is assumed to occur instantaneously and can be described by a liquid/gas partitioning coefficient, k (this is the inverse of Henry's constant, K_H). The steady-state governing equations for the transport of radon-222 in these two regions is as follows:

$$D_{eff}^{(1)} \frac{d^2 C_g^{(1)}}{dx^2} - kq \frac{dC_g^{(1)}}{dx} - \lambda C_g^{(1)} \left(\theta_g^{(1)} + k\theta_w^{(1)} \right) = 0 \qquad (1)$$

$$D_{eff}^{(2)} \frac{d^2 C_g^{(2)}}{dx^2} - kq \frac{dC_g^{(2)}}{dx} - \lambda C_g^{(2)} \left(\theta_g^{(2)} + k\theta_w^{(2)} \right) + \dot{Q} = 0 \qquad (2)$$

$$D_{eff}^{(3)} \frac{d^2 C_g^{(3)}}{dx^2} - kq \frac{dC_g^{(3)}}{dx} - \lambda C_g^{(3)} \left(\theta_g^{(3)} + k\theta_w^{(3)} \right) = 0 \qquad (3)$$

where

$$D_{eff} = \frac{0.07}{10^4} e^{\left[-4\left(S_l - S_l \phi^2 + S_l^5 \right) \right]} \qquad (4)$$

$$\dot{Q} = \frac{E\ Ci_{226}}{SA_{226} 1000} \frac{\lambda_{226}}{V} \qquad (5)$$

where the superscripts (1), (2), and (3) denote the three regions shown in Figure E1-1, C_g is the radon gas-phase concentration [kg/m^3], x is the distance from the surface [m] (positive downward), D_{eff} is the effective diffusion coefficient [m^2/s] for combined gas and aqueous phases (Rogers et al., 1984), S_l is the liquid saturation [-], k is the water/gas partitioning coefficient (i.e., water concentration/gas concentration) [-], q is the Darcy infiltration rate [m/s], λ is the decay coefficient for radon-222 and is calculated as ln(2)/half-life [1/s], θ_g and θ_w are the gas and moisture volumetric contents, respectively, $\dot{Q}$ is the volumetric generation rate of radon-222

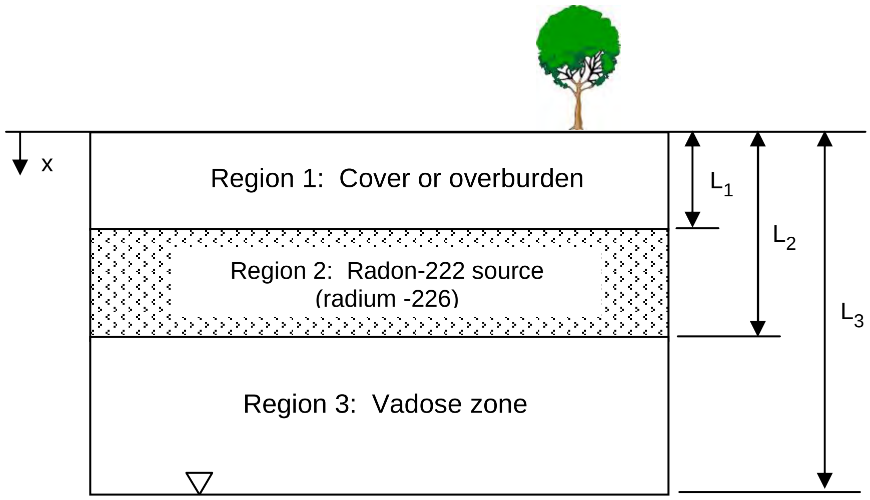


Figure E1-1 Conceptual Model of Three-Region Radon-Transport Model

[kg/m^3/s], E is the emanation factor for radon-222 that accounts for containment of the radium-226 (0 = complete containment; 1 = no containment), Ci_{226} is the concentration of radium-226 in curies, SA_{226} is the specific activity of radium-226 [curies/gram], λ_{226} is the decay coefficient for radium-226 [1/s], and V is the total volume of the contaminated waste zone (region 2). In this derivation, we assume local equilibrium between the gas and aqueous phases; therefore, the equation can be expressed entirely in terms of the gas concentration, C_g, and the partitioning coefficient, k, is used to convert between the gas concentration and aqueous concentration.

The boundary conditions for this system are as follows: (1) the radon concentration at the surface in region 1 is zero (this is conservative because it creates the largest gradient for radon flux to the atmosphere); (2) the radon concentration in region 1 is equal to the radon concentration in region 2 at the interface of regions 1 and 2; (3) the radon flux in region 1 reaching the interface between regions 1 and 2 must be equal to the radon flux entering region 2; (4) the radon concentration in region 2 is equal to the radon concentration in region 3 at the interface of regions 2 and 3; (5) the radon flux in region 2 reaching the interface between regions 2 and 3 must be equal to the radon flux entering region 3; and (6) the radon concentration infinitely far away from the source (as $x \rightarrow \infty$) goes to zero. These boundary conditions can be expressed as follows:

$$C_g^{(1)}(x=0)=0 \tag{6}$$

$$\begin{aligned} C_g^{(1)}(x=L_s) &= C_g^{(2)}(x=L_s) \\ C_w^{(1)}(x=L_s) &= C_w^{(2)}(x=L_s) \end{aligned} \tag{7}$$

$$D_{eff}^{(1)} \left. \frac{dC_g^{(1)}}{dx} \right|_{x=L_s} = D_{eff}^{(2)} \left. \frac{dC_g^{(2)}}{dx} \right|_{x=L_s} \tag{8}$$

$$C_g^{(2)}(x = L_s) = C_g^{(3)}(x = L_s)$$
$$C_w^{(2)}(x = L_s) = C_w^{(3)}(x = L_s) \tag{9}$$

$$D_{eff}^{(2)} \left. \frac{dC_g^{(2)}}{dx} \right|_{x=L_s} = D_{eff}^{(3)} \left. \frac{dC_g^{(3)}}{dx} \right|_{x=L_s} \tag{10}$$

$$C_g^{(3)}(x \to \infty) = 0 \tag{11}$$

If we assume that the soil properties and hydrologic conditions are the same in all three regions, the solutions to the ordinary differential equations (1) through (3) for the three regions can be expressed as follows:

$$C_g^{(1)} = c_1 e^{r_1 x} + c_2 e^{r_2 x} \tag{12}$$

$$C_g^{(2)} = c_3 e^{r_1 x} + c_4 e^{r_2 x} + Q_{source} \tag{13}$$

$$C_g^{(3)} = c_5 e^{r_1 x} + c_6 e^{r_2 x} \tag{14}$$

where

$$c_1 = -c_2 \tag{15}$$

$$c_2 = \frac{c_3 e^{r_1 L_1}\left(r_1 - r_2\right) - r_2 Q_{source}}{e^{r_1 L_1}\left(r_2 - r_1\right)} \tag{16}$$

$$c_3 = \frac{r_2 Q_{source}}{e^{r_1 L_2}\left(r_1 - r_2\right)} \tag{17}$$

$$c_4 = \frac{c_2\left(e^{r_2 L_1} - e^{r_1 L_1}\right) - c_3 e^{r_1 L_1} - Q_{source}}{e^{r_2 L_1}} \tag{18}$$

$$c_5 = 0 \tag{19}$$

$$c_6 = \frac{c_3 e^{r_1 L_2} + c_4 e^{r_2 L_2} Q_{source}}{e^{r_2 L_2}} \tag{20}$$

$$r_1 = \frac{kq + \sqrt{(kq)^2 + 4D_{eff}\lambda_{eff}}}{2D_{eff}} \tag{21}$$

$$r_2 = \frac{kq - \sqrt{(kq)^2 + 4D_{eff}\lambda_{eff}}}{2D_{eff}} \tag{22}$$

$$\lambda_{eff} = \lambda\left(\theta_g + k\theta_w\right) \tag{23}$$

$$Q_{source} = \frac{\dot{Q}}{\lambda_{eff}} \tag{24}$$

Equations (12) through (24) yield the solutions for the gas concentrations in the three regions defined in Figure E1-1. The aqueous concentration can be obtained by multiplying the gas concentration at any location by the liquid/gas partition coefficient, *k*. The groundwater concentration at the interface of the vadose zone and the water table, $C_w^{(3)}(L_3)$, can be expressed as follows:

$$C_w^{(3)}(L_3) = k\,C_g^{(3)}(L_3) \tag{25}$$

The upward flux of radon-222 gas at the surface, q_s [kg/m^2/s] can be determined by evaluating the gas-phase concentration gradient at the surface (region 1) using Fick's Law:

$$q_s = -\left(-D_{eff} \left. \frac{dC_g^{(1)}}{dx} \right|_{x=0} \right) = D_{eff}\,c_2(r_2 - r_1) \tag{26}$$

The negative sign preceding the term in parentheses is to account for the positive downward direction of *x*. Equation (26) is used to estimate the radon gas flux at the surface in the performance assessment, and Equation (25) is used to determine the radon groundwater concentration. The concentration and flux of radon can be converted to pCi/L and pCi/m^2/s using the specific activity of radon (Table E-2) and appropriate unit conversions.

PLATES

CONSTRUCTION PLANS FOR

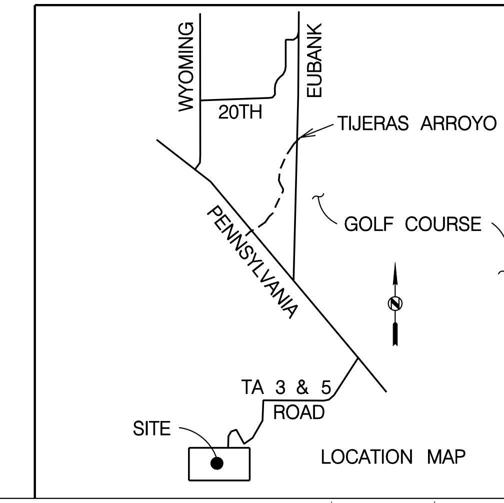
MIXED WASTE LANDFILL CLOSURE COVER
SANDIA NATIONAL LABORATORIES

ALBUQUERQUE, NEW MEXICO

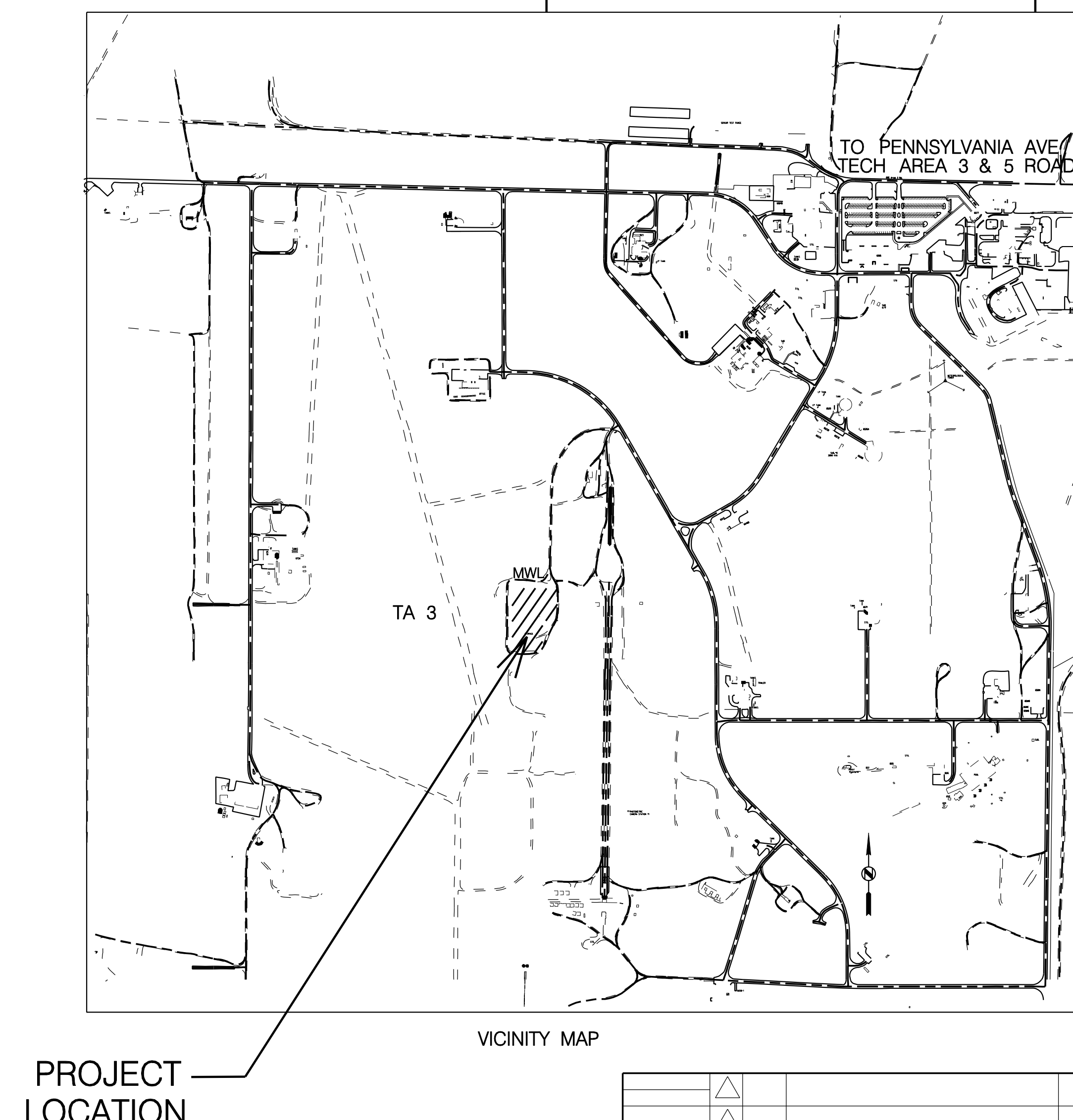
JULY 29, 2005

INDEX TO DRAWINGS

PLATE	REVISION	TITLE	DRAWING NUMBER
1		TITLE SHEET/INDEX TO DRAWINGS/PROJECT LOCATION MAP	999997/A6.88
2		EXISTING SITE PLAN	999997/A6.89
3		SUBGRADE GRADING PLAN	999997/A6.90
4		FINAL COVER GRADING PLAN	999997/A6.91
5		FINAL COVER CROSS SECTIONS	999997/A6.92
6		MISCELLANEOUS DETAILS	999997/A6.93



LOCATION MAP



VICINITY MAP

	REV	DATE	DESCRIPTION	DWN	CKD	APP
	B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.
P.O. OR W.O. PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP

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SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

TITLE SHT./INDEX TO DWGS./PROJ. LOCATION MAP

MIXED WASTE LANDFILL
PROJECT LOCATION MAP

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./xx
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901

FILE NAME: 999997A6.88

Bohannan Huston
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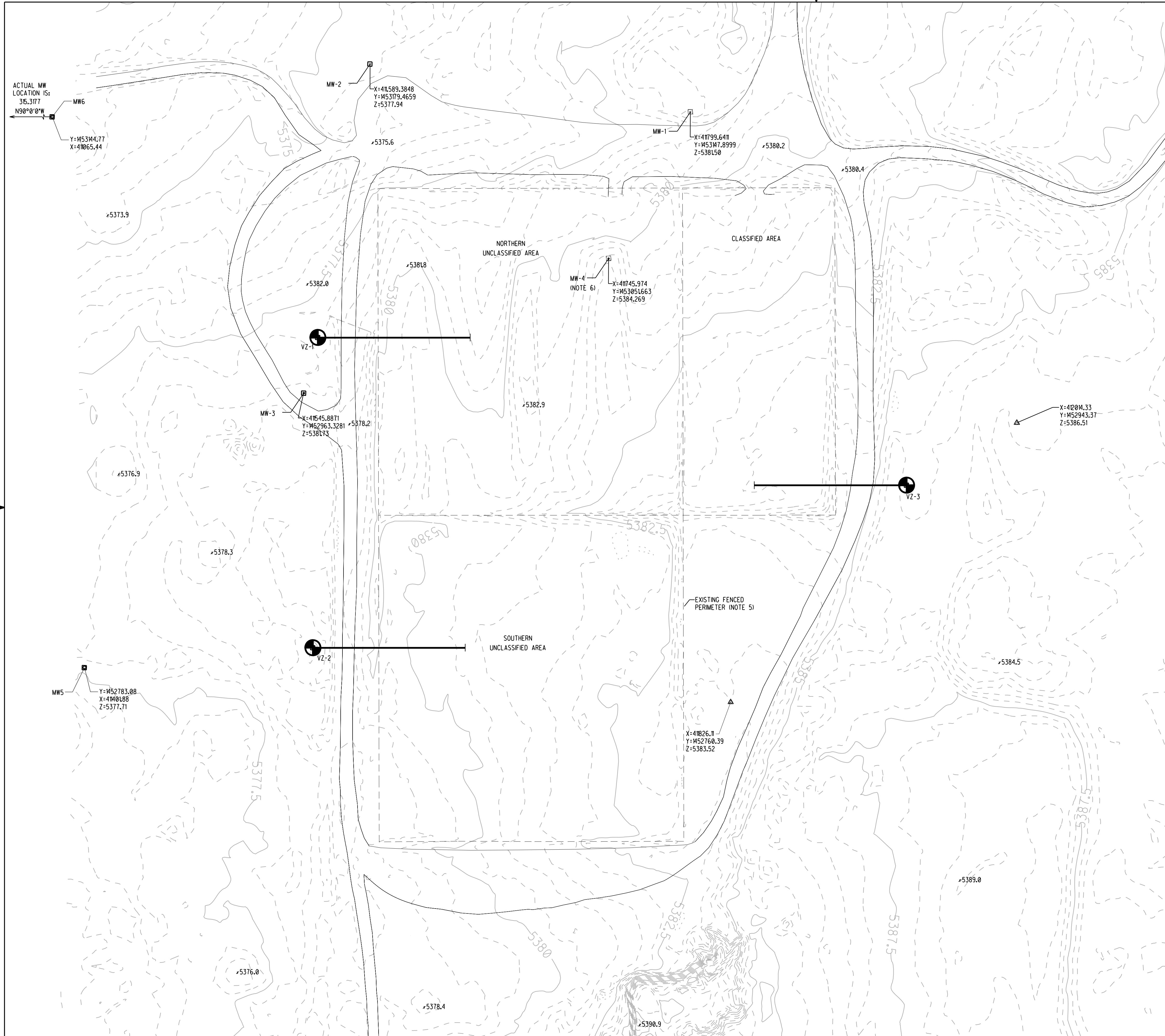
SIZE D+ | DRAWING NO./SHEET 999997/A6.88 | PLATE 1

REFERENCE FILES:



GENERAL NOTES

1. THE VECTOR IMAGES ON THIS COMPUTER PLOTTED MAP WERE GENERATED FROM DATA COMPILED BY DIGITAL STEREOPHOTOGRAMMETRIC METHODS USING 1:2000 NOMINAL SCALE VERTICAL AERIAL PHOTOGRAPHY EXPOSED ON MARCH 22, 1999 AT A FLIGHT HEIGHT OF APPROXIMATELY 1,000 FEET ABOVE MEAN TERRAIN. THE FILM WAS EXPOSED IN A ZEISS RMKA 15/23 AERIAL CAMERA, SERIAL NUMBER 127792, CALIBRATED FOCAL LENGTH 153.509 mm.

2. THE TOPOGRAPHIC IMAGES ON THIS MAP WERE GENERATED FROM DIGITAL TERRAIN MODEL (DTM) DATA ACQUIRED FROM THE AERIAL PHOTOGRAPHY. THE DATA DEPICTED ON THIS MAP IS INTENDED FOR USE AT A SCALE OF 1:360 (1"=30') AND A CONTOUR INTERVAL OF 0.5 FEET FOR THE PURPOSE OF PLANNING AND SITE DESIGN. BOHANNAN HUSTON, INC. ASSUMES NO RESPONSIBILITY FOR THE QUALITY, ACCURACY OR COMPLETENESS OF THE DATA WHEN USED FOR OTHER THAN THE INTENDED PURPOSE OR WHEN USED AT OTHER THAN THE COMPILED SCALE.

3. THIS MAP WAS COMPILED TO MEET AMERICAN SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING (ASPRS) CLASS 1 ACCURACY STANDARDS FOR A SCALE OF 1:30 AND A CONTOUR INTERVAL OF 1.0 FOOT. THE ROOT MEAN SQUARE ERROR (RMSE) OF COORDINATES OF WELL-DEFINED FEATURES SHOULD BE EXPECTED TO BE LESS THAN 0.3 FEET. THE RMSE OF ELEVATIONS OF BREAK LINES AND MASS POINTS COMPRISING THE DTM SHOULD BE EXPECTED TO BE LESS THAN 0.33 FEET UNLESS OBSCURED BY CULTURAL FEATURES, VEGETATION OR SHADOWS.

4. COORDINATE SYSTEM IS BASED ON THE NEW MEXICO STATE PLANE COORDINATE SYSTEM, CENTRAL ZONE, NAD27. THE VERTICAL DATUM IS BASED ON NGVD29
GRID TO GROUND= 1.000348922
BASED ON CONTROL POINT LIM NO. 34
DELTA ALPHA -00 10' 07".

5. THE CONTRACTOR SHALL PREPARE EXISTING LANDFILL SURFACE BY CLEARING, GRUBBING AND COMPACTION. EXISTING PERIMETER FENCES SHALL BE REMOVED BY SANDIA NATIONAL LABORATORIES PRIOR TO BEGINNNING CONSTRUCTION. CONTRACTOR SHALL INSTALL NEW ADMINISTRATIVE CONTROL FENCE AND GATE. SEE DETAIL D, PLATE 6.

6. MONITORING WELL MW-4 SHALL BE PRESERVED AND EXTENDED SUCH THAT THE TOP OF THE WELL CASING IS LOCATED A MINIMUM OF 30 INCHES ABOVE THE FINAL GRADE OF THE COVER. THE WELL CASING SHALL BE FIT WITH A STEEL PROTECTIVE COVER AND LOCKING TOP CAP.

   THE PROTECTIVE COVER SHALL BE CONSTRUCTED OF STEEL PIPE MEETING ASTM STANDARD A 120-78 OR API STANDARD 5L, AND SHALL EXTEND A MINIMUM OF 12 INCHES BELOW FINAL GRADE AND A MINIMUM OF 30 INCHES ABOVE THE FINAL GRADE OF THE COVER. THE OUTER CASING AND TOP CAP SHALL BE PAINTED WITH A RUST PREVENTIVE PRIMER COAT AND A FINAL COAT OF RUST PREVENTIVE PAINT (SAFETY YELLOW), AS MANUFACTURED BY RUSTOLEUM, OR APPROVED EQUIVALENT.

   A CONCRETE PAD SHALL BE PROVIDED AT THE GROUND SURFACE AROUND THE OUTER WELL CASING. THE CONCRETE PAD SHALL MEASURE THREE FEET BY THREE FEET, AND BE A MINIMUM OF SIX INCHES THICK. REFER TO DETAIL E, PLATE 6. SOIL BENEATH THE CONTRETE PAD SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

   MONITORING WELL MW-4 EXTENSION SHALL BE CONSTRUCTED OF SCHEDULE 80 PVC WITH AN ID OF 4.768" AND AN OD OF 5.563".

7. CONTRACTOR SHALL BE SUPPLIED SUBGRADE AND FINAL GRADING PLANS IN HARDCOPY AND MICROSTATION FORMAT.

8. EXISTING LANDFILL ROADS SHALL BE ABANDONED. CONTRACTOR SHALL CONSTRUCT A NEW PERIMETER ROAD OUTSIDE OF ADMINISTRATIVE FENCE BOUNDARY BY BLADING A 10' WIDE EARTHEN ROAD FOLLOWING EXISTING GROUND.

9. WATER TO BE USED DURING CONSTRUCTION IS WITHIN 0.5 MILES OF PROJECT AREA. LOCATION WILL BE PROVIDED BY SANDIA NATIONAL LABORATORIES.

LEGEND

- EXISTING FENCE
- 5384.5 — EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- EXISTING GRADED ROAD
- EXISTING GROUNDWATER MONITORING WELLS
- PROJECT BENCHMARKS
- EXISTING SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES

30' 15' 0 30'
SCALE 1"=30'
CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

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ALBUQUERQUE, NEW MEXICO

EXISTING SITE

MIXED WASTE LANDFILL EXISTING SITE PLAN

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./XX
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.89

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SIZE: D+ | DRAWING NO./SHEET: 999997/A6.89 | PLATE: 2

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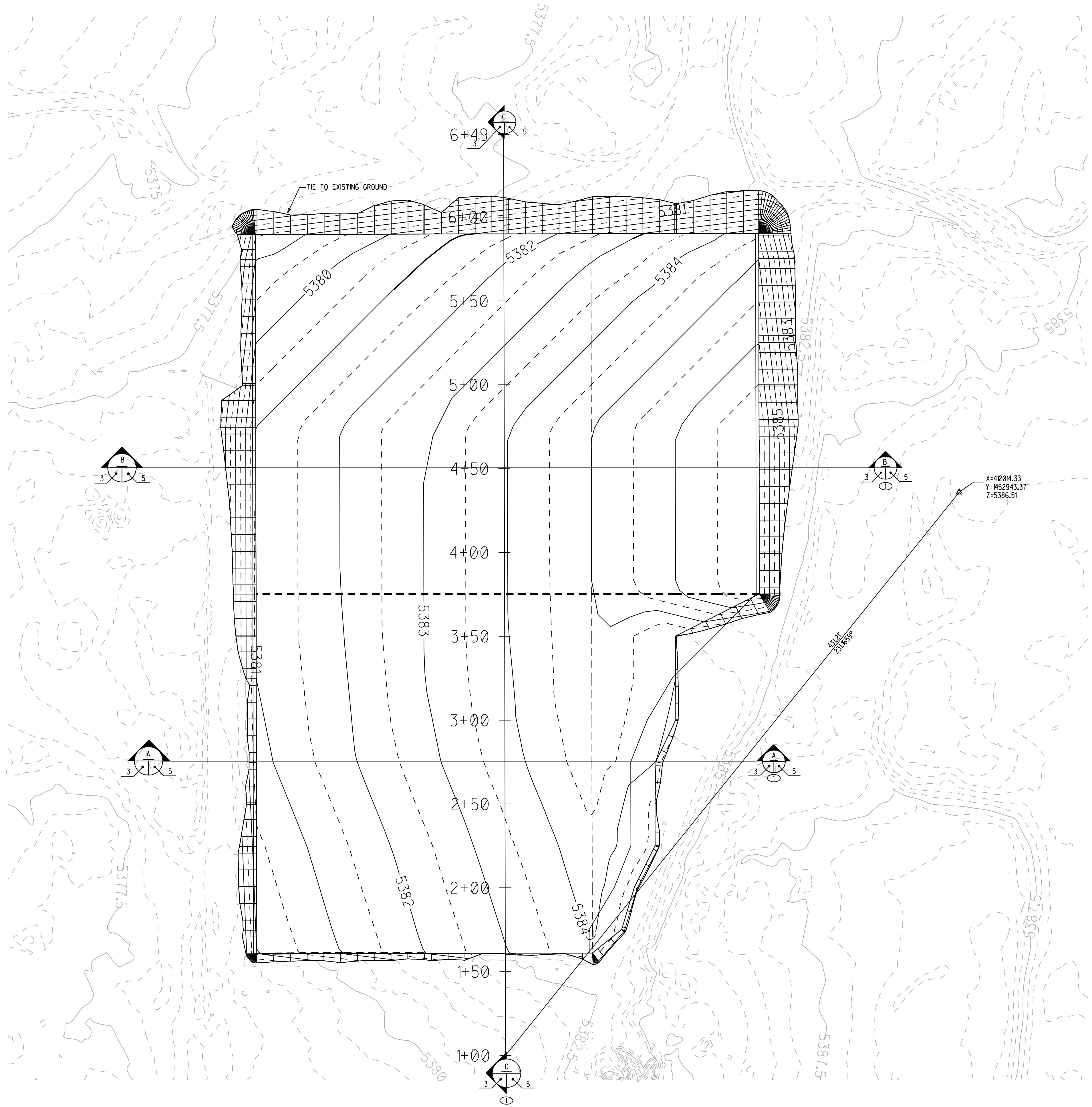

GENERAL NOTES

1. THE SUBGRADE GRADING PLAN SHOWS THE CONTOURS FOR THE TOP OF THE SUBGRADE.
2. BORROW SITE FOR SUBGRADE FILL IS APPROXIMATELY 1.5 MILES SOUTH OF PROJECT AREA.
3. THE CONTRACTOR SHALL CLEAR GRUB PREPARE, AND COMPACT THE EXISTING LANDFILL SURFACE PRIOR TO PLACEMENT OF THE BIOINTRUSION BARRIER LAYER. THE CONTRACTOR SHALL MOISTEN THE SOIL TO APPROXIMATE OPTIMUM MOISTURE (+ OR - 2%) AND COMPACT/PROOF ROLL THE SURFACE UTILIZING 10 PASSES OF A ROLLER. DEPRESSIONS THAT ARE FORMED WITH THE PROOF-ROLLING SHALL BE FILLED WITH MOISTENED, CLEAN FILL, AND THE FILLED AREA RECOMPACTED WITH 10 PASSES OF THE ROLLER. THE ROLLER SHALL HAVE A MINIMUM TOTAL BALLASTED WEIGHT OF 25 TONS AND A MINIMUM PNEUMATIC TIRE PRESSURE OF 90 PSI. NO PROOF ROLLING SHALL BE ALLOWED WITHIN A 2' RADIUS OF ANY WELL, MEASURING DEVICE, OR OTHER PLACED SURFACE AS DESIGNATED BY THE OPERATOR AND/OR CQA ENGINEER.
4. SUBGRADE FILL SHALL BE OBTAINED FROM TA-3 BORROW PITS. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). SUBGRADE SHALL BE PLACED TO ACHIEVE A CENTRAL CROWN AND A UNIFORM 2 PERCENT GRADE. APPROXIMATELY 6500 CY OF FILL SHALL BE REQUIRED FOR SUBGRADE.
5. ASSUMED SHRINKAGE FACTOR FOR FILL IS 25 PERCENT.
6. CONTRACTOR SHALL SURVEY ELEVATIONS OF SUBGRADE TO MEET CONSTRUCTION SPECIFICATIONS.

KEYED NOTES

(1) SECTIONS A-A, B-B, AND C-C ON PLATE 5 SHOW SUBGRADE AND FINAL GRADING SECTIONS.

ESTIMATED BORROW QUANTITIES	
CUT	0.60 CY
FILL	6,500 CY

LEGEND

- 5388 — EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- 5390 — SUBGRADE INDEX CONTOUR
- SUBGRADE INTERMEDIATE CONTOUR
- PROJECT BENCHMARKS

30' 15' 0 30'

SCALE 1"=30'

CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	H.C.S.	H.C.S.

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ALBUQUERQUE, NEW MEXICO

SUBGRADE

MIXED WASTE LANDFILL SUBGRADE GRADING PLAN

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./XX
DATE	07.29.05

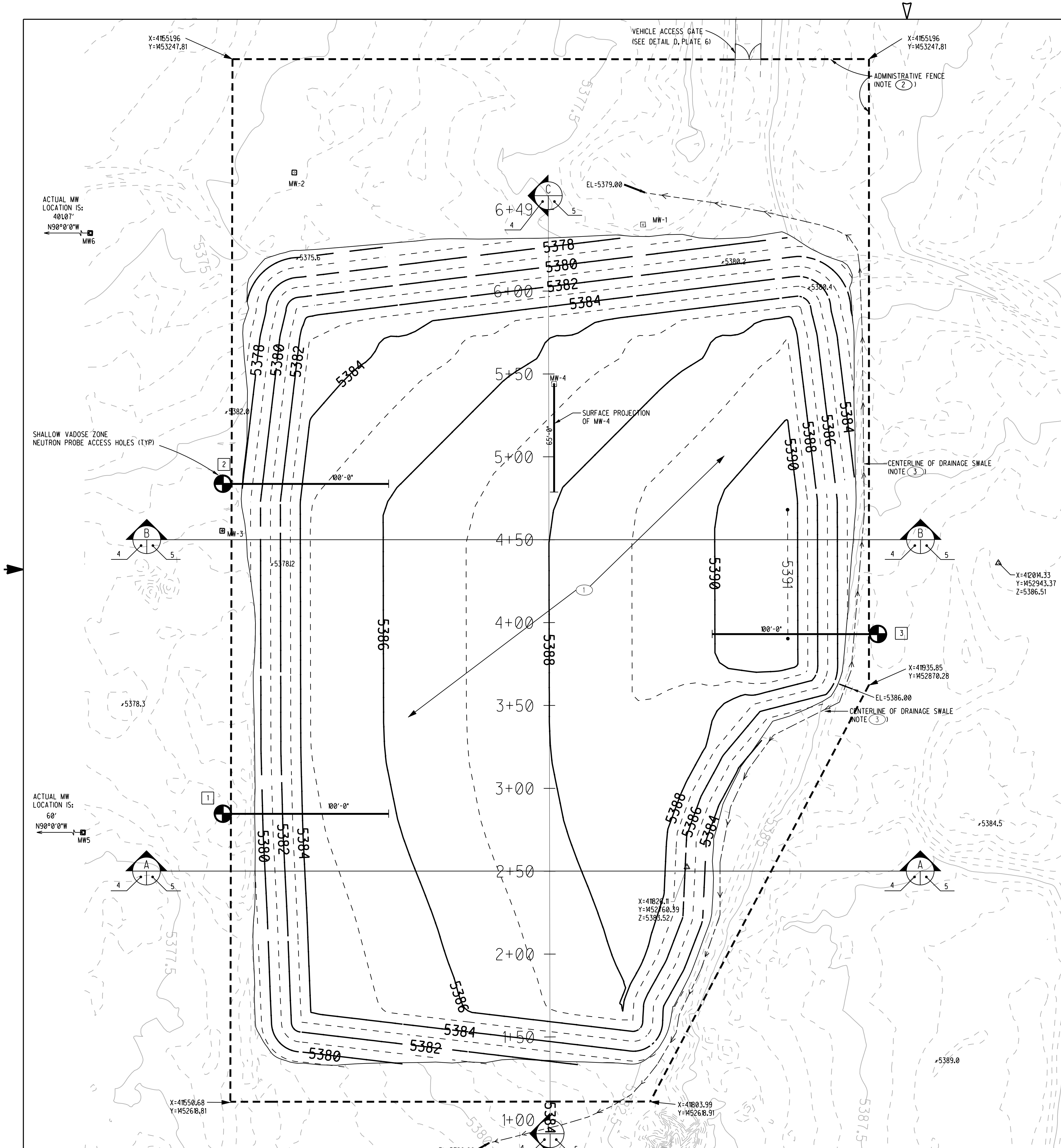
CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.90

ENGINEERS PLANNERS PHOTOGRAMMETRISTS SURVEYORS SOFTWARE DEVELOPERS

SIZE D+ DRAWING NO./SHEET 999997/A6.90 PLATE 3

REFERENCE FILES:



GENERAL NOTES

1. BORROW SITE FOR NATIVE SOIL LAYER FILL AND TOPSOIL LAYER IS APPROXIMATELY 1.5 MILES SOUTH OF THE PROJECT AREA.
2. NATIVE SOIL LAYER FILL SHALL BE OBTAINED FROM TA-3 BORROW PITS. APPROXIMATELY 13,200 CUBIC YARDS OF FILL SHALL BE REQUIRED FOR THE NATIVE SOIL LAYER. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). ANY GRADE STAKES USED ON THE PROJECT SHALL BE REMOVED AND BACKFILLED WITH COVER MATERIAL TO MEET CONSTRUCTION SPECIFICATIONS.
3. THE TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL LAYER SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). TOPSOIL SHALL BE ADMIXED 25 PERCENT BY VOLUME WITH 3/8-INCH CRUSHED GRAVEL (ASTM D448, SIZE #8). APPROXIMATELY 3,900 CY WILL BE REQUIRED FOR THE TOPSOIL LAYER.
4. BIOINTRUSION LAYER MATERIALS: THE BIOINTRUSION BARRIER MATERIAL SHALL BE CONSTRUCTED USING A GRADED ROCK RIPRAP. RIPRAP SIZE SHALL BE OF STONE SIZE SO THAT 50 PERCENT OF THE PIECES, BY WEIGHT, SHALL BE LARGER THAN THE D50 SIZE(4"). THE WELL GRADED MATERIAL SHALL BE A MIXTURE COMPOSED PRIMARILY OF LARGER STONE SIZES BUT WITH A SUFFICIENT MIXTURE OF OTHER SIZES TO FILL THE SMALLER VOIDS BETWEEN THE STONES. THE DIAMETER OF THE LARGEST STONE SIZE IN SUCH A MIXTURE SHALL BE 6" (1.5 TIMES) THE D50 SIZE OF 4". THE THICKNESS OF THE BIOINTRUSION BARRIER MATERIAL LAYER SHALL BE A MINIMUM OF 1' AND A MAXIMUM OF 1.25'.

   THE BIOINTRUSION LAYER SHALL BE OBTAINED FROM A LOCAL SUPPLIER AND STOCKPILED SOUTH OF THE SITE BY THE OPERATOR FOR THE CONTRACTOR'S USE.

SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES					
HOLE	SURFACE LOCATION X	SURFACE LOCATION Y	MEASURED DEPTH (FT)	ANGLE	AZIMUTH
1	411546.155	1452792.603	200	30°	90°
2	411546.155	1452991.693	200	30°	90°
3	411941.355	1452901.054	200	30°	270°

KEYED NOTES

(1) THE FINAL COVER CONTOURS INDICATE TOP OF THE FINAL COVER.

(2) CONTRACTOR SHALL INSTALL AN ADMINISTRATIVE FENCE AROUND PERIMETER OF CONSTRUCTED LANDFILL COVER. ADMINISTRATIVE FENCE SHALL BE CONSTRUCTED ACCORDING TO DETAIL D, PLATE 6.

(3) CONTRACTOR SHALL CONSTRUCT A DRAINAGE SWALE IN ACCORDANCE WITH DETAIL C, PLATE 6. DRAINAGE SWALE SHALL BE CONSTRUCTED TO ENSURE POSITIVE DRAINAGE USING ELEVATIONS SHOWN ON THIS PLAN AS A GENERAL GUIDE.

SEEDING PLAN

1. SEEDING SHALL COMPLY WITH CONSTRUCTION SPECIFICATION 02930, RECLAMATION SEEDING AND MULCHING.
2. THE FOLLOWING SEED MIX SHALL BE USED FOR SEEDING OF THE FINAL GRADE, BORROW LOCATION, LAYDOWN AREAS, AND OTHER LOCATIONS IMPACTED BY CONSTRUCTION ACTIVITIES:

SEED SPECIES	SEEDING RATE PURE LIVE SEED (POUNDS PER ACRE)
BLACK GRAMA	6.0
GALLETA GRASS	8.0
RING MUHLY	3.0
SPIKE DROPSEED	3.0

ESTIMATED BORROW QUANTITES	
TOPSOIL LAYER	3900 CY
BIOINTRUSION LAYER	4900 CY
NATIVE SOIL LAYER	13,200 CY

LEGEND

- 5384.5 — EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- FINAL ADMINISTRATIVE FENCE
- 5384.5 — FINAL COVER INDEX CONTOUR
- FINAL COVER INTERMEDIATE CONTOUR
- MW-4 — GROUNDWATER MONITORING WELL
- DRAINAGE SWALE CENTERLINE
- 1 — SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES
- PROJECT BENCHMARKS

30' 15' 0 30'

SCALE 1"=30'

CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
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ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

FINAL COVER

MIXED WASTE LANDFILL FINAL COVER GRADING PLAN

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./xx
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.91

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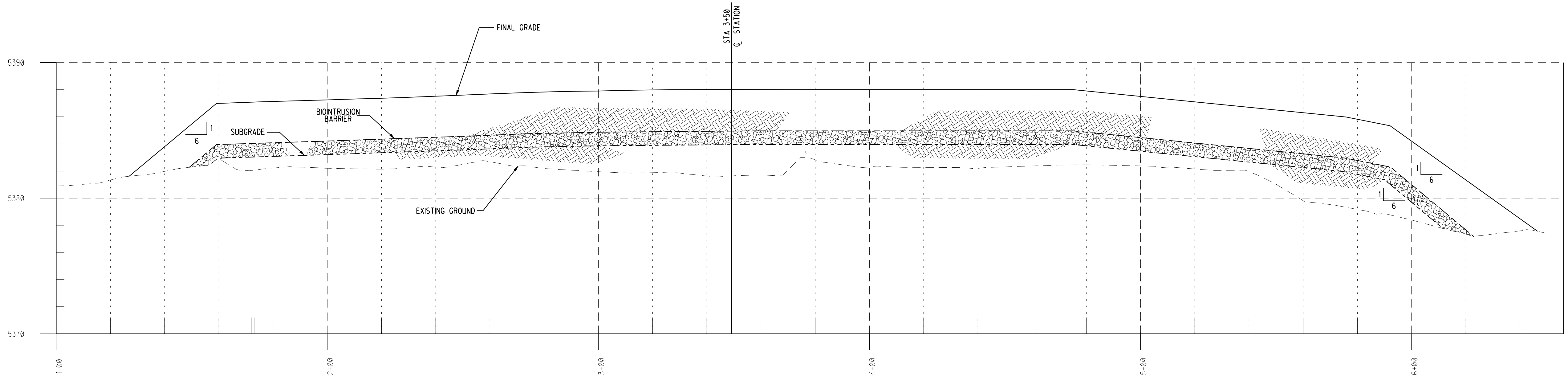
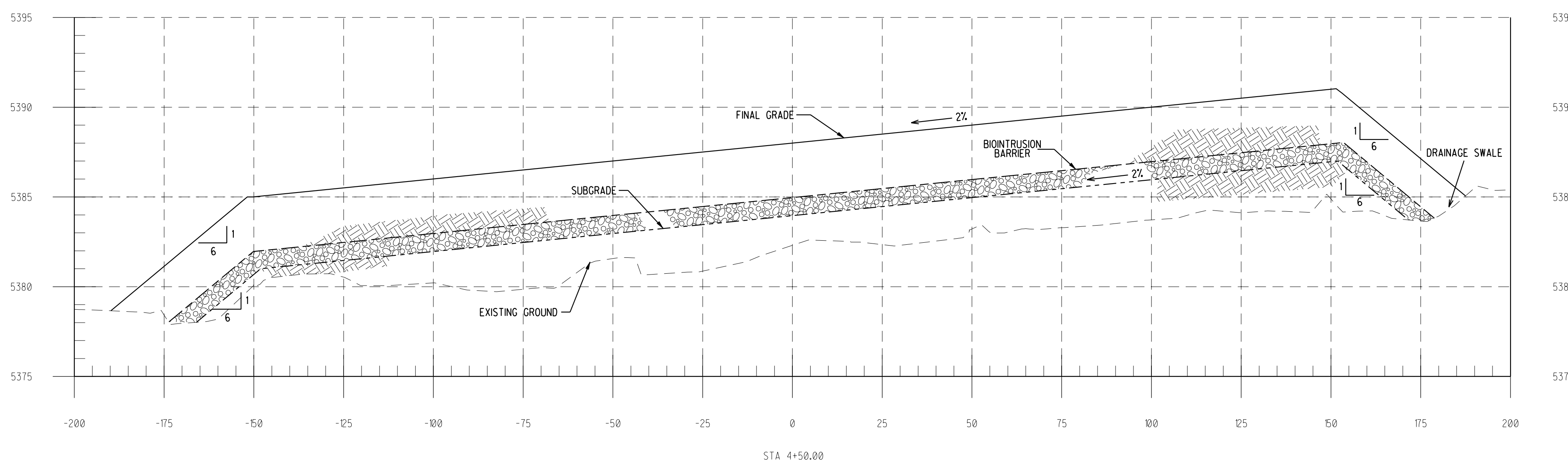
SIZE D+ DRAWING NO./SHEET 999997/A6.91 PLATE 4

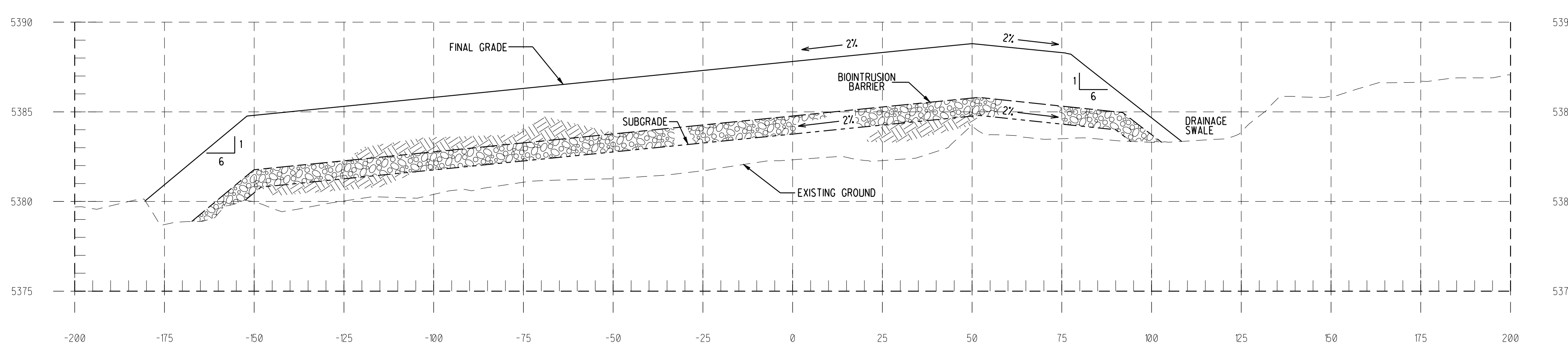
REFERENCE FILES:



SECTION C-C



SECTION B-B



SECTION A-A

LEGEND

- FINAL GRADE
- BIOINTRUSION BARRIER
- SUBGRADE
- EXISTING GROUND

20′ 10′ 0 20′
HORIZ. SCALE 1"=20′
VERT. SCALE 1"=4′

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

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CROSS SECTIONS

MIXED WASTE LANDFILL FINAL COVER CROSS SECTIONS

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./xx
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823
FILE NAME: 999997A6.92
REFERENCE FILES:

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SIZE D+ DRAWING NO./SHEET 999997/A6.92 PLATE 5

KEYED NOTES

(1) CONCRETE SHALL HAVE A MINIMUM F'c OF 3000 P.S.I.

(2) SOIL DIRECTLY BELOW CONCRETE PADS SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

(3) THE CONTRACTOR SHALL CLEAR GRUB PREPARE, AND COMPACT THE EXISTING LANDFILL SURFACE PRIOR TO PLACEMENT OF THE BIOINTRUSION BARRIER LAYER. THE CONTRACTOR SHALL MOISTEN THE SOIL TO APPROXIMATE OPTIMUM MOISTURE (+ OR - 2%) AND COMPACT/PROOF ROLL THE SURFACE UTILIZING 10 PASSES OF A ROLLER. DEPRESSIONS THAT ARE FORMED WITH THE PROOF-ROLLING SHALL BE FILLED WITH MOISTENED, CLEAN FILL, AND THE FILLED AREA RECOMPACTED WITH 10 PASSES OF THE ROLLER. THE ROLLER SHALL HAVE A MINIMUM TOTAL BALLASTED WEIGHT OF 25 TONS AND A MINIMUM PNEUMATIC TIRE PRESSURE OF 90 PSI. NO PROOF ROLLING SHALL BE ALLOWED WITHIN A 2' RADIUS OF ANY WELL, MEASURING DEVICE, OR OTHER PLACED SURFACE AS DESIGNATED BY THE OPERATOR AND/OR CQA ENGINEER.

SUBGRADE FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. SUBGRADE FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

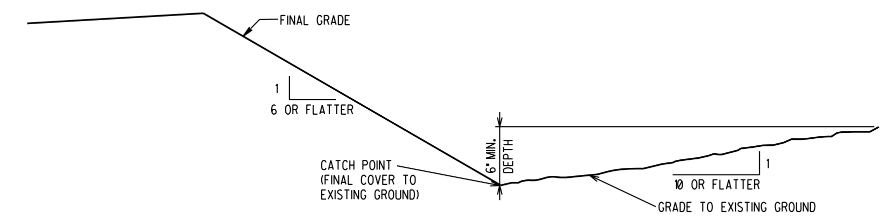
BIOINTRUSION LAYER MATERIALS: THE BIOINTRUSION BARRIER MATERIAL SHALL BE CONSTRUCTED USING A GRADED ROCK RIPRAP. RIPRAP SIZE SHALL BE OF STONE SIZE SO THAT 50 PERCENT OF THE PIECES, BY WEIGHT, SHALL BE LARGER THAN THE D50 SIZE(4"). THE WELL GRADED MATERIAL SHALL BE A MIXTURE COMPOSED PRIMARILY OF LARGER STONE SIZES BUT WITH A SUFFICIENT MIXTURE OF OTHER SIZES TO FILL THE SMALLER VOIDS BETWEEN THE STONES. THE DIAMETER OF THE LARGEST STONE SIZE IN SUCH A MIXTURE SHALL BE 6" (1.5 TIMES) THE D50 SIZE OF 4". THE THICKNESS OF THE BIOINTRUSION BARRIER MATERIAL LAYER SHALL BE A MINIMUM OF 1' AND A MAXIMUM OF 1.25'.

THE BIOINTRUSION LAYER SHALL BE OBTAINED FROM A LOCAL SUPPLIER AND STOCKPILED SOUTH OF THE SITE BY THE OPERATOR FOR THE CONTRACTOR'S USE.

THE NATIVE SOIL LAYER SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. NATIVE SOIL LAYER SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

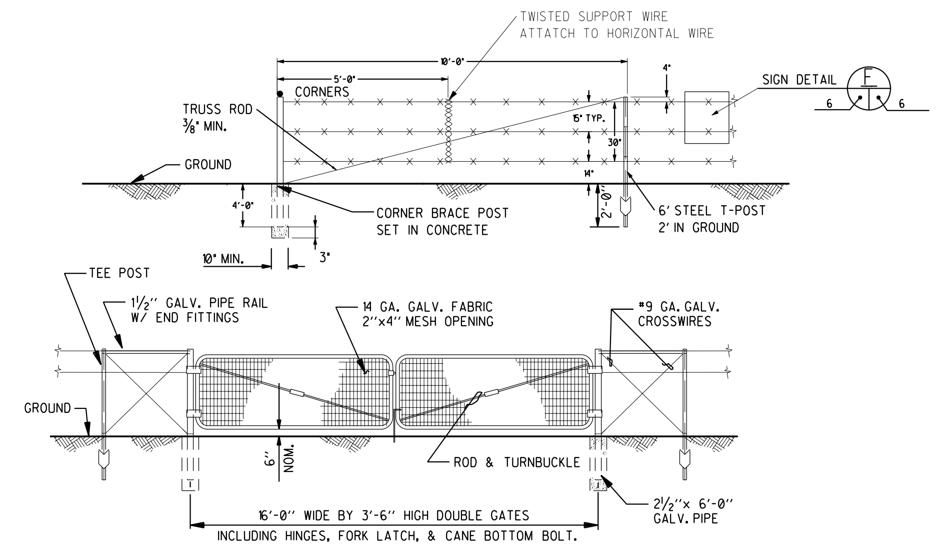
THE TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL LAYER SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). TOPSOIL SHALL BE ADMIXED 25 PERCENT BY VOLUME WITH 3/8-INCH CRUSHED GRAVEL (ASTM D448, SIZE #8). APPROXIMATELY 3,700 CY WILL BE REQUIRED FOR THE TOPSOIL LAYER.

(4) ADMINISTRATIVE CONTROL FENCE SHALL BE STRAND BARBED WIRE WITH TEE-POSTS DRIVEN INTO THE GROUND AND STEEL CORNER POSTS SET IN CONCRETE. GATE SHALL BE A TUBULAR STEEL GALVANIZED GATE, 2 INCH DIAMETER, 40 INCHES IN HEIGHT. ALL END AND CORNER POSTS SHALL BE BRACED BY MEANS OF DIAGONAL TRUSS RODS.



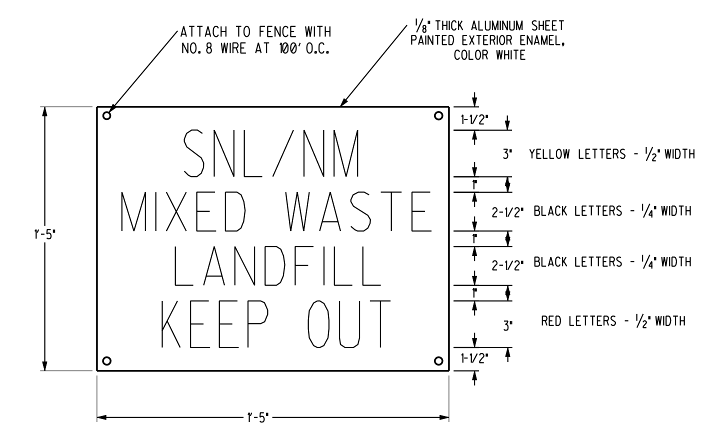
TYPICAL DRAINAGE SWALE SECTION

C DETAIL 4 / 6 NTS



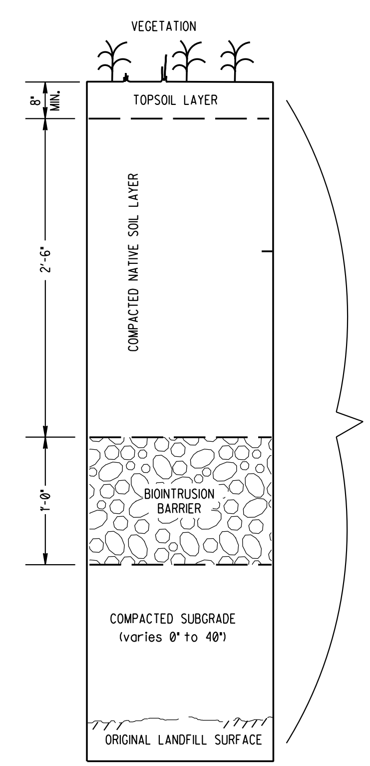
ADMINISTRATIVE CONTROL FENCE AND GATE

D DETAIL 4 / 6 NTS (4)



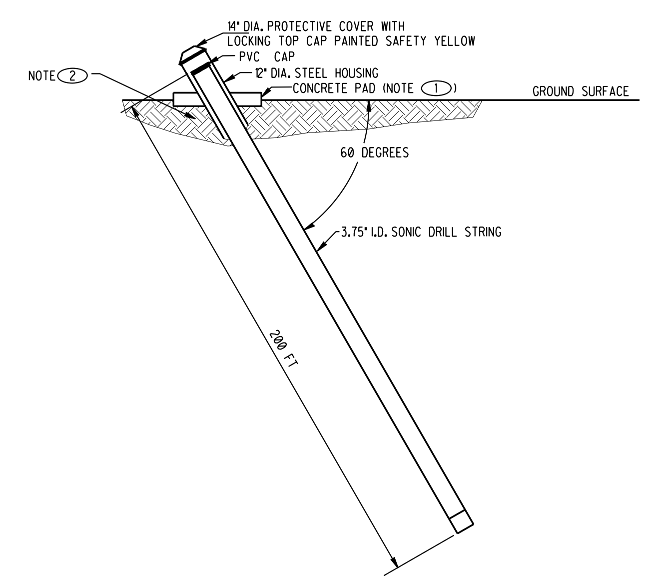
SIGNAGE

F DETAIL 6 / 6 NTS



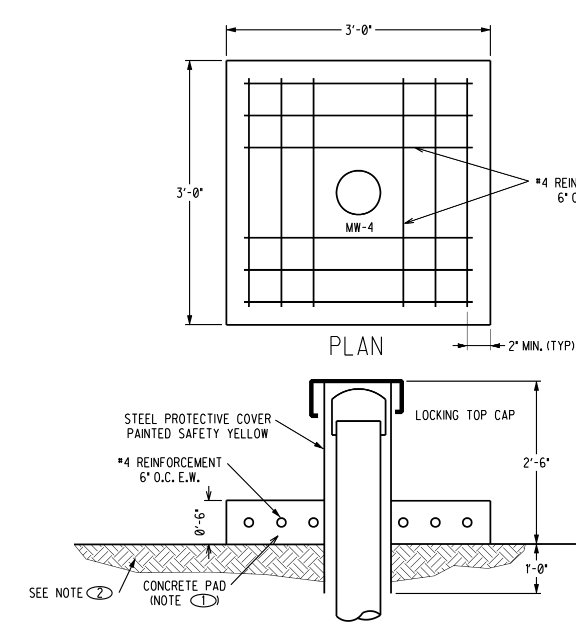
COVER CROSS SECTION

A DETAIL 4 / 6 NTS (3)



SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLE

B DETAIL 4 / 6 NTS



PROFILE

MW-4 EXTENSION

E DETAIL 4 / 6 NTS

REV	DATE	DESCRIPTION	DWN	CKD	APP
B	7/29/05	ISSUED FOR VOLUNTARY CORRECTIVE MEASURE	M.T.D.	G.A.W.	H.C.S.
A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

P.O. OR W.O.
PROJECT NO.

U.S. DEPARTMENT OF ENERGY
KIRTLAND AREA OFFICE
ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

MISCELLANEOUS DETAILS

MIXED WASTE LANDFILL MISCELLANEOUS DETAILS

P.O. OR W.O.	
PROJECT NO.	
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	G.A.W.
APPROVED BY	H.C.S./XX
DATE	07.29.05

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.93

REFERENCE FILES:

Bohannan Huston

SIZE D+ DRAWING NO./SHEET 999997/A6.93 PLATE 6