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# Mixed Waste Landfill Corrective Measures Study Final Report Sandia National Laboratories, Albuquerque, New Mexico

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## Abstract

The Mixed Waste Landfill occupies 2.6 acres in the north-central portion of Technical Area 3 at Sandia National Laboratories, Albuquerque, New Mexico. The landfill accepted low-level radioactive and mixed waste from March 1959 to December 1988.

This report represents the Corrective Measures Study that has been conducted for the Mixed Waste Landfill. The purpose of the study was to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the site. Based upon detailed evaluation and risk assessment using guidance provided by the U.S. Environmental Protection Agency and the New Mexico Environment Department, the U.S. Department of Energy and Sandia National Laboratories recommend that a vegetative soil cover be deployed as the preferred corrective measure for the Mixed Waste Landfill.

The cover would be of sufficient thickness to store precipitation, minimize infiltration and deep percolation, support a healthy vegetative community, and perform with minimal maintenance by emulating the natural analogue ecosystem. There would be no intrusive remedial activities at the site and therefore no potential for exposure to the waste. This alternative poses minimal risk to site workers implementing institutional controls associated with long-term environmental monitoring as well as routine maintenance and surveillance of the site.

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## Executive Summary

[*The Mixed Waste Landfill Corrective Measures Study Report was submitted to the New Mexico Environment Department on May 21, 2003 for technical review and comment. The New Mexico Environment Department issued a Notice of Deficiency to the Department of Energy and Sandia National Laboratories on November 5, 2003. The Department of Energy and Sandia National Laboratories responded to the Notice of Deficiency on December 19, 2003. On January 5th, 2004, the New Mexico Environment Department determined that the Mixed Waste Landfill Corrective Measures Study Report was complete. The Mixed Waste Landfill Corrective Measures Study Report was revised based upon the New Mexico Environment Department Notice of Deficiency and the revised Mixed Waste Landfill Corrective Measures Study Final Report is published herein in its final technical format.*]

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. The Resource Conservation and Recovery Act (RCRA) investigative process identified tritium as the primary contaminant of concern at the MWL. Tritium has been a consistent finding at the MWL since environmental studies were initiated in 1969. Tritium occurs in surface and near-surface soil in and around the classified area of the landfill.

On October 11, 2001, the New Mexico Environment Department (NMED) directed the U.S. Department of Energy (DOE) and SNL/NM to conduct a Corrective Measures Study (CMS) for the MWL. A CMS Workplan (SNL/NM December 2001) was written by the SNL/NM Environmental Restoration Project in accordance with requirements set forth in Module IV (Hazardous and Solid Waste Amendments) of the DOE and SNL/NM RCRA Permit. The CMS Workplan was submitted to the NMED on December 19, 2001. The CMS Workplan included a description of the general approach of the investigation and potential remedies, a definition of the overall objectives of the study, specific plans for evaluating remedies, schedules for conducting the study, and the proposed format for the presentation of information. The CMS Workplan was approved with conditions by the NMED on October 10, 2002.

This final report represents the CMS that has been conducted for the MWL at SNL/NM. 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. The DOE and SNL/NM implemented a streamlined approach to remedy selection. The CMS establishes corrective action objectives for the MWL that are designed to protect human health and the environment and identifies corrective measures alternatives that will achieve the corrective action objectives.

In establishing corrective measures objectives and alternatives for the CMS, it was assumed that institutional controls (ICs) would be maintained at the MWL for the next 100 years. ICs are implicit in all proposed alternatives and include environmental monitoring, site surveillance and maintenance, and access controls. Corrective action objectives are based upon occupational (site worker), public health, and environmental exposure criteria; U.S. Environmental Protection Agency (EPA) guidance; and applicable state and federal regulations. Corrective action objectives developed for the MWL are designed to protect human health and the environment and take into consideration source areas, pathways, and receptors. The corrective action objectives developed for the MWL consist of the following: 1) minimize exposure to site workers, the public, and wildlife; 2) limit migration of contaminants to groundwater such that regulatory limits are not exceeded; 3) minimize biological intrusion into buried waste and any resulting release and redistribution of contaminants to potential receptors; and 4) prevent or limit human intrusion into buried waste over the long term.

Corrective measures alternatives are based upon the results of the MWL Phase 1 RCRA Facility Investigation (RFI), the Phase 2 RFI, MWL groundwater monitoring, environmental studies conducted at the MWL since 1969, and public input. Corrective measures alternatives rely upon preferred technologies identified by the EPA's scientific and engineering evaluations of performance data on technology implementation at similar sites. Preferred technologies are screened using three primary criteria: 1) responsiveness to corrective action objectives, 2) implementability, and 3) performance.

Corrective measures alternatives developed for the MWL make use of individual technologies or various combinations of technologies based upon engineering practice to determine which of the candidate technologies are suitable for the site. Alternatives are developed to reduce the large number of candidate technologies to a manageable number of alternatives for detailed evaluation. EPA guidance recommends that three general criteria be used in the development of alternatives: 1) effectiveness, 2) implementability, and 3) cost.

Four corrective measures alternatives were found suitable for the MWL and evaluated in detail. These alternatives include three containment alternatives and one excavation alternative:

1. Alternative I.a—No Further Action (NFA) with ICs;
2. Alternative III.b—Vegetative Soil Cover;
3. Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier; and
4. Alternative V.e—Future Excavation.

Each alternative is technically reliable and meets the corrective action objectives established in the CMS for the MWL.

Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, one candidate corrective measures alternative clearly presents the overall lowest risk to human health and the environment while minimizing costs and meeting MWL corrective action objectives. This alternative is Alternative I.a—NFA with ICs, which was originally proposed for the MWL in September 1996 after completion of the RCRA investigative process.

However, the DOE and SNL/NM recommend Alternative III.b—Vegetative Soil Cover—as the preferred corrective measure for the MWL. Relative to Alternative I.a, Alternative III.b offers additional protection against exposure to waste in landfill disposal cells, further minimizes infiltration of water, and mitigates bio- and human intrusion into buried waste without significant added cost in construction and long-term monitoring, surveillance and maintenance, and access controls.

Under Alternative III.b, a vegetative soil cover would be deployed on the existing landfill surface. The cover would be of sufficient thickness to store precipitation and support a healthy vegetative community and perform with minimal maintenance by emulating the natural analogue ecosystem. There would be no intrusive activities at the site and therefore no potential for exposure to waste. This alternative also poses minimal risk to site workers implementing ICs associated with environmental and groundwater monitoring as well as routine maintenance and surveillance of the site.

Alternative III.b is consistent with EPA directives regarding presumptive remedies for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) municipal waste and military landfills. Presumptive remedies are preferred technologies for common categories of sites, and are expected to ensure consistent selection of remedial actions and to be used at all appropriate sites except under unusual site-specific circumstances. The EPA is committed to consistency of results between RCRA corrective action and Superfund remedial action programs, and any revisions to the CERCLA remedial expectations or the CERCLA remedy selection process will likely be incorporated into RCRA corrective action.

In selecting Alternative III.b as the preferred corrective measure for the MWL, the DOE and SNL/NM are demonstrating their commitment to protect the environment, preserve the health and safety of the public and their employees, and serve as responsible corporate citizens in meeting the community's environmental goals.

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## Acronyms and Abbreviations

| | |
|---|---|
| AEA | Atomic Energy Act |
| bgs | below ground surface |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| Ci | curies |
| CMS | Corrective Measures Study |
| COC | contaminant of concern |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| EPA | U.S. Environmental Protection Agency |
| ER | Environmental Restoration |
| g | gram |
| HI | hazard index |
| HQ | hazard quotient |
| HSWA | Hazardous and Solid Waste Amendments |
| IC | Institutional Controls |
| KAFB | Kirtland Air Force Base |
| mrem | millirem |
| MWL | Mixed Waste Landfill |
| NFA | No Further Action |
| NMAC | New Mexico Administrative Code |
| NMED | New Mexico Environment Department |
| pCi | picocuries |
| PPE | personal protective equipment |
| R/hr | Roentgen per hour |
| RACER | RACER-2001 |
| RCRA | Resource Conservation and Recovery Act |
| RFI | RCRA Facility Investigation |
| SNL/NM | Sandia National Laboratories/New Mexico |
| SVOCs | semivolatile organic compounds |
| SWMU | Solid Waste Management Unit |
| TA | Technical Area |
| TEDE | total effective dose equivalent |
| VOCs | volatile organic compounds |
| yr | year |

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# 1. Introduction

On October 11, 2001, the New Mexico Environment Department (NMED) directed that the U.S. Department of Energy (DOE) and Sandia National Laboratories/New Mexico (SNL/NM) conduct a Corrective Measures Study (CMS) for the Mixed Waste Landfill (MWL) in Technical Area (TA)-3 at SNL/NM. The NMED requested that the CMS meet the requirements set forth in Sections N, O, P, Q, and S of Module IV (Hazardous and Solid Waste Amendments [HSWA] Requirements) of the Permittees' Resource Conservation and Recovery Act (RCRA) Permit. The HSWA Module provides guidance on the scope and the approach for the CMS. The NMED directed that, pursuant to Module IV, Section N.2, the DOE and SNL/NM provide a CMS Workplan to the NMED for review and approval. This CMS is based upon combined U.S. Environmental Protection Agency (EPA) and NMED guidance, which incorporates the SNL/NM HSWA Permit, and the EPA 1996 Subpart S Initiative (EPA May 1996).

The DOE and SNL/NM submitted the CMS Workplan to the NMED on December 19, 2001. The CMS Workplan included a description of the general approach of the investigation and potential remedies, a definition of the overall objectives of the study, specific plans for evaluating remedies, schedules for conducting the study, and the proposed format for the presentation of information. The CMS Workplan was approved with conditions by the NMED on October 10, 2002. In the conditions, the NMED requested that the DOE and SNL/NM include resumes for individuals writing the CMS Final Report and a budget indicating the estimated total cost of the CMS. Information satisfying these conditions was transmitted to the NMED on January 24, 2003.

Documentation, including the CMS Workplan and this CMS Final Report, is part of the Administrative Record File for the MWL and is available to the public. Information repositories have been established at DOE's Public Reading Rooms located at the Government Information Department, Zimmerman Library, University of New Mexico; the Community Resources Information Office, 7007 Wyoming Blvd NE, Suite C in Albuquerque; and at the NMED Hazardous Waste Bureau offices at 2905 Rodeo Park Drive East, Building 1, in Santa Fe, New Mexico. A notice will be published in local newspapers when information is added to the Administrative Record File regarding the CMS for the MWL. Additional repositories may be added and/or locations changed to better meet the needs of the public.

## 1.1 CMS Approach

The purpose of the CMS is to identify and screen, develop, and evaluate potential corrective measures alternatives and recommend the corrective measure(s) action to be taken at the MWL. In keeping with the goals of the Final RCRA Corrective Action Plan (EPA 1994), the DOE and SNL/NM elect to implement a streamlined approach to remedy selection, enabling the Permittees to move rapidly from the CMS to implementation of the corrective measure(s). EPA anticipates that for most RCRA facilities, the studies needed for developing sound, environmentally protective remedies are relatively straightforward and may not require extensive evaluation of numerous remedial alternatives. Such studies can be tailored to fit the complexity and scope of the remedial situation presented by the facility (EPA 1994).

The use of a streamlined approach for the MWL is justified based upon the results of both the MWL Phase 1 and Phase 2 RCRA Facility Investigations (RFIs) (SNL/NM 1990, Peace et al. September 2002), and MWL groundwater monitoring (Goering et al. December 2002). The results of these reports are presented in Sections 1.7.2, 1.7.3, and 1.7.4, respectively.

The EPA anticipates that a streamlined CMS would be appropriate for the following types of situations:

- "Low-risk" facilities where environmental problems are relatively small, and where releases present minimal exposure concerns

- High-quality remedies proposed by the Permittee that are highly protective and consistent with remedial objectives

- Facilities with straightforward remedial solutions that have proven effective in similar situations

- Phased remedies where the nature of the environmental problem dictates development of a remedy in phases with follow-up studies as appropriate to deal with remaining remedial needs at the facility.

The MWL meets all of the above criteria for a streamlined approach. The MWL is a low-risk site where the release of tritium presents minimal exposure concern; proposed remedies are highly protective and consistent with corrective action objectives. Proposed remedies have proven effective at similar sites (EPA September 1993, EPA 1994, EPA 1996), and remedies may be phased over time to address future remedial needs. This CMS Final Report addresses the scope of the remedial situation presented by the MWL.

Long-term stewardship of the MWL will be addressed in a separate document, the MWL Post-Closure Care Plan, scheduled for submittal to the NMED in 2004. A detailed description of planned monitoring activities, the frequency at which they will be performed, and corrective action triggers will be determined in consultation with the NMED and addressed in this post-closure care document.

## 1.2 Site Location and Description

SNL/NM 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/NM is managed by the DOE and is operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation. SNL/NM performs research and development in support of various energy and weapons programs as well as national security; SNL/NM also performs work for the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission, and other federal agencies.

SNL/NM research and administration facilities occupy 2842 acres and are divided into 5 TAs, (designated 1 through 5) and several test areas. TA-1, TA-2, and TA-4 are separate research facilities in the north-central 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 encompasses 2000 acres.

The MWL is a 2.6-acre fenced compound located in north-central TA-3 at SNL/NM (Figure 1-3). The MWL was opened as the “TA-3 low-level radioactive waste dump” in March 1959. In a DOE environmental survey report dated April 1988, the TA-3 low-level radioactive dump was labeled a “mixed waste site” and has since been referred to as the TA-3 “Mixed Waste Landfill.”

The MWL is designated as a Soil Contamination Area, a Radioactive Materials Management Area, and a HSWA Solid Waste Management Unit (SWMU), subject to state and federal corrective action regulations. The NMED is the lead regulatory agency for the corrective action process.

## 1.3 Site Operational History

The MWL accepted containerized and uncontainerized low-level radioactive waste and minor amounts of mixed waste from SNL/NM research facilities and off-site DOE and Department of Defense 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. Disposal cells at the landfill are unlined and were backfilled and compacted to grade with stockpiled soil.

There are two distinct disposal areas at the MWL: 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 trenches. Records indicate that trenches were 15 to 25 feet wide, 150 to 180 feet long, and 15 to 20 feet deep. Trenches were backfilled with soil on a quarterly basis and, once filled with waste, were capped with the original soil that had been excavated and locally stockpiled.

The classified area contains wastes that present the greatest security, worker safety, and environmental concerns. Wastes in the classified area include military hardware, radioactive constituents (e.g., cobalt-60, cesium-137, tritium, radium-226), activation products (e.g., cobalt-60), multiple fission products (e.g., cesium-137, strontium-90), high specific-activity wastes (e.g., tritium, cobalt-60), plutonium, thorium, and depleted uranium.

All 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, shoe 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.

Containment and disposal of routine waste commonly occurred using tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, and 55-gallon steel and polyethylene drums. Larger items, such as glove boxes, spent fuel shipping casks, and contaminated soils, 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, or yellow powder before containerization and disposal. Historically, questions have been raised about disposal of liquids at the landfill. Drilling and sampling evidence from the MWL Phase 1 and Phase 2 RFIs demonstrate that uncontainerized liquids were not disposed of at the landfill.

A detailed MWL waste inventory, by pit and trench, is provided in the Environmental Restoration (ER) Project “Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, June 15, 1998” (SNL/NM June 1998).

## 1.4 RCRA Corrective Action Program

The federal plan for site cleanups was expanded in 1984 with the passage of the HSWA, which amended the RCRA. These amendments to RCRA provided new authority to the EPA, directing the agency (or authorized states) to require corrective action for releases of hazardous waste from any facility seeking a RCRA permit.

The State of New Mexico is authorized by the EPA to implement the hazardous waste management provisions of RCRA for treatment, storage, and disposal facilities within the state. SNL/NM manages hazardous wastes under a RCRA operating permit. For treatment and storage of mixed wastes (greater than 90 days), SNL/NM currently operates under interim status and has submitted a RCRA Part B permit application for continued operation of these sites.

RCRA authorizes the EPA and EPA-authorized states to regulate the management of hazardous waste. Specifically exempted from regulation under RCRA were “source, special nuclear or byproduct material as defined by the Atomic Energy Act (AEA) of 1954...” (42 USC 6903). Byproduct material, as defined by the AEA, is “any radioactive material, except special nuclear material, yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material” (42 USC 2014[e][1]) and includes the radioactive wastes generated by the DOE.

Due to RCRA's exemption of byproduct material, the status of mixed waste (containing radioactive and hazardous constituents) is unclear. In 1986, the EPA determined that wastes containing both hazardous and radioactive constituents were subject to regulation under RCRA (51 FR 24504, July 3, 1986). DOE followed this EPA interpretation with the “byproduct rule,” 10 Code of Federal Regulations (CFR) Part 962, in which DOE clarified the term byproduct material and its exclusion under RCRA, and acknowledged that the nonradioactive hazardous component of mixed waste is subject to RCRA. Thus, the EPA regulates the hazardous constituents of mixed waste, but not the radioactive constituents. The EPA has delegated RCRA authority for ongoing hazardous waste management operations to the NMED. Hazardous waste in New Mexico is regulated pursuant to the New Mexico Hazardous Waste Act and New Mexico Hazardous Waste Management regulations. Radioactive waste and the radioactive component of mixed waste is regulated by the DOE under its authority from the AEA.

## 1.5 Corrective Action 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/NM RCRA operating permit. Under the corrective action program, SNL/NM is required to investigate and remediate, if necessary, the SWMUs identified in the HSWA Module of the permit. SNL/NM completed the RCRA investigative process for the MWL in September 1996. In December 2001, the NMED directed the DOE and SNL/NM to conduct a CMS that meets the requirements specified in the HSWA Module.

Due to the lack of prescriptive HSWA guidance and the practical similarities of landfill corrective action under HSWA and landfill closure under RCRA, the DOE and SNL/NM have elected to use the RCRA landfill closure requirements as guidance, when appropriate, in evaluating remedies.

Hazardous waste landfill closure requirements are codified under 20.4.1.500 New Mexico Administrative Code (NMAC), 40 CFR Part 264, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” Subpart G (Facility Closure Standards) and Subpart N (Landfills). The NMED, the lead regulatory agency, has adopted the federal regulations as written and incorporated them into the New Mexico Hazardous Waste Management Regulations 20.4.1 NMAC. 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 20.4.1.500 NMAC, 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 . . .”

## 1.6 Closure Requirements Under DOE Orders

Low-level radioactive and mixed waste disposal operations at the MWL followed the requirements set forth in DOE Order 5820.2, “Radioactive Waste Management” (DOE 1984) and the subsequent DOE Order 5820.2A (DOE 1988). On July 9, 1999, DOE Order 5820.2A was cancelled and replaced by DOE Order 435.1 (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 workers, the public, and the environment.

The DOE fulfills its responsibility for conducting and overseeing radioactive material operations under the AEA authority at its contractor-operated facilities through DOE orders, which define requirements or standards for closures. DOE orders and federal and state regulations that contain pertinent requirements for final closure of 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)
- 20.4.1.500 NMAC, 40 CFR 261–270, RCRA hazardous waste regulations (used as guidance)
- 10 CFR 835, “Occupational Radiation Protection”

## 1.7 Description of Current Conditions

### 1.7.1 Current Site Status

SNL/NM completed the investigative phase of the RCRA corrective action process at the MWL in September 1996. SNL/NM proposed no further action (NFA) for the site and recommended continued groundwater monitoring as well as environmental monitoring and surveillance. In September 1997, the NMED denied SNL/NM’s request for NFA at the MWL and requested that a landfill cover that met the requirements of 20 NMAC 4.1, Subpart VI, 40 CFR 265.310 be deployed at the site (Dinwiddie September 1997). A landfill cover design was submitted to the NMED in September 1999 (Peace et al. March 2003). The 1999 cover design submittal represents Alternative III.b—Vegetative Soil Cover—one of the corrective measures alternatives considered in this CMS.

### 1.7.2 MWL Phase 1 RFI Results

A Phase 1 RFI was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL (SNL/NM 1990). The objective was to determine the nature and extent of contamination, the source of contamination, the release and transport mechanism(s), and the pathway(s) of contaminant migration.

Air, surface soil, and subsurface soil samples were collected and analyzed during Phase 1 RFI activities to determine whether hazardous or radioactive constituents had been released to the environment. The Phase 1 RFI results indicated that tritium is the primary contaminant of concern (COC) and that it has migrated from MWL disposal cells into the surrounding soil. Elevated tritium levels were detected in classified area surface soil (0 to 0.5 feet below ground surface [bgs]) and near-surface soil (0.5 to 30 feet bgs). Air samples indicated that tritium emissions were at or below the background range for tritium in air.

### 1.7.3 MWL Phase 2 RFI Results

A Phase 2 RFI was conducted from 1992 to 1996 to thoroughly investigate environmental impacts associated with disposal activities at the MWL (Peace et al. September 2002). The MWL Phase 2 RFI included a detailed examination of landfill historical records; radiological surveys; soil sampling for background metals and radionuclides; nonintrusive geophysical surveys; active and passive soil-gas surveys; surface soil sampling for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), RCRA metals, and tritium; borehole sampling for VOCs, SVOCs, RCRA metals, and radionuclides; vadose zone tests; aquifer pumping tests; and a risk assessment of the landfill.

A number of contaminants were identified at the MWL during the Phase 2 RFI. These contaminants included VOCs, SVOCs, metals, and tritium. VOCs in soil gas were detected to depths of 30 feet bgs. VOCs, SVOCs, and metals (with the exception of beryllium) were detected in subsurface soil at levels below proposed Subpart S action levels or action levels obtained from toxicity information. Background concentrations of beryllium in soils have been found to be high at KAFB (IT 1996). Radionuclides, with the exception of tritium, were all below their respective minimum detectable activities or within background ranges.

The Phase 2 RFI confirmed that tritium is the primary COC. Tritium has been a consistent finding at the MWL since environmental studies were initiated at SNL/NM in 1969. Tritium occurs in surface and near-surface soil in and around the classified area of the landfill at activities ranging from 1100 picocuries (pCi)/gram (g) in surface soil to 206 pCi/g in near-surface soil (Figure 1-4). The highest tritium activities 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 activity falls off rapidly to a few pCi/g of soil. Tritium also occurs as a diffuse air emission from the landfill, releasing 0.09 Ci/year (yr) into the atmosphere. The effective dose equivalent exposure to on-site (KAFB) receptors from air emissions of tritium from the MWL is $8.5 \times 10^{-6}$ millirem (mrem)/yr. The effective dose equivalent exposure to off-site receptors from tritium air emissions from the MWL is $1.1 \times 10^{-5}$ mrem/yr. The dose to off-site receptors is greater than the dose to on-site receptors because off-site receptors are modeled to have fruit trees and a garden from which tritium is ingested.

The results of a detailed risk assessment conducted for the MWL indicate that the MWL poses insignificant risk to human health or the environment under an industrial land-use scenario. MWL constituents present little risk to potential receptors. Tritium activities at the MWL will decrease steadily with time due to the relatively short half-life of 12.3 years. Because of tritium's short half-life, negligible groundwater recharge, and a declining regional water table, tritium does not pose a threat to groundwater.

### 1.7.4 Groundwater Monitoring

The MWL monitoring well network consists of seven wells. Five wells were installed between October 1988 and February 1993; two additional wells were installed in November 2000. A total of 33 sampling events have been conducted through October 2002 since groundwater sampling began at the MWL in September 1990. Typically, each new monitoring well is sampled quarterly for two years. Sampling frequency may be reduced by the NMED to semiannually or annually if no contamination is detected. Currently, all seven MWL monitoring wells are sampled annually in April.

Groundwater samples have been analyzed for a wide variety of parameters, including radionuclides, RCRA metals, VOCs and SVOCs, major ions, and perchlorate. The extensive groundwater analytical data collected to date indicate that no contaminants have migrated to groundwater from the MWL (Goering et al. December 2002).

# 2. Identification and Screening of Corrective Measures Alternatives

## 2.1 Introduction

As stated in Section 1.1, the purpose of the CMS is to identify and screen, develop, and evaluate potential corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. Because there has been no significant migration of contaminants from the MWL, the CMS can focus on containment, stabilization, and excavation technologies that can be used to prevent or limit any future migration of contaminants from landfill waste disposal cells. This section of the CMS identifies corrective measures alternatives that may be used to achieve the corrective action objectives established for the MWL. The corrective measures alternatives are screened to eliminate those technologies that may not prove feasible to implement, that rely on technologies unlikely to perform satisfactorily, or that would not achieve the corrective action objectives within a reasonable period of time.

The EPA provides guidance for identifying and screening corrective measures alternatives for the purposes of remediation (EPA December 1986, EPA June 1988, EPA 1990, EPA August 1994, EPA December 1996). The identification and screening process followed in this CMS addresses a range of applicable corrective measures alternatives and presents relevant information required to select a suitable approach for remediation. Selection of corrective measures alternatives proceeds in a series of steps designed to reduce the range of potential technologies and to retain those technologies from which a final remedy may be selected. Implementation of a preferred remedy would not restrict future management of the site or preclude future remedial alternatives.

## 2.2 Corrective Action Objectives

Corrective action objectives are designed to protect human health and the environment, and are based upon occupational (site worker), public health, and environmental exposure criteria; information gathered during assessment and characterization; EPA guidance; and applicable state and federal regulations. Therefore, the corrective action objectives become the basis upon which the CMS is founded.

To be protective of human health and the environment, corrective action objectives must consider source areas, pathways, and receptors. Objectives must be developed to ensure that the source area, the transport pathway, or both, do not impact receptors. Therefore, the current distribution and potential migration of contaminants and the risks associated with current or past releases must be considered when developing corrective action objectives.

Corrective action objectives developed for the MWL consist of the following:

1. Minimize exposure to site workers, the public, and wildlife by

   - Ensuring dose to site workers is less than 2 rem/yr total effective dose equivalent (TEDE) from all exposure pathways

   - Ensuring dose to representative members of the public is less than 25 mrem/yr TEDE from all exposure pathways (DOE 1999)

   - Ensuring dose to representative members of the public via the air pathway is less than 10 mrem/yr TEDE (DOE 1999)

   - Ensuring that the radon emission rate to ambient air does not exceed 20 pCi/square meters/second

   - Ensuring that dose to wildlife is less than 0.1 rad/day from all exposure pathways

2. Limit migration of contaminants to groundwater such that regulatory limits are not exceeded

3. Minimize biological intrusion into buried waste and any resulting release and redistribution of contaminants to potential receptors

4. Prevent or limit human intrusion into buried waste over the long term

## 2.3 General Corrective Measures

General corrective measures are families of alternatives that meet the corrective action objectives and include passive responses, such as NFA and institutional controls (ICs), as well as active responses that use potential technologies to address containment, treatment, excavation, storage, and disposal of waste. General corrective measures identified for the MWL may incorporate complementary combinations of these families of alternatives. These include:

1. NFA
2. ICs
3. Containment/Engineering Controls
4. Stabilization/*In Situ* Treatment
5. Excavation/Storage/Treatment/Disposal

## 2.4 Identification and Screening of Preliminary Corrective Measures Alternatives—Overview

Preliminary corrective measures alternatives for remediation of the MWL are based upon the results of the MWL Phase 1 RFI, the Phase 2 RFI, MWL groundwater monitoring, environmental studies conducted at the MWL since 1969, and public input. Preliminary corrective measures alternatives rely on preferred technologies identified by the EPA's scientific and engineering evaluations of performance data on technology implementation at similar sites (EPA September 1993, EPA August 1994, EPA December 1996).

Preferred technologies were screened using the following criteria: 1) responsiveness to corrective action objectives, 2) implementability, and 3) performance. Technologies that passed this screening were retained and carried forward to the development of corrective measures alternatives in Chapter 3.0.

After each preferred technology was evaluated using these three criteria, the technology was "Accepted" or "Rejected." To be accepted, a technology had to receive a "Yes" ranking for both responsiveness to corrective action objectives and implementability, and at least a "Fair" ranking for its performance record. This evaluation process provided a selection of technologies most likely to be responsive to corrective action objectives, implementability, and performance.

### 2.4.1 Responsiveness to Corrective Action Objectives

For a technology to be retained, it had to address at least one of the corrective action objectives (Section 2.2). A "Yes" ranking indicates that a technology is responsive to one or more of the corrective action objectives. A "No" ranking indicates that a technology is not responsive to any of the corrective action objectives. Both short- and long-term responsiveness was considered in the ranking. Technologies that were clearly limited in being responsive to corrective action objectives were rejected without further consideration.

### 2.4.2 Implementability

Implementability addresses both the technical and administrative feasibility of applying a technology. Under this criterion, technologies were evaluated based upon the availability of resources and equipment, and the constructibility of the corrective action. The nature of the technology had to be such that it could be implemented in a safe, cost-effective, and timely manner. Waste characteristics, site accessibility, available area, and potential land use of the site that may affect the implementation of a specific technology were considered. Mobilization and permitting or approval requirements had to be practical and previously demonstrated at similar projects. Preliminary consideration was also given to regulatory constraints such as waste handling, shipment, disposal, and treatment requirements that would affect the implementation of a technology. Technologies that were not technically or administratively feasible were rejected.

### 2.4.3 Performance

The performance of a technology is ranked "Good," "Fair," or "Poor" based upon the technology's performance as demonstrated elsewhere (EPA September 1993, EPA August 1994, EPA December 1996). Ranking was predicated on the long-term performance of the technology. Technologies with a record of proven reliability were considered to have "Good" performance records. Technologies with an acceptable record of reliability or promising field- or pilot-testing results were considered to have "Fair" records. Technologies with a record of poor reliability or those still in the conceptual stage of development were considered to have “Poor” performance records.

## 2.5 Identification and Screening of Preliminary Corrective Measures Alternatives—Application

The following sections and Table 2-1 provide an evaluation of preferred technologies based upon the screening criteria discussed above. Technologies retained after this screening were used to develop the specific corrective measures alternatives discussed in Chapter 3.0. A general discussion of site and waste characteristics and technology limitations is presented in the comments section of Table 2-1. Appendix A provides a general discussion of each technology.

### 2.5.1 General Corrective Measure I—NFA

The NFA corrective measures alternative is used to provide a baseline against which remedial action technologies can be compared. The NFA response can be implemented with or without ICs. ICs may include environmental monitoring, surveillance and maintenance, and access controls throughout the post-closure care period. The NFA response is readily implemented and is the least expensive corrective measure possible.

### 2.5.2 General Corrective Measure II—ICs

The institutional controls utilized in this corrective measure include long-term monitoring, long-term surveillance and maintenance, and long-term access controls (e.g., signage, fencing, and security patrols). These controls have been implemented successfully at the MWL since 1959. The effectiveness and implementability of these controls has been demonstrated at many waste disposal sites throughout the U.S. The application of these controls is implicit in all corrective measures alternatives unless otherwise noted.

### 2.5.3 General Corrective Measure III—Containment/Engineering Controls

These technologies involve physical containment of individual landfill disposal cells or the landfill as a whole. Containment technologies include horizontal and vertical physical barriers to prevent water infiltration and contaminant migration. Some of the technologies are complementary. Rejected technologies are not suitable because of questionable performance or site-specific conditions. Reasons for rejection of individual technologies are described in the comments section of Table 2-1.

### 2.5.4 General Corrective Measure IV—Stabilization/*In Situ* Treatment

These technologies permanently alter the physical or chemical state of wastes in landfill disposal cells. *In situ* treatment technologies are applicable to buried solid wastes as a means of stabilization and encapsulation, and include corrective measures such as vitrification. Rejected technologies were not implementable due to site-specific conditions or limited performance. Reasons for rejection of individual technologies are described in the comments section of Table 2-1.

### 2.5.5 General Corrective Measure V—Excavation/Storage/Treatment/ Disposal

These technologies refer to the physical removal of wastes for treatment, containment, and/or storage prior to permanent storage and/or disposal. Technologies that treat removed wastes may be implemented on or off site. Any technology of this class would require on-site capabilities for removal, shielding, handling, characterization, storage, repackaging, shipping, and disposal of radioactive and mixed waste. A storage and disposal response would be used for excavation. Rejected technologies were found to be incompatible with waste activity, storage, shipping, and/or waste acceptance criteria. Reasons for rejection of individual technologies are described in the comments section of Table 2-1.

## 2.6 Evaluation of Corrective Measures Alternatives and Selection of Technologies

Table 2-2 summarizes the technologies accepted or rejected following the identification and screening of preliminary corrective measures alternatives. This screening resulted in the selection of candidate technologies which are acceptable for use in developing the corrective measures alternatives for the MWL. The corrective measures alternatives accepted for development are discussed in Chapter 3.0.

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# 3. Development of Corrective Measures Alternatives

The development of corrective measures alternatives is based upon the identification and screening of applicable technologies in Chapter 2.0, which resulted in the selection of eight candidate technologies as well as the NFA baseline alternatives. The NFA with ICs alternative is used to provide a baseline against which remedial action technologies are compared. This chapter develops corrective measures alternatives using individual technologies or various combinations of these technologies based upon engineering practice to determine which of the candidate technologies are suitable for the site. Technologies considered suitable are carried forward to Chapter 4.0 for detailed evaluation.

## 3.1 Alternatives Development—Overview

The accepted technologies listed in Table 2-2 are systematically considered in developing alternatives for the MWL. The NFA alternative is retained for baseline and comparative purposes. Key concepts in the development of alternatives are discussed below.

- ICs are a component in all proposed alternatives, including the NFA baseline alternative. The three IC measures are described in Table 2-1 (i.e., long-term monitoring, long-term site surveillance and maintenance, and long-term access controls). In developing alternatives, it is assumed that some form of IC will be maintained at the MWL for the next 100 years, which is the longest period of time that active ICs can be relied upon for purposes of conducting performance assessment (NRC 10 CFR 61 2002). This is a reasonable assumption given that the MWL is located in TA-3, a remote area of SNL/NM that the DOE or another federal entity will control for the foreseeable future.

- Field data and supporting modeling studies indicate that tritium from the landfill will not impact groundwater, which occurs approximately 500 feet bgs. Contaminants are unlikely to reach groundwater due to negligible recharge, high evapotranspiration, and an extensive vadose zone composed of alluvial soils with low hydraulic conductivities. Chapters 3.0 and 4.0 of the CMS focus on the development and evaluation of corrective measures alternatives that will further reduce the migration of potential contaminants at the MWL.

- The results of the Phase 1 and Phase 2 RFIs and groundwater monitoring demonstrate that contaminant release at the MWL over the past 45 years has been minimal. The existing operational cover has performed quite well in the natural environment of the semi-arid Southwest. Existing natural and engineering controls have been successful in limiting the ponding and infiltration of water, the release of contaminants, and bio-intrusion; preventing human intrusion; and limiting exposure of waste due to wind and water erosion.

- The alternatives under consideration were identified by SNL/NM ER Project technical staff with input from the NMED, the EPA, the DOE Oversight Bureau, the Albuquerque Citizen's Advisory Board, the Bernalillo County Groundwater Protection Board, the State of New Mexico Land Office, the City of Albuquerque, and the Waste-Management Education and Research Consortium. Public participation in the CMS was solicited by the DOE between

January 17 and March 8, 2002. Excavation with aboveground retrievable storage and partial excavation of hot spots (e.g., the classified area) were options proposed by the public.

The candidate technologies accepted in Chapter 2.0 for use in developing corrective measures alternatives are listed below.

- Vegetative Soil Cover
- RCRA Subtitle C Cap
- Bio-Intrusion Barrier
- Complete Excavation with Aboveground Retrievable Storage
- Complete Excavation with Off-Site Disposal
- Partial Excavation with Aboveground Retrievable Storage
- Partial Excavation with Off-Site Disposal
- Future Excavation

Development of alternatives is used to reduce the large number of candidate technologies to a manageable number of alternatives for detailed evaluation in Chapter 4.0. EPA guidance (EPA September 1993) recommends that three general criteria be used for alternative development: 1) effectiveness, 2) implementability, and 3) cost. The next three subsections describe how these criteria are employed in this CMS.

### 3.1.1 Effectiveness

The effectiveness criterion is based upon the responsiveness to each corrective action objective listed in Section 2.2.

### 3.1.2 Implementability

The implementability criterion considers: 1) constructibility, 2) site worker health and safety, and 3) site maintenance requirements.

The constructibility of an alternative refers to the ease of installation, degree of construction difficulty or extent of logistical problems. To be acceptable, an alternative must be considered constructible based upon judgment rendered by experienced professionals.

With respect to health and safety, each alternative was evaluated for the level of protection that must be provided during construction to minimize occupational health and safety hazards to site workers. These hazards include external or internal radiation exposure, chemical exposure, danger from construction and process machinery, heat stress, pressure hazards, noise, and ergonomic work strain. The health and safety risk of each alternative was ranked as low, medium, or high, depending upon the associated health and safety hazards to site workers.

Site maintenance requirements consist of long-term activities required to ensure continued performance of the implemented alternative.

### 3.1.3 Cost

The cost criterion addresses the cost estimate of an alternative based upon direct capital costs on a net present value basis. Cost estimates were developed using conceptual designs with sufficient detail for determining material quantities, labor time, and unit prices. The estimated total cost for each alternative includes materials, equipment, and labor needed to accomplish the corrective measure.

The cost estimates were provided by RACER, an engineering software model that uses parametric methodologies for estimating costs. RACER was designed to provide engineers, managers, estimators, and technical support personnel with a tool to quickly develop cost estimates for environmental projects. The cost models are based upon generic engineering solutions for complex environmental projects, technologies, and processes. The generic engineering solutions were derived from historical project information, government laboratories, construction management agencies, vendors, contractors, and engineering analyses. When a cost estimate is created in RACER, the generic engineering solutions are tailored to reflect specific quantities of work, which are priced using current price data.

RACER is a comprehensive program incorporating cost models for remedial design, remedial action, operations and maintenance, long-term monitoring, and site closeout. The system is used primarily for development of programming or budgetary cost estimates for environmental remediation projects. Contingency costs included in RACER-2001 (RACER) cost estimates range from 20 percent for covers and caps to 31 percent for excavation. Actual excavation experience at the SNL/NM Chemical Waste Landfill indicates contingency costs can be as high as 150 percent.

Cost summary details for the aboveground retrievable storage facility are provided in Appendix B. Additional cost details are provided in Appendix C. Costs for remote handling and/or robotic excavation of the classified area are provided in Appendix D. Cost was used for comparative purposes only in Chapter 3. No alternatives were eliminated from detailed evaluation in Chapter 4 because of cost considerations exclusively.

## 3.2 Alternatives Development—Application

Corrective measures alternatives for the MWL are developed by making selections from the various candidate technologies listed in Section 3.1. Table 3-1 summarizes the development of alternatives. In Table 3-1, general corrective measures are shown in the first column. Alternative designations and descriptions for each general corrective measure are shown in the second and third columns. Individual technologies are shown as column headings in columns 4 through 15. Alternatives are developed by placing an “X” in rows under the appropriate column heading, indicating the potential technology or technologies comprising a specific alternative for a given general corrective measure. The alternatives depicted in Table 3-1 are evaluated sequentially in the following subsections based upon the three general criteria outlined in Sections 3.1.1 (Effectiveness), 3.1.2 (Implementability), and 3.1.3 (Cost). ICs are not shown as a general corrective measure in Table 3-1 because they are implicit in all alternatives (see column headings).

### 3.2.1 MWL Alternative I.a—NFA with ICs

Under this alternative, the current ICs and groundwater monitoring would continue. Soil would be added to the existing landfill surface to bring the operational cover to a central crown and uniform grade to prevent ponding and promote surface runoff. This baseline alternative is generally responsive to the corrective action objectives as long as ICs are maintained. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.1.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* ICs will preserve the integrity of the operational cover as long as ICs are maintained. The improved operational cover would provide further protection against water infiltration and the release of contaminants such that regulatory limits are not exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* ICs will protect the operational cover from burrowing mammals and deep-rooted plants as long as ICs are maintained.

*Prevent or Limit Human Intrusion.* ICs will provide adequate protection against human intrusion as long as ICs are maintained.

#### 3.2.1.2 Implementability

*Constructibility.* Construction and logistical problems associated with NFA and ICs are insignificant. The addition of soil to the existing landfill surface to bring the operational cover to a central crown and uniform grade presents minimal constructibility concerns. Soil would be added using standard earth-moving and grading equipment. A major advantage of this alternative is its simplicity of construction.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety risk for site workers is ranked low.

*Maintenance.* Long-term activities to ensure continued performance of the improved operational cover are minimal. The operational cover would be maintained using standard earth-moving and grading equipment. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis and maintenance performed as warranted.

#### 3.2.1.3 Cost

Direct capital costs for the NFA with ICs alternative are $1,082,143. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.2 MWL Alternative III.a—Bio-Intrusion Barrier

Under this alternative, a bio-intrusion barrier would be constructed once soil is added to the existing landfill surface to bring the operational cover to a central crown and uniform grade. The barrier would be composed of a layer of gravel and cobbles to limit intrusion of burrowing mammals and deep-rooted plants. This alternative is directly responsive to Corrective Action Objectives 1, 3, and 4, and is generally responsive to Corrective Action Objective 2. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.2.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. A bio-intrusion barrier would extend the life of the operational cover, reduce water and wind erosion, and promote the accumulation of wind-blown sand in void spaces within the barrier, all of which reduce exposure risk to site workers, the public, and wildlife. A bio-intrusion barrier, however, would increase water infiltration through the cover by limiting evapotranspiration.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* Water infiltration would increase due to reduced evapotranspiration. A long-term increase in water infiltration may increase the potential for the release of contaminants such that regulatory limits are exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* A bio-intrusion barrier would be an effective deterrent to burrowing mammals and deep-rooted plants for as long as the barrier and ICs are maintained.

*Prevent or Limit Human Intrusion.* A barrier of resistant rock, such as granite or quartzite, along with ICs would be an effective deterrent to human intrusion.

#### 3.2.2.2 Implementability

*Constructibility.* Construction and logistical problems associated with deployment of a bio-intrusion barrier are minimal. The addition of soil to the existing landfill surface to bring the operational cover to a central crown and uniform grade presents minimal constructibility concerns. Added soil and the bio-intrusion barrier would be constructed using standard earth-moving and grading equipment. Materials for construction of the bio-intrusion barrier are readily available from off-site suppliers.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety risk for site workers is ranked low.

*Maintenance.* Long-term activities to ensure continued performance of the bio-intrusion barrier are minimal. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.2.3 Cost

Direct capital costs for the operational cover and bio-intrusion barrier alternative are $2,201,668. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.3 MWL Alternative III.b—Vegetative Soil Cover

Under this alternative, a vegetative soil cover of sufficient thickness to store precipitation and support a healthy vegetative community would be deployed on the existing landfill surface. The vegetative soil cover would be composed of multiple lifts of compacted soil to further isolate buried waste from the surface environment and to minimize infiltration of water. A topsoil layer, admixed with gravel, would be vegetated with native plants to mitigate surface erosion and to promote evapotranspiration. A cover constructed of compacted natural soil will perform with minimal maintenance by emulating the natural analogue ecosystem. The performance of vegetative covers and their analogues has been studied extensively and recommended for deployment in the arid and semi-arid environments of the western United States (Anderson 1997, Anderson and Forman 2002, and Hakonson 1997). This alternative is directly responsive to corrective action objectives as long as ICs are maintained. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.3.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. A vegetative soil cover of sufficient thickness to store precipitation and support a healthy vegetative community would extend the life of the operational cover, reduce water and wind erosion, and mitigate bio- and human intrusion into waste disposal cells, all of which reduce exposure risk to site workers, the public, and wildlife.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* A vegetative soil cover would be centrally crowned to promote surface run-off and prevent ponding and infiltration of water. The soil cover would function as a water reservoir, storing water until removed by evapotranspiration. The soil cover would provide sufficient storage capacity to provide protection against water infiltration and the release of contaminants such that regulatory limits are not exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* The addition of several feet of compacted fill on the operational cover would be an added deterrent to bio-intrusion into waste disposal cells for as long as the vegetative soil cover and ICs are maintained.

*Prevent or Limit Human Intrusion.* Construction of a vegetative soil cover on the operational cover would be an added deterrent to human intrusion into waste disposal cells for as long as the vegetative soil cover and ICs are maintained.

#### 3.2.3.2 Implementability

*Constructibility.* Construction and logistical problems associated with deployment of a vegetative soil cover are minimal. The addition of compacted fill to the existing landfill surface to bring the operational cover to a central crown and uniform grade presents minimal constructibility concerns. Compacted fill and the topsoil layer would be deployed using standard earth-moving, compaction, and grading equipment. Materials used to construct the barrier are readily available on site. Simplicity of construction is a major advantage of vegetative soil covers.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety risk for site workers is ranked low.

*Maintenance.* Long-term activities to ensure continued performance of the cover are minimal. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.3.3 Cost

Direct capital costs for the vegetative soil cover alternative are $1,953,501. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.4 MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier

Under this alternative, a bio-intrusion barrier composed of a layer of gravel and cobbles would be constructed on the existing landfill surface before deployment of a vegetative soil cover. Descriptions of the bio-intrusion barrier and the vegetative soil cover are presented in subsections 3.2.2 and 3.2.3, respectively. This alternative is directly responsive to corrective action objectives as long as ICs are maintained. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.4.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. A vegetative soil cover of sufficient thickness to store precipitation and support a healthy vegetative community and employing a bio-intrusion barrier at depth would further extend the life of the operational cover and mitigate bio- and human intrusion into waste disposal cells. This alternative further reduces the exposure risk to site workers, the public, and wildlife.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* Placing a gravel and cobble bio-intrusion barrier at the base of the vegetative soil cover would take added advantage of the capillary break effect at the gravel and cobble/existing landfill surface interface. A capillary break would further limit water infiltration and migration of contaminants to groundwater such that regulatory limits are not exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* A vegetative soil cover employing a bio-intrusion barrier at depth would provide additional protection against bio-intrusion into waste disposal cells without affecting the performance of the overlying soil cover as long as the vegetative soil cover and ICs are maintained. The gravel and cobble barrier would be the lower limit to which mammals could potentially penetrate the cover.

*Prevent or Limit Human Intrusion.* A vegetative soil cover employing a bio-intrusion barrier would be an added deterrent to human intrusion into waste disposal cells for as long as the vegetative soil cover and ICs are maintained.

#### 3.2.4.2 Implementability

*Constructibility.* Construction and logistical problems associated with the deployment of a vegetative soil cover employing a bio-intrusion barrier at depth are minimal. The addition of compacted fill to the existing landfill surface to bring the operational cover to a central crown and uniform grade, construction of the bio-intrusion barrier, and deployment of the vegetative soil cover would be accomplished by using standard earth-moving, compaction, and grading equipment. Materials for construction of the barrier are readily available from off-site suppliers. Materials for construction of the vegetative soil cover are readily available on site.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety risk for site workers is ranked low.

*Maintenance.* This alternative may increase the potential for wind and water erosion due to the increased area and elevation of the vegetative soil cover. The bio-intrusion barrier would add a minimum of 2 feet in finished elevation to the cover. Long-term activities to ensure continued performance of the cover and barrier are moderate. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.4.3 Cost

Direct capital costs for the vegetative soil cover with a bio-intrusion barrier alternative are $2,527,007. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.5 MWL Alternative III.d—RCRA Subtitle C Cap

Under this alternative, a RCRA Subtitle C cap would be deployed on the existing landfill surface. A minimum of three layers comprise a RCRA Subtitle C cap including: 1) an uppermost vegetation/soil layer, underlain by a minimum of 24 inches of compacted soil sloped between 3 and 5 percent; 2) a drainage layer composed of a minimum of 12 inches of sand underlain by a flexible membrane liner to convey water out of the cap; and 3) a lowermost moisture barrier with a minimum of 24 inches of compacted clay to prevent infiltration. The primary function of a RCRA Subtitle C cap is to limit water infiltration into waste disposal cells to minimize leachate that could migrate to groundwater. This alternative is directly responsive to Corrective Action Objectives 1, 3, and 4, and is generally responsive to Corrective Action

Objective 2. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.5.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. A RCRA Subtitle C cap would extend the life of the operational cover, reduce water and wind erosion, and mitigate bio- and human intrusion into waste disposal cells, all of which reduce exposure risk to site workers, the public, and wildlife.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* A RCRA Subtitle C cap would be centrally crowned to promote surface run-off and prevent ponding and infiltration of water. The uppermost vegetation/soil layer would function as a water reservoir, storing water until removed by evapotranspiration. The flexible membrane liner and compacted clay liner, however, may not perform as intended in arid and semi-arid environments in the long term. Flexible membrane liners are susceptible to soil instability, tension and shear failure (Allen April 2001, Hewitt and Phillip 1999). Compacted clay liners are susceptible to desiccation and shrinkage (Yesiller et al. 2000, Daniel and Wu 1993, EPA May 1991). Desiccation and shrinkage of the compacted clay liner may create conduits of preferential flow. Flow through the cap would increase the likelihood for the migration of contaminants to groundwater such that regulatory limits may be exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* The addition of several feet of compacted fill on the operational cover would be an added deterrent to bio-intrusion into waste disposal cells for as long as the RCRA Subtitle C cap and ICs are maintained.

*Prevent or Limit Human Intrusion.* Construction of a RCRA Subtitle C cap on the operational cover would be an added deterrent to human intrusion into waste disposal cells for as long as the vegetative soil cover and ICs are maintained.

#### 3.2.5.2 Implementability

*Constructibility.* Construction and logistical problems associated with deployment of a RCRA Subtitle C cap are moderate. Provisions for collection and disposal of water that would accumulate on the drainage layer may increase construction complexity and costs. Rigorous quality assurance and quality control measures would be required to properly seal overlapping sheets of flexible membrane liner and to prevent construction damage to the liner as overlying compacted soil is added. Meeting construction specifications for the compacted clay liner would increase construction costs moderately. Materials for construction of the barrier are readily available from off-site suppliers.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety risk for site workers is ranked low.

*Maintenance.* Performance of compacted clay and flexible membrane liners in dry climates is unknown in the long term. Activities to ensure continued performance of the structural and hydraulic integrity of the cap are moderate. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.5.3 Cost

Direct capital costs for the RCRA Subtitle C cap alternative are $2,850,872. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.6 MWL Alternative III.e—RCRA Subtitle C Cap with Bio-Intrusion Barrier

Under this alternative, a bio-intrusion barrier composed of a layer of gravel and cobbles would be included in the RCRA Subtitle C cap described in Section 3.2.5. The EPA recommends that a 3-foot barrier be placed between the vegetation/soil layer and the drainage layer. This alternative is directly responsive to Corrective Action Objectives 1, 3, and 4, and generally responsive to Corrective Action Objective 2. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.6.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. A RCRA Subtitle C cap employing a bio-intrusion barrier at depth would further extend the life of the operational cover and mitigate bio- and human intrusion into waste disposal cells. This alternative further reduces exposure risk to site workers, the public, and wildlife.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* A bio-intrusion barrier placed between the vegetation/soil layer and the drainage layer would displace the soil reservoir, decreasing the water storage capacity of the soil layer. A decrease in water storage capacity would increase water infiltration and drainage from the drainage layer. Increased lateral drainage and accumulation of water around the perimeter of the cap and subsequent infiltration would increase the potential for leachate formation and the migration of contaminants to groundwater such that regulatory limits may be exceeded.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* A RCRA Subtitle C cap employing a bio-intrusion barrier would provide added protection against bio-intrusion into waste disposal cells as long as the cap and ICs are maintained.

*Prevent or Limit Human Intrusion.* A RCRA Subtitle C cap employing a bio-intrusion barrier would be an added deterrent to human intrusion into waste disposal cells for as long as the cap and ICs are maintained.

#### 3.2.6.2 Implementability

*Constructibility.* Construction and logistical problems associated with deployment of a RCRA Subtitle C cap with a bio-intrusion barrier are moderate. Provision for the bio-intrusion barrier and for collection and disposal of water that would accumulate on the drainage layer would increase construction costs and complexity. Additional soil would need to be added to the vegetation/soil layer to compensate for the loss of water storage capacity. Materials for construction of the barrier are readily available from off-site suppliers.

*Health and Safety.* Health and safety concerns for site workers are minimal. There would be no intrusive activities at the site. No potential for exposure to waste exists. Health and safety for site risk workers is ranked low.

*Maintenance.* This alternative would increase the potential for wind and water erosion due to the increased area and elevation of the finished cap. The bio-intrusion barrier would add 3 feet in elevation to the cap. Long-term activities to ensure continued performance of the cap and barrier are moderate. Surveillance for erosion, intrusion, and trespass would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.6.3 Cost

Direct capital costs for the RCRA Subtitle C cap with a bio-intrusion barrier alternative are $3,636,474. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.7 MWL Alternative V.a—Complete Excavation with Aboveground Retrievable Storage

Under this alternative, the landfill would be excavated and the wastes would be placed into permanent, on-site, aboveground, retrievable storage facilities. Secure, high-bay warehouses for processing and storage of classified and unclassified waste would be built on site, adjacent to the landfill, to minimize handling and transportation logistics and cost. A conceptual layout of on-site facilities is shown in Figures 3-1 and 3-2. This alternative is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. This alternative is directly responsive to Corrective Action Objectives 2, 3, and 4. Excavation removes the waste from existing underground disposal cells but transfers the risk to aboveground storage facilities. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.7.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses significant exposure risk to site workers, the public, and wildlife. Personal protective equipment (PPE) would not be effective against radioactive materials exposure during excavation and transport due to penetrating gamma radiation. Fugitive emissions may be generated during excavation that would pose health and safety risks to on- and off-site receptors.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* This alternative would eliminate the potential for migration of contaminants to groundwater by removing wastes from disposal cells.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* This alternative would eliminate the potential for biological intrusion into buried waste and any resulting release and redistribution of contaminants to potential receptors by removing wastes from disposal cells.

*Prevent or Limit Human Intrusion.* This alternative would eliminate the potential for human intrusion into buried waste by removing wastes from disposal cells. The on-site warehouses for processing and storage of classified and unclassified waste would have to be secured to prevent unauthorized entry.

#### 3.2.7.2 Implementability

*Constructibility.* Construction and logistical problems associated with excavation and aboveground retrievable storage are significant. Appropriate time, distance, and shielding to protect site workers from exposure to penetrating gamma radiation will require the use of remote handling and/or robotic equipment during excavation, sorting, segregation, and stockpiling of waste. All materials removed from the landfill would be considered mixed waste until properly characterized. Characterization, containerization, transport, and storage of waste also may require the use of remote handling and/or robotic equipment to protect site workers from radioactive materials exposure. Despite the use of remote handling and/or robotic equipment, site workers will remain at risk for exposure. Remote/robotic inspection, sorting, and sampling of waste may be necessary to separate mixed waste into its various radioactive and hazardous components. The use of remote handling and/or robotic equipment would significantly increase excavation and characterization costs, complexity, and logistics. Excavation of the classified area would require separate, secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, transport, and storage. Different waste streams will present different implementability concerns and restrictions. Some waste streams may not have viable disposal solutions other than on-site, long-term storage. On-site characterization of hazardous and mixed waste may take 10 to 20 years. Regulations would limit the duration of storage of hazardous and mixed waste and pretreatment of waste may be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. Operating permits would be required for potential treatment of waste and permanent, on-site storage of waste.

*Health and Safety.* Excavation and characterization of waste presents serious health and safety concerns for site workers. Adequate time, distance, and shielding and remote handling and/or robotic equipment would be necessary to mitigate health and safety issues due to the high dose rates associated with exposure to radioactive waste (e.g., calculations for the Co-60 sources in SP-5 would be on the order of 3.5 Ci each after 42 years decay that would result in exposure rates of around 57 Roentgen per hour [R/hr] at 1 foot for each source or 700 R/hr at 1 foot for all 12 sources. On contact, acute dose rates would be hundreds of R/hr higher resulting in lethal doses to site workers). Fugitive emissions to on-site receptors would have to be controlled. Health and safety risk for site workers is ranked high.

*Maintenance.* Long-term activities to maintain the security and structural and hydraulic integrity of the warehouses for storage of classified and unclassified waste are moderate. Surveillance would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.7.3 Cost

Direct capital costs for two waste disposition options were developed for the Complete Excavation with Aboveground Retrievable Storage alternative. Option A assumes that all soil and waste will be stored on site in high-bay warehouses. Option B assumes only waste will be stored on site in high-bay warehouses; the soil, including tritium-contaminated soil, will be returned to the excavation as backfill. A conceptual layout of on-site facilities for Options A and B is shown in Figures 3-1 and 3-2, respectively. Direct costs for Option A are $545,620,660. Direct costs for Option B are $416,018,751. Costs for remote handling and/or robotic equipment were applied to excavation of the classified area only (Appendix D). The cost breakdown for individual excavation alternatives is provided in Table 3-3. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.8 MWL Alternative V.b—Complete Excavation with Off-Site Disposal

Under this alternative, the landfill would be excavated and the waste would be shipped to an off-site, licensed facility for disposal. Secure, high-bay warehouses for processing and temporary storage of classified and unclassified waste would be built on site, adjacent to the landfill, to minimize handling and transportation logistics and cost. A conceptual layout of on-site facilities is shown in Figure 3-3. This alternative is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. This alternative is directly responsive to Corrective Action Objectives 2, 3, and 4. Excavation removes the waste from existing underground disposal cells but transfers the risk to another site. Transportation to an off-site disposal facility greatly impacts costs and increases accident and exposure risk to the public. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.8.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses significant exposure risk to site workers, the public, and wildlife. PPE would not be effective against exposure to radioactive materials during excavation and transport because of penetrating gamma radiation. Fugitive emissions may be generated during excavation that would pose health and safety risks to on- and off-site receptors.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* This alternative would eliminate the potential for migration of contaminants to groundwater by removing buried wastes from disposal cells.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* This alternative would eliminate the potential for biological intrusion into buried waste and any resulting release and redistribution of contaminants to potential receptors.

*Prevent or Limit Human Intrusion.* This alternative would eliminate the potential for human intrusion into buried waste. The on-site warehouses for processing and temporary storage of classified and unclassified waste would have to be secured to prevent unauthorized entry.

#### 3.2.8.2 Implementability

*Constructibility.* Construction and logistical problems associated with excavation and off-site disposal are significant. Appropriate time, distance, and shielding to protect site workers from exposure to penetrating gamma radiation will require the use of remote handling and/or robotic equipment during excavation, sorting, segregation, and stockpiling of waste. All materials removed from the landfill would be considered mixed waste until properly characterized. Characterization, containerization, transport, and temporary storage of waste also may require the use of remote handling and/or robotic equipment to protect site workers from radioactive materials exposure. Exposure risk to site workers will remain despite the use of remote handling and/or robotic equipment. Remote/robotic inspection, sorting, and sampling of waste may be necessary to separate mixed waste into its radioactive and hazardous components. The use of remote handling and/or robotic equipment would increase excavation and characterization costs, complexity, and logistics significantly. Excavation of the classified area would require separate, secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, transport, and temporary storage. Different waste streams will present different implementability concerns and restrictions. Some waste streams may not have viable disposal solutions other than on-site, long-term storage. On-site characterization of hazardous and mixed waste may take 10 to 20 years. Regulations would limit the duration of storage of hazardous and mixed waste. Operating permits would be required for treatment of waste if pretreatment of waste is required before shipment. Transportation of waste to an off-site facility must be in compliance with U.S. Department of Transportation (DOT) regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria.

*Health and Safety.* Excavation and characterization presents serious health and safety concerns for site workers. Adequate distance and shielding or remote handling and/or robotic equipment will be necessary to mitigate health and safety issues due to the high dose rates associated with exposure to radioactive waste (e.g., calculations show that radiation from Co-60 sources in SP-5 would be on the order of 3.5 Ci per source after 42 years of decay and would result in exposure rates of 57 R/hr at 1 foot per source or 700 R/hr at 1 foot for all 12 sources. On contact, acute dose rates would be hundreds of R/hr higher resulting in a lethal dose). Fugitive emissions to receptors would have to be controlled. Health and safety risk for site workers is ranked high.

*Maintenance.* Long-term activities to maintain the security and structural and hydraulic integrity of the warehouses for temporary storage of classified and unclassified waste are moderate. Surveillance would be conducted on a routine basis and maintenance performed as warranted.

#### 3.2.8.3 Cost

Direct capital costs for two waste disposition options were developed for the Complete Excavation with Off-Site Disposal alternative. Option A assumes that all soil and waste will be transported to an off-site disposal facility immediately following on-site processing. Option B assumes only waste will be transported to an off-site disposal facility immediately following on-site processing; the soil, including tritium-contaminated soil, will be returned to the excavation as backfill. A conceptual layout of on-site facilities for Options A and B is shown in Figure 3-3. Direct costs for Option A are $702,088,516. Direct costs for Option B are $579,110,303. Costs for remote handling and/or robotic equipment were applied to excavation of the classified area only (Appendix D). The cost breakdown for individual excavation alternatives is provided in Table 3-3. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.9 MWL Alternative V.c—Partial Excavation with Aboveground Retrievable Storage

Under this alternative, the landfill would be partially excavated, which would entail excavation of the classified area only. The excavated waste would be placed into permanent, aboveground retrievable storage facilities. The unclassified area would have to be addressed with additional remedial measures such as containment or stabilization. Secure, high-bay warehouses for processing and storage of classified waste would be built on site, adjacent to the landfill, to minimize handling and transportation logistics and costs. A conceptual layout of on-site facilities is shown in Figures 3-4 and 3-5. This alternative is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. This alternative is directly responsive to Corrective Action Objectives 2, 3, and 4. Partial excavation removes the waste from existing underground disposal cells but transfers the risk to aboveground storage facilities. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.9.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses significant exposure risk to site workers, the public, and wildlife. PPE would not be effective against exposure to radioactive materials during excavation and transport because of penetrating gamma radiation. Fugitive emissions may be generated during excavation that would pose health and safety risks to on- and off-site receptors.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* This alternative would eliminate the potential for migration to groundwater of contaminants from classified area disposal cells. Migration from unclassified area disposal cells would need to be addressed with additional remedial measures.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* This alternative would eliminate the potential for biological intrusion into classified area waste and any resulting release and redistribution of contaminants to potential receptors by removing wastes from the classified area disposal cells. Biological intrusion into unclassified area disposal cells would need to be addressed with additional remedial measures.

*Prevent or Limit Human Intrusion.* This alternative would eliminate the potential for human intrusion into buried wastes by removing wastes from the classified area disposal cells. Human intrusion into unclassified area disposal cells as well as into aboveground retrievable storage would need to be addressed with additional measures.

#### 3.2.9.2 Implementability

*Constructibility.* Construction and logistical problems associated with partial excavation are significant. Appropriate time, distance, and shielding to protect site workers from exposure to penetrating gamma radiation will require the use of remote handling and/or robotic equipment during excavation, sorting, segregation, and stockpiling of waste. All materials removed from the classified area would be considered mixed waste until properly characterized. Characterization, containerization, and transport of waste also may require the use of remote handling and/or robotic equipment to protect site workers from radioactive materials exposure. Exposure risk to site workers will remain despite the use of remote handling and/or robotic equipment. Remote/robotic inspection, sorting, and sampling of waste may be necessary to separate mixed waste into its radioactive and hazardous components. The use of remote handling and/or robotic equipment would significantly increase excavation and characterization costs, complexity, and logistics. Excavation of the classified area would require secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, transport, and storage. Different waste streams will present different implementability concerns and restrictions. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment of waste may be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. On-site characterization of hazardous and mixed waste may take up to 10 years. Operating permits would be required for treatment of waste if pretreatment is required before storage. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization.

*Health and Safety.* Partial excavation and characterization presents serious health and safety concerns for site workers. Adequate distance and shielding or remote handling and/or robotic equipment will be necessary to mitigate health and safety issues due to the high dose rates associated with exposure to radioactive waste (e.g., calculations show that radiation from Co-60 sources in SP-5 would be on the order of 3.5 Ci per source after 42 years of decay and would result in exposure rates of 57 R/hr at 1 foot per source or 700 R/hr at 1 foot for all 12 sources. On contact, acute dose rates would be hundreds of R/hr higher resulting in a lethal dose). Fugitive emissions to receptors would have to be controlled. Health and safety risk for site workers is ranked high.

*Maintenance.* Long-term activities to maintain the security and structural and hydraulic integrity of the warehouses for classified waste storage are moderate. Surveillance would be conducted on a routine basis, and maintenance performed as warranted.

### 3.2.9.3 Cost

Direct capital costs for two waste disposition options were developed for the Partial Excavation with Aboveground Retrievable Storage alternative. Option A assumes that all classified area soil and waste will be stored on site in high-bay warehouses. Option B assumes only waste will be stored on site in high-bay warehouses; the soil, including tritium-contaminated soil, will be returned to the excavation as backfill. A conceptual layout of on-site facilities for Options A and B is shown in Figures 3-4 and 3-5, respectively. Direct costs for Option A are $139,718,215. Direct costs for Option B are $103,569,857. Costs for remote handling and/or robotic equipment were applied to excavation of the classified area (Appendix D). The cost breakdown for individual excavation alternatives is provided in Table 3-3. Estimated costs for all alternatives are provided in Table 3-2.

## 3.2.10 MWL Alternative V.d—Partial Excavation with Off-Site Disposal

Under this alternative, the landfill would be partially excavated, which would entail excavation of the classified area and shipment of waste to an off-site, licensed facility for disposal. The unclassified area would have to be addressed with additional remedial measures such as containment or stabilization. Secure, high-bay warehouses for processing and temporary storage of classified waste would be built on site, adjacent to the landfill, to minimize handling and transportation logistics and costs. A conceptual layout of on-site facilities is shown in Figure 3-6. This alternative is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. This alternative is directly responsive to Corrective Action Objectives 2, 3, and 4. Partial excavation removes the waste from existing underground disposal cells but transfers the risk to another site. Transportation to an off-site disposal facility greatly impacts costs and increases accident and exposure risk to the public. The effectiveness, implementability, and cost of this alternative are discussed below.

### 3.2.10.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses significant exposure risk to site workers, the public, and wildlife. PPE would not be effective against exposure to radioactive materials during excavation and transport because of penetrating gamma radiation. Fugitive emissions may be generated during excavation that would pose health and safety risks to on- and off-site receptors.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* This alternative would eliminate the potential for migration to groundwater of contaminants from classified area disposal cells. Migration from unclassified area disposal cells would need to be addressed with additional remedial measures.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* This alternative would eliminate the potential for biological intrusion into classified area waste and any resulting release and redistribution of contaminants to potential receptors by removing wastes from classified area disposal cells. Biological intrusion into unclassified area disposal cells would need to be addressed with additional remedial measures.

*Prevent or Limit Human Intrusion.* This alternative would eliminate the potential for human intrusion into buried waste by removing wastes from classified area disposal cells. Human intrusion into unclassified area disposal cells would need to be addressed with additional remedial measures.

### 3.2.10.2 Implementability

*Constructibility.* Construction and logistical problems associated with partial excavation are significant. Appropriate time, distance, and shielding to protect site workers from exposure to penetrating gamma radiation will require the use of remote handling and/or robotic equipment during excavation, sorting, segregation, and stockpiling of waste. All materials removed from the classified area would be considered mixed waste until properly characterized. Characterization, containerization, and transport of waste also may require the use of remote handling and/or robotic equipment to protect site workers from exposure to radioactive materials. Exposure risk to site workers will remain despite the use of remote handling and/or robotic equipment. Remote/robotic inspection, sorting, and sampling of waste may be necessary to separate mixed waste into its radioactive and hazardous components. The use of remote handling and/or robotic equipment would significantly increase excavation and characterization costs, complexity, and logistics. Excavation of the classified area would require separate, secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, transport, and temporary storage. Different waste streams will present different implementability concerns and restrictions. Some waste streams may not have viable disposal solutions other than on-site, long-term storage. On-site characterization of hazardous and mixed waste may take up to 10 years. Operating permits would be required for treatment of waste if pretreatment is required before shipment. Regulations would limit the duration of storage of hazardous and mixed waste. Transportation of waste to an off-site facility must be in compliance with DOT regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization.

*Health and Safety.* Partial excavation and characterization presents serious health and safety concerns for site workers. Adequate distance and shielding or remote handling and/or robotic equipment may be necessary to mitigate health and safety issues due to the high dose rates associated with exposure to radioactive waste (e.g., calculations show that radiation from Co-60 sources in SP-5 would be on the order of 3.5 Ci per source after 42 years of decay and would result in exposure rates of 57 R/hr at 1 foot per source or 700 R/hr at 1 foot for all 12 sources. On contact, acute dose rates would be hundreds of R/hr higher resulting in a lethal dose). Fugitive emissions to receptors would have to be controlled. Health and safety risk for site workers is ranked high.

*Maintenance.* Long-term activities to maintain the security and structural and hydraulic integrity of the warehouses for temporary storage of classified waste are moderate. Surveillance would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.10.3 Cost

Direct capital costs for two waste disposition options were developed for the Partial Excavation with Off-Site Disposal alternative. Option A assumes that all soil and waste will be transported to an off-site disposal facility immediately following on-site processing. Option B assumes only waste will be transported to an off-site disposal facility immediately following on-site processing; the soil, including tritium-contaminated soil, will be returned to the excavation as backfill. A conceptual layout of on-site facilities for Options A and B is shown in Figure 3-6. Direct costs for Option A are $157,360,724. Direct costs for Option B are $116,638,183. Costs for remote handling and/or robotic equipment were applied to excavation of the classified area (Appendix D). The cost breakdown for individual excavation alternatives is provided in Table 3-3. Estimated costs for all alternatives are provided in Table 3-2.

### 3.2.11 MWL Alternative V.e—Future Excavation

Under this alternative, the landfill would be completely excavated at some future date. Future excavation would entail shipment of waste to an off-site, licensed facility for disposal. Secure, high-bay warehouses for processing and storage of classified and unclassified waste would be built on site, adjacent to the landfill, to minimize handling and transportation logistics and costs. A conceptual layout of on-site facilities is shown in Figure 3-7. This alternative is directly responsive to corrective action objectives. The effectiveness, implementability, and cost of this alternative are discussed below.

#### 3.2.11.1 Effectiveness

*Minimize Exposure to Site Workers, the Public, and Wildlife.* This alternative poses little exposure risk to site workers, the public, and wildlife. Total radionuclide activity will have decayed to safer levels (Figure 3-8 demonstrates the significant reduction in total radionuclide activity in the MWL inventory in the future). Fugitive emissions may be generated during excavation that pose health and safety risks to on- and off-site receptors.

*Limit Migration of Contaminants to Groundwater Such That Regulatory Limits Are Not Exceeded.* This alternative would eliminate the potential for migration of contaminants to groundwater by removing wastes from disposal cells.

*Minimize Biological Intrusion into Buried Waste and Any Resulting Release and Redistribution of Contaminants to Potential Receptors.* This alternative would eliminate the potential for biological intrusion into buried waste and any resulting release and redistribution of contaminants to potential receptors.

*Prevent or Limit Human Intrusion.* This alternative would eliminate the potential for human intrusion into buried waste.

#### 3.2.11.2 Implementability

*Constructibility.* Construction and logistical problems associated with future excavation are significant. Excavation and characterization would not require the use of remote handling and/or robotic equipment to protect site workers from exposure to radioactive materials because of the reduction in radioactivity through natural decay (Figure 3-8). The waste removed from the landfill would be considered mixed waste until properly characterized. Excavation of the classified area would require separate, secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, transport, and temporary storage. Different waste streams will present different implementability concerns and restrictions. Some waste streams may not have viable disposal solutions other than on-site, long-term storage. Operating permits to accumulate and characterize hazardous and mixed waste on site may be required from the NMED. Additional operating permits may be required for treatment of waste if pretreatment is required before storage and/or shipment. Future regulations may limit the duration of storage of hazardous and mixed waste, and pretreatment of waste may be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. Transportation of waste to an off-site facility must be in compliance with DOT regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. Some wastes may not have a disposal path.

*Health and Safety*. Excavation and characterization presents moderate health and safety concerns for site workers. Fugitive emissions to receptors would have to be controlled. Health and safety risk for site workers is ranked medium.

*Maintenance.* Long-term activities to maintain the security and structural integrity of warehouses for storage of classified and unclassified waste are moderate. Surveillance would be conducted on a routine basis, and maintenance performed as warranted.

#### 3.2.11.3 Cost

Direct capital costs for the Future Excavation alternative are $235,603,841. Costs for shipment of waste to an off-site, licensed facility for disposal are included. A conceptual layout of on-site facilities is shown in Figure 3-7. Estimated costs for all alternatives are provided in Table 3-2. The cost breakdown for the individual excavation alternatives is provided in Table 3-3.

## 3.3 Alternatives Development—Summary

Development of corrective measures alternatives using individual technologies or various combinations of technologies resulted in the selection of four candidate corrective measures that are suitable for the site. The alternative development process discussed in this chapter eliminates three types of alternatives: 1) those that do not provide adequate protection of human health and the environment; 2) those that are not implementable; and 3) those that are clearly more costly without providing significantly greater protection. Remedies that prevent or limit future migration of contaminants from landfill waste disposal cells can be implemented quickly and easily with less difficulty, and cost less without sacrificing protection of human health and the environment are preferred. The alternative development evaluation criteria summary is presented in Table 3-4.

Based upon the evaluation criteria, the four corrective measures alternatives listed below were determined to be suitable for the MWL:

- Alternative I.a—NFA with ICs
- Alternative III.b—Vegetative Soil Cover
- Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier
- Alternative V.e—Future Excavation

These alternatives are carried forward to Chapter 4.0 for detailed evaluation.

Although these four corrective measures alternatives are evaluated individually in Chapter 4, these alternatives can be combined to formulate additional corrective measures for the landfill. For example, III.b and V.e can be combined readily by taking individual evaluations provided in Chapter 4 and placing them in series depending on projected need. When one combines III.b and V.e, the resulting corrective measure for the MWL would be short-term remediation employing a vegetative soil cover with long-term remediation employing complete excavation.

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# 4. Evaluation of Corrective Measures Alternatives

The development of corrective measures alternatives in Chapter 3.0 resulted in the selection of four candidate alternatives for detailed evaluation based upon EPA and NMED guidance, including the SNL/NM HSWA Permit (NMED September 1997), and the 1996 Subpart S Initiative (EPA May 1996). The evaluations conducted in this detailed analysis build upon previous analyses conducted during the development of alternatives in Chapter 3.0 and incorporate additional risk assessment for each of the four candidate alternatives.

## 4.1 Alternative Evaluation—Overview

The alternatives considered suitable for the site in Table 3-4 are systematically considered in this final, detailed evaluation of corrective measures alternatives for the MWL. Several key concepts that must be considered in reviewing the alternatives evaluated in this chapter are discussed below.

- ICs are a component in all candidate alternatives. ICs include all three measures described in Table 2-1 (i.e., long-term monitoring, long-term site surveillance and maintenance, and long-term access controls). In evaluating alternatives, it is assumed that some form of ICs will be maintained at the MWL for the next 100 years, which is the longest period of time that active ICs can be relied upon for purposes of conducting performance assessment (NRC 10 CFR 61 2002). This is a reasonable assumption given that the MWL is located in TA-3, a remote area of SNL/NM that the DOE or another federal entity will control for the foreseeable future.

- As long as the operational cover is maintained and ICs are in place, CMS corrective action objectives are satisfied.

- Groundwater monitoring is an integral part of long-term stewardship and will continue at the MWL for the foreseeable future (Goering et al. December 2002, SNL/NM August 2001).

The four candidate alternatives considered suitable for the site in Chapter 3.0 and carried forward for detailed evaluation are listed below.

- Alternative I.a—NFA with ICs
- Alternative III.b—Vegetative Soil Cover
- Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier
- Alternative V.e— Future Excavation

Detailed evaluation is used to determine which candidate alternative developed in Chapter 3.0 will be recommended for remedial action of the MWL in Chapter 5.0. Five evaluation criteria are considered appropriate by the EPA and the NMED in selecting an alternative that represents a technology or combination of technologies that address the environmental issues at the site. The five evaluation criteria are as follows:

1. Long-term reliability and effectiveness
2. Reduction of toxicity, mobility, or volume of wastes
3. Short-term effectiveness
4. Implementability
5. Cost

The following sections describe how these evaluation criteria are employed in this CMS.

## 4.2 Description of Evaluation Criteria for Detailed Analysis

The order of the evaluation criteria listed above is not intended to establish an implicit ranking, nor does it suggest the relative importance each criterion might have at the site. There are circumstances in which any given criterion might receive particular weight (e.g., long-term effectiveness may rule out alternatives that might achieve remedial goals in the short term, but at the expense of creating new or greater future risks that may necessitate a future corrective action). Conversely, alternatives that significantly reduce potential or actual human exposure in the short term may be preferred over alternatives that eliminate long-term risks, but at the cost of lengthening the period during which potential exposure exists. A general description of the five criteria and how they will be used in alternative selection is provided in the following sections.

### 4.2.1 Long-Term Reliability and Effectiveness

Each candidate alternative was evaluated for long-term reliability and effectiveness. This factor includes consideration of the level of risk that will remain after implementation of the alternative, the extent of long-term monitoring and other management controls that will be required after implementation of the alternative, the uncertainties associated with leaving hazardous waste in place, and the potential for failure of the alternative. An alternative that reduces risk with little long-term management and that has proven effective under similar conditions is preferred by the EPA and the NMED.

### 4.2.2 Reduction of Toxicity, Mobility, or Volume of Wastes

Each candidate alternative was evaluated for its reduction in toxicity, mobility, and volume of hazardous waste and hazardous constituents. An alternative that incorporates treatment to more completely and permanently reduce the toxicity, mobility, and volume of hazardous waste and constituents is preferred by the EPA and the NMED.

### 4.2.3 Short-Term Effectiveness

Each candidate alternative was evaluated for its short-term effectiveness. This factor includes consideration of the short-term reduction in existing risk that the alternative would achieve; the time needed to achieve that reduction; and the potential short-term risks to the community, site workers, and the environment during implementation of the alternative. An alternative that quickly reduces short-term risk without creating significant additional risk is preferred by the EPA and the NMED.

### 4.2.4 Implementability

Each candidate alternative was evaluated for its implementability, or the difficulty of implementing the alternative. This factor includes consideration of installation and construction difficulties; operation and maintenance difficulties; difficulties with cleanup technology(ies); permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. An alternative that can be implemented quickly and easily while posing lesser difficulty is preferred by the EPA and the NMED.

### 4.2.5 Cost

Each candidate alternative was evaluated for cost, which included capital costs and operation and maintenance costs. Capital costs consisted of construction and installation costs; equipment costs; and indirect costs including engineering costs, legal fees, permitting fees, start-up and shakedown costs; and contingency allowances. Operation and maintenance costs were estimated for 30 years only and include operating labor and material costs, maintenance labor and material costs, replacement costs, utilities, monitoring and reporting costs, administrative costs, indirect costs, and contingency allowances. A 30-year period was selected due to software limitations and to be compatible with long-term groundwater monitoring cost projections. All costs were calculated on their net present value. An alternative that is less costly but does not sacrifice protection of human health and the environment is preferred by the EPA and the NMED.

The costs for a given alternative in Chapter 3.0 will differ from costs for the same alternative in Chapter 4.0. This difference is due to the type of assumptions and the depth of analysis for each given alternative. For example, Chapter 3.0 includes direct costs for conceptual designs whereas Chapter 4.0 includes direct and indirect costs for actual designs.

## 4.3 Alternatives Evaluation—Application

Candidate alternatives for the MWL were evaluated using the criteria listed in Section 4.2. Alternative evaluation is depicted in Table 4-1. In the table, candidate alternatives are shown as column headings with the alternative number and description. Evaluation criteria are provided as row headings. Evaluation is provided for each candidate alternative in text format directly below each alternative. The alternatives depicted in Table 4-1 are evaluated sequentially in the following sections based upon the five evaluation criteria outlined in Section 4.2. ICs are not shown in Table 4-1 because they are implicit in all candidate alternatives. NFA with No ICs is not included in this chapter for detailed evaluation; however, this alternative is used as the baseline for risk assessment analysis and is included in Table 4-2 and Appendix E.

### 4.3.1 MWL Alternative I.a—NFA with ICs

Under this candidate alternative, the operational cover would be maintained and current ICs and groundwater monitoring would continue. Additional soil would be used to bring the landfill surface to a central crown and uniform grade to prevent ponding and promote surface runoff. A schematic of the NFA with ICs alternative is shown in Figure 4-1.

There would be no intrusive activities at the site. No potential for exposure to the buried waste exists. This alternative poses minimal risk to site workers implementing ICs associated with both groundwater monitoring and routine maintenance and surveillance of the site.

#### 4.3.1.1 Long-Term Reliability and Effectiveness

The magnitude of risk remaining after implementation of this alternative in terms of potential exposure to COCs to a human receptor is quantified as a hazard index (HI) of 0.00 and an excess cancer risk of 1E-9 for an industrial land use scenario (Table 4-1). The HI is a measure of potential noncarcinogenic adverse effects from exposure to COCs. This alternative's risk compares to an HI of 0.07 and an excess cancer risk of 3E-6 for the risk baseline NFA with No ICs. The NMED guideline is 1 and 1E-5 for the HI and excess cancer risk, respectively. Therefore, the long-term risk associated with this alternative is below NMED guidelines. Detailed risk assessment and summary tables are provided in Appendix E.

For radiological COCs and an industrial land use scenario, the incremental TEDE is 3.3E-1 mrem/yr, which is below the EPA guideline of 15 mrem/yr. The estimated excess cancer risk associated with radionuclides is 2.2E-6. The baseline risk that can be attributed to radiological COCs is the same. Based upon an uncertainty analysis, ecological risk is very low. The NMED guideline is a hazard quotient (HQ) of 1. HQs greater than 1 were originally predicted for barium at the landfill; however, closer examination of the exposure assumptions revealed an overestimation of risk primarily attributed to exposure concentration and background risk. The total radiation dose rates are predicted to be 1.6E-3 rad/day for the deer mouse and 1.6E-3 rad/day for the burrowing owl. The dose rates for the deer mouse and the burrowing owl are considerably less than the NMED guideline and the corrective action objective for a dose of 0.1 rad/day to wildlife.

The uncertainty associated with keeping the waste in place in the landfill disposal cells is low. The determination of the nature, rate, and extent of contamination is based upon an initial conceptual model validated with extensive, multimedia sampling (SNL/NM March 1993, Peace et al. September 2002). There is low uncertainty in the land use scenario and the potentially affected populations. The parameter values used in the calculations are conservative and the calculated intakes are likely to be overestimated. Toxicological parameter values were taken from EPA national and regional databases. The overall uncertainty in all of the steps in the risk assessment process is considered insignificant with respect to the conclusion reached.

ICs, such as access and deed restrictions, would be used when appropriate to supplement the engineering controls for short- and long-term management of the MWL to prevent or limit exposure to wastes and to ensure the effectiveness of this alternative. Existing access restrictions would remain in place for a minimum of 100 years to limit human access and inadvertent human intrusion.

Long-term monitoring activities to ensure continued performance of the operational cover would include surveillance for erosion, intrusion, and trespass. These activities would be conducted on a routine basis (e.g., quarterly) and maintenance performed as warranted. Groundwater and tritium in surface soil and vegetation would continue to be monitored on an annual basis for the foreseeable future.

The potential for failure of this alternative is very low. The existing landfill surface has actually aggraded over the last 30 years, increasing in thickness, due to the accumulation of wind-blown sand. ICs will ensure the effectiveness of the operational cover. Although the MWL is located in a TA over which the DOE expects to maintain control indefinitely, there is some uncertainty as to the ability to maintain ICs over the long term. Review of the site and monitoring data at five-year intervals under stewardship will reduce the uncertainty associated with the long-term effectiveness and permanence of ICs. If this alternative fails to perform effectively, corrective action will be taken to meet remedial goals.

If ICs are relinquished, the remaining risk posed by the buried waste in the landfill disposal cells would increase. However, the operational cover has been effective during the past 30 years with minimal maintenance and is expected to limit water infiltration and mitigate bio-intrusion well into the future. ICs implemented in 1959 have effectively restricted human access and prevented inadvertent human intrusion and are unlikely to be relinquished in the future due to DOE land use projections. The long-term reliability (up to 1000 years) of the operational cover has not been demonstrated; however, this alternative will require minimal maintenance and retain its effectiveness by taking advantage of native soils and plants and natural hydrologic processes.

#### 4.3.1.2 Reduction of Toxicity, Mobility, or Volume

This candidate alternative does not include any waste treatment options, which are limited for low-level radioactive and mixed waste. As such, this alternative does not reduce waste toxicity or volume. Overall reduction of toxicity will occur over time through radioactive decay (Figure 3-8). The mobility of radioactive and mixed waste will be minimized by limiting water infiltration, bio-intrusion, human access, and inadvertent human intrusion.

#### 4.3.1.3 Short-Term Effectiveness

The reduction in short-term risk is expressed as an incremental HI of 0.07 and an incremental excess cancer risk of 3.31E-6 for nonradiological COCs under an industrial land use scenario. For radiological COCs and an industrial land use scenario, the incremental TEDE remains unchanged under this criterion as do the ecological risks. The time required to implement this alternative and achieve the reduction in risk is one month. Short-term risks for implementing this alternative include potential injuries and fatalities associated with transportation and remediation. The transportation injuries and fatalities are predicted to be 1.8E-2 and 4.9E-4, respectively. Implementation injuries and fatalities (including long-term monitoring) are predicted to be 9.5E-2 and 2.4E-3, respectively. Determination of injury and fatality rates is provided in Appendix E.

#### 4.3.1.4 Implementability

This candidate alternative poses no administrative or technical implementation challenges. Construction and logistical problems associated with improving and maintaining the operational cover are insignificant. The addition of soil to the existing landfill surface to bring the operational cover to a central crown presents minimal constructibility concerns. Soil would be added using standard earth-moving and grading equipment. The integrity and performance of the operational soil cover can be easily monitored. Soil for maintaining the operational cover is readily available on site.

#### 4.3.1.5 Cost

Capital and operation and maintenance costs for the NFA with ICs alternative are $1,772,882. Estimated capital and operation and maintenance costs for all alternatives are provided in Table 4-3.

### 4.3.2 MWL Alternative III.b—Vegetative Soil Cover

Under this candidate alternative, a vegetative soil cover comprised of multiple lifts of compacted soil would be deployed on the existing landfill surface to isolate buried waste from the surface environment and to further minimize infiltration of water. A topsoil layer, admixed with gravel, would be vegetated with native plants to promote transpiration and to mitigate wind and water erosion. A cover constructed of natural soil would perform with minimal maintenance by emulating the natural analogue ecosystem. A schematic of the Vegetative Soil Cover alternative is shown in Figure 4-2.

This alternative involves minimal intrusive activities at the site. No potential for exposure to waste exists. There would be minimal risk to site workers implementing ICs associated with both groundwater monitoring and routine maintenance and surveillance of the site.

#### 4.3.2.1 Long-Term Reliability and Effectiveness

The magnitude of the risk remaining after implementation of this alternative in terms of potential exposure to COCs to a human receptor is qualified as both an HI and an excess cancer risk that approaches zero for an industrial land use scenario. The addition of approximately 5 feet of compacted fill would eliminate pathways between the contaminant source and the human receptor. The present risk is an HI of 0.07 and an excess cancer risk of 3E-6. The NMED guideline is 1 and 1E-5 for the HI and excess cancer risk, respectively. Therefore, the long-term risk associated with this alternative is below NMED guidelines. Detailed risk assessment and summary tables are provided in Appendix E.

For radiological COCs and an industrial land use scenario, the incremental TEDE is 2.4E-5 mrem/yr, which is below the EPA guideline of 15 mrem/yr. The estimated excess cancer risk associated with radionuclides is 3.4E-10. The baseline risk that can be attributed to radiological COCs is 3.3E-1 mrem/yr and 2.2E-6 for the TEDE and excess cancer risk, respectively. The ecological risks are very low. NMED guidelines for conducting ecological risk assessments at SNL/NM limits the effective depth to which ecological receptors burrow or root to reach source contamination to 5 feet bgs. The combined thickness of the operational and vegetative soil covers exceeds 5 feet, thus eliminating ecological pathways and reducing the risk to 0.

The uncertainty associated with keeping the waste in landfill disposal cells is low. The determination of the nature, rate, and extent of contamination was based upon an initial conceptual model validated with extensive, multimedia sampling (SNL/NM March 1993, Peace et al. September 2002). There is low uncertainty in the land use scenario and the potentially affected populations. The parameter values used in the calculations are conservative and the calculated intakes are likely to be overestimated. Toxicological parameter values were taken from EPA national and regional databases. The overall uncertainty in all of the steps in the risk assessment process is considered insignificant with respect to the conclusion reached.

ICs, such as access and deed restrictions, will be used when appropriate to supplement engineering controls for short- and long-term management of the MWL to prevent or limit exposure to wastes and to ensure the effectiveness of this alternative. Existing access restrictions would remain in place for a minimum of 100 years to limit human access and inadvertent human intrusion.

Long-term monitoring activities to ensure continued performance of the vegetative soil cover would include monitoring for moisture and contaminants (e.g., tritium) in the environment and surveillance for erosion, intrusion, and trespass. These activities would be conducted on a routine basis (e.g., quarterly), and maintenance performed as warranted. Groundwater and tritium in surface soil and vegetation would continue to be monitored on an annual basis for the foreseeable future.

The potential for failure of this alternative is very low. Vegetative soil covers have been designed to emulate the natural analogue ecosystem. They use existing climatic and vegetative conditions to minimize infiltration of water and surface erosion. They contain no “man-made” materials that could deteriorate over time and fail. Although the MWL is located in a TA over which the DOE expects to maintain control indefinitely, there is some uncertainty as to the ability to maintain ICs over the long term. Review of the site and monitoring data at five-year intervals under stewardship will reduce the uncertainty associated with the long-term effectiveness and permanence of ICs. If this alternative fails to perform effectively, corrective action will be taken to meet remedial goals.

If ICs are relinquished, the remaining risk posed by the wastes in the landfill disposal cells would increase. However, vegetative soil covers have performed well with minimal maintenance and are expected to limit water infiltration and mitigate bio-intrusion well into the future. ICs implemented in 1959 have effectively limited human access and prevented inadvertent human intrusion and are unlikely to be relinquished in the future due to DOE land use projections. The long-term reliability (up to 1000 years) of vegetative soil covers has not been demonstrated; however, field demonstrations and modeling indicate that this alternative will require minimal maintenance and maintain its effectiveness by taking advantage of native soils and plants and natural hydrologic processes.

In order to assure the continued effectiveness of the cover, maintenance and monitoring of the site would be required throughout the IC period once vegetation is established. The site would need to remain fenced to provide protection against unexpected disturbance, and regular inspections and maintenance would need to be performed to ensure the integrity of the vegetative cover to mitigate erosion and ponding of water, as well as promote the growth of native vegetation.

#### 4.3.2.2 Reduction of Toxicity, Mobility, or Volume

This alternative does not include any waste treatment options, which are limited for low-level radioactive and mixed waste. As such, this alternative does not reduce waste toxicity or volume. Overall reduction of toxicity will occur over time through radioactive decay (Figure 3-8). The mobility of radioactive and mixed waste will be minimized by limiting water infiltration and bio-intrusion, as well as preventing inadvertent human intrusion by additional compacted fill and the application of ICs.

#### 4.3.2.3 Short-Term Effectiveness

The reduction in short-term risk is expressed as an incremental HI of 0.07 and an incremental excess cancer risk of 3.31E-6 for nonradiological COCs under an industrial land use scenario. For radiological COCs under an industrial land use scenario, the incremental TEDE is reduced by 3.3E-1 mrem/yr and the excess cancer risk is reduced by 2.2E-6. The ecological risks are further reduced by the addition of compacted fill. The time required to implement this alternative and achieve the reduction in risk is four months. Short-term risks for implementing the alternative include potential injuries and fatalities associated with transportation and remediation. The transportation injuries and fatalities are predicted to be 4.9E-2 and 1.3E-3, respectively. The injuries and fatalities for completion of the alternative (including long-term monitoring) are predicted to be 2.6E-1 and 3.2E-3, respectively. Determination of injury and fatality rates is provided in Appendix E.

#### 4.3.2.4 Implementability

This candidate alternative poses no administrative or technical implementation challenges. Construction and logistical problems associated with deployment of a vegetative soil cover are minimal. The addition of compacted fill to the existing surface to bring the operational cover to a central crown and uniform grade presents minimal constructibility concerns. Compacted fill and the topsoil layer would be constructed using standard earth-moving, compaction, and grading equipment. The topsoil layer, admixed with gravel, would serve to control erosion of the cover while native vegetation is established. Thereafter, native vegetation would provide additional erosion control and decrease infiltration of moisture through the cover by transpiration. Materials used to construct the cover and topsoil layer are readily available on site. A major advantage of soil covers is simplicity of construction. The integrity and performance of the cover can be easily monitored. Fill for maintaining the cover is readily available on site.

#### 4.3.2.5 Cost

Capital and operation and maintenance costs for the Vegetative Soil Cover alternative are $4,335,274. Estimated capital and operation and maintenance costs for all alternatives are provided in Table 4-3.

### 4.3.3 MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier

Under this candidate alternative, a bio-intrusion barrier composed of a layer of cobbles or boulders would be constructed on the existing landfill surface before deployment of a vegetative soil cover. The vegetative soil cover would be comprised of multiple lifts of compacted soil to isolate buried waste from the surface environment and to further minimize infiltration of water. A topsoil layer, admixed with gravel, would be vegetated with native plants to promote transpiration and to mitigate wind and water erosion. A cover constructed of natural soil would perform with minimal maintenance by emulating the natural analogue ecosystem. A schematic of the Vegetative Soil Cover with Bio-Intrusion Barrier alternative is shown in Figure 4-3.

This alternative involves minimal intrusive activities at the site. No potential for exposure to waste exists. There would be minimal risk to site workers implementing ICs associated with groundwater monitoring and routine maintenance and surveillance of the site.

#### 4.3.3.1 Long-Term Reliability and Effectiveness

The magnitude of risk remaining after implementation of this alternative in terms of potential exposure to COCs to a human receptor is qualified as both an HI and an excess cancer risk that approaches zero for an industrial land use scenario. The addition of a bio-intrusion barrier and approximately 5 feet of compacted fill would eliminate pathways between the contaminant source and the human receptor. The present risk is an HI of 0.07 and excess cancer risk of 3E-6. The NMED guideline is 1 and 1E-5 for the HI and excess cancer risk, respectively. Therefore, the long-term risk associated with this alternative is below NMED guidelines. Detailed risk assessment and summary tables are provided in Appendix E.

For radiological COCs under an industrial land use scenario, the incremental TEDE is 2.4E-5 mrem/yr, which is below the EPA guideline of 15 mrem/yr. The estimated excess cancer risk associated with radionuclides is 3.4E-10. The baseline risk that can be attributed to the radiological COCs is 3.3E-1 mrem/yr and 2.2E-6 for the TEDE and excess cancer risk, respectively. The ecological risks are very low. NMED guidelines for conducting ecological risk assessments at SNL/NM limits the effective depth to which ecological receptors burrow or root to reach source contamination to 5 feet bgs. The combined thicknesses of the operational cover, the bio-intrusion barrier, and the vegetative soil cover exceed 5 feet, thus eliminating ecological pathways and reducing the risk to 0.

The uncertainty associated with keeping the waste in the landfill disposal cells is low. The determination of the nature, rate, and extent of contamination was based upon an initial conceptual model validated with extensive, multimedia sampling (SNL/NM March 1993, Peace et al. September 2002). There is low uncertainty in the land use scenario and the potentially affected populations. The parameter values used in the calculations are conservative and the calculated intakes are likely to be overestimated. Toxicological parameter values were taken from EPA national and regional databases. The overall uncertainty in all of the steps in the risk assessment process is considered insignificant with respect to the conclusion reached.

ICs, such as access and deed restrictions, will be used when appropriate to supplement engineering controls for short- and long-term management of the MWL to prevent or limit exposure to wastes and to ensure the effectiveness of this alternative. Existing access restrictions would remain in place for a minimum of 100 years to limit human access and inadvertent human intrusion.

Long-term monitoring activities to ensure continued effectiveness of the vegetative soil cover and bio-intrusion barrier would include monitoring for moisture and contaminants (e.g., tritium) in the environment and surveillance for erosion, intrusion, and trespass. These activities would be conducted on a routine basis (e.g., quarterly), and maintenance performed as warranted. Groundwater and tritium in surface soil and vegetation would continue to be monitored on an annual basis for the foreseeable future.

The potential for failure of this alternative is very low. Vegetative soil covers have been designed to emulate the natural analogue ecosystem. They use existing climatic and vegetative conditions to minimize infiltration of water and surface erosion. They contain no "man-made" materials that could deteriorate over time and fail. Although the MWL is located in a TA over which the DOE expects to maintain control indefinitely, there is some uncertainty as to the ability to maintain ICs over the long term. Review of the site and monitoring data at five-year intervals under stewardship will reduce the uncertainty associated with the long-term effectiveness and permanence of ICs. If this alternative fails to perform effectively, corrective action will be taken to meet remedial goals.

If ICs are relinquished, the remaining risk posed by the wastes in the landfill disposal cells would increase. However, vegetative soil covers have performed well with minimal maintenance and are expected to limit water infiltration and mitigate bio-intrusion well into the future. ICs implemented in 1959 have effectively limited human access and prevented inadvertent human intrusion and are unlikely to be relinquished in the future due to DOE land use projections. The long-term reliability (up to 1000 years) of vegetative soil covers with bio-intrusion barriers has not been demonstrated, however, field demonstrations and modeling indicate that this alternative will require minimal maintenance and maintain its effectiveness by taking advantage of native soils and plants and natural hydrologic processes.

In order to assure the continued effectiveness of the cover, maintenance and monitoring of the site would be required throughout the IC period once vegetation is established. The site would need to remain fenced to provide protection against unexpected disturbance, and regular inspections and maintenance would need to be performed to ensure the integrity of the vegetative cover to mitigate erosion and ponding of water, as well as promote the growth of native vegetation.

#### 4.3.3.2 Reduction of Toxicity, Mobility, or Volume

This alternative does not include any waste treatment options, which are limited for low-level radioactive and mixed waste. As such, this alternative does not reduce waste toxicity or volume. Overall reduction of toxicity will occur over time through radioactive decay (Figure 3-8). The mobility of radioactive and mixed waste will be minimized by limiting water infiltration, bio-intrusion, and preventing inadvertent human intrusion by the additional compacted fill and the application of ICs.

#### 4.3.3.3 Short-Term Effectiveness

The reduction in short-term risk is expressed as an incremental HI of 0.07 and an incremental excess cancer risk of 3.31E-6 for nonradiological COCs under an industrial land use scenario. For radiological COCs under an industrial land use scenario, the incremental TEDE is reduced by 3.3E-1 mrem/yr and the excess cancer risk is reduced by 2.2E-6. The ecological risks are further reduced by the addition of compacted fill to the bio-intrusion barrier. The time required to implement this alternative and achieve the reduction in risk is four months. Short-term risks for implementing the alternative include potential injuries and fatalities associated with transportation and remediation. The transportation injuries and fatalities are predicted to be 2.5E-1 and 6.6E-3, respectively. The injuries and fatalities for completion of the remedial action (including long-term monitoring) are predicted to be 3.2E-1 and 3.5E-3, respectively. Determination of injury and fatality rates is provided in Appendix E.

#### 4.3.3.4 Implementability

This candidate alternative poses no administrative or technical implementation challenges. Construction and logistical problems associated with deployment of a vegetative soil cover employing a bio-intrusion barrier are moderate. The addition of compacted fill to the existing surface to bring the operational cover to a central crown and uniform grade presents minimal constructibility concerns. Materials for construction of the bio-intrusion barrier are readily available from off-site suppliers. The bio-intrusion barrier, compacted fill, and topsoil layer would be constructed using standard earth-moving, compaction, and grading equipment. The topsoil layer, admixed with gravel, would serve to control erosion of the cover while native vegetation is established. Thereafter, native vegetation would provide additional erosion control and decrease infiltration of moisture through the cover by transpiration. Materials used to construct the cover and topsoil layer are readily available on site. A major advantage of soil covers is simplicity of construction. The integrity and performance of the cover can be easily monitored. Fill for maintaining the cover is readily available on site.

#### 4.3.3.5 Cost

Capital and operation and maintenance costs for the Vegetative Soil Cover with Bio-Intrusion Barrier alternative are $7,096,859. Estimated capital and operation and maintenance costs for all alternatives are provided in Table 4-3.

### 4.3.4 MWL Alternative V.e—Future Excavation

Under this candidate alternative, the landfill would be completely excavated at some future date. Future excavation would entail either aboveground retrievable storage of waste and/or shipment of waste to an off-site, licensed facility for disposal. Secure, high-bay warehouses for processing and storage of classified and unclassified waste would be built on site, adjacent to the landfill to minimize handling and transportation logistics and costs. Separate facilities would be required for classified and unclassified waste. A schematic of the Future Excavation alternative is shown in Figure 4-4.

#### 4.3.4.1 Long-Term Reliability and Effectiveness

The magnitude of the risk remaining after implementation of this alternative in terms of potential exposure to COCs to a human receptor is qualified as both an HI and an excess cancer risk that approaches zero for the industrial land use scenario. This is due to the assumption that COC concentrations will be reduced to approximate background levels after excavation. The present risk is an HI of 0.07 and an excess cancer risk of 3E-6. The NMED guideline is 1 and 1E-5 for the HI and excess cancer risk, respectively. Therefore, the long-term risk associated with this alternative is below NMED guidelines. Detailed risk assessment and summary tables are provided in Appendix E.

For radiological COCs under an industrial land use scenario, the incremental TEDE and associated excess cancer risk would also approach zero assuming radiological constituent concentrations are reduced to approximate background levels. Accordingly, the TEDE would be below the EPA guideline of 15 mrem/yr. The current risk that can be attributed to radiological COCs is 3.3E-1 mrem/yr and 2.2E-6 for the TEDE and excess cancer risk, respectively. The ecological risks are very low. Once COCs are removed to approximate background levels, the ecological risk will approach zero.

The uncertainty associated with long-term effectiveness and reliability is low. Removing the source material will cause the risk to both human and ecological receptors to approach zero.

The potential for failure of this alternative is very low. High specific-activity wastes will have decayed to safer levels (Figure 3-8). Remaining exposure potential to low-specific activity waste will be managed by implementing adequate administrative and engineering controls during excavation, waste processing, and storage.

#### 4.3.4.2 Reduction of Toxicity, Mobility, or Volume

This alternative does not include any waste treatment options. Future treatment options for low-level radioactive and mixed waste are unknown. As such, this alternative does not reduce waste toxicity or volume. Volume may actually increase due to waste segregation and storage requirements. Overall reduction of toxicity will have occurred over time through radioactive decay (Figure 3-8). The mobility of radioactive and mixed waste is eliminated by removing the waste from landfill disposal cells and placing it into a controlled environment.

#### 4.3.4.3 Short-Term Effectiveness

There is no reduction in short-term risk for nonradiological COCs until the landfill has been completely excavated and validation sampling has been completed. Once COCs have been removed, the nonradiological human health risk approaches zero. For radiological COCs and an industrial land use scenario, the incremental TEDE increases by 3.23E+3 mrem/yr and the excess cancer risk increases by 3.7E-2, until the radiological risk drivers are removed. The short-term ecological risks are also identical to baseline risk until the COCs are removed. At that time, ecological risk also approaches zero. The time required to implement this alternative and achieve the reduction in risk is two years. Short-term risks for implementing the alternative include potential injuries and fatalities associated with transportation and remediation. The transportation injuries and fatalities are predicted to be 8.8E-1 and 2.3E-1, respectively. The injuries and fatalities for completion of the alternative (including long-term monitoring) are predicted to be 2.2E+0 and 1.1E-2, respectively. Determination of injury and fatality rates is provided in Appendix E.

Worker risk associated with the implementation of this alternative is assessed in the context of worker health and safety regulations and is based upon the assumption that all site workers will adhere rigorously to DOE, state, and federal worker safety regulations and that administrative and engineered barriers will be implemented to protect site workers. This assessment context differs substantially from previously evaluated alternatives because site workers will be involved in the excavation and handling of radioactive and mixed waste. The potential injuries and fatalities summarized above are based upon estimated man-hours and mileage and do not assume any direct exposure to, or contact with, potential contamination sources due to excavation activities.

#### 4.3.4.4 Implementability

This candidate alternative poses significant administrative and technical implementation challenges. Complete excavation of the landfill will require a minimum of two years. The design and construction of support facilities, which precede excavation, will take three to five years. Excavation and characterization activities present significant concerns and will be conducted under rigorous DOE, state, and federal worker safety regulations. Wastes removed from the landfill would be considered mixed waste until properly characterized. Excavation of the classified area would require separate, secure facilities for sorting, segregation, and stockpiling of waste, as well as for characterization, containerization, and storage. Different waste streams will present different implementability concerns and restrictions. Operating permits to accumulate and characterize hazardous and mixed waste on site may be required from the NMED. Additional operating permits may be required for treatment of waste if pretreatment is required before storage or shipment.

#### 4.3.4.5 Cost

Capital costs for MWL Alternative V.e—Future Excavation are $325,704,159, including waste disposal costs. Because there are no operations and maintenance costs for Alternative V.e, operations and maintenance costs are not included in the estimate. Estimated capital and operation and maintenance costs for all alternatives are provided in Table 4-3.

## 4.4 Alternatives Evaluation—Summary

Detailed evaluation of candidate alternatives resulted in MWL Alternative I.a (NFA with ICs) presenting the lowest overall risk of all the alternatives considered. Risk to human health and ecological receptors residing at the landfill may be slightly higher than alternatives that offer a bio-intrusion barrier and/or vegetative soil cover. However, as with the other candidate alternatives, transportation and remediation injuries and fatalities drive the risk. A summary of risk assessment of candidate alternatives is provided in Table 4-2.

For Alternative I.a (NFA with ICs), the HI, a measure of potential noncarcinogenic adverse effects from exposure to COCs, is approximately zero for human health and ecological receptors. The predicted number of human health cancers from nonradiological COCs is 1E-09 (i.e., a probability of 1 in a billion additional cancers); the predicted number of human health cancers from radiological COCs is 2.2E-06 (i.e., a probability of approximately 2 in 1 million additional cancers). The predicted number of injuries and fatalities for both transportation and remediation is 0.1 injuries and 0.0029 fatalities. Although the risk is driven by transportation and remediation activities, the overall risk for NFA with ICs is very low.

The risk for the remaining candidate alternatives increases as the remedial options increase in complexity, both in the number of site workers and in the time involved in implementing the alternative. Again, risk is driven by the transportation and remediation injuries and fatalities. Future Excavation presents the greatest risk of all candidate alternatives.

The HI for Alternative V.e (Future Excavation) is 0.07 for human health receptors and approximately zero for ecological receptors. The predicted number of human health cancers from nonradiological COCs is 3E-06 (i.e., a probability of 3 in 1 million additional cancers); the predicted number of human health cancers from radiological COCs is 3.7E-02 (i.e., a probability of approximately 4 in 100 additional cancers). The predicted number of injuries and fatalities for both transportation and remediation was 3 injuries and 0.03 fatalities. The overall risk for future excavation is very high when compared to the other candidate alternatives.

Alternative I.a (NFA with ICs) presents the lowest overall cost of all the alternatives considered. The EPA considers cost an important consideration in selecting corrective measures. Cost can and should be considered when choosing among candidate alternatives that meet the evaluation criteria. EPA believes that several alternatives will meet all the evaluation criteria and in that situation, cost becomes an important consideration in choosing the alternative that most appropriately addresses the circumstances at the site and provides the most efficient use of Agency and facility owner resources (EPA December 1996).

# 5. Selection of Corrective Measures Alternative(s)

The purpose of this CMS is to identify, develop, and evaluate corrective measures alternatives and recommend the corrective measure(s) to be taken at the MWL. As part of this CMS process, 16 technologies in 5 general corrective measures families were screened against CMS corrective action objectives and criteria specified by the EPA and the NMED (Table 2-1). Screening of these technologies resulted in the selection of eight candidate technologies for development of corrective measures alternatives. Development of corrective measures alternatives using individual technologies or various combinations of these technologies resulted in the selection of the four candidate corrective measures alternatives listed below that are suitable for the site.

- Alternative I.a—NFA with ICs
- Alternative III.b—Vegetative Soil Cover
- Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier
- Alternative V.e—Future Excavation

Based upon detailed evaluation and risk assessment using guidance provided by the EPA and the NMED, one candidate corrective measures alternative clearly presents the lowest overall risk to human health and the environment, while minimizing cost and meeting CMS corrective action objectives. This alternative is Alternative I.a—NFA with ICs. This alternative was originally proposed for the MWL in September 1996 after completion of the RCRA investigative process.

However, the DOE and SNL/NM recommend that Alternative III.b—Vegetative Soil Cover, be selected as the preferred corrective measure for the MWL. Relative to Alternative I.a—NFA with ICs, Alternative III.b offers additional protection against direct contact with the waste in the landfill disposal cells, further minimizes infiltration of water, and mitigates bio- and human intrusion without significant added cost in construction and long-term monitoring, surveillance, and maintenance. Alternative III.b—Vegetative Soil Cover would be the most propitious corrective measure in the arid and semi-arid environment of the Southwest. This selection is based upon years of dialogue with the NMED and the public in determining the best approach for closure of the site.

Under Alternative III.b, a vegetative soil cover would be deployed on the existing landfill surface. There would be no intrusive activities at the site. No potential for exposure to waste exists. A cover constructed of natural soil would perform with minimal maintenance by emulating the natural analogue ecosystem. This alternative also poses minimal risk to site workers implementing ICs associated with environmental and groundwater monitoring and routine maintenance and surveillance of the site. The risk to human health and the environment after implementation of this alternative is well below EPA and NMED guidelines, with an excess cancer risk of 3.4E-10, a HI of 0.00, and a radiological TEDE of 2.4E-5 mrem/yr.

Alternative III.b is consistent with EPA directives regarding presumptive remedies for Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) municipal waste landfill sites (EPA September 1993, EPA August 1994, EPA December 1996). Presumptive remedies are preferred technologies for common categories of sites based upon historical patterns of remedy selection and the EPA's scientific and engineering evaluation of performance data on technology implementation. Presumptive remedies are expected to ensure consistent selection of remedial actions and to be used at all appropriate sites except under unusual site-specific circumstances.

The EPA established source containment as the presumptive remedy for municipal waste landfills under CERCLA in September 1993. The EPA anticipated that the presumptive remedy would be applicable to a significant number of landfills found at military facilities. Additionally, the EPA continues to seek greater consistency among cleanup programs, especially in the process of selecting response actions for sites regulated under CERCLA and corrective measures for facilities regulated under RCRA. In general, even though EPA’s presumptive remedies were developed for CERCLA sites, the EPA states that the CERCLA presumptive remedies should also be used at RCRA Corrective Action sites to focus RFI, simplify evaluation of remedial alternatives in the CMS, and influence remedy selection (EPA December 1996).

In selecting Alternative III.b (Vegetative Soil Cover) as the preferred corrective measure for the MWL, the DOE and SNL/NM are demonstrating their commitment to protect the environment, to preserve the health and safety of the public and their employees, and to serve as responsible corporate citizens in meeting the community's environmental goals.

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# FIGURES

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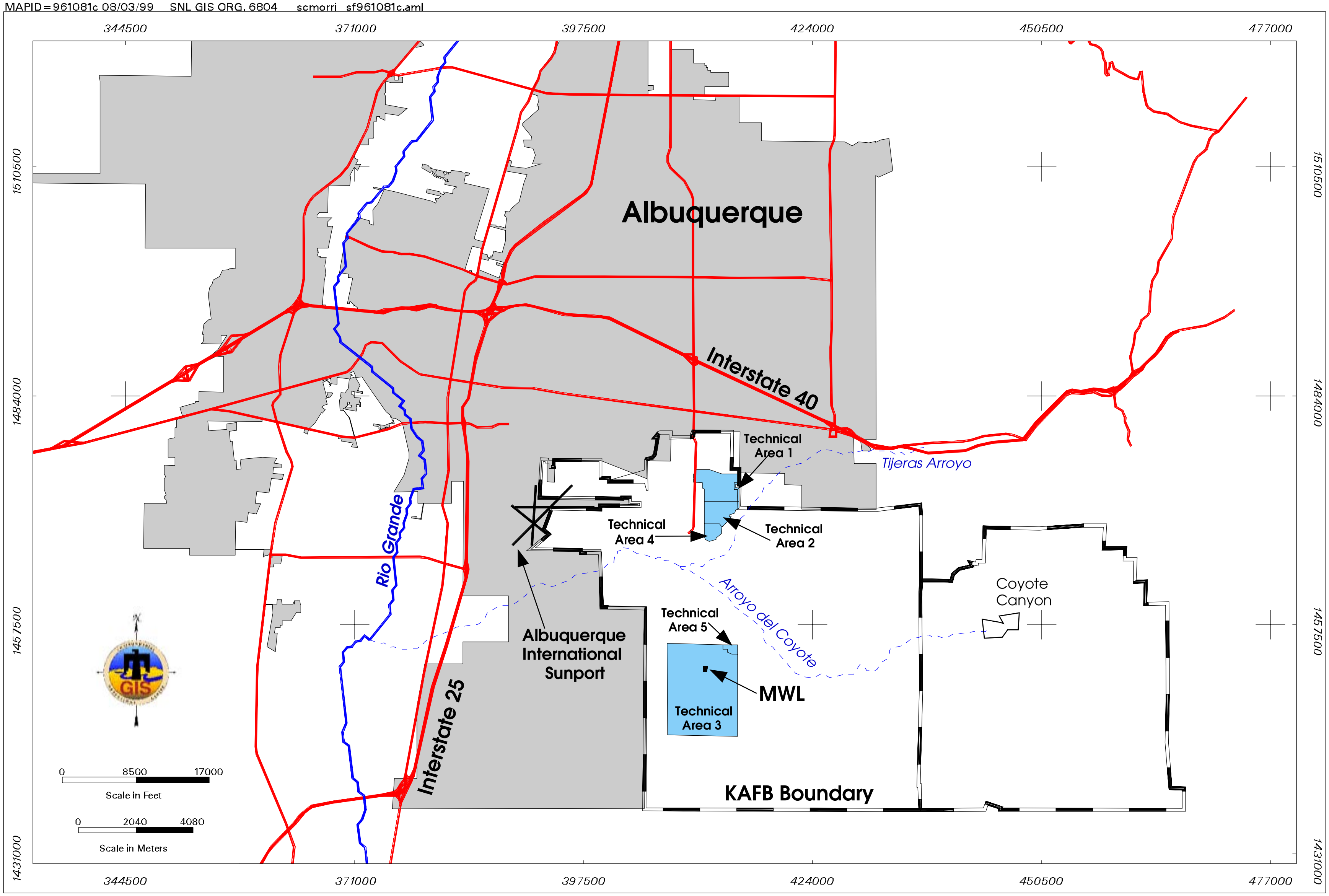


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**Figure 1-1 Location of Kirtland Air Force Base and Sandia National Laboratories, New Mexico Technical Areas**

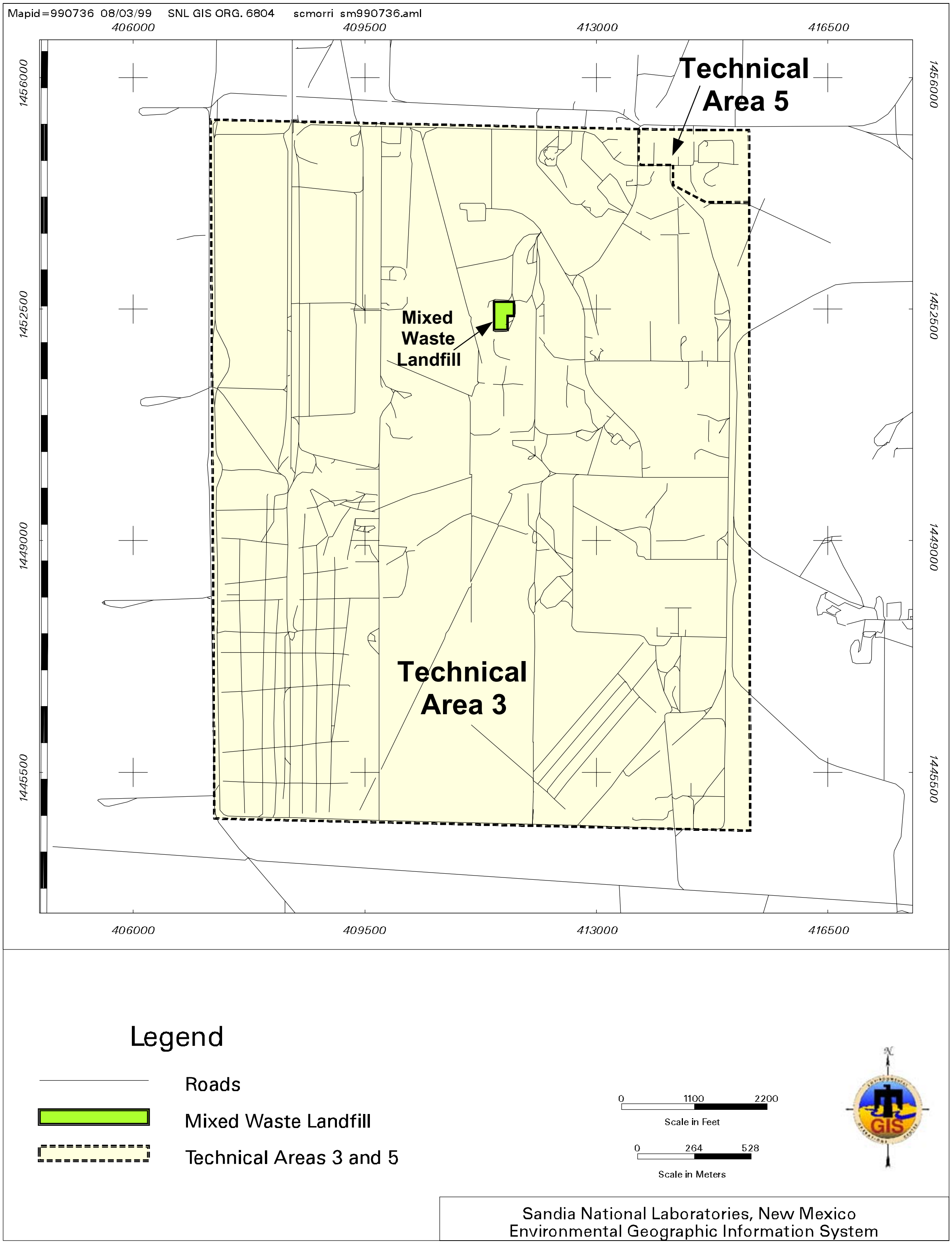


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**Figure 1-2 Location of Technical Areas 3 and 5 and the Mixed Waste Landfill**

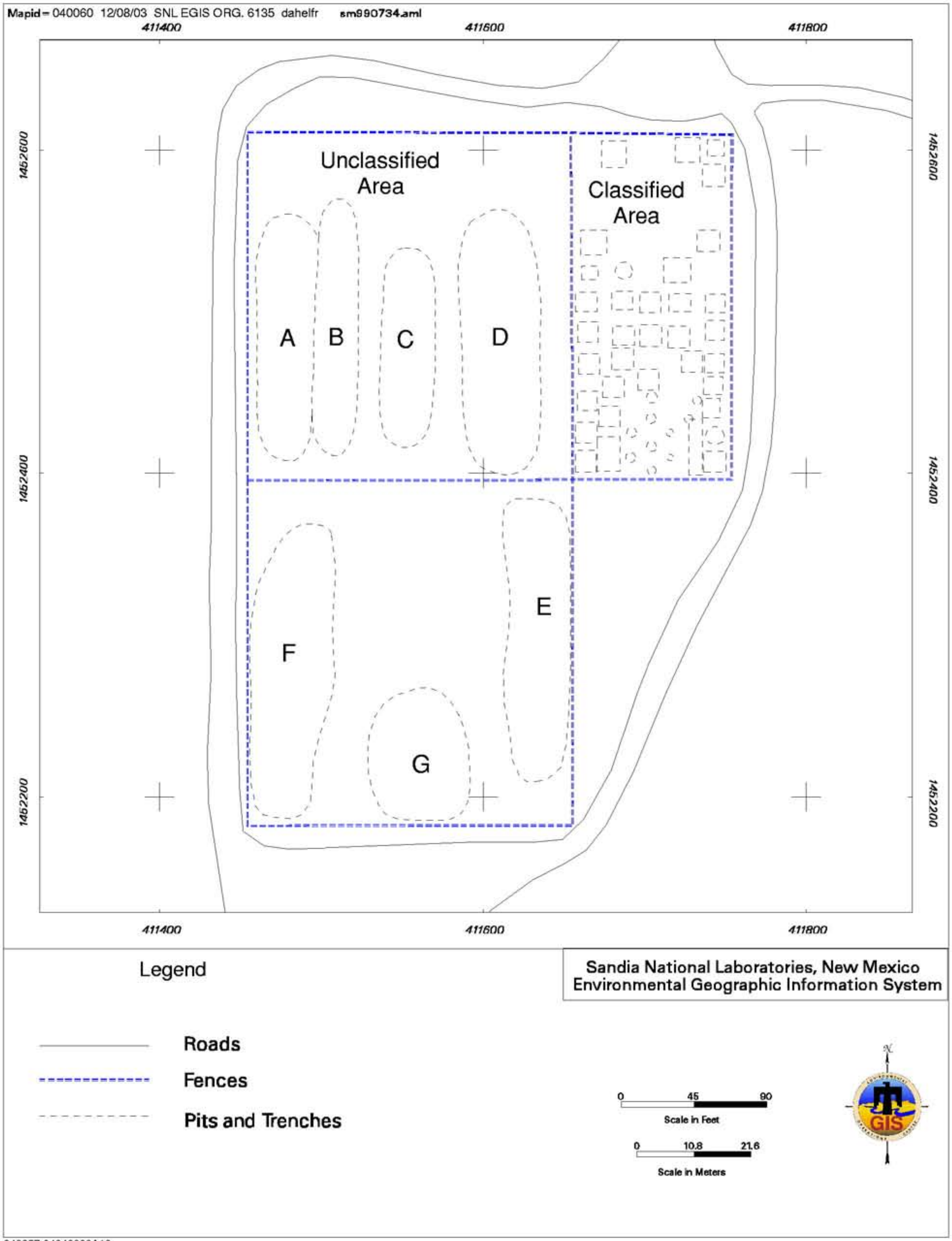


**Figure 1-3**
**Map of the Mixed Waste Landfill**

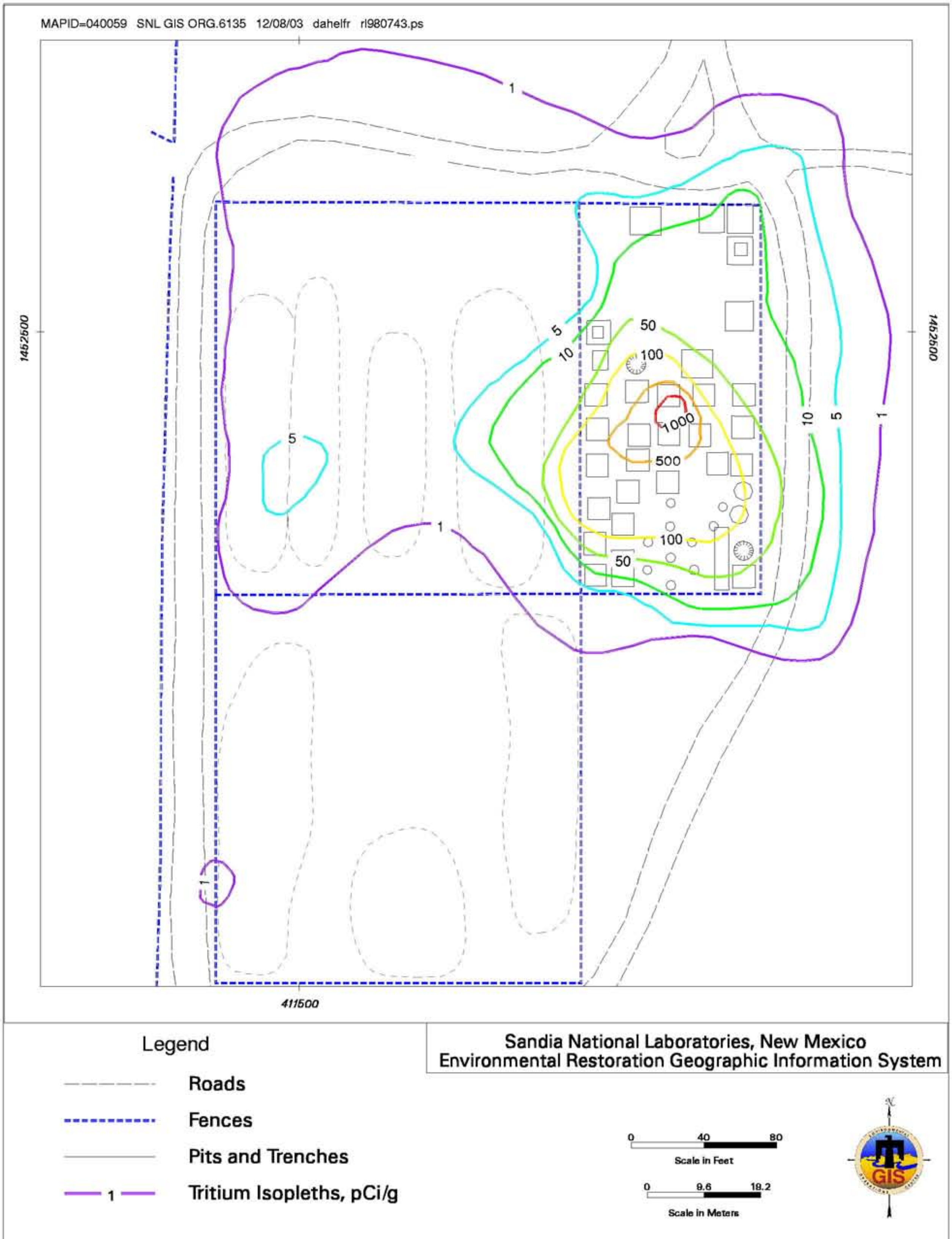


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**Figure 1-4**
**Tritium in Surface Soil Soils at the Mixed Waste Landfill (1993)**

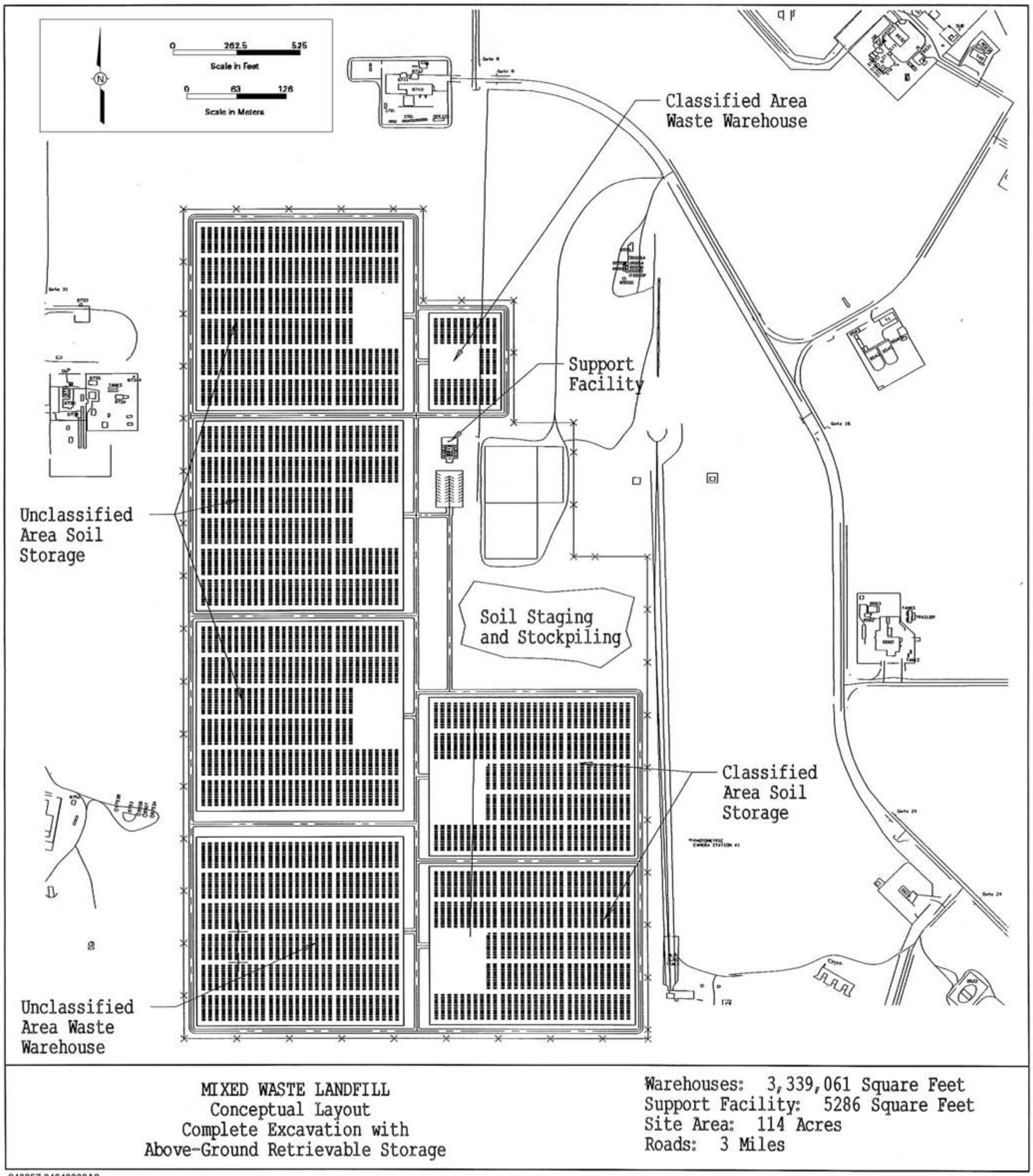


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**Figure 3-1 Completed Excavation with Aboveground Retrievable Storage**

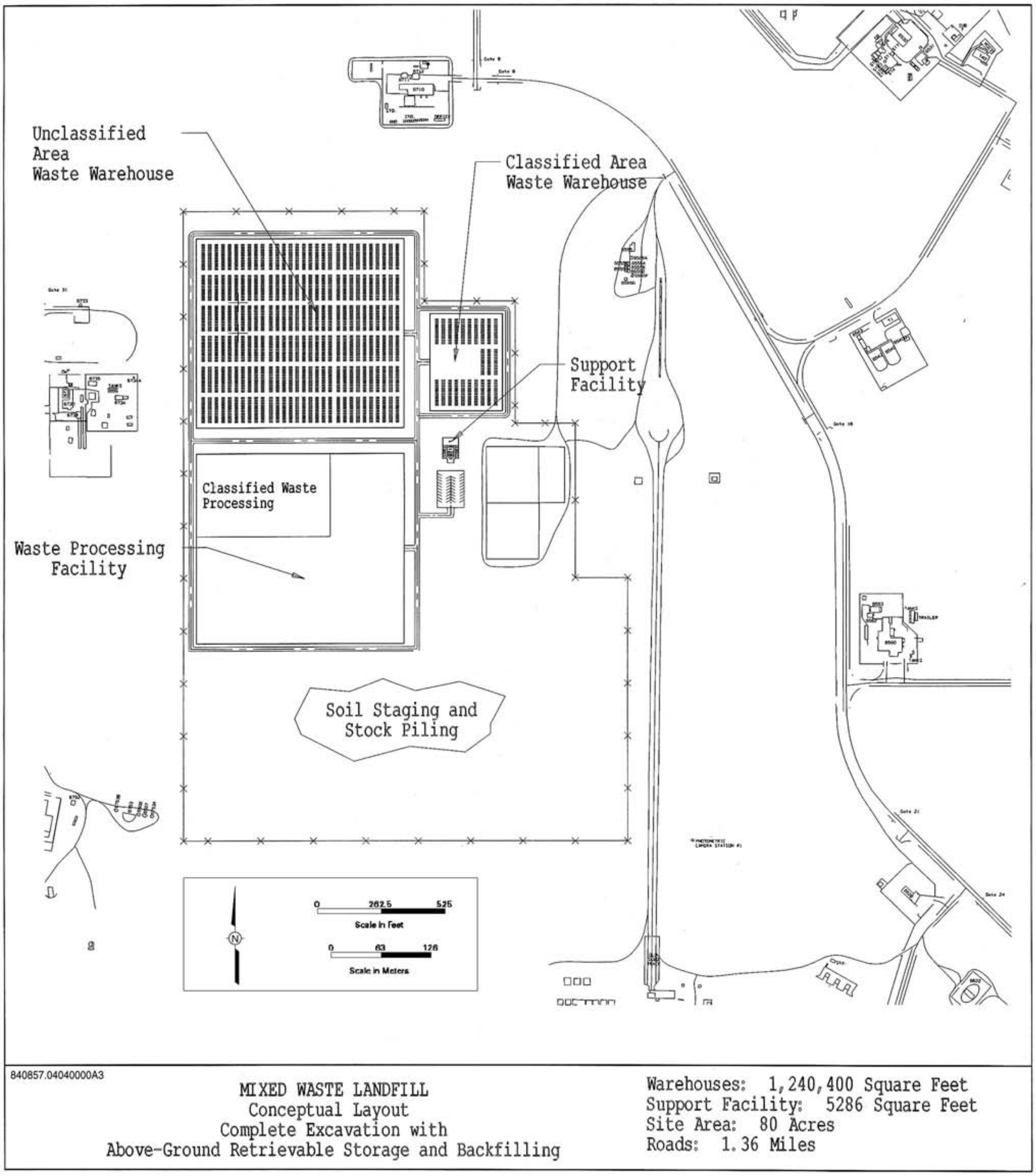


**Figure 3-2 Complete Excavation with Aboveground Retrievable Storage and Backfilling**

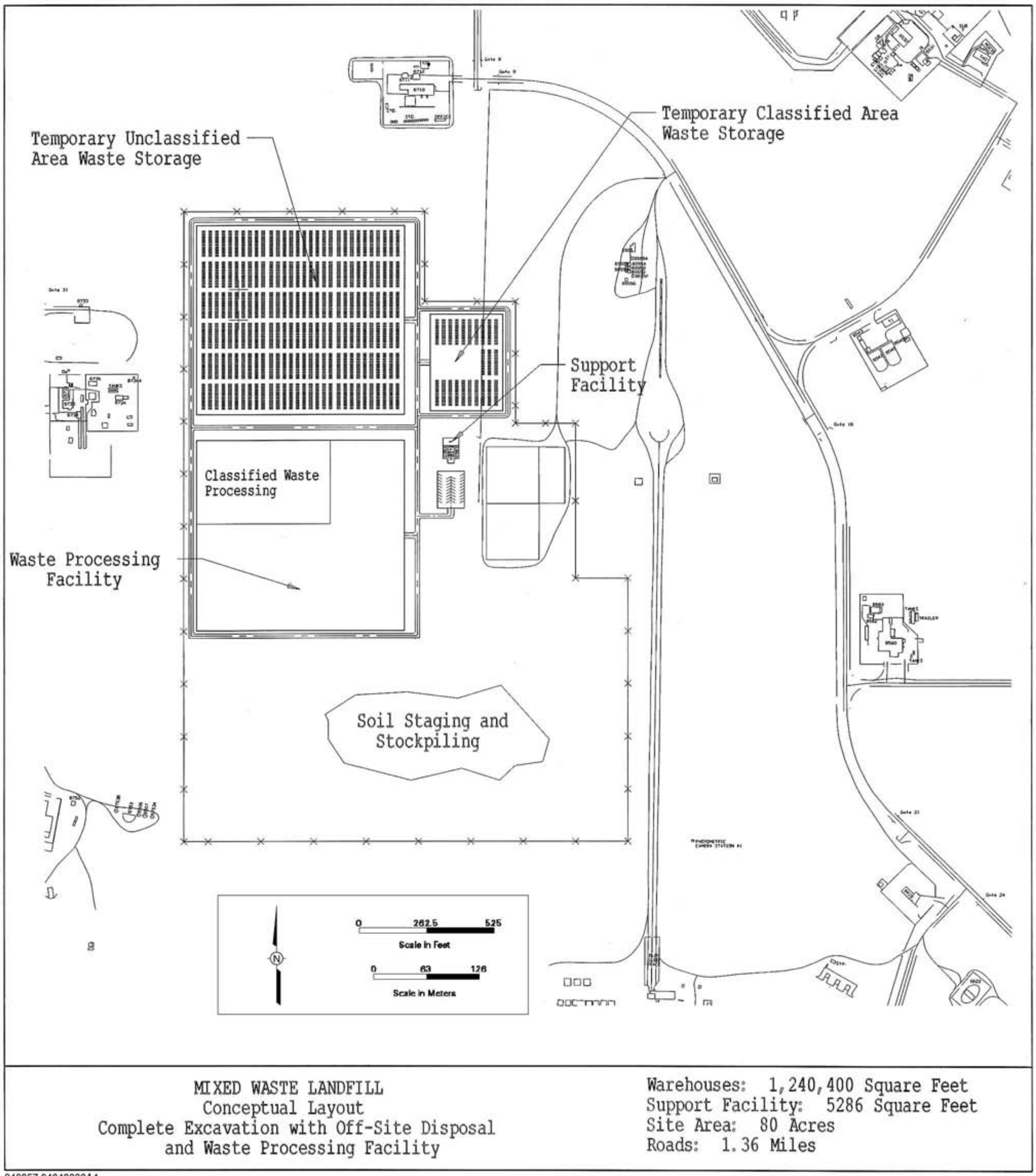


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**Figure 3-3 Complete Excavation with Offsite Disposal and Backfilling**

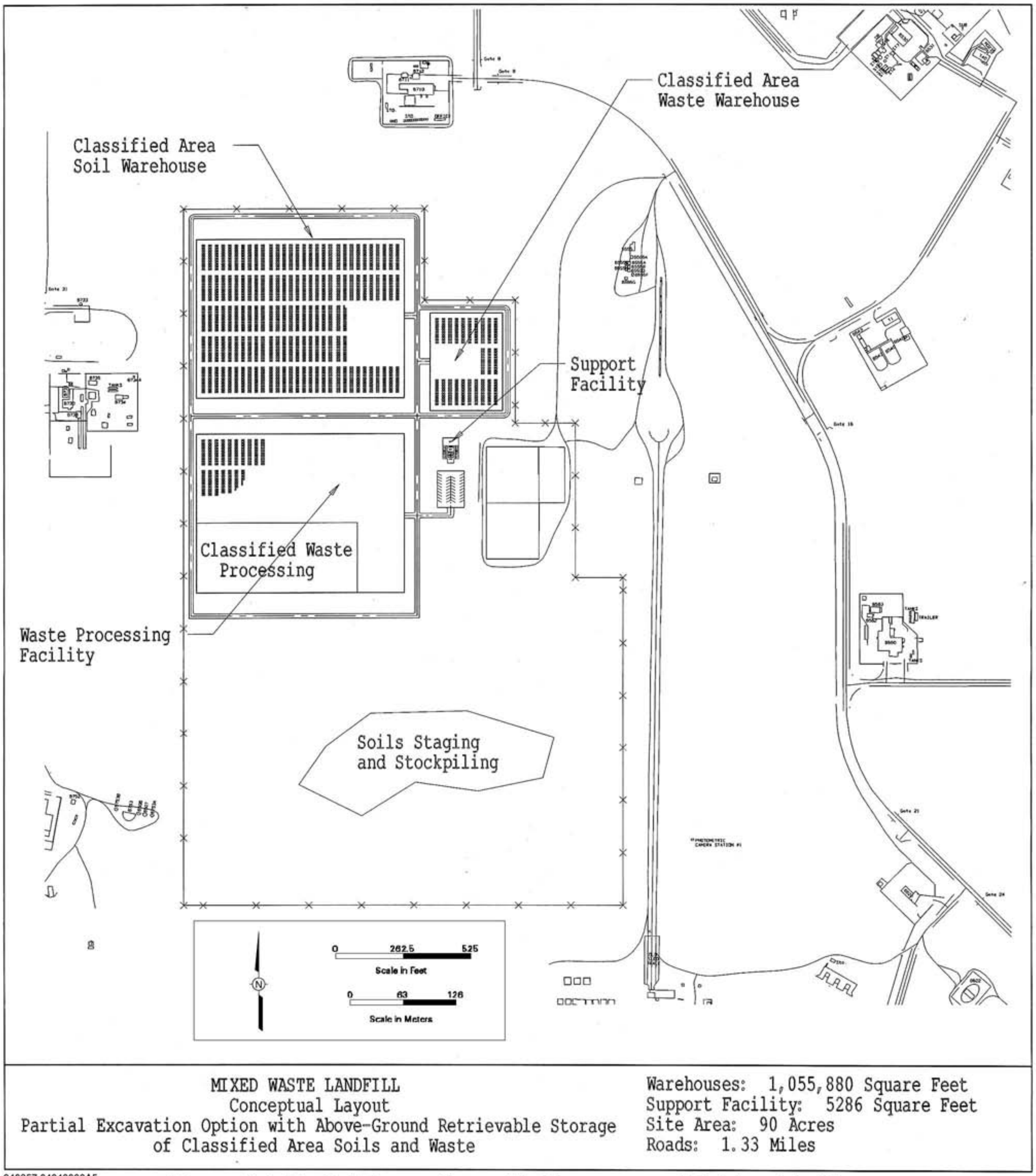


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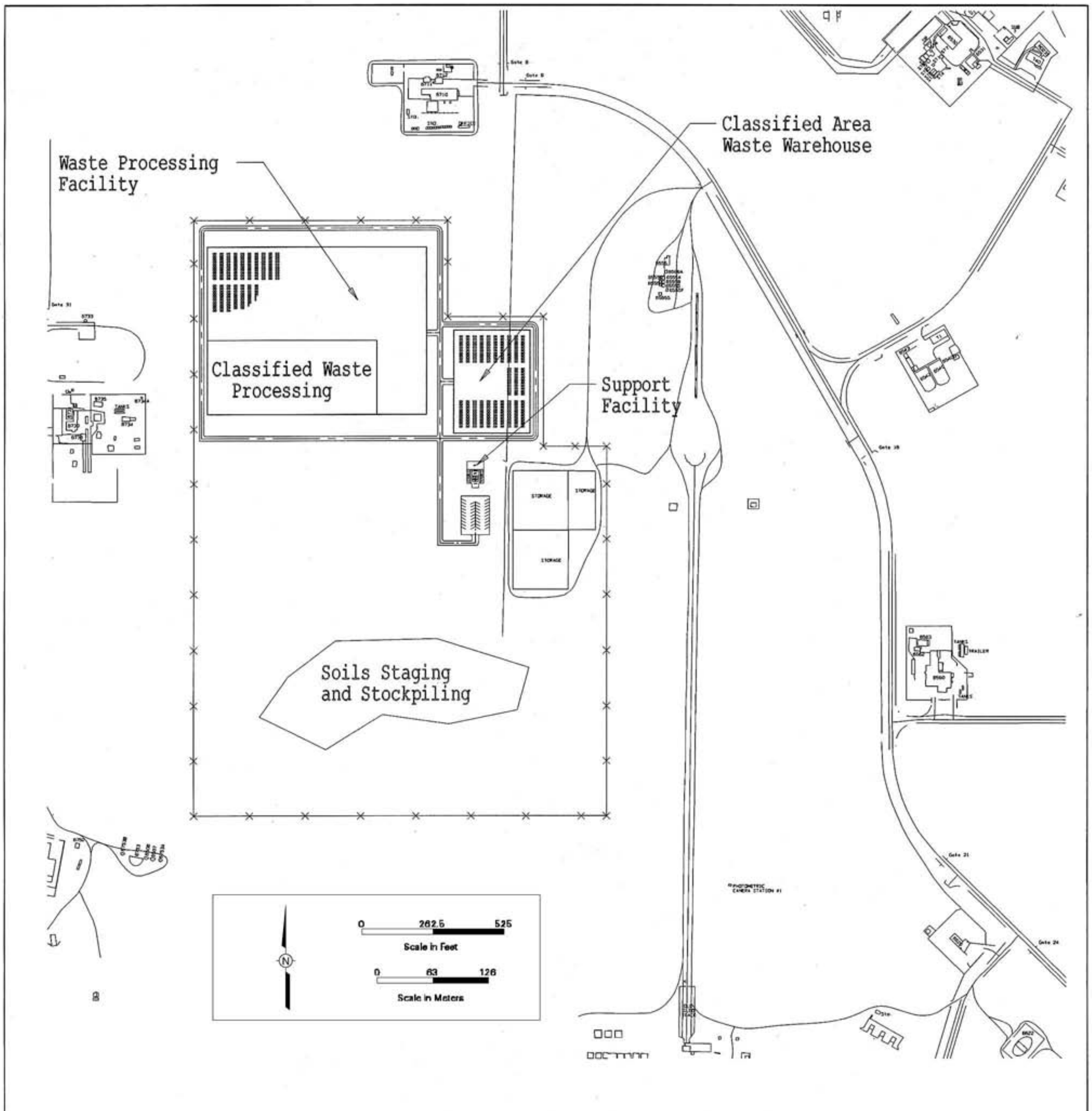
**Figure 3-4 Partial Excavation with Aboveground Retrievable Storage**

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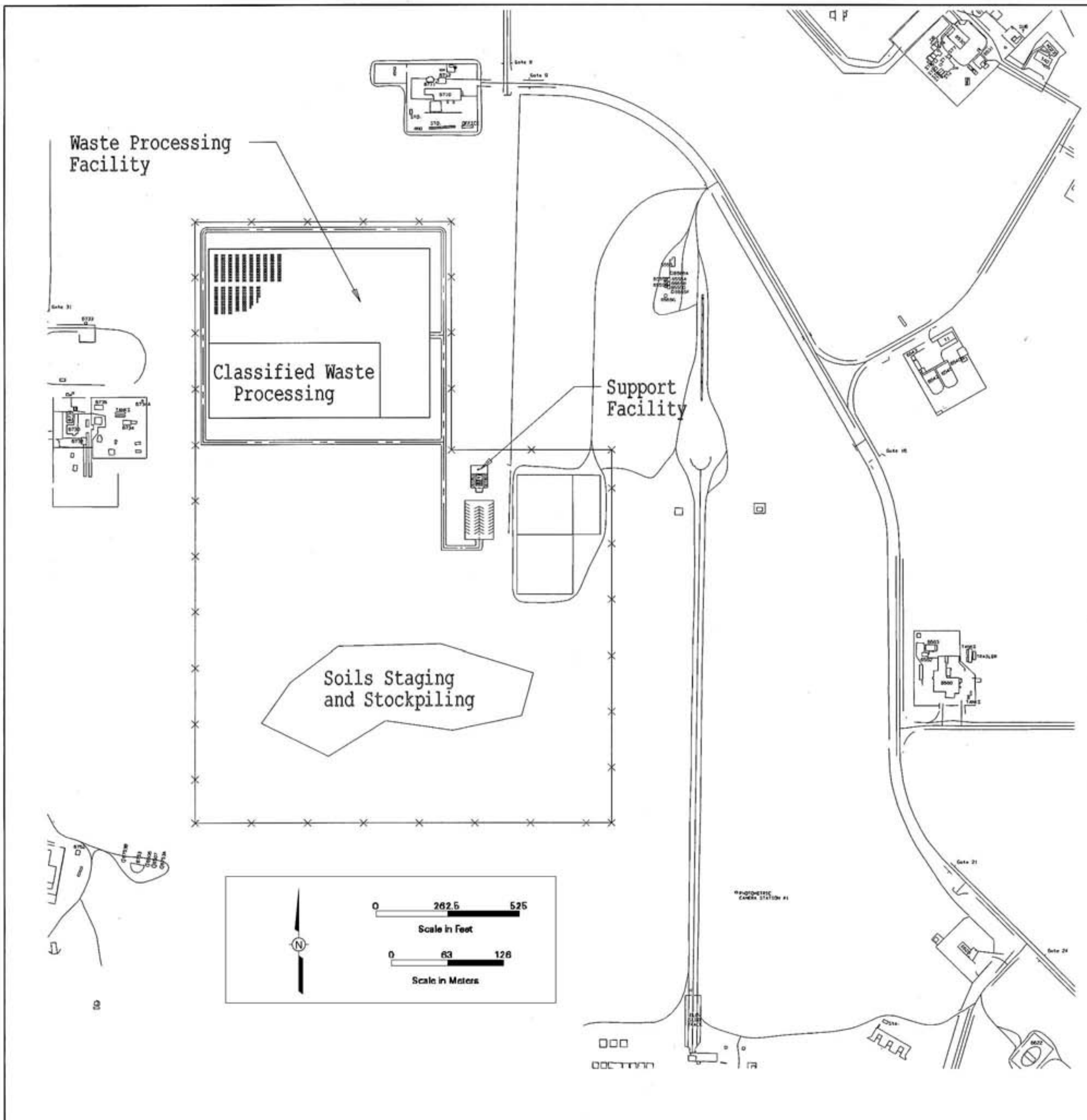
MIXED WASTE LANDFILL
Conceptual Layout
Partial Excavation with Aboveground Retrievable Storage
of Classified Area Waste and Backfilling

Warehouses: 579,140 Square Feet
Support Facility: 5286 Square Feet
Site Area: 66.75 Acres
Roads: 1 Mile

**Figure 3-5 Partial Excavation with Aboveground Retrievable Storage and Backfilling**




MIXED WASTE LANDFILL
Conceptual Layout
Partial Excavation with Off-Site Disposal of
Classified Area Soils and Waste

Warehouses: 476,740 Square Feet
Support Facility: 5286 Square Feet
Site Area: 63 Acres
Roads: .75 Miles

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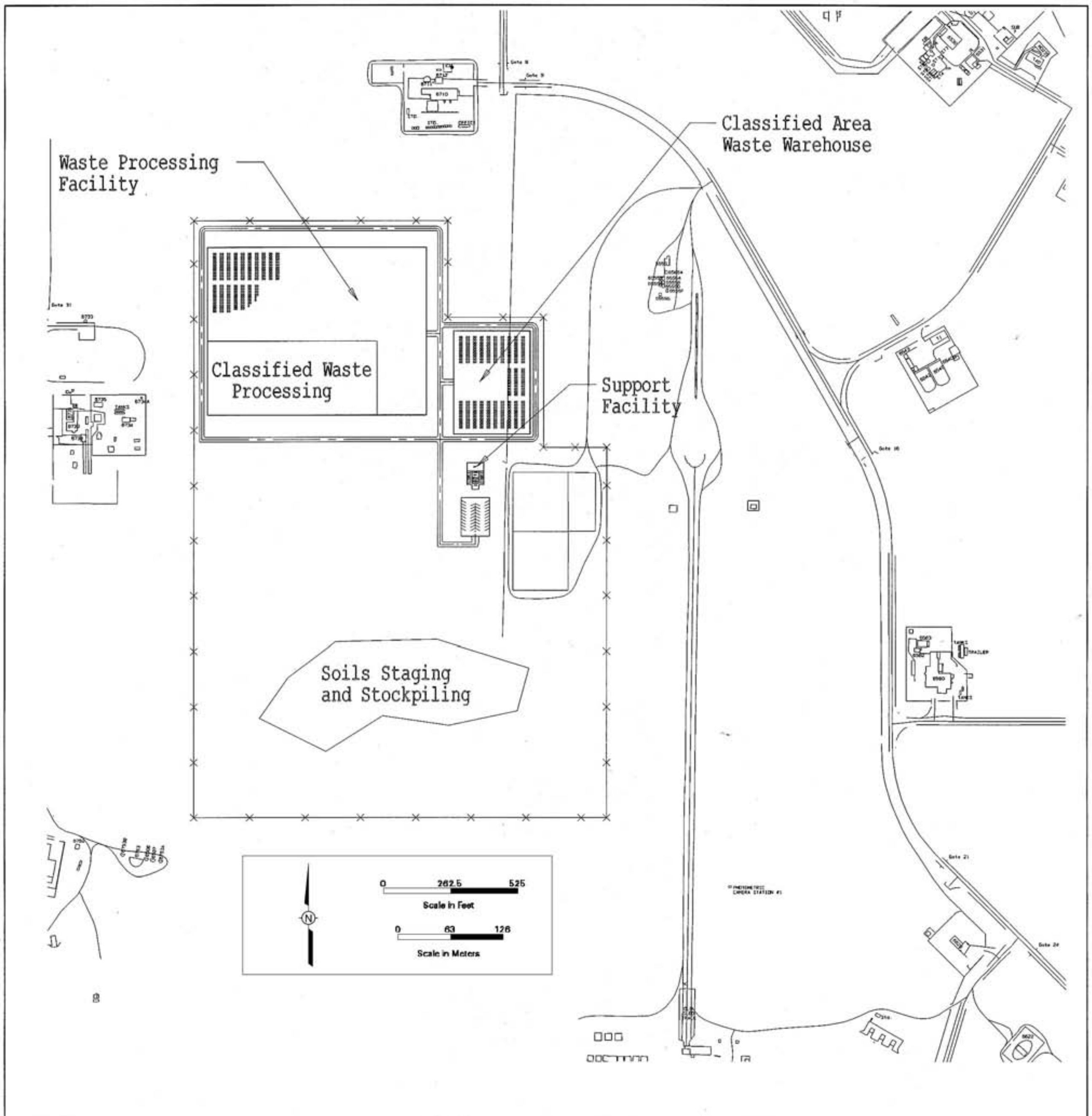
**Figure 3-6 Partial Excavation with Off-Site Disposal and Backfilling**




MIXED WASTE LANDFILL
Conceptual Layout
Future Partial Excavation with Aboveground Retrievable Storage of Classified Area Waste and Backfilling

Warehouses: 579,140 Square Feet
Support Facility: 5286 Square Feet
Site Area: 66.75 Acres
Roads: 1 Mile

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**Figure 3-7 Future Excavation**

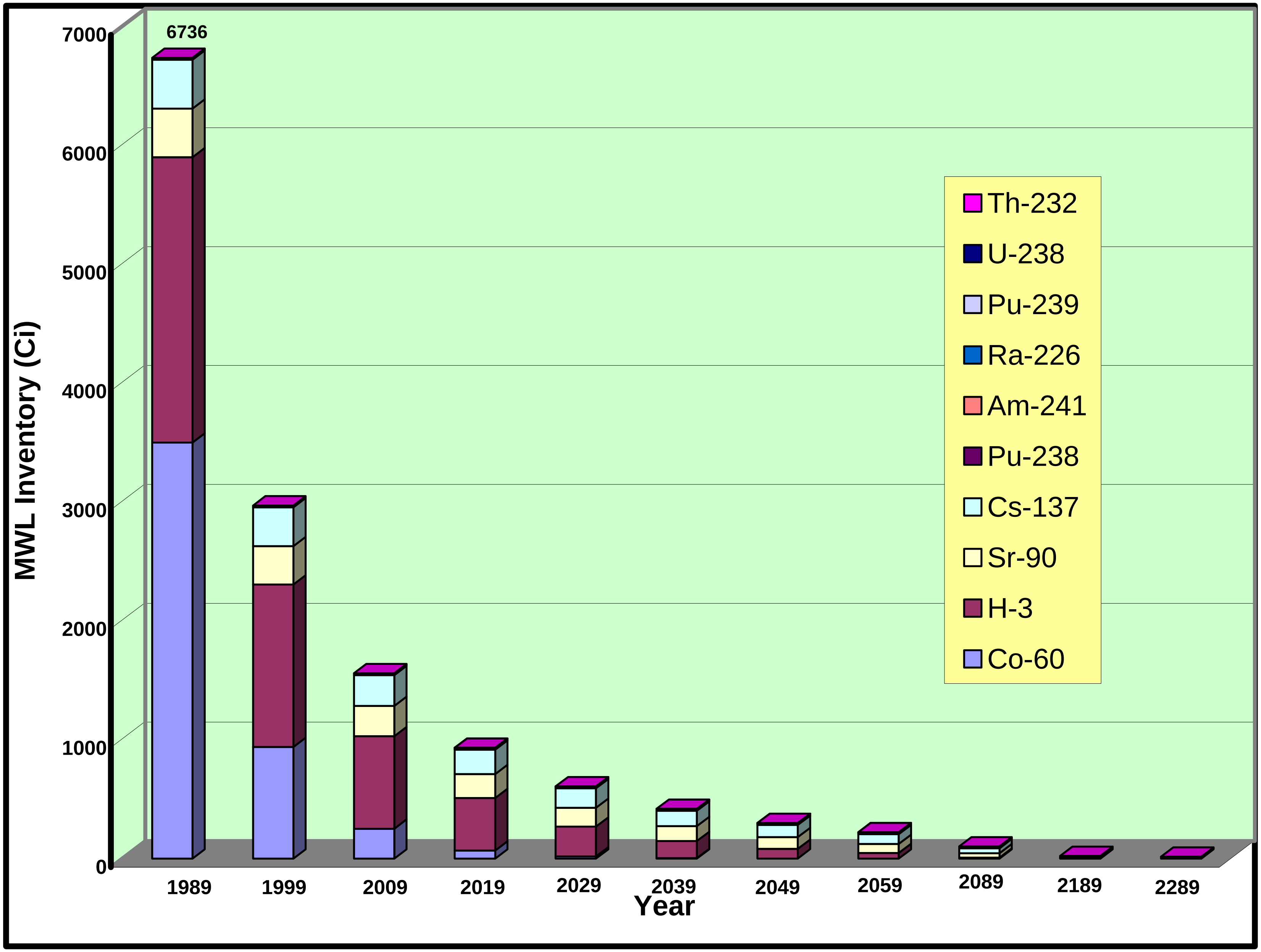


**Figure 3-8. Reduction in total radionuclide activity in the MWL inventory over time.**

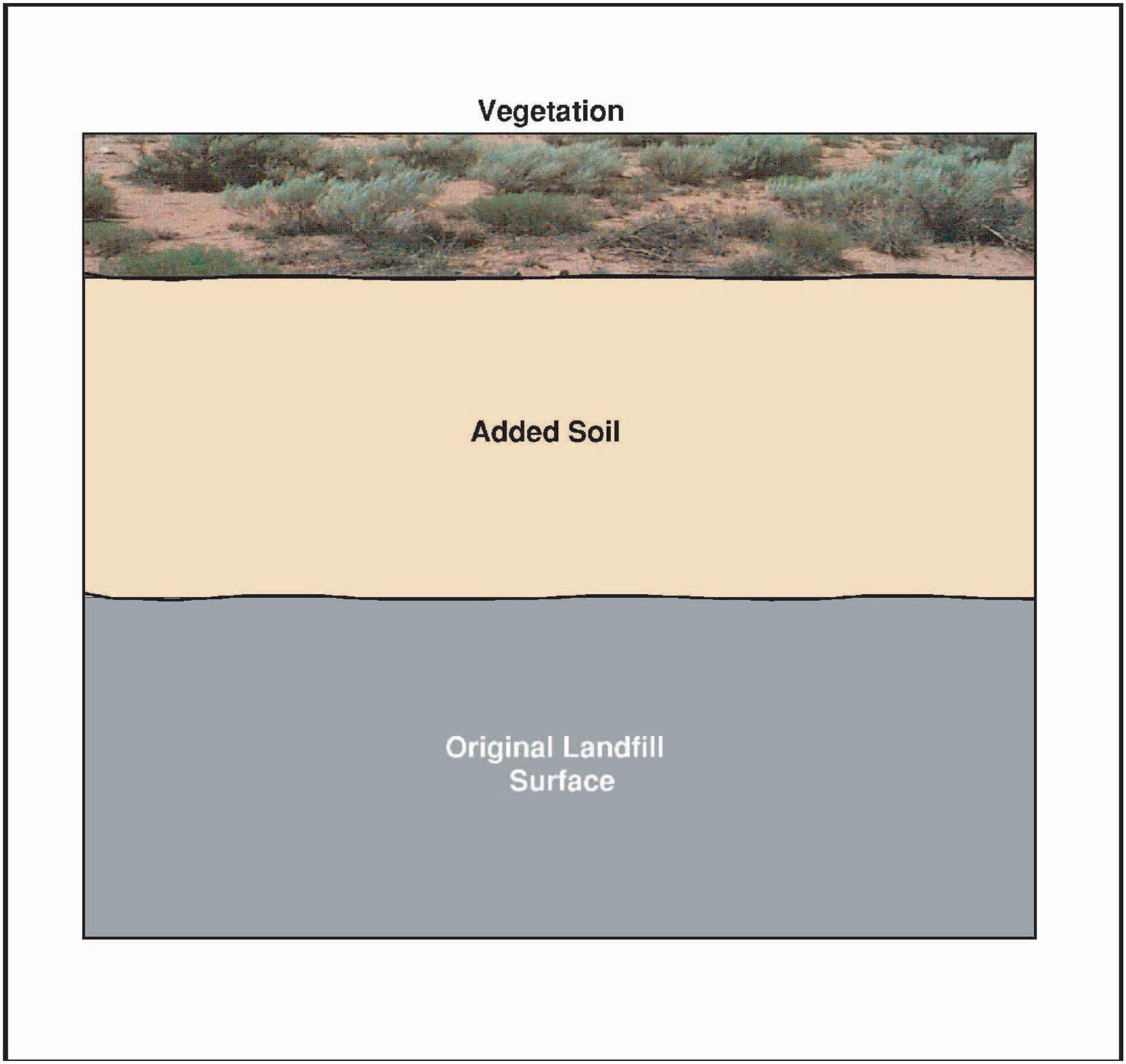


**Figure 4-1 No Further Action with Institutional Controls**

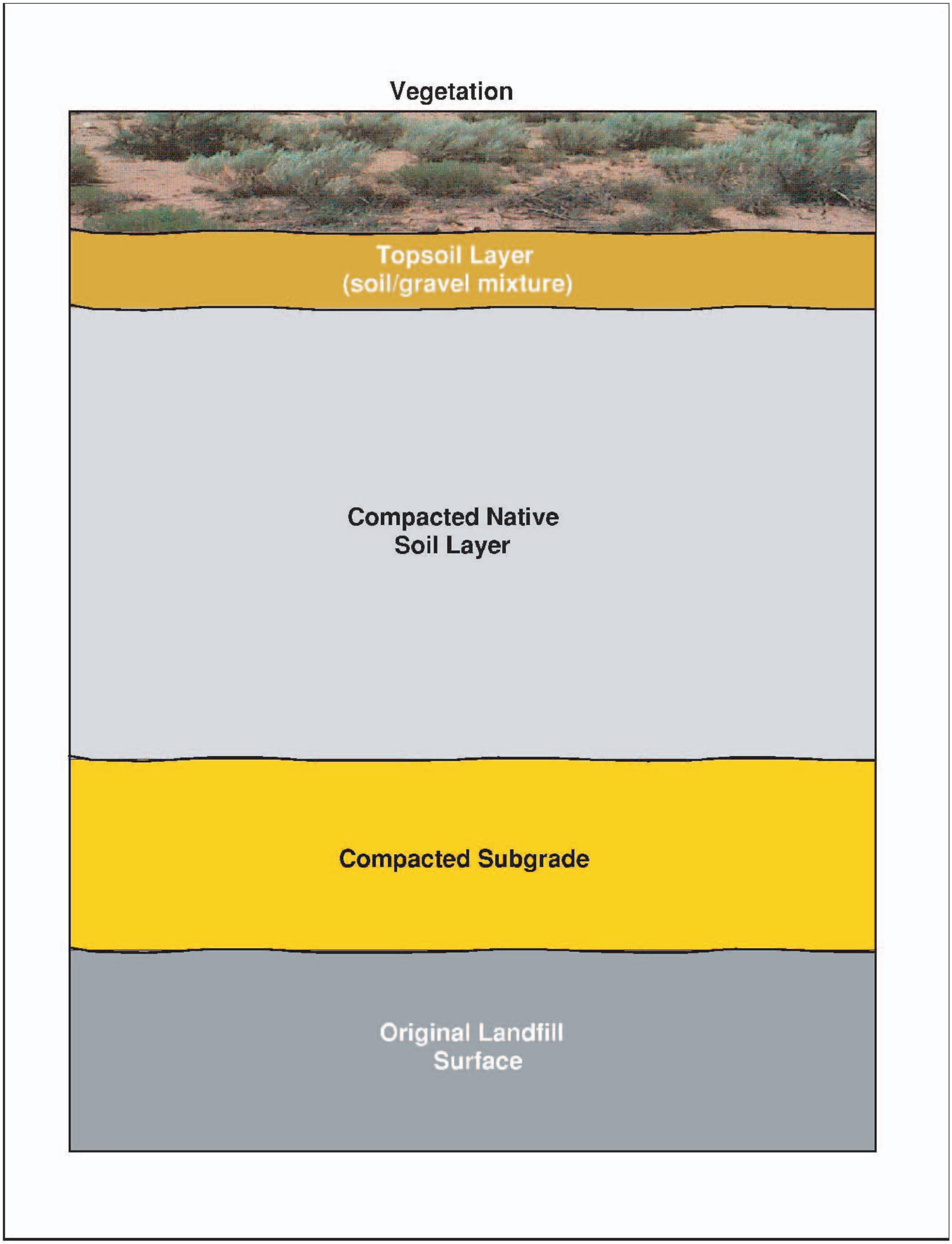


**Figure 4-2 Vegetative Soil Cover**

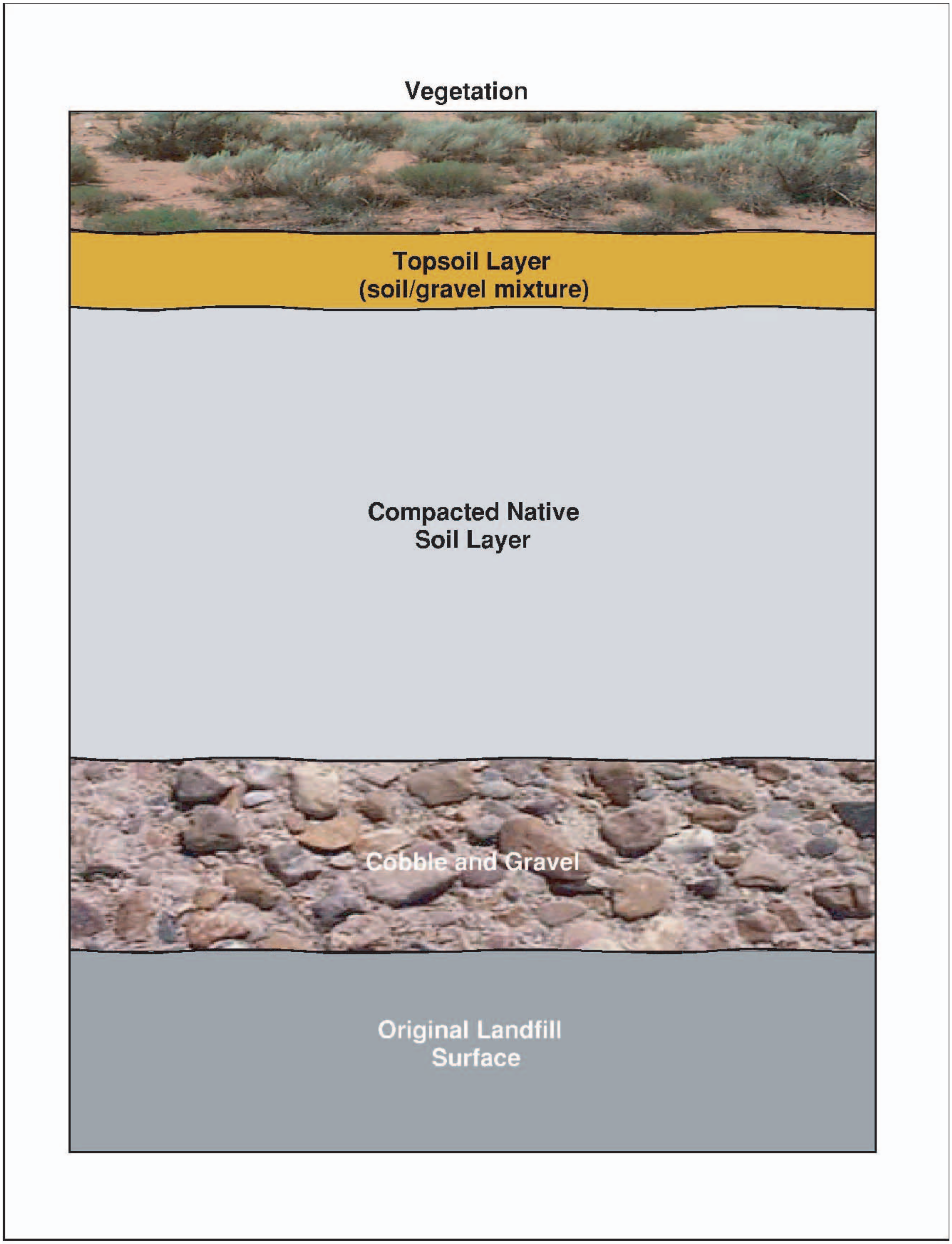


**Figure 4-3 Vegetative Soil Cover with Bio-Intrusion Barrier**

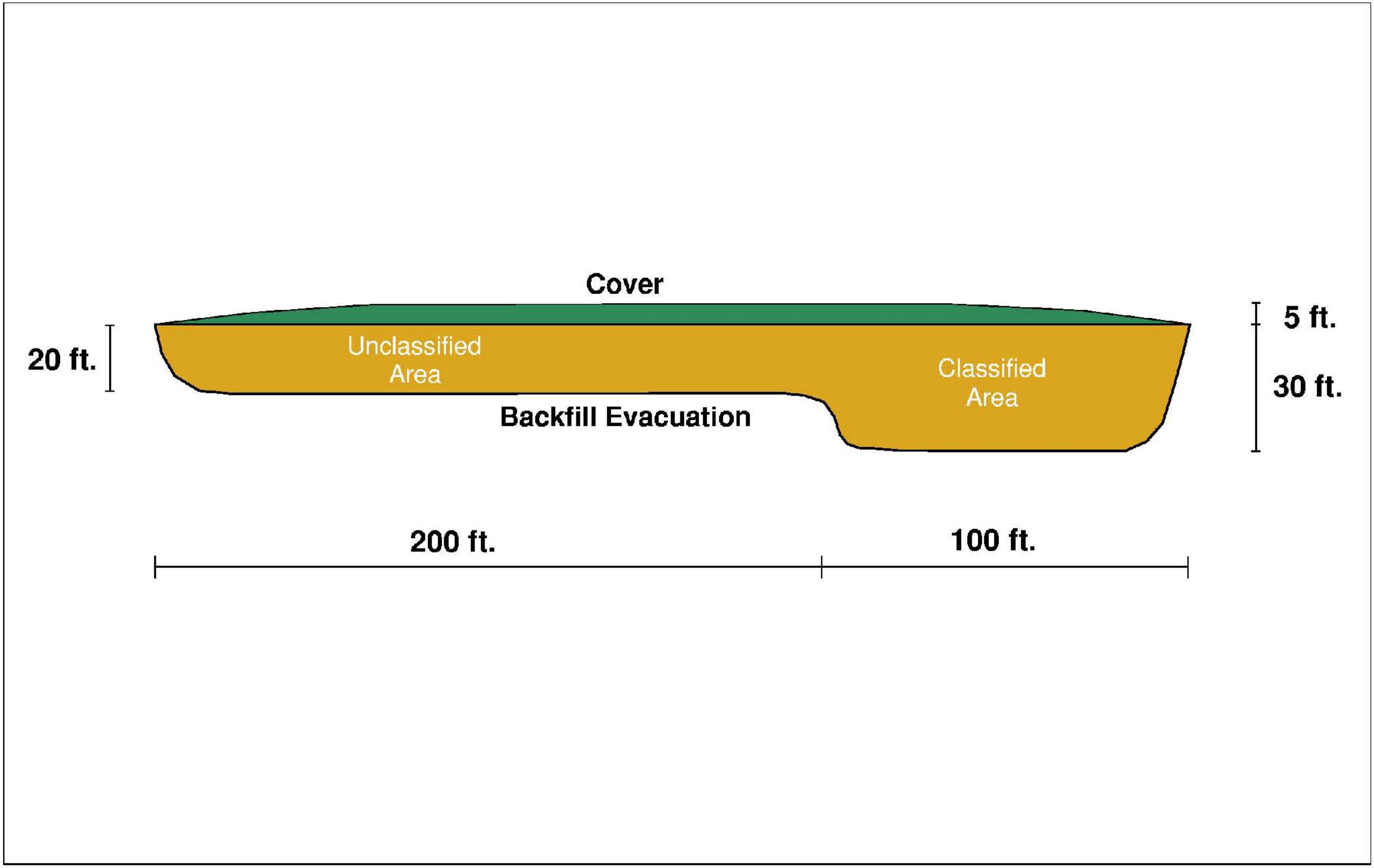


Figure 4-4 Future Excavation

# TABLES

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**Table 2-1**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsiveness to Corrective Action Objectives | Implementability | Performance |
| NFA | NFA is a general corrective measure that is carried through the CMS in order to provide a baseline for comparison against remedial action technologies. NFA can be implemented with or without ICs.<br>a) NFA with no ICs<br>b) NFA with ICs | No<br>Yes | Yes<br>Yes | Poor<br>Fair |
| Comments | | | | |
| NFA with no ICs is not responsive to corrective action objectives because it does not minimize exposure to site workers, the public, and wildlife; limit migration of contaminants to groundwater; minimize biological intrusion into buried waste; or prevent or limit human intrusion. NFA with ICs is generally responsive to Corrective Action Objectives 1, 2, 3, and 4. ICs include long-term monitoring, long-term surveillance and maintenance, and long-term access controls. The NFA corrective measure is technically and administratively implementable. The long-term performance of the existing operational cover is unknown due to the lack of documentation regarding design, materials used, and construction quality assurance. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsiveness to Corrective Action Objectives | Implementability | Performance |
| ICs | Long-Term Monitoring: This technology would involve the installation of monitoring devices to: 1) detect the presence and extent of moisture and contaminants (e.g., tritium) in the environment; 2) assist in determining the human health and environmental impact of water infiltration and any contaminant releases; and 3) evaluate the performance of site closure measures. Long-term monitoring may include sampling of surface water, soil, soil gas, vegetation, air, and groundwater. | No | Yes | Good |
| Comments | | | | |
| Long-term monitoring alone is not responsive to corrective action objectives because it does not minimize exposure to site workers, the public, and wildlife; limit migration of contaminants to groundwater; minimize biological intrusion into buried waste; or prevent or limit human intrusion. However, when used in conjunction with other technologies, it may increase the overall effectiveness of corrective measures. Long-term monitoring has been employed effectively at the MWL since 1969. Continuation and/or modification of the existing controls is technically and administratively implementable. Monitoring systems have a long industrial record of proven performance. Individual components of the monitoring systems will require periodic upgrades and/or replacement. Additionally, staff must be trained and funded to collect and analyze data for the systems in order to be useful in the long-term. Although monitoring alone does not limit water infiltration or the release and migration of contaminants, it is effective in demonstrating the performance of corrective measures. Monitoring may also detect the failure of a corrective measure and the need for corrective action. Long-term monitoring is retained as an implicit part of all corrective measures alternatives. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsiveness to Corrective Action Objectives | Implementability | Performance |
| ICs | Long-Term Surveillance and Maintenance: These controls would involve routine inspection and maintenance of the site on a regular basis, including seeding and mulching, minor grading to address subsidence and erosion issues, and maintenance of drainage features. The site maintenance program would be commensurate with long-term needs and requirements. | Yes | Yes | Good |
| Comments | | | | |
| Long-term surveillance and maintenance alone are not responsive to Corrective Action Objective 4, but are responsive to Corrective Action Objectives 1, 2 and 3. However, when used in conjunction with other technologies, surveillance and maintenance may increase the overall effectiveness of corrective measures. Surveillance and maintenance have been effectively employed at the MWL since 1959. Continuation and/or modification of the existing controls is technically and administratively implementable. Surveillance and maintenance have a long industrial record of proven performance. Although surveillance and maintenance alone do not limit water infiltration or the release and migration of contaminants, these controls are effective in maintaining the performance of corrective measures. Surveillance may also detect the failure of a corrective measure and the need for corrective action. Long-term surveillance and maintenance are retained as an implicit part of all alternatives. | | | | |

Refer to footnotes at end of table.

## Table 2-1 (Continued)
## Description and Evaluation of General Corrective Measures

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsiveness to Corrective Action Objectives | Implementability | Performance |
| ICs | Long-Term Access Controls: These controls would involve both physical access and administrative controls to prevent or limit human exposure to contaminants. Physical access controls would involve perimeter signage, fencing, monuments, and security patrols. Administrative controls would include land use restrictions. | Yes | Yes | Good |
| Comments | | | | |
| Long-term access controls alone are not responsive to Corrective Action Objectives 1, 2, and 3, but are responsive to Corrective Action Objective 4. However, when used in conjunction with other technologies, these controls may increase the overall effectiveness of corrective measures. Long-term access controls have been employed effectively at the MWL since 1959. Continuation and/or modification of existing controls is technically and administratively implementable. Long-term access controls have a long industrial record of proven performance. Physical access controls are currently in place at TA-3 and at the MWL. These include perimeter signs, fencing, and security patrols. Signage and fencing will require periodic replacement, and staff must be trained and funded to conduct surveillance and maintenance. Physical access and administrative controls provide an extra degree of protection of human health and are simple to implement. Long-term access controls are retained as an implicit part of all alternatives. | | | | |

Refer to footnotes at end of table.

## Table 2-1 (Continued)
## Description and Evaluation of General Corrective Measures

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsiveness to Corrective Action Objectives | Implementability | Performance |
| Containment | Vegetative Soil Cover: This technology would involve the construction of a natural soil cover to limit water infiltration and direct surface water away from the landfill.  A diverse community of native plants would be established on the cover to extract water and minimize wind and water erosion.  A cover constructed of natural soil will function with minimal maintenance by emulating the natural analogue ecosystem. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1, 2, 3, and generally responsive to Corrective Action Objective 4. This technology is technically and administratively implementable and has been effectively demonstrated at existing, low-level radioactive and mixed waste landfills in Nevada and Idaho.  Natural soil to construct the cover is readily available at the site.  A major advantage of a soil cover is its simplicity of construction.  The performance of vegetative covers and their analogues has been studied extensively and recommended for deployment in the arid and semiarid environments of the western United States.  Vegetative soil covers are designed to emulate natural analogues that have performed for thousands of years with minimal infiltration. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation: Responsiveness to Corrective Action Objectives | Technology Evaluation: Implementability | Technology Evaluation: Performance |
|---|---|---|---|---|
| Containment | Structural Barriers: This technology would involve the construction of a concrete or asphalt barrier over the MWL to minimize water infiltration and limit biological and inadvertent human intrusion into waste disposal cells. | Yes | Yes | Poor |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1 and 4, but is not responsive to Corrective Action Objectives 2 and 3. This technology is technically and administratively implementable and has been demonstrated at existing, low-level radioactive and mixed waste landfills in New Mexico and South Carolina. Materials used for construction of structural barriers are readily available, and structural barriers are simple to construct. Concrete and asphalt barriers are often used for short-term control of vertical water infiltration and to limit biological and human intrusion. The long-term performance of structural barriers is limited by susceptibility to loading, weathering, and cracking, which impairs the structural integrity of the barrier and facilitates the infiltration of water through the barrier into waste disposal cells. IC's would have to be employed to maintain and eventually replace these types of barriers. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Containment | RCRA Subtitle C Cap: This technology would involve the construction of an engineered cap using natural soil and man-made materials.  A cap would consist of layers of soil, compacted clay, and flexible membrane liners.  A diverse community of native plants would be established on the cover to extract water and minimize wind and water erosion. | Yes | Yes | Fair |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1 and 3, and is generally responsive to Corrective Action Objectives 2 and 4.  This technology is technically and administratively implementable and has been the baseline technology for hazardous and radioactive waste landfills in the United States since 1989.  Materials used to construct RCRA Subtitle C caps are readily available.  A minor disadvantage of the RCRA Subtitle C caps is their complexity of construction.  Greater care is required to ensure the hydraulic integrity of compacted clay and flexible membrane liners.  RCRA Subtitle C caps may not perform well in arid and semiarid environments due to potential deterioration of compacted clay and flexible membrane liners. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Containment | Bio-Intrusion Barrier: This technology would involve the use of gravel and cobbles (rip rap) or woven wire mesh to limit intrusion by deep-rooted plants and burrowing mammals. A bio-intrusion barrier could be used as a stand-alone technology or in conjunction with a cap or cover. A bio-intrusion barrier constructed of resistant material such as gravel and cobbles may also serve as an effective human intrusion barrier. | Yes | Yes | Fair |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1, 3, and 4, but is not responsive to Corrective Action Objective 2. The bio-intrusion barrier is technically and administratively implementable. Materials used to construct bio-intrusion barriers are readily available from off-site suppliers. A bio-intrusion barrier can be constructed on the existing landfill surface. An advantage of a bio-intrusion barrier is its simplicity of construction. The performance of wire mesh bio-intrusion barriers has not been established. The short-term performance of rip-rap bio-intrusion barriers within covers has been studied recently in Idaho. The results of field and pilot tests indicate that long-term performance is promising. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Containment | Containment Cells: This technology would involve the use of subsurface horizontal and vertical barriers to isolate buried waste from the environment. Grout curtains and slurry walls are common applications of subsurface barriers. | Yes | Yes | Poor |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1, 3, and 4, and is generally responsive to Corrective Action Objective 2. Installation of subsurface barriers involves extensive intrusive activity that raises exposure concerns for site workers. This technology is technically and administratively implementable. Containment cells could be deployed around individual waste disposal cells or around and under the landfill as a whole. Grouting may involve directional drilling equipment and injection of pressurized fluids. Slurry walls involve vertical trenching and backfilling with bentonite or cement mixtures. Performance of subsurface barriers is limited by the inability of nonintrusive techniques to confirm barrier continuity (e.g., the base of the barrier). | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Stabilization/*In situ* Treatment | *In Situ* Vitrification: This technology would involve using an electric current at extremely high temperatures to convert soil and waste to a crystalline mass, which is a chemically stable, leach-resistant, vitreous material. The process destroys and/or removes organic material while retaining heavy metals and radionuclides. | Yes | Yes | Poor |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4, but is not responsive to Corrective Action Objective 1. *In situ* vitrification increases the risk of exposure to radioactive and hazardous vapors for site workers. This technology is implementable at the MWL but the heterogeneity and size of waste may affect its effectiveness. Vitrification temperatures up to 2,000°C would generate and release radioactive and hazardous vapors to the environment. An off-gas hood and treatment system would be needed to collect and treat these vapors. A volume reduction in the soil matrix of 20 to 50% may occur (e.g., a 20-ft deep melt would create a depression of 4 to 10 ft). Performance is limited by the inability of nonintrusive techniques to confirm complete vitrification. *In situ* vitrification would severely limit future remedial alternatives for the MWL (e.g., wastes may remain at the MWL forever). | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Stabilization/*In-situ* Treatment | *In Situ* Grouting or Chemical Fixation: This technology would involve either physical stabilization (grouting) or chemical stabilization (fixation) of wastes within waste disposal cells. | Yes | Yes | Poor |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4, but is not responsive to Corrective Action Objective 1. *In situ* grouting and chemical fixation involves extensive intrusive activity that raises exposure concerns for site workers. This technology is technically and administratively implementable. Stabilization with physical and chemical agents would require direct access to waste disposal cells. This technology requires injection of pressurized fluids directly into waste. Performance of grout or chemical reagents is limited by the directional control of the drilling technology delivering the grout or chemical reagents, the proper viscosity of the fluids, effective mixing, and the inability of nonintrusive techniques to confirm fluid delivery at depth and complete encapsulation and stabilization. *In situ* grouting or chemical fixation would severely limit future remedial alternatives for the MWL (e.g., wastes may remain at the MWL forever). | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Excavation/ Storage/ Treatment/ Disposal | Complete Excavation with Aboveground, Retrievable Storage: This technology would involve complete excavation of the MWL and permanent storage of wastes in an on-site, aboveground, retrievable storage facility. This technology would require on-site capabilities for removal, shielding, handling, characterization, repackaging, transport, and storage of radioactive and mixed waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and aboveground retrievable storage would require the construction of secure, high-bay warehouses to stockpile, process, store, and monitor waste. Regulations would limit the duration and storage of hazardous and mixed waste, and pretreatment of waste may be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Excavation/ Storage/ Treatment/ Disposal | Complete Excavation with Off-Site Disposal: This technology would involve complete excavation of the MWL and shipment of wastes to a licensed, off-site facility. This technology would require on-site capabilities for removal, shielding and handling, and temporary on-site facilities for characterization, pretreatment, and repackaging prior to shipment and disposal of the waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and off-site disposal would require the construction of secure, high-bay warehouses to stockpile, process, package, store, and ship waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment of waste, including demilitarization of classified waste, may be required before shipment. Transportation of waste to an off-site facility may pose DOT and public health concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation: Responsive to Corrective Action Objectives | Technology Evaluation: Implementability | Technology Evaluation: Performance |
|---|---|---|---|---|
| Excavation/ Storage/ Treatment/ Disposal | Partial Excavation with Aboveground Retrievable Storage: This technology would involve excavation of the classified area of the MWL and permanent storage of wastes in an on-site, aboveground, retrievable storage facility. The classified area was selected because it contains various radioactive sources, tritium, uranium, and activation and fission products. This technology would require on-site capabilities for removal, shielding, handling, characterization, repackaging, transport, and storage of radioactive and mixed waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and aboveground retrievable storage would require the construction of secure, high-bay warehouses to stockpile, process, store, and monitor waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment of waste would be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation: Responsive to Corrective Action Objectives | Technology Evaluation: Implementability | Technology Evaluation: Performance |
|---|---|---|---|---|
| Excavation/ Storage/ Treatment/ Disposal | Partial Excavation with Off-Site Disposal: This technology would involve excavation of the classified area of the MWL and shipment of wastes to a licensed, off-site facility for disposal. The classified area was selected because it contains radioactive sources, tritium, activation products, and wastes that pose national security concerns. This technology would require on-site capabilities for removal, shielding, handling, and temporary on-site facilities for characterization, pretreatment, and repackaging prior to shipment and disposal of the waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term. Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and off-site disposal would require the construction of secure, high-bay warehouses to stockpile, process, package, store, and ship waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment, including demilitarization of classified waste, may be required before shipment. Transportation of waste to an off-site facility must be in compliance with DOT regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Concluded)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Excavation/ Storage/ Treatment/ Disposal | Future Excavation: This technology would involve complete excavation of the MWL at some time in the future when remote handling and/or robotics equipment would not be necessary. Aboveground retrievable storage and/or shipment of waste to a licensed, off-site facility for disposal would be employed. This technology would require on-site capabilities for removal and handling of waste and temporary on-site facilities for characterization, pretreatment, and repackaging of waste prior to permanent storage on site or shipment to a licensed, off-site facility for disposal. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 1, 2, 3, and 4. This technology is technically and administratively implementable. Excavation would be conducted when total radionuclide activity has decayed to safer levels than those that currently exist. Fugitive emissions generated from excavation activities may pose health risks to site workers and the public. Excavation would require the construction of secure, high-bay warehouses to stockpile, process, store, and monitor waste prior to disposition. Regulations may limit the duration of storage of hazardous and mixed waste, and pretreatment of waste, including demilitarization of classified waste, may be required. It is likely that some waste would need to be shipped off site for treatment and disposal. Transportation of waste to an off-site facility must be in compliance with DOT regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. | | | | |

CMS Corrective Measures Study
°C Degrees Celsius
DOT U.S. Department of Transportation
ft Foot (feet)
IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act
TA Technical Area

**Table 2-2**
**Results of Technology Screening for the MWL**

| Technology | Screening Criteria | | | |
|---|---|---|---|---|
| | **Responsiveness to Corrective Action Objectives[a] (Yes/No)** | **Implementability[b] (Yes/No)** | **Performance (Good, Fair, Poor)** | **Screening Evaluation (Accepted/ Rejected)** |
| NFA with no ICs | No | Yes | Poor | Rejected |
| NFA with ICs | Yes | Yes | Fair | Accepted |
| Long-Term Monitoring | No | Yes | Good | NA[c] |
| Long-Term Surveillance and Maintenance | Yes | Yes | Good | NA[c] |
| Long-Term Access Controls | Yes | Yes | Good | NA[c] |
| Vegetative Soil Cover | Yes | Yes | Good | Accepted |
| Structural Barriers | Yes | Yes | Poor | Rejected |
| RCRA Subtitle C Cap | Yes | Yes | Fair | Accepted |
| Bio-Intrusion Barrier | Yes | Yes | Fair | Accepted |
| Containment Cells | Yes | Yes | Poor | Rejected |
| *In Situ* Vitrification | Yes | Yes | Poor | Rejected |
| *In Situ* Grouting or Chemical Fixation | Yes | Yes | Poor | Rejected |
| Complete Excavation with Aboveground Retrievable Storage | Yes | Yes | Good | Accepted |
| Complete Excavation with Off-Site Disposal | Yes | Yes | Good | Accepted |
| Partial Excavation with Aboveground Retrievable Storage | Yes | Yes | Good | Accepted |
| Partial Excavation with Off-Site Disposal | Yes | Yes | Good | Accepted |
| Future Excavation | Yes | Yes | Good | Accepted |

[a]"Yes" implies that the technology is responsive to at least one of the corrective action objectives.
[b]"Yes" implies that the technology is technically or administratively implementable.
[c]ICs are implicit in all proposed corrective measures alternatives.

IC Institutional Controls
MWL Mixed Waste Landfill
NA Not applicable
NFA No Further Action
RCRA Resource Conservation and Recovery Act

## Table 3-1
## Development of Corrective Measures Alternatives for the MWL

| General Corrective Measure | Alternative | Description | Technology: NFA | Long-Term Monitoring | Long-Term Surveillance & Maintenance | Long-Term Access Controls | Vegetative Soil Cover | RCRA Subtitle C Cap | Bio-Intrusion Barrier | Complete Excavation with Aboveground Retrievable Storage | Complete Excavation with Off-Site Disposal | Partial Excavation with Aboveground Retrievable Storage | Partial Excavation with Off-Site Disposal | Future Excavation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I.a | NFA with ICs | X | X | X | X | | | | | | | | |
| Containment | III.a | Bio-Intrusion Barrier | | X | X | X | | | X | | | | | |
| | III.b | Vegetative Soil Cover | | X | X | X | X | | | | | | | |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | | X | X | X | X | | X | | | | | |
| | III.d | RCRA Subtitle C Cap | | X | X | X | | X | | | | | | |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | | X | X | X | | X | X | | | | | |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | | | | | | | | X | | | | |
| | V.b | Complete Excavation with Off-Site Disposal | | | | | | | | | X | | | |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | | | | X | | | | | | X | | |
| | V.d | Partial Excavation with Off-Site Disposal | | | | X | | | | | | | X | |
| | V.e | Future Excavation | | X | X | X | | | | | | | | X |

IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act

**Table 3-2**
**Estimated Direct Costs for MWL Corrective Measures Alternatives**

| General Corrective Measure | Alternative | Description | Direct Cost |
|---|---|---|---|
| | I.a | NFA with ICs | $1,082,143 |
| Containment | III.a | Bio-Intrusion Barrier | $2,201,668 |
| | III.b | Vegetative Soil Cover | $1,953,501 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | $2,527,007 |
| | III.d | RCRA Subtitle C Cap | $2,850,872 |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | $3,636,474 |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage—Option A | $545,620,660 |
| | | Complete Excavation with Aboveground Retrievable Storage—Option B | $416,018,751 |
| | V.b | Complete Excavation with Off-Site Disposal—Option A | $702,088,516 |
| | | Complete Excavation with Off-Site Disposal—Option B | $579,110,303 |
| | V.c | Partial Excavation with Aboveground Retrievable Storage—Option A | $139,718,215 |
| | | Partial Excavation with Aboveground Retrievable Storage—Option B | $103,569,857 |
| | V.d | Partial Excavation with Off-Site Disposal—Option A | $157,360,724 |
| | | Partial Excavation with Off-Site Disposal—Option B | $116,638,183 |
| | V.e | Future Excavation | $211,544,567 |

IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act

**Table 3-3**
**Cost Breakdown for Individual Excavation Alternatives**

| Alternative | Description | Cost of Excavation, Characterization, and Transportation | Cost of Aboveground Retrievable Storage Facility and/or Waste Processing Facility | Total Direct Cost |
|---|---|---|---|---|
| V.a | Complete Excavation with Aboveground Retrievable Storage—Option A | $420,059,569 | $125,561,091 | $545,620,660 |
| | Complete Excavation with Aboveground Retrievable Storage—Option B | $367,196,113 | $48,822,638 | $416,018,751 |
| V.b | Complete Excavation with Off-Site Disposal—Option A | $653,265,878 | $48,822,638 | $702,088,516 |
| | Complete Excavation with Off-Site Disposal—Option B | $530,287,665 | $48,822,638 | $579,110,303 |
| V.c | Partial Excavation with Aboveground Retrievable Storage—Option A | $97,997,927 | $41,720,288 | $139,718,215 |
| | Partial Excavation with Aboveground Retrievable Storage—Option B | $79,510,583 | $24,059,274 | $103,569,857 |
| V.d | Partial Excavation with Off-Site Disposal—Option A | $138,479,388 | $18,881,336 | $157,360,724 |
| | Partial Excavation with Off-Site Disposal—Option B | $97,756,847 | $18,881,336 | $116,638,183 |
| V.e | Future Excavation | $211,544,567 | $24,059,274 | $235,603,841 |

## Table 3-4
## Summary of Development of Corrective Measures Alternatives for the MWL

| General Corrective Measure | Alternative | Description | Effectiveness at Meeting Corrective Action Objectives: Minimize Exposure to Workers, the Public, and Wildlife | Effectiveness at Meeting Corrective Action Objectives: Limit Migration of Contaminants to Groundwater | Effectiveness at Meeting Corrective Action Objectives: Minimize Biological Intrusion into Waste | Effectiveness at Meeting Corrective Action Objectives: Prevent or Limit Human Intrusion | Implementability: Constructability Concerns | Implementability: Worker Health and Safety Risk | Implementability: Maintenance Requirements | Evaluation Summary |
|---|---|---|---|---|---|---|---|---|---|---|
| | I.a | NFA with ICs | Yes | Yes | Yes | Yes | Insignificant | Low | Minimal | Suitable |
| Containment | III.a | Bio-Intrusion Barrier | Yes | No | Yes | Yes | Minimal | Low | Minimal | Unsuitable |
| | III.b | Vegetative Soil Cover | Yes | Yes | Yes | Yes | Minimal | Low | Minimal | Suitable |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | Yes | Yes | Yes | Yes | Minimal | Low | Minimal | Suitable |
| | III.d | RCRA Subtitle C Cap | Yes | No | Yes | Yes | Moderate | Low | Moderate | Unsuitable |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | Yes | No | Yes | Yes | Moderate | Low | Moderate | Unsuitable |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.b | Complete Excavation with Off-Site Disposal | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.d | Partial Excavation with Off-Site Disposal | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.e | Future Excavation | Yes | Yes | Yes | Yes | Significant | Medium | Moderate | Suitable |

IC — Institutional Controls
MWL — Mixed Waste Landfill
NFA — No Further Action
RCRA — Resource Conservation and Recovery Act

[a]This alternative's failure in meeting Corrective Action Objective 1 is limited to the short term because of the increased exposure during excavation. In the long term, this alternative meets Corrective Action Objective 1 in minimizing exposure to workers, the public, and wildlife.

## Table 4-1
## Summary Evaluation of MWL Candidate Corrective Measures Alternatives

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| **Long-Term Reliability and Effectiveness** | | | | |
| Magnitude of Remaining Risk(s) after Implementation of the Alternative | Nonrad: HI = 0.00; excess cancer risk = 1E-9; risk below NMED guidelines.<br><br>Rad: TEDE = 3.3E-1 mrem/yr; excess cancer risk = 2.2E-6; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 2.4E-5 mrem/yr; excess cancer risk = 3.4E-10; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 2.4E-5 mrem/yr; excess cancer risk = 3.4E-10; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 0.00 mrem/yr; excess cancer risk = 0; below EPA guidelines.<br><br>Ecorisk approximately 0.<br><br>Risk approaches 0 assuming COCs are removed to background screening levels. |
| Extent of Long-Term Monitoring | Minimum of 70 years. The operational cover will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | Minimum of 70 years. The vegetative soil cover will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | Minimum of 70 years. The vegetative cover with bio-intrusion barrier will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | No monitoring required after excavation. |
| Uncertainties Associated with Leaving Waste in Place | Low | Low | Low | NA – No waste left in place. |

Refer to footnotes at end of table.

## Table 4-1 (Continued)
## Summary Evaluation of MWL Candidate Corrective Measures Alternatives

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| Potential for Failure of Alternative | Very Low | Very Low | Very Low | NA – No waste left in place. |
| **Reduction in Toxicity, Mobility, and Volume** | | | | |
| Reduction in Toxicity | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | Relative to the landfill, toxicity will be reduced. Relative to the waste, no reduction other than natural radioactive decay. |
| Reduction in Mobility | Minimal bio-intrusion, human access, and inadvertent human intrusion protection. | Minimized by limiting water infiltration, bio-intrusion, human access, and inadvertent human intrusion. | Minimized by limiting water infiltration, bio-intrusion, human access, and inadvertent human intrusion. | Eliminated by removal of waste from landfill disposal cells. |
| Reduction in Volume | None | None | None | Potential increase in volume |
| **Short-Term Effectiveness** | | | | |
| Short-Term Reduction in Existing Risk(s) | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE unchanged.<br><br>Ecorisk unchanged. | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE reduced by 3.3E-1 mrem/yr; excess cancer risk reduced by 2.2E-6.<br><br>Ecorisk reduced. | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines<br><br>Rad:<br>TEDE reduced by 3.3E-1 mrem/yr; excess cancer risk reduced by 2.2E-6.<br><br>Ecorisk reduced. | Nonrad:<br>None (assumes maximum concentrations reported during characterization).<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE increased by 3.23E+3 mrem/yr; excess cancer risk increased by 3.7E-2.<br><br>Ecorisk unchanged. |
| Time Needed to Achieve Reduction in Risk(s) | 1 month | 4 months | 4 months | 2 years (excavation only) |

Refer to footnotes at end of table.

## Table 4-1 (Concluded)
## Summary Evaluation of MWL Candidate Corrective Measures Alternatives

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| Short-Term Risk(S) Posed to Site Workers, the Community, and the Environment During Implementation of the Alternative | Transportation:<br>Injuries: 1.8E-2<br>Fatalities: 4.9E-4<br><br>Implementation:<br>Injuries: 9.5E-2<br>Fatalities: 2.4E-3 | Transportation:<br>Injuries: 4.9E-2<br>Fatalities: 1.3E-3<br><br>Implementation:<br>Injuries: 2.6E-1<br>Fatalities: 3.2E-3 | Transportation:<br>Injuries: 2.5E-1<br>Fatalities: 6.6E-3<br><br>Implementation:<br>Injuries: 3.2E-1<br>Fatalities: 3.5E-3 | Transportation:<br>Injuries: 8.8E-1<br>Fatalities: 2.3E-1<br><br>Implementation:<br>Injuries: 2.2E+0<br>Fatalities: 1.1E-2 |
| **Implementability** | | | | |
| Availability of Materials, Equipment, and Contractors | Readily available | Readily available | Readily available | Readily available |
| Technical and Administrative Difficulties | None. Addition of soil presents minimal concerns. | None. Addition of compacted fill presents minimal concerns. | None. Addition of compacted fill and the barrier present moderate concerns. | Significant. Excavation and characterization activities present significant concerns. |
| Permits and Approvals | Air quality | Air quality | Air quality | Digging, rad worker, waste storage, waste treatment, air quality |
| **Cost** | | | | |
| Capital and Operation and Maintenance Costs (Net Present Value) | $1,772,882 | $4,335,274 | $7,096,859 | $325,704,159 |

COC Contaminant of concern.
Ecorisk Ecological risk
EPA U.S. Environmental Protection Agency
HI Hazard Index
IC Institutional Controls
mrem/yr Millirem(s) per year
MWL Mixed Waste Landfill
NA Not applicable
NFA No Further Action
NMED New Mexico Environment Department
Rad Radiological
TEDE Total Effective Dose Equivalent

## Table 4-2
## Summary of the MWL CMS Alternatives Risk Results

| Alternatives | Human Health (IND) | | Ecological | | Transportation and Remediation Total Predicted Injuries and Fatalities | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Transportation | | Remediation | |
| | Nonrad | Rad | Nonrad | Rad (rad/day) | Injuries | Fatalities | Injuries | Fatalities |
| MWL Risk Baseline—NFA with No ICs | HI = 0.07<br>CR = 3E-6 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | No Transportation Risk | | No Remediation Risk | |
| MWL–Ia.<br>NFA with ICs | HI = 0.00<br>CR = 1E-9 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | 0.018 | 0.00049 | 0.095 | 0.0024 |
| MWL–IIIb. Vegetative Soil Cover | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.049 | 0.0013 | 0.26 | 0.0032 |
| MWL–IIIc. Vegetative Soil Cover with<br>Bio-Intrusion Barrier | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.25 | 0.0066 | 0.32 | 0.0035 |
| MWL–V.e Future Excavation | HI = 0.07<br>CR = 3E-6 | TEDE = 3.23E3 mrem/yr<br>CR = 3.7E-2 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.88 | 0.023 | 2.22 | 0.011 |

CMS Corrective Measures Study
CR Cancer Risk
HI Hazard Index
HQ Hazard Quotient
IC Institutional Controls
IND Industrial
mrem/yr Millirem(s) per year
MWL Mixed Waste Landfill
NFA No Further Action
Rad Radiological
TEDE Total Effective Dose Equivalent

## Table 4-3
## Detailed Cost Breakdowns for Candidate Corrective Measures Alternatives, Including Capital Costs, Operation and Maintenance Costs, Administrative Costs, and Escalation

| General Corrective Measure | Alternative | Description | Cost Component | Cost Breakdown | | |
|---|---|---|---|---|---|---|
| | | | | Direct Cost[a] | Markups[b] | Total Cost |
| NFA | I.a | NFA with ICs | Capital Cost[c] | $1,082,143 | $690,739 | $1,772,882 |
| | | | Operations & Maintenance[d] | $0 | $0 | $0 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $1,772,882 |
| Containment | III.b | Vegetative Soil Cover | Capital Cost[c] | $1,953,501 | $1,525,040 | $3,478,541 |
| | | | Operations & Maintenance[d] | $309,301 | $547,432 | $856,733 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $4,335,274 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | Capital Cost[c] | $2,527,007 | $1,959,816 | $4,486,823 |
| | | | Operations & Maintenance[d] | $849,300 | $1,760,736 | $2,610,036 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $7,096,859 |
| Excavation | V.e | Future Excavation | Capital Cost[c] | $235,603,841 | $ 90,100,318 | $325,704,159 |
| | | | Operations & Maintenance[d] | $0 | $0 | $0 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $325,704,159 |

[a]Direct costs include material, labor, and equipment used to implement the alternative.
[b]Markups are all costs other than direct costs that do not contribute to the alternative, and include SNL/NM's administrative costs (loads) and contingency allowances.
[c]Capital costs include construction and installation costs, equipment costs, and indirect costs such as engineering costs, legal fees, permitting fees, and startup and shakedown costs.
[d]Operation and maintenance costs are estimated for 30 years only, and include operating labor and materials costs, maintenance labor and materials costs, replacement costs, utilities, monitoring and reporting costs, administrative costs, and indirect costs.
[e]Total costs are based upon net present value, and do not include escalation.

IC Institutional Controls
NA Not applicable
NFA No Further Action
SNL/NM Sandia National Laboratories/New Mexico

# APPENDIX A

## Descriptions of Preferred Technologies

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# Descriptions of Preferred Technologies

# 1. No Further Action

No Further Action is a general corrective measure used to provide a baseline for comparison against remedial action technologies. Under the No Further Action response, institutional controls are optional. No Further Action may include long-term monitoring, long-term surveillance and maintenance, and long-term access controls. The No Further Action response without institutional controls is not appropriate for the MWL. The No Further Action response with institutional controls, however, is appropriate for the MWL and is retained for baseline comparison analysis. The No Further Action response with institutional controls is readily implementable and the least expensive response action possible.

# 2. Institutional Controls

Institutional controls are passive measures that are used to prevent unacceptable exposure to contaminants that could pose risks to human health and the environment. They are typically used in conjunction with structural engineering controls as part of a final remedy. Effective institutional controls must be low-cost, highly effective, easily implementable, and adaptable over relatively long periods of time. Often, they must outlive the institutions that create them. Thus, they need to be easily transferred to subsequent authorities having control of the land under consideration.

Institutional controls require clear human responsibilities and the active performance of measures to achieve these responsibilities. Examples are controlling access to a closed site by means of security guards; performing frequent, site surveillance and maintenance; controlling or cleaning up releases; or monitoring environmental parameters related to remedial measure(s) performance. Institutional controls depend on the design of controls and engineering structures. Examples are permanent markers or monuments placed at a closed site; public records and archives; government ownership and regulations regarding land or resource use; and other methods of preserving knowledge about a specific location, design, and contents of a closed site. Structural controls include physical barriers such as gates, fences, and natural barriers to keep mammals and trespassers away from a site; signs to warn people of dangers; and engineered barriers that contain or restrict actual or potential contaminant migration.

## 2.1 Long-Term Monitoring

Long-term environmental monitoring is used to measure the physical and/or chemical properties of an environmental medium, such as soil, air, biota, surface water, or groundwater. For remedial action applications, monitoring may be used to detect surface and/or subsurface releases from waste management or disposal facilities, to characterize temporal variations, or to document the progress and performance of remedial action.

Monitoring of soil or stream sediment is used to evaluate the nature and extent of contaminants, the physical characteristics of the contaminated materials, or the effectiveness of remediation. Physical characteristics such as subsidence may also be monitored. Soil vapor monitoring is commonly used to verify the effectiveness of vapor extraction systems or other treatment systems. Surface water monitoring uses various methods to characterize water quality in streams, wetlands, or other impoundments. Monitoring may also require the use of devices to measure volumetric flow rates in streams or pipes. Groundwater monitoring typically involves the use of monitoring wells and/or piezometers. Monitoring wells are designed to measure groundwater elevation, perform aquifer pumping tests, or collect groundwater samples for analysis. Piezometers are designed primarily to measure groundwater elevations only.

Long-term monitoring provides a degree of protection of human health and the environment and is relatively simple to implement. It is an implicit part of all corrective measures alternatives for the MWL. Long-term environmental monitoring alone is not responsive to corrective action objectives but when used in conjunction with other technologies, may increase the overall effectiveness of corrective measures.

## 2.2 Long-Term Site Surveillance and Maintenance

Long-term site surveillance and maintenance includes on-site activities designed to help recognize and control waste sites and promote the longevity of other remedial responses. Typical activities include controlling vegetation (mulching/seeding), limited grading to fill areas of subsidence and erosion, and maintenance of site drainage features to minimize the formation of the rills and gullies. Site maintenance may also include maintaining perimeter security fences, warning signs, and monuments.

Long-term site surveillance and maintenance controls provide a degree of protection of human health and the environment and are relatively simple to implement. It is an implicit part of all corrective measures alternatives for the MWL. Long-term site surveillance and maintenance alone is not responsive to corrective action objectives but when used in conjunction with other technologies, may increase the overall effectiveness of corrective measures.

## 2.3 Long-Term Access Controls

Long-term access controls include measures involving temporary or permanent physical restrictions to prevent or reduce animal and human exposure to contaminants. Controls can also be used to prevent vandalism of on-site remedial equipment or disturbance of containment and monitoring systems. Regular monitoring and maintenance of access controls is required for the measures to effectively deter site trespass. Access controls generally include site security measures such as fences and signs. Fences are used to completely surround the restricted area. Fences must be in good repair. Signs are posted around the facility with a legend warning of the hazard at the site. They are posted at each entrance to the restricted unit and at other appropriate locations in sufficient numbers to be seen from any approach.

In addition to access controls, administrative controls such as land use restrictions may also be used to prevent or reduce future human or environmental exposure to contaminants remaining at the site. Excavation permit restrictions may be used to permanently prohibit excavation or subsurface construction. Land use restrictions may also be a temporary measure used while other remedial actions are taking place.

In the long-term, if the property were ever to be transferred to non-federal ownership, the U.S. Government would create a deed for the new property owner. The deed would include notification disclosing the former waste management and disposal activities, as well as remedial actions taken at the site, and any continuing monitoring commitments. The deed notification would, in perpetuity, notify any potential purchaser that the property had been used for the management and disposal of hazardous waste. The deed would also include deed restrictions precluding residential use of the property. However, the need for these deed restrictions may be re-evaluated at the time of transfer in the event that contamination no longer poses an unacceptable risk under industrial use. In addition, if the site were ever to be transferred to non-federal ownership, a survey plat of the area would be prepared, certified by a professional land surveyor, and recorded with the appropriate county recording agency.

Access and administrative controls provide a degree of protection of human health and the environment and are relatively simple to implement. They are an implicit part of all corrective measures alternatives for the MWL. Long-term access controls alone are not responsive to corrective action objectives but when used in conjunction with other technologies, may increase the overall effectiveness of corrective measures.

# 3. Containment Technologies

Containment technologies involve the construction of a barrier to isolate contaminated media. When properly constructed and maintained, containment technologies can provide a reliable and effective method for controlling direct exposure to waste and minimizing contaminant transport through leaching, erosion, and/or bio-uptake.

## 3.1 Vegetative Soil Cover

This technology involves the deployment of a monolithic soil cover to limit water infiltration and direct surface water away from a disposal site. A diverse community of native plants would be established on the cover to extract water and mitigate wind and water erosion. A cover constructed of natural materials will function with minimal maintenance over the long-term as a natural ecosystem.

The goal of the EPA-recommended design of landfill caps is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize further maintenance, and to protect human health and the environment considering future use of the site. The EPA accepts alternative designs that consider site-specific conditions, such as climate and the nature of the waste, that meet the intent of the regulations. A fundamental concern of the EPA with cap designs is that all components are stable, and that the cap performs as intended without posing a significant risk to human health and the environment.

Vegetative soil covers are composed of multiple lifts of compacted, native soil. The cover is built by adding successive lifts of native soil over an existing landfill surface to form a soil monolith of sufficient thickness to store precipitation and support a healthy vegetative community. A topsoil layer is added that is seeded with native vegetation to mitigate surface erosion and promote evapotranspiration. During the institutional control period, native soil can be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers and rills that may result from surface erosion. At the end of institutional control, additional native soil can be added to accommodate any future subsidence and erosion. Because the cover is constructed without rigid layers, it can accommodate differential subsidence without undue impairment of its performance.

Vegetative covers are intended to meet the RCRA requirements of Title 40 CFR 264.310. Vegetative soil covers minimize water migration into contaminated media. Cover maintenance is minimized by using a monolithic soil layer. Individual layers, such as those used in traditional RCRA Subtitle C caps, are rigid and would require extensive maintenance and repair due to deterioration. Cover erosion is minimized by using erosion control measures such as gravel admixtures within the topsoil layer. Covers are centrally crowned and sloped at 2 to 5 percent. Subsidence is accommodated by using a “soft,” self-healing design. The permeability of cover soils is less than or equal to the permeability surrounding subsoils eliminating the “bathtub” effect.

Performance of alternative covers cannot be isolated from the performance of the prospective site. Natural site conditions, integrated with the cover, produce a “system performance” that will ensure that the alternative design adequately meets the regulatory requirements and functions as a natural ecosystem. Institutional controls, such as environmental monitoring, site surveillance and maintenance, and access controls are also components of this response action.

## 3.2 Structural Barriers

This technology involves the deployment of a single-layer concrete slab on grade or asphalt barrier on grade to minimize water infiltration. This technology would also mitigate biological and inadvertent human intrusion. This technology is usually reserved for temporary or short-term use in controlling the vertical migration of contaminants by reducing or eliminating surface water percolation through the soil column. Support for a robust concrete structure may require dynamic compaction of soils or placement of pilings.

Various structural cap designs and capping materials are available. Common structural caps include concrete slabs placed on grade or thin-shelled concrete or steel domes. The design must include sloping and drainage control. These materials are readily available, and construction costs for structural barriers are low in comparison to more complicated, composite cap designs.

Structural caps are generally supported either by pilings or by the disposal site surface. Pile-supported caps are less sensitive to settlement of the subbase, but may require extensive intrusive activities to place the pilings. Barriers that are supported by the disposal area surface do not require extensive intrusive activities, but generally require compaction of the surface prior to barrier construction. The selection of the design and materials depends on the nature of the site to be covered, the function and design life of the barrier, the local climate and hydrogeology, the geotechnical considerations that affect settling potential, the availability of materials, and the intended future use of the site.

The integrity of a structural barrier is susceptible to weathering effects, such as rusting and corrosion, differential settlement of underlying material, and loading. Deterioration of barriers leads to cracking and breaching, enabling water to reach the waste. Consequently, barrier integrity must be maintained as long as the contaminants continue to pose a potential threat to human health or the environment. Maintenance includes inspections, vegetation control, monitoring for evidence of subsidence, routine repair, and eventual replacement.

Structural barriers employ well-established materials and are designed for short-term durability. However, their maintenance costs are high and the effectiveness of barriers is limited because of their susceptibility to weathering, cracking, subsidence, and loading.

## 3.3 RCRA Subtitle C Caps

This technology involves the construction of an engineered cap using natural and synthetic materials. A RCRA Subtitle C cap is composed of a minimum of three layers: 1) an uppermost vegetation/soil layer, underlain by a minimum of 24 in. of compacted soil sloped between 3 and 5 percent; 2) a drainage layer, a minimum of 12 in. of sand, underlain by a flexible membrane liner to convey water out of the cap; and 3) a lowermost moisture barrier, a minimum of 24 in. of compacted clay, to prevent infiltration. The primary function of a RCRA cap is to limit water infiltration into waste disposal cells in order to minimize creation of leachate that could migrate to groundwater.

Natural clay or soil amended with bentonite is commonly used for the lowermost moisture barrier. The permeability of this compacted clay layer is required to be no more than $1.0 \times 10^{-7}$ cm/s. The overlying drainage layer allows lateral drainage off of and away from the moisture barrier. It is generally composed of a sand or gravel layer that is placed on a flexible membrane liner that overlies the moisture barrier. Under normal, unsaturated conditions, the drainage layer acts as a capillary barrier; i.e., the large pores of the sand or gravel inhibit capillary flow from the overlying soil layer. Under saturated conditions, such as might occur after heavy rainfall, the drainage layer serves as a high permeability conduit to drain water laterally off the compacted clay layer to the perimeter of the cap. The upper soil layer would consist of compacted soil of sufficient thickness to store precipitation and support a healthy vegetative community.

## 3.4 Bio-Intrusion Barriers

This technology involves the use of gravel and cobbles (rip rap), woven wire mesh, or other materials to limit intrusion by deep-rooted plants and burrowing mammals. The purpose of a bio-intrusion barrier is to minimize intrusion into waste disposal cells and to extend the life of a cap or cover by minimizing degradation from biotic intrusion. If a bio-intrusion barrier were constructed from a resistant material such as granite or quartzite, the layer may also serve as an effective human intrusion barrier. A bio-intrusion barrier can extend the lifetime of a cover by preventing intrusion by deep-rooted plants and burrowing mammals. Even if a bio-intrusion barrier consisting of gravel and cobbles or woven wire mesh were deployed, it would not be effective against ants, the largest potential biomass that may penetrate a cap or cover. Bio-intrusion barriers are designed for long-term durability with minimal maintenance requirements, however the long-term performance of bio-intrusion barriers has not been demonstrated. The short-term performance of bio-intrusion barriers within caps and covers has been studied recently in Idaho. The results of field and pilot tests indicate that long-term performance is promising.

## 3.5 Containment Cells

This technology involves the use of subsurface horizontal and vertical barriers to isolate buried waste from the environment and to prevent the release and migration of contaminants. Grout curtains and slurry walls would be preferred over geomembranes and sheet pile walls due to ease of installation. When properly constructed and maintained, containment cells can provide a reliable and effective method for controlling contaminant transport.

Grout curtains are low permeability barriers constructed using injection of fluids under pressure. Grouting fluids are typically composed of cement, bentonite, or specialty fluids such as silicate or lignochrome grout. The material that is selected must be compatible with the site geology, soil characteristics, and the waste itself. The grout must have the proper hardening time considering the method of injection. This will ensure that the grout does not harden so quickly that it does not reach the areas where it is needed, and that is does not harden so slowly that it spreads too thinly. Furthermore, the grout must be able to harden and remain competent in the presence of the waste itself. The method of grout emplacement must also be selected. Permeation grouting injects a low-viscosity grout into the soil at low pressure, filling the voids without significantly changing the structure or volume of the soil. Jet grouting, in contrast, injects grout at high pressure and velocity, which destroys the structure of the soil and mixes the grout and soil to form a relatively homogeneous mass.

There are four frequently used grout methodologies available: stage-down, stage-up, grout port, and vibrating beam. In the stage-down method, a borehole is drilled to the full depth of the wall and grout is injected as the drill is withdrawn. In the stage-up method, the grout is injected starting at the top of the borehole and continuing to the desired depth. The grout port method uses a slotted injection pipe and a double packer to inject the grout at specific intervals. In the vibrating beam method, an I-beam is vibrated into the soil to the desired depth, then grout is injected as the beam is withdrawn. Horizontal grout curtains are constructed to form horizontal barriers using methods similar to vertical barriers, except that the adjacent grout injection zones would completely overlap to cover a broad horizontal area. Alternatively, grout holes can be installed using horizontal drilling methods.

Slurry walls are vertical subsurface barriers constructed to limit horizontal migration of contaminants. This technology requires that an open trench be excavated and filled with slurry. The slurry wall (and trench) is generally 3 ft wide, and may be up to 20 ft deep. The slurry usually consists of cement or a soil-bentonite mixture. A soil “saw” is a common implement to create a slurry wall. It uses soil-cutting blades or a steel cable combined with high-pressure grouting jets to mix soil and grouting fluids to produce a homogeneous grout wall of uniform thickness.

Geomembranes are synthetic sheets that are placed by hand in trenches around the contaminated media. Geomembranes are relatively new, and there are concerns about the long-term efficiency and compatibility of the synthetic fibers with organic solvents.

Sheet pile walls are constructed by driving steel sheets into the ground to the desired depth. Sheet piling can be constructed of various materials. Steel with interlocking joints is frequently used. Grouting can also be used to seal the joints. Sheet pile walls are often used where both an impermeable barrier and excavation adjacent to the barrier are desired.

Containment cells are capable of confining leaking waste sites without disturbing the waste itself. A common benefit of a subsurface barrier system is that the waste remains fixed, allowing additional time to develop final remediation alternatives. Barriers are limited by the directional control of the drilling technology and by the inability of non-intrusive techniques to verify barrier continuity. Consistency, dimensions, and continuity of the grout barriers cannot be directly observed, and preferential flow of grout in higher permeability zones within heterogeneous soils can create discontinuities in the barrier.

# 4. *In Situ* Treatment

*In situ* treatment technologies treat contaminated media in place. For soil containing organic constituents, *in situ* treatment technologies generally involve physical, chemical, and/or biological treatment processes that immobilize the contaminants or that reduce contaminant concentrations in soil. Relative to comparable *ex situ* treatment technologies, *in situ* remedial technologies have the advantages of minimal handling of contaminated media and lower capital cost.

## 4.1 Dynamic Compaction

Dynamic compaction reduces soil void spaces and increases soil density. The technology involves a mobile crane that drops a dead weight on the ground surface. Important design considerations include the amount of weight, height of drop, and the number of drops at each location. Drop distance is determined by the size and weight of the dead weight and the depth of the material to be affected. Maximum economical depths for dynamic compaction are about 40 feet . Maximum densification energy can be achieved with weights of 30 to 40 tons dropped from up to 100 feet. In most cases, compacted backfill is placed over the affected area to return the land surface to grade. A cap may be placed over the compacted backfill and underlying waste. The increased density of the affected area contributes to overall site stability and reduces water infiltration.

## 4.2 *In Situ* Vitrification

This technology involves an electric current to convert soil and waste at extremely high temperatures to a crystalline mass. The crystalline mass is a chemically stable, leach-resistant, vitreous material similar to obsidian or basalt rock. The process destroys and/or removes organic material while immobilizing heavy metals and radionuclides. *In situ* vitrification greatly reduces contaminant mobility via leaching and biotic uptake. Due to the high temperature induced during vitrification, the process also destroys or removes organic contaminants in the waste medium. Furthermore, *In situ* vitrification provides long-term stability to the site and reduces the long-term possibility of human intrusion.

*In situ* vitrification is accomplished by inserting electrodes into the ground at the desired treatment depth or in surface soils and advancing them to depth during the melting process. A conductive mixture of flaked graphite and glass frit is placed among the electrodes to act as a starter path. The starter path is necessary because dry soil is not conductive after the conduction path in soil pore water is boiled away. Electrical power is charged to the electrodes, which establishes a current through the soil along the starter path. The resulting heat in the starter path reaches between 1400° and 2000°C and begins to melt the surrounding soil. The starter is consumed by oxidation, and the current is transferred to the soil, which is electrically conductive in the molten state. The molten mass grows outward at a rate of approximately 4 to 6 tons per hour, or 1 to 2 inches per hour. Under favorable site conditions, vitrification of an area 30 ft by 30 ft and 30 ft deep can be achieved. The process is repeated in adjacent areas until the desired area and volume of soil has been vitrified. The molten mass is then allowed to cool into a stable, microcrystalline solid. Cooling may take several years. Emissions from the soil are captured using a vacuum pressurized hood and treated in an off-gas treatment system. The size and type of the treatment system is dependent on the amount of organic contaminant in the soil to be treated.

The *In situ* vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt. Radionuclides (including transuranic isotopes and fission products) and inorganics are trapped in the solid product.

Factors that limit the applicability and effectiveness of the technology include rubble exceeding 20 percent by weight, combustible organics exceeding 5 to 10 weight percent, and inorganics exceeding 15 weight percent. Inclusions such as highly concentrated contaminant layers, void volumes, containers, metal scrap, general refuse, demolition debris, rock, or other heterogeneous materials also limit the effectiveness. Significant disadvantages of the technology include the possibility that heating of the soil will cause subsurface migration of contaminants into clean areas. *In situ* vitrification limits future remedial alternatives and waste may remain at the site indefinitely.

## 4.3 Stabilization (*In Situ* Grouting and Chemical Fixation)

This technology would involve either physical stabilization (grouting) or chemical stabilization (fixation) by injection of a fluid under pressure directly into waste disposal cells and contaminated media. The technology may be applied to pits, trenches, soils, or containers such as underground storage tanks. The grout envelops contaminated media and occupies soil void spaces, hardens, and immobilizes contamination in a cement-like matrix. In addition to immobilization, the technology also increases strength, decreases permeability, and provides many other geotechnical improvements without requiring excavation. This technology is typically used for wastes that leach heavy metals or other inorganic contaminants to immobilize the hazardous constituents. The process is not generally applicable to soils that are contaminated by volatile organic compounds, polychlorinated biphenyls, or pesticides.

The difference between the *in situ* grouting technology and the containment cell technology is that *in situ* grouting involves grouting the waste itself, whereas grouting associated with containment is performed adjacent to the waste.

When applied to soils, the grout is emplaced using pressure injection. Grouting fluids are typically comprised of cement or bentonite. Less frequently used reagents include silicate or lignochrome grout, pozzolanic-based materials, thermoplastic materials, and organic polymers. An innovative mix of ferrous sulfate hydrates combined with calcium hydroxide is currently under development as an *in situ* solidification slurry. The material that is selected must be compatible with the site geology, soil characteristics, and the waste itself. The grout must have the proper hardening time considering the method of injection. This will ensure that the grout does not harden so quickly that it does not reach the areas it is needed, and that is does not harden so slowly that it spreads too thinly. Furthermore, the grout must be able to harden and remain competent in the presence of the waste itself. The method of grout emplacement must also be selected. Permeation grouting injects a low-viscosity grout into soil at low pressure, filling the voids without significantly changing the structure or volume of the soil. Jet grouting, in contrast, injects grout at high pressure and velocity which destroys the structure of the soil and mixes the grout and soil to form a relatively homogeneous mass.

*In situ* chemical fixation includes a class of technologies where contaminants are chemically immobilized or isolated from migration or exposure. This is an emerging technology whereby contaminated soils are treated to convert inorganics into relatively immobile forms. An example of chemical fixation is stabilization of elemental mercury using calcium sulfides. Chemical fixation of soil is generally limited to surface soil, where the reagent is applied directly to the soil in a powdered, granular, or liquid form. Chemical fixation of groundwater is generally limited to permeable reactive walls.

*In situ* grouting or chemical fixation may limit future remedial alternatives and wastes may remain at the site indefinitely.

# 5. Excavation/Treatment/Disposal/Storage

Excavation technologies include removal, shielding, handling, storage, repackaging, transportation, and disposal of contaminated media. These technologies represent the most aggressive response to the contamination problems at a given site. Relative to *in situ* treatment technologies, *ex situ* treatment has the advantage of greater certainty in verification of the effectiveness of treatment and greater certainty that all contaminated media has been treated effectively.

Digging, scraping, ramping, scooping, and vacuuming may accomplish excavation of contaminated materials from hazardous waste sites. Removal is effective because contaminated materials are physically removed from the site. Excavations can range from narrow trench-like excavations to large pit-like excavations. Excavation above the water table can be done with very little secondary migration.

The equipment and sequence of operations used depend on physical characteristics of the site, the contaminated materials, dimension and depth of the excavation, size of the project, desired rate of excavation, degree of excavation accuracy required, available work space, and haul distances. Typical types of excavation equipment include long-reach backhoes, front-end loaders, cranes and attachments, scrapers, bulldozers, clamshells, draglines, hydraulic dredges, and vacuum trucks. After the buried wastes are exhumed, the area is normally backfilled with suitable materials and compacted to grade.

Although excavation can be effective, it requires shielding, handling, transporting, and treating or disposing of contaminated materials, resulting in greater potential of short-term exposure to site workers and the environment. Adequate controls against soil dispersion must be included to minimize the effects of spillage or the passage of contaminated equipment. Control of fugitive dust and vapor transport may be of particular concern. Extensive precautions to protect excavation side slopes and safety of remediation workers are required. Removing non-containerized wastes make exhumation relatively dangerous compared to original disposal of the wastes. Safety and environmental concerns must be balanced against the benefits of removal. Excavation of contaminated soil is limited to the practical depth of excavation. The excavation of deep contaminated soils is often prohibitively expensive.

Bulk material storage is used to store solids, liquids, and sometimes gases on-site, either as waste or as a material for treating waste, such as stabilization agents or dewatering additives. Common storage methods include waste piles, containers, and tanks.

Waste piles store solid waste above or on the ground. In the past, waste stored on soil or permeable surfaces permitted leaching of contaminants into shallow soils and groundwater. Currently, regulations require impermeable surfaces and leak detection with monitoring under waste piles.

Leak-tight containers are used to store or stage solids and semi-solids. Fifty-five gallon drums are common. Roll-off dumpster containers are sometimes used for larger volumes because of their low height, thereby allowing access with a backhoe and ease of transportation and loading onto tilt-bed trucks. To provide leak-tight characteristics, containers with gasketted hatches are available and lining.

Portable tanks are often used for storing pumpable sludges, wastewater, or other liquids. Bulk storage and interim treatment vessels include portable steel tanks, which range in capacity from 50 to 20,000 gallons, and portable high-density polyethylene tanks up to 15,000 gallons.

Depending on the climate, storage of stabilization/solidification agents, such as cement, fly ash, or lime, may be in surface impoundments.

Aboveground storage of waste requires secondary containment such as a lined dike or a larger tank placed around a storage vessel or a vault. Regulations require secondary containment to be large enough to contain 100 percent of the capacity of the largest tank or 10 percent of all tanks within its boundary. Containment must also be sized to hold a 24-hour rain event in addition to tank volumes.

Incineration is the thermal destruction of hazardous wastes in the presence of adequate oxygen for combustion. Incineration destroys halogenated and nonhalogenated organic wastes, including volatile organic compounds, polychlorinated biphenyls, and pesticides, through combustion under net oxidizing conditions. Toxic organic contaminants are permanently destroyed by high-temperature oxidation; however, a residual ash is created that may contain heavy metals and toxic products of incomplete combustion. Air pollution control systems (such as quench chambers, baghouse filters, gas absorbers, and mist eliminators) frequently must be incorporated into incinerator design to capture particulates, aerosols, hydrogen chloride, sulfur oxides, and other emissions.

Wastes generated at SNL/NM may be shipped off-site to a licensed, waste disposal facility. Disposal includes placement of waste materials in a permanent repository that is subsequently managed to ensure that contaminants are not reintroduced into the environment.

Transportation methods discussed here apply to off-site movement of hazardous wastes. On-site waste movement will be considered “material handling” because there is no use of public rights-of-way. Off-site transport is subject to the restrictions imposed by RCRA and the U.S. Department of Transportation. Material characteristics and economics are the primary concerns in deciding what form of transportation to use. There are three primary methods of waste transportation for containerized or bulk material: truck-highway, barge/ship-waterway, and railroad. At SNL/NM, only truck-highway is an acceptable process option. The outer surfaces of transport vehicles must be thoroughly decontaminated before leaving a hazardous waste site and again after discharging their load at the receiving facility. Transportation is retained as an ancillary process in conjunction with disposal of material off-site.

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# APPENDIX B

## Cost Summary Details for On-Site Facilities: High-Bay Warehouses and Waste-Processing Facilities

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# Cost Summary Details for On-Site Facilities: High-Bay Warehouses and Waste-Processing Facilities

This appendix contains the cost summary details for the high-bay warehouse and waste-processing facilities to be used in MWL Alternative V.a, Complete Excavation with Aboveground Retrievable Storage (ARS). These cost details were developed using the *PACES* (Parametric Construction Cost Estimating System) program.

*PACES* is a PC-based budgeting and cost estimating system that prepares parametric cost estimates for new facility construction, renovation, and life cycle cost, and is better suited than RACER for these types of estimates. *PACES* uses an integrated system of architectural and engineering parameters, construction criteria and methodologies, and worldwide knowledge bases priced against current cost data. It has been used to estimate costs for over $20 billion of completed construction for public agencies and private owners since 1982. It has been independently validated on over $4 billion worth of completed construction over the past 15 years.

The proposed ARS facility for MWL Alternative V.a, shown in Figure B-1, will cover an area of 104.6 acres and will contain seven high-bay warehouses and a support facility office. The storage facility will include four unclassified soil and waste storage warehouses, each with an area of 569,999 $ft^2$; two classified soil storage warehouses, each with an area of 477,803 $ft^2$; one classified waste storage warehouse with an area of 103,459 $ft^2$; and a storage facility office with an area of 5,286 $ft^2$. Cost details for this storage facility are presented in this appendix.

High-bay warehouses are required for all excavation scenarios, including those scenarios with planned off-site disposal of waste. High-bay warehouses are needed to meet waste characterization, segregation, storage, and security requirements. The number of warehouses required for each excavation scenario was determined based on

- the quantity of soil and waste to be excavated
- whether or not excavated soils are returned to the excavation, and
- the disposal scenario (ARS versus off-site disposal).

Costs for these storage facilities were determined by summing the costs for the individual warehouse components required for each excavation scenario (Table B-1). These costs are included in Table 3-3 of the CMS. Conceptual layouts for each high-bay warehouse facility are shown in Figures 3-1 through 3-7 of the text.

Assumptions used to estimate warehouse requirements and costs for each excavation scenario include the following.

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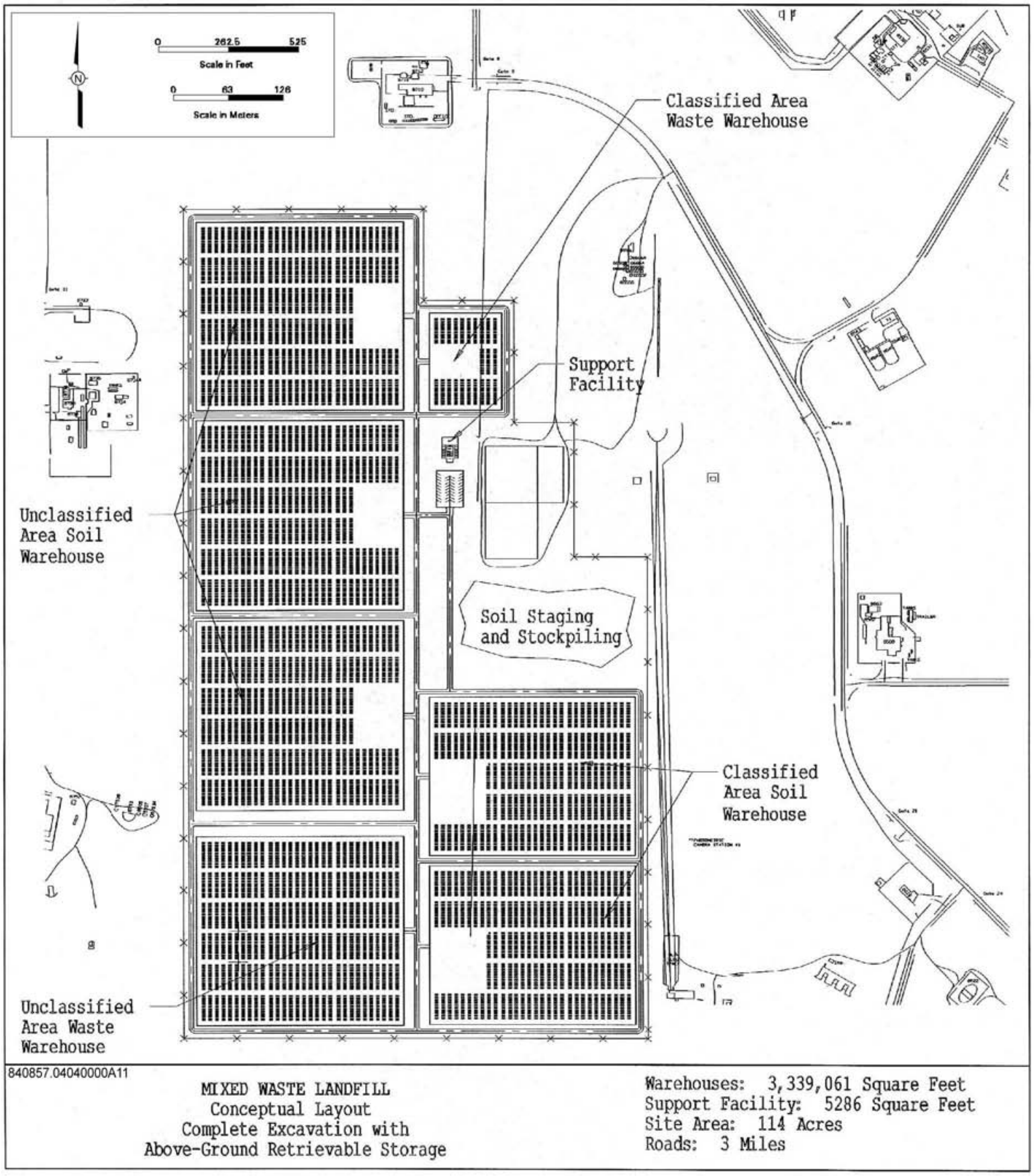


**Figure B-1 Proposed Aboveground Retrievable Storage Facility for Complete Excavation (MWL Alternative V.a)**

## Table B-1
## Cost Breakdowns for High-Bay Warehouse Facilities Required for Each Excavation Scenario

| Alternative | Description | Number of Warehouses Required | | | | | Total Direct Cost[c] ($) |
|---|---|---|---|---|---|---|---|
| | | Unclassified Soil Storage Warehouse | Unclassified Waste Storage Warehouse | Classified Soil Storage Warehouse | Classified Waste Storage Warehouse | Storage Facility Office[b] | |
| | **Direct Cost of Each Warehouse[a]:** | **$20,778,390** | **$21,114,374** | **$17,563,199** | **$5,080,123** | **$684,704** | |
| V.a | Complete Excavation with Aboveground Retrievable Storage - Option A | 3 | 1 | 2 | 1 | 1.00 | $125,561,091 |
| | Complete Excavation with Aboveground Retrievable Storage - Option B | 0 | 2 | 0 | 1 | 0.43 | $48,822,638 |
| V.b | Complete Excavation with Off-Site Disposal - Option A | 0 | 2 | 0 | 1 | 0.43 | $48,822,638 |
| | Complete Excavation with Off-Site Disposal - Option B | 0 | 2 | 0 | 1 | 0.43 | $48,822,638 |
| V.c | Partial Excavation with Aboveground Retrievable Storage - Option A | 0 | 0 | 2 | 1 | 0.43 | $41,720,288 |
| | Partial Excavation with Aboveground Retrievable Storage - Option B | 0 | 0 | 1 | 1 | 0.29 | $24,059,274 |
| V.d | Partial Excavation with Off-Site Disposal - Option A | 0 | 0 | 1 | 0 | 0.14 | $18,881,336 |
| | Partial Excavation with Off-Site Disposal - Option B | 0 | 0 | 1 | 0 | 0.14 | $18,881,336 |
| V.e | Future Excavation | 0 | 0 | 1 | 1 | 0.29 | $24,059,274 |

[a]Direct cost of each warehouse was estimated using the PACER software package.
[b]Size (and cost) of the storage facility office was adjusted depending on the number of total warehouses required. This column represents the relative size of the storage facility office.
[c]Total direct costs for all high-bay warehouse facilities were calculated by multiplying the number of high-bay warehouses required by the cost of each warehouse, adding the cost of site preparation work ( $1,220,322) and the cost of the storage facility office.

- Materials excavated from MWL pits and trenches are segregated into two components: soil and waste.

- Excavated materials are segregated into low-level radioactive waste and mixed waste. Excavated soil is considered low-level radioactive waste. Waste contained in pits and trenches is considered mixed waste.

- Volume estimates for the excavated soil and waste are based on the depths of the excavation: 30 ft for the classified area; 20 ft for the unclassified area; and the surface expression of each pit or trench based on geophysical signature. The side-slope of the excavation is 3:1. The volume ratio of cut soil to bank soil is 1.3 to 1. Volume estimates for excavated materials are summarized in Table B-2.

**Table B-2**
**Volume Estimates for Complete Excavation**

| Excavated Material | Unclassified Area | Classified Area |
|---|---|---|
| Soil | 59,700 $yd^3$ | 32,147 $yd^3$ |
| Waste | 20,861 $yd^3$ | 2,626 $yd^3$ |

- Under Excavation Option A, excavated soils are either stored in the ARS facility or disposed of off-site. Under Excavation Option B, all excavated soils are returned to the excavation as fill.

- Waste containerization and shipping must meet Nevada Test Site and EnviroCare of Utah waste acceptance criteria.

- Soils will be stored in 7 ft by 4 ft by 2 ft ("742") steel containers which will be filled to full capacity (2 $yd^3$). Waste from the pits and trenches will be stored in 7 ft by 4 ft by 4 ft ("744") steel containers which will be filled to 70 percent of full capacity (2.9 $yd^3$).

- SNL/NM waste management requirements will limit stacking of 742 containers to 3 high and stacking of the 744 containers to 2 high. Fourteen ft of aisle space is required for forklift access in all high-bay warehouses and three ft of walking space is required between all containers for inspections.

- Distances used to develop cost estimates for the high-bay warehouse facilities include 1500 ft to a central alarm station; 500 ft to a sewer tie; 1000 ft to clean water; and 1500 ft to power.

# APPENDIX C

## Additional Cost Details

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# Additional Cost Details

This appendix includes additional details on the cost estimates for the MWL CMS. These details include a description of the cost estimating software, the assumptions behind the long term monitoring costs, the estimation of waste volumes, and waste characterization and disposal costs. Definitions for key cost parameters are also included.

# 1. Cost Estimating Software

Costs for MWL CMS alternatives were primarily developed using the *RACER* (Remedial Action Cost Engineering and Requirements) *2001*™ cost-estimating model. *RACER* is a Windows-based environmental remediation/corrective action cost-estimating system, originally developed by the Air Force. *RACER* uses parametric estimating techniques to provide capital, operations, and maintenance cost estimates for remediation/corrective action projects. It is used by EPA, DOD, DOE, industry, state agencies, and environmental consultants to estimate costs for all phases of corrective action. *RACER* has been validated, verified, and accredited by the U.S. Amy Corps of Engineers, the Air Force Civil Engineer Support Agency, and Price Waterhouse Coopers.

Costs for ARS high-bay warehouse facilities were estimated using the *PACES* (Parametric Construction Cost Estimating System) program, which is better suited for developing costs for buildings and infrastructure.

# 2. Long-Term Monitoring Costs and Assumptions:

**Groundwater, Soil, Vegetation, and Air Monitoring Costs.** Costs for thirty years of groundwater, soil, vegetation, and air monitoring are included in the following alternatives:

- Alternative MWL I.a - NFA with Institutional Controls
- Alternative MWL III.a. - Bio-Intrusion Barrier
- Alternative MWL III.b - Vegetative Cover
- Alternative MWL III.c - Vegetative Soil Cover with Bio-Intrusion Barrier
- Alternative MWL III.d - RCRA C Cap
- Alternative MWL III.e - RCRA C Cap with Bio-Intrusion Barrier
- Alternative MWL V.e - Future Excavation

Costs for 30 years of surveillance and maintenance are also included. Surveillance and maintenance activities may include seeding, mulching, grading, erosion control, signage, and fencing.

A detailed description of groundwater, soil, vegetation, and air monitoring activities, the frequency at which they will be performed, and corrective action triggers will be determined in consultation with the NMED and addressed in the MWL Post-Closure Care Plan.

Groundwater monitoring may consist of annual sampling of 5 monitoring wells, with one duplicate sample and one waste management sample. Groundwater samples may be analyzed for tritium, gross alpha/beta activity, gamma spectroscopy, target analyte list metals, volatile organic compounds, nitrate, major ions, and alkalinity. The estimated monitoring well life is 20 years. No costs are included for plugging and abandoning wells or construction of new wells.

Soil monitoring may consist of annual sampling of 8 soil locations at the MWL. Soil samples may be analyzed for tritium and gamma spectroscopy. Vegetation monitoring may consist of annual collection of 4 vegetation samples at the MWL. Vegetation samples may be analyzed for tritium and gamma spectroscopy. Air monitoring may consist of annual collection of 4 air samples at the MWL. Air samples may be analyzed for tritium, gamma spectroscopy, and gross alpha/beta activity.

The MWL CMS cost estimates do not include costs for sampling and analysis plans, which will be included in the MWL Post-Closure Care Plan.

# 3. Vadose Zone Monitoring Costs

Costs for installation of a vadose zone monitoring system and thirty years of vadose zone monitoring are included in the following alternatives:

- Alternative MWL III.a. - Bio-Intrusion Barrier
- Alternative MWL III.b - Vegetative Cover
- Alternative MWL III.c - Vegetative Soil Cover with Bio-Intrusion Barrier
- Alternative MWL III.d - RCRA C Cap
- Alternative MWL III.e - RCRA C Cap with Bio-Intrusion Barrier
- Alternative MWL V.e - Future Excavation

The vadose zone monitoring system may include three vadose FLUTe sampling systems installed to a depth of 250 ft bgs and three neutron probe access holes installed at a 45-degree angle to a depth of 142 ft bgs. Vadose zone monitoring boreholes will be installed using conventional drilling technology. A detailed description of vadose zone monitoring activities, the frequency at which they will be performed, and corrective action triggers will be determined in consultation with the NMED and addressed in the MWL Post-Closure Care Plan.

The vadose FLUTe systems may include 5 access ports, installed at increments of 50 ft to 250 ft bgs. The ports may be sampled annually for tritium and volatile organic compounds. Neutron probe access holes may be monitored annually for moisture content to 142 ft bgs. More frequent vadose zone sampling and neutron moisture monitoring may be advantageous during the first two years of monitoring to establish baseline conditions. The additional costs for more frequent sampling are not included in this module.

# 4. Waste Volume Estimates

Waste volume estimates are based on the depth of excavation and the dimensions of each pit and trench (Table C-1). The excavation cost estimates in Chapter 3 assume that the classified area will be excavated to a depth of 30 ft and the unclassified area excavated to a depth of 20 ft. For sidewall protection, the side-slopes (rise:run) will be 3:1. Excavated material will be segregated into soil and debris. All material from pits and trenches is considered debris with the exception of the upper three feet of backfill soil in each pit and trench. Debris includes waste as well as packaging, containers, demolition and construction materials and contaminated soil. All excavated material from outside the pits or trenches is assumed to be soil.

Soil volume expansion after excavation was accounted for by assuming a volume ratio of 1.3 to 1 for excavated soils to bank soils. This ratio was estimated based on engineering experience with similar excavation activities at the Chemical Waste Landfill (CWL) and at borrow pits established west of the Corrective Action Management Unit (CAMU).

# 5. Waste Characterization and Disposal

Waste characterization costs are based on characterization costs determined during the CWL excavation. Characterization of soil will cost approximately \$1000/yd$^3$. Characterization of debris will cost approximately \$10,000/yd$^3$.

Waste shipping and disposal costs are a function of whether the waste is radioactive or mixed waste. All debris from pits and trenches is considered mixed waste. All excavated soil is considered radioactive waste. The estimated disposal cost for mixed waste is \$8100/yd$^3$. The estimated disposal cost for radioactive waste is \$810/yd$^3$. These costs were obtained directly from the SNL/NM Radioactive and Mixed Waste Management Facility (RWMF).

# 6. Waste Storage Requirements

Waste storage and shipping containers must meet Nevada Test Site and EnviroCare of Utah waste acceptance criteria. Soils will be stored in 7 ft by 4 ft by 2 ft (“742”) steel containers

## Table C-1
## Soil and Debris Volumes Calculated from MWL Trench and Pit Dimensions

| Trench/Pit | Length (ft) | Width (ft) | Diameter (ft) | Depth (ft) | Area ($ft^2$) | Volume ($ft^3$) | Volume of Soil[c] in Trench/Pit ($ft^3$) | Volume of Debris[d] in Trench/Pit ($ft^3$) |
|---|---|---|---|---|---|---|---|---|
| Unclassified Area | | | | | | | | |
| Trench A | 153 | 33 | NA[a] | 15 | 5080.37[b] | 76206 | 15241 | 60964 |
| Trench B | 157 | 25 | NA | 15 | 3925.5 | 58882 | 11776 | 47106 |
| Trench C | 121 | 31 | NA | 15 | 3753.7 | 56306 | 11261 | 45044 |
| Trench D | 162 | 45 | NA | 20 | 7308.3 | 146165 | 21925 | 124241 |
| Trench E | 175 | 37 | NA | 15 | 6493.9 | 97409 | 19482 | 77927 |
| Trench F | 180 | 44 | NA | 20 | 7861.7 | 157233 | 23585 | 133648 |
| Trench G | 81 | 54 | NA | 20 | 4371.0 | 87420 | 13113 | 74307 |
| Classified Area | | | | | | | | |
| Pit SP-1 | 8 | 6 | NA | 15 | 48 | 720 | 144 | 576 |
| Pit SP-2 | 34 | 8 | NA | 15 | 272 | 4080 | 816 | 3264 |
| Pit SP-3 | 14 | 10 | NA | 15 | 140 | 2100 | 420 | 1680 |
| Pit SP-4 | 8 | 8 | NA | 20 | 64 | 1280 | 192 | 1088 |
| Pit SP-5 | 10 | 10 | NA | 20 | 100 | 2000 | 300 | 1700 |
| Pit 1 | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 2 | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 3A | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 3B | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 4 | NA | NA | 7 | 15 | 38 | 577 | 115 | 462 |
| Pit 5 | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 6 | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 7 | NA | NA | 7 | 15 | 38 | 577 | 115 | 462 |
| Pit 8 | NA | NA | 6 | 15 | 28 | 424 | 85 | 339 |
| Pit 9 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 10 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 11 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 12 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 13 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 14 | 12 | 12 | NA | 25 | 144 | 3600 | 432 | 3168 |
| Pit 15 | 12 | 12 | NA | 25 | 144 | 3600 | 432 | 3168 |
| Pit 16 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 17 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 18 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 19 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 21 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 24 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 25 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 26 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 27 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 28 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |

Refer to footnotes at end of table.

**Table C-1 (Concluded)**
**Soil and Debris Volumes Calculated from MWL Trench and Pit Dimensions**

| Trench/Pit | Length (ft) | Width (ft) | Diameter (ft) | Depth (ft) | Area ($ft^2$) | Volume ($ft^3$) | Volume of Soil[c] in Trench/Pit ($ft^3$) | Volume of Debris[d] in Trench/Pit ($ft^3$) |
|---|---|---|---|---|---|---|---|---|
| Pit 30 | NA | NA | 4 | 15 | 13 | 188 | 38 | 151 |
| Pit 31 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 32 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 33 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 34 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 35 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit 36 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit U-1 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit U-2 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |
| Pit U-3 | 10 | 10 | NA | 25 | 100 | 2500 | 300 | 2200 |

[a]NA - Not Applicable.
[b]The exact area of each trench was calculated by Sandia's Graphical Information System (GIS) group, based on geophysical survey data of MWL trenches obtained during the Phase 2 RFI.
[c]The upper 3 feet of each trench or pit are assumed to contain backfilled soil, rather than debris. For the purpose of cost estimating, this soil was considered to be low level radioactive waste, rather than mixed waste. The remainder of each trench or pit was considered debris and mixed waste.
[d]Debris includes packaging, containers, demolition and construction materials, and the radioactive wastes themselves.

which will be filled to full capacity (2 $yd^3$). Waste from the pits and trenches will be stored in 7 ft by 4 ft by 4 ft (“744”) steel containers which will be filled to 70 percent of full capacity (2.9 $yd^3$). SNL/NM waste management requirements limit stacking of 742 containers to 3 high and stacking of 744 containers to 2 high. Fourteen ft of aisle space is required for forklift access in all high-bay warehouses. Three ft of space is required between all waste boxes for inspections.

# 7. Operations and Maintenance Costs

All operations and maintenance costs were calculated by RACER for alternatives which were carried through to Chapter 4 of the CMS. Operations and maintenance costs were estimated for thirty years. Operations and maintenance costs for the future excavation scenario were considered to be negligible ($0) although there will be some O&M costs for operations of the high-bay warehouse facility. No costs are included for decontamination and decommissioning (D&D) of the facility.

# 8. CMS Cost Definitions

**Contingency—**An unknown or unforeseen condition that might increase cost during the execution of a project; used in an estimate to cover costs for contingency.

**Direct Costs—**Direct costs include all of the costs that can be directly attributed to a particular item of work or activity required to accomplish the project. Direct costs include direct labor costs (which includes wages paid to employees who conduct the work); the cost for purchasing materials used in the performance of the project; and the cost of construction equipment used in the performance of the work. The prime contractor's direct cost also includes the total subcontractor's price including overhead and profit.

**Escalation—**Price adjustment, from the current date to the date on which work will be performed.

**Inflation Factors for Direct Costs—**All inflation factors were default parameters used by the *RACER* program, and are based on Office of Management and Budget inflation factors.

**Markup—**Markups are all costs other than direct costs that do not become a permanent part of the facilities nor contribute to the studies or design. Markup templates are included in the *RACER* program.

**Source of Cost Data from *RACER*—**The database used by *RACER* is the ECHOS© cost database. ECHOS©, the Environmental Cost Handling Options and Solutions, gathers, monitors, and develops detailed line-items and component costs needed to prepare or verify cost estimates for environmental restoration projects.

# APPENDIX D

## Technical Approach and Cost Estimate for Excavation of the Classified Area Using Robotics

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# Technical Approach and Cost Estimate for Excavation of the Classified Area Using Robotics

# 1. Introduction

## 1.1 Purpose of this Summary

The intent of this evaluation is to outline the technical approach, equipment required, and resulting cost associated with the remote and/or robotics excavation and characterization of the classified area of the MWL at SNL/NM. The classified area is 100 ft. by 215 ft. in dimension. The proposed excavation would be to 30 ft. in depth. The total volume of the excavation including sloping (3:1) of the pit walls is estimated to be 27,354 $yd^3$. This area of the landfill includes multiple waste disposal pits containing a wide range of radiologically contaminated items, some of which have been incased in concrete resulting is several very large and heavy objects which may have to be broken up *in situ* prior to removal.

## 1.2 Background (Previous Projects)

The foundation for this technical approach and cost proposal for remote and/or robotics excavation of the classified area is based on several projects that have completed within the DOE complex, which required remote operations for removal and characterization of contaminated soil and debris.

### 1.2.1 Remote Excavation of Material Disposal Area-P, Los Alamos National Laboratory, Los Alamos, New Mexico

Material Disposal Area-P was operated from 1950 to 1984 and received materials from the burning of high explosives (HE), HE-contaminated equipment and material, barium nitrate, construction debris from the D&D of Manhattan-era buildings, as well as trash, vehicles, empty drums, and miscellaneous containers.

To mitigate the dangers of a detonation during excavation of the disposal area, all initial excavation operations were performed remotely. A computer-controlled, 62,000 lb. tracked excavator coupled with a hydraulic manipulator was used for all initial excavation and sorting of disposal debris. Over a 23-month period, approximately 32,000 $yds^3$ of explosive contaminated soil, including 607 tons of steel, and 500 tons of concrete were remotely excavated from the landfill.

### 1.2.2 Technical Area II Landfill Remediation, Sandia National Laboratories, Albuquerque, New Mexico

During remediation of the landfills contained within SNL/NM Technical Area II, there was a risk of site personnel encountering several potentially high hazardous materials. A remote robotic manipulation and excavation system was deployed for characterization and retrieval of buried chemical, explosive, and radioactive materials discovered during excavation operations.

Remote operations were conducted for approximately 85 days during the course of this project. During daily operations, surface material was removed in six- to twelve-inch lifts until a suspicious object was visually detected. The excavator bucket was then curled under the boom and placed on the ground. The robotic manipulator was deployed and used to scan, inspect, and retrieve the object.

### 1.2.3 Historical Radioactive and Mixed Waste Disposal Request Validation and Disposal Project (HDRV), Sandia National Laboratories, Albuquerque, New Mexico

A remote robotic system was developed, deployed, and operated to perform drilling, cutting, and manipulation tasks on 34 unknown radioactive contaminated cylindrical objects. A fully integrated robotic system was developed and deployed. The system consisted of robot manipulator, a tool rack, and a workbench. Site operations were conducted for approximately 11 days, followed by removal of the system over a two-day period.

During site operations, individual cylindrical objects were robotically retrieved and placed in the vise. A hole was drilled into the end of the object, and Tritium, $O_2$, and lower explosive level (LEL) sensors were utilized by the robotic system to characterize the contents. In Addition, the robotic system was used to consolidate the contents of the cylinders into a single 5-gallon container.

# 2. Assumptions

- Based on previous remote excavation activities, a soil and debris removal rate of 300 $yd^3$ per week is assumed to be achievable for the classified area.

- Using a total estimated soil volume of 27,354 $yd^3$ and the above mentioned removal rate of 300 $yd^3$ per week, the total time for remote excavation of the classified area of the MWL is 91 weeks.

- All initial excavation and removal of soil and debris would be accomplished remotely.

- All initial characterization and sampling of debris would be accomplished remotely in close proximity to the point of excavation.

- All initial characterization and sampling of soil would be under taken at an adjacent staging area.

- The radiological contamination levels in the excavated soil would not be high enough to preclude the use of personnel to operate the equipment required to characterize and sample the soil.

# 3. Technical Approach

## 3.1 Remote Excavation

Prior to the start of remote operations, a project trailer would be setup with direct line of site to the classified area. Housed within the trailer will be the Operator Control Console (OCC) for all the remote equipment. The distance between the points of excavation and all project support buildings would be determined by a hazard analysis to ensure all site personnel would maintain a safe distance during the removal activities. In addition, any obstructions between the OCC and the excavation, which could cause radio interference with the remote equipment, would be removed.

For the excavation, a conventional tracked excavator equipped for remote computer controlled operations would be employed in addition to a passive screen (Grizzly) used to separate soil and debris. The Grizzly would be built so that a standard 20-$yd^3$ roll-off could be placed under the screen to catch the soil. An excavation plan would be developed to enable the most efficient method for removal of soil from the landfill. During site operations, the excavator and Grizzly would be placed in close proximity to the area identified for excavation, and a roll-off would be placed into position. Under remote computer control, one- to two-foot lifts of soil would be removed from the area and placed on the passive screen. Excavation would continue until a sufficient amount of debris will have accumulated on the screen. At this point, excavation would stop and the debris would be removed remotely in preparation for characterization. Soil removal activities would resume and this cycle would continue until the roll-off was filled. At that time, an initial gross radiation survey would be completed to insure "safe to move criteria" had been met. The full roll-off would be replaced and removal operations would resume.

## 3.2 Soil/Debris Radiation Characterization and Sampling

### 3.2.1 Debris

For on-site characterization of the debris removed from the classified area, a self-contained characterization system would be used to perform the remote radiological analysis of the material. The system would consist of a horizontal conveyor belt that passes into a chamber containing the detection equipment necessary to characterize the debris. The conveyor belt would continue through the detection chamber and on to a material sampling and packaging section.  At this point, two robotic manipulators and an overhead crane would be used to remove samples of the material for future analysis as well as to place the residual material into Standard Waste Boxes (SWB) or radiation shielded containers where appropriate.  The debris characterization system would be skid-mounted and placed adjacent to the Grizzly during the removal operation.

### 3.2.2 Soils

At a staging area adjacent to the excavation site, the full roll-offs would be stored until enough material had accumulated to begin the soil and sampling process.  A segmented gate counter would be employed to characterize and sort the excavated material.  In this system, the contaminated material is placed on a conveyor and passed through an array of radiation detection sensors that identify the amount and type of radiation present in the soil.  An active gate at the end of the conveyor is used to direct the material to several piles based on the sensor data.  A soil storage area would be developed to house the separated piles prior to disposal.  In this way, 100 percent of the excavated soil can be screened and separated in preparation for disposal. After the material has been separated, soil samples can be taken for each lot for analysis of the hazardous chemical composition.

# 4. Cost Estimate

Based on a soil removal rate of 300 $yd^3$ per week and a total excavation duration of 91 weeks, the total estimated cost to excavate, segregate, characterize, and place in interim storage the material currently contained in the classified area of the MWL is $24,923,585.00.  This figure results in a per cubic yard cost of  $911.15.

**Cost Break Down**

| Item | Description | Unit Cost | Quantity | Cost |
|---|---|---|---|---|
| Document Preparation | Development of Operation Specific HASP, SOP, Excavation Plan, and Operations Plan. Costs based on historical data from similar projects | $63.75/hr | 11,500 hr | $733,125 |
| Mobilization | Preparation, Transportation, and setup of remote excavation systems and facilities | $500,000/ea | 1 | $500,000 |
| Remote Excavation | Historical cost based on LANL MDA-P remote excavation.  This cost includes personnel, equipment, and all overhead associated with remote excavation | $480/$yd^3$ | 27,389 $yd^3$ | $13,146,720 |

## Cost Break Down (Concluded)

| Item | Description | Unit Cost | Quantity | Cost |
|---|---|---|---|---|
| System Maintenance | Maintenance of excavator, characterization systems, and all related systems | $1000/wk | 91 | $91,000 |
| Mobile Crane | 50-ton crane with 80-ft reach for use in conjunction with remote equipment & operator | $140/hr | 4550 hr | $637,000 |
| Remote Debris Characterization System | Remote system including conveyor belt, characterization chamber, robotic manipulators, and external power systems | $730,000/ea | 1 ea | $730,000 |
| SEGMENTED GATE COUNTER | System used to characterize all soils | $250/yd$^3$ | 27,389/yd$^3$ | $6,847,250 |
| RADIATION SAFETY/MONITORING | Entire suite of radiation detection and monitoring equipment | $142,740/ea | 1 ea | $142,740 |
| ADDITIONAL CHARACTERIZATION PERSONNEL | Staff for debris characterization system and radiation safety | $160,000/FTE | 8 FTE | $1,280,000 |
| ROLL-OFF | Temporary soil storage, 20 yd$^3$ ea | $5,000/ea | 40 | $200,000 |
| STANDARD WASTE BOX | Storage for LLW debris | $750/ea | 21 | $15,750 |
| SHIELDED CONTAINERS | Storage for high-emitting debris | $5,000/ea | 20 | $100,000 |
| DEMOBILIZATION | Decontamination, shutdown, disassembly, disposal and transport of remote related equipment. | $500,000/ea | 1 | $500,000 |
| **TOTAL COST** | | | | $24,923,585 |

# 5. Conclusion

The above cost estimate takes into account, from previous historical project experience, the major expenses associated with the remote handling and/or robotics excavation and characterization of the soil and debris contained within the classified area of the MWL. Until a more detailed development of project operations, the special procedures associated with the nuclear materials contained within the site, and all associated site-specific requirements have been undertaken, the costs developed in this document are at best within 20 percent of the actual costs which might be expected for the excavation of a site with the level of complexity of the MWL.

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# APPENDIX E

## Risk Assessment for the MWL

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# THE MIXED WASTE LANDFILL: RISK ASSESSMENT REPORT

On October 11, 2001, the New Mexico Environment Department (NMED) directed that the U.S. Department of Energy (DOE) and Sandia National Laboratories/New Mexico (SNL/NM) conduct a Corrective Measures Study (CMS) for the Mixed Waste Landfill (MWL) in Technical Area (TA)-3 at SNL/NM. The following presents a human health and ecological risk evaluation for the potential remedial alternatives selected in the CMS. This risk assessment evaluates potential chemical and radiological risks as well as the potential injuries and fatalities that may occur for each remedial alternative. In addition, the risk assessment includes the MWL Risk Baseline Analysis—No Further Action (NFA) with No Institutional Controls (ICs). Under the baseline risk analysis, the current IC and groundwater monitoring would be terminated. The existing operational cover would remain undisturbed in its present condition. This analysis is included in this risk assessment as the baseline scenario because it represents current conditions at the site. The following corrective measures (CMs) have been proposed for the MWL. No Further Action with No ICs is presented in this risk assessment.

- MWL Alternative I.a—NFA with ICs. Under this alternative, the existing operational cover would be maintained and current IC and groundwater monitoring would continue. The landfill surface would be built up with additional soil to form a central crown and uniform grade that will prevent ponding and promote surface runoff.

- MWL Alternative III.b—Vegetative Soil Cover. Under this alternative, a soil cover with native plants would be established over the existing operational cover. Multiple lifts of compacted soil would further isolate buried waste from the surface environment and minimize infiltration of water. A topsoil layer, admixed with gravel, would be planted with native vegetation to mitigate surface erosion and promote evapotranspiration. A cover constructed of compacted natural soil would require minimal maintenance and emulate the natural ecosystem.

- MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier. Under this alternative, a bio-intrusion barrier composed of a layer of cobbles or boulders would be constructed over the existing operational cover before establishing the vegetative soil cover.

- MWL Alternative V.e—Future Excavation. Under this alternative, the landfill would be completely excavated and waste would either be contained in an aboveground, retrievable storage system or shipped to a licensed facility for off-site disposal. Secure, high-bay warehouses for processing and storing classified and unclassified waste would be built adjacent to the landfill to minimize handling and transportation and costs.

## I. Site Description and History

SNL/NM is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico. The MWL, located 3.5 miles south of SNL/NM's central facilities and 5 miles southeast of Albuquerque International Sunport, is a fenced, 2.6-acre compound in the north-central portion of TA-3. The elevation is 5,381 feet above mean sea level.

The MWL, which operated from March 1959 to December 1988, served as the primary disposal site for SNL/NM technical and remote test areas involved in nuclear weapons research and development. The MWL was originally designated as the “TA-3 low-level radioactive dump” in March 1959 when the existing low-level radioactive dump in TA-2 was closed. Approximately 100,000 cubic feet of radioactive and mixed waste were disposed of in the MWL during the period of its operation. From 1989 to 1996, the southern unclassified area was used for temporary, aboveground storage of containerized, low-level radioactive and mixed waste. This aboveground storage area was referred to as the Interim Storage Site (ISS).

A detailed MWL waste inventory, by pit and trench, is provided in Attachment 2-1 of “Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA [Resource Conservation and Recovery Act] Facility Investigation,” June 15, 1998 (SNL/NM June 1998).

The MWL consists of two distinct disposal areas, including the classified area that occupies 0.6 acre, and the unclassified area that occupies 2.0 acres. Wastes in the classified area were disposed of in a series of unlined, vertical pits. Historical records indicate that the early pits were 3 to 5 feet in diameter and 15 feet deep. Later pits measured 10 feet in diameter and 25 feet deep. After the pits had been filled with waste, they were backfilled with soil and capped with concrete. Wastes in the unclassified area were disposed of in a series of unlined, parallel, north-south–oriented excavated trenches. Records indicate that the trenches were 15 to 25 feet wide, 150 to 180 feet long, and 15 to 20 feet deep and were reportedly backfilled with soil on a quarterly basis. Once filled with waste, the trenches were capped with soil that had been generated from the original excavation and stockpiled.

Waste was commonly contained in tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, 55-gallon drums, and 55-gallon polyethylene drums for disposal. 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, shoe covers, coveralls, high-efficiency particulate air filters, prefilters, tygon tubing, watch glasses, polyethylene bottles, beakers, balances, pH meters, screws, bolts, saw blades, paper tissues, 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 Phase 1 RCRA Facility Investigation (RFI) was conducted in 1989 and 1990 to determine whether a release of contaminants had occurred at the site and to begin characterizing the nature and extent of possible releases. The Phase 1 investigation indicated that tritium was the primary constituent of concern (COC). No organic contaminants were identified. A Phase 2 RFI was initiated in 1992 to thoroughly determine the source of contamination, define the nature and extent of the contamination, identify potential transport pathways for contaminants, evaluate potential risks posed by the levels of contamination identified, and recommend remedial action, if warranted, for the landfill.

Data collected during the Phase 2 RFI were evaluated using U.S. Environmental Protection Agency (EPA) approved methods (EPA November 1986). Initially, a constituent population was statistically compared to natural background concentrations. Constituents that fail the statistical comparison were further analyzed for spatial distribution. Those constituents that failed the statistical comparison to background screening levels and showed a strong spatial correlation were identified as potential COCs. RFI fieldwork was performed in accordance with the MWL Phase 2 RFI Work Plan approved in May 1995 (SNL/NM March 1993) and the comment responses to the EPA Notice of Deficiency, approved in May 1995 (SNL/NM November 1994).

The RFI strategy included radiological surveys; soil sampling for background metals and radionuclides; surface geophysical surveys; active and passive soil gas surveys; surface soil sampling for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), target analyte list (TAL) metals, and tritium; and borehole sampling for VOCs, SVOCs, TAL metals, and radionuclides; vadose zone tests; and a risk assessment. The Phase 2 RFI was completed in 1995 and confirmed the finding of the Phase 1 RFI that tritium was the primary COC.

## I.1 MWL Groundwater Data

Groundwater monitoring at the MWL has been conducted since September 1990, with a total of 34 groundwater sampling events to date. Sampling was initially conducted on a quarterly basis, but later reduced to semiannually and eventually annually. Groundwater was characterized for major ion chemistry, and analyzed for a variety of potential contaminants, including radionuclides (tritium, uranium, plutonium, strontium-90, gamma spectroscopy, and gross alpha/beta), heavy metals, VOCs, SVOCs, other Appendix IX organic compounds, nitrate, and perchlorate.

The extensive analytical data collected indicate that groundwater beneath the MWL is not contaminated. These data are presented in the “Mixed Waste Landfill Groundwater Report: 1990 through 2001” (Goering et al. December 2002). Because concentrations of constituents in groundwater beneath the MWL are at background levels and do not indicate contamination, and because depth to groundwater at the MWL makes groundwater an unlikely pathway for contaminant transport in the future, groundwater data are not evaluated in this risk assessment.

## I.2 ISS Sampling and Closure

The ISS was used for aboveground storage of containerized hazardous and mixed waste from 1989 until 1996 and formally closed under RCRA in January 2002. The ISS occupied the southern half of the unclassified area of the MWL.

In March 2001, soil sampling was conducted as part of the formal closure process for the ISS under the direction of NMED. Soil samples were collected at 25 locations across the ISS and analyzed for RCRA metals, VOCs, SVOCs, and radionuclides. Sampling results indicated the presence of low activities of plutonium-238 and -239, as well as uranium-238 in one area of the ISS.

## II. Data Quality Objectives

The MWL sampling and analysis followed standard EPA procedures for sample collection, quality assurance (QA)/quality control (QC), and statistical analysis.

The MWL RFI followed the phased approaches proposed in the MWL Phase 2 RFI Work Plan (SNL/NM March 1993). Protocols for sampling and analysis followed the methodologies outlined in the Environmental Restoration (ER) Project QA Project Plan and operating procedures (OPs) developed specifically for the ER Project Implementation Plan. Table 1 provides a complete list of OPs used during the MWL RFI and during subsequent groundwater and soil sampling events. All RFI fieldwork followed task-specific health and safety plans.

MWL RFI analytical data were reviewed to determine whether an analyte was present as a contaminant. This involved a statistical comparison to local background screening values coupled with an examination of the analyte’s spatial distribution. Initially, an analyte’s population was compared to local background values using EPA approved methods (EPA November 1986). Any analyte failing the statistical comparison to background concentrations was further examined for spatial distribution. Those analytes that both failed the statistical comparison to background screening values and showed a strong spatial correlation were identified as potential COCs.

All MWL RFI activities followed QA/QC protocols that comprise, in part, collecting the appropriate field QC samples, including equipment blanks, method blanks, duplicate samples, matrix and matrix spike duplicate samples, and trip blanks. QA/QC samples accounted for no less than 5 percent of all samples collected for the MWL RFI.

The QA/QC procedures implemented during the RFI and subsequent sampling activities also included verification and validation of the analytical results according to guidelines contained in Administrative Operational Procedure (AOP) 94-27 (SNL/NM May 1994) and/or AOP 00-003 (SNL/NM January 2000). This verification includes reviewing sample holding times, equipment rinsate, method, and trip blank results and comparing duplicate samples.

Table 2 summarizes the data collected during the MWL Phase 2 RFI that was used for this risk assessment including surface and subsurface soil samples. Tables 3a through 3c summarize the analytical methods and data quality requirements necessary to adequately characterize MWL soils for hazardous or radiological constituents. A total of 1,044 soil samples were collected and analyzed during the MWL Phase 2 RFI. A total of 198 surface soil samples were collected during closure of the ISS. An additional 67 surface soil samples and 14 borehole samples were collected as confirmatory sampling for ISS closure.

**Table 1**
**SNL/NM ER OPs Applicable to the MWL**

| OP Number | Title |
|---|---|
| AOP 94-40 | ER Project Site Posting and Security |
| FOP 94-01 | Safety Meetings, Inspections, and Preentry Briefings |
| FOP 94-05 | Borehole Lithologic Logging |
| FOP 94-21 | Shallow Soil Gas Sampling |
| FOP 94-22 | Deep Soil Gas Sampling |
| FOP 94-23 | Hand Auger and Thin-Wall Tube Sampler |
| FOP 94-25 | Documentation of Field Activities |
| FOP 94-26 | General Equipment Decontamination |
| FOP 94-27 | Thin-Walled Tube Sampling of Soils |
| FOP 94-28 | Health and Safety Monitoring of Organic Vapors (Flame Ionization Detector and Photoionization Detector |
| FOP 94-34 | Field Sample Management and Custody |
| FOP 94-38 | Drilling Methods and Drill Site Management |
| FOP 94-52 | Spade and Scoop Method for Collection of Soil Samples |
| FOP 94-57 | Decontaminating Drilling and Other Field Equipment |
| FOP 94-68 | Field Change Control |
| FOP 94-69 | Personnel Decontamination (Level D, C & B Protection) |
| FOP 94-71 | Land Surveying |
| FOP 94-78 | ER Project Waste Management and Characterization Procedure |
| FOP 94-81 | Establishment and Management of Less-Than-90-Day Accumulation Areas for ER Project Sites |
| FOP 95-23 | Shallow Subsurface Drilling and Soil Sampling Using Hydraulic Augers or the Geoprobe® Soil Core Sampler |
| FOP 94-48 | Sampling Groundwater Monitoring Wells |
| FOP 94-95 | Designing and Installing Groundwater Monitoring Wells |
| AOP 00-03 | Data Validation Procedure for Chemical and Radiochemical Data, Kevin Lambert, MDM |
| FOP 95-23 | Shallow Subsurface Drilling and Soil Sampling Using Hydraulic Augers or the Geoprobe® Soil Core Sampler |

AOP = Administrative operational procedure.
ER = Environmental Restoration.
FOP = Field operating procedure
MWL = Mixed Waste Landfill.
OP = Operation procedures.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 2**
**Summary of Sampling Performed to Meet Data Quality Objectives for the MWL**

| Media | Potential COC Source | Site Area | Number of Sampling Locations | Sampling Location Rationale |
|---|---|---|---|---|
| Surface soil | Low-level radioactive and mixed waste | 2.6 | 102 samples from 92 sampling locations in the northern and southern unclassified areas, the classified area, and outside the fenced perimeter of the MWL. Samples were analyzed for tritium (1992)<br><br>100 samples from 25 sampling locations in the northern and southern unclassified areas and the classified area. Samples were analyzed for VOCs, SVOCs, TAL metals, and gamma spectroscopy (1996)<br><br>198 samples from 25 sampling locations in the ISS. Samples were analyzed for RCRA metals plus beryllium and uranium, VOCs, SVOCs, gamma spectroscopy, gross alpha/beta, isotopic plutonium, and tritium (2001).<br><br>67 samples from 46 locations in and around the ISS. Samples were analyzed for isotopic plutonium and gamma spectroscopy (2001). | Determine areal extent and level of surface contamination at the MWL. Sampling locations were based upon a grid scheme that included the area around the MWL and the area inside of the fenced perimeter of the MWL. |
| Subsurface soil | Low-level radioactive and mixed waste | 2.6 | 532 samples from 15 boreholes. Samples were analyzed for VOCs, SVOCs, TAL metals, isotopic uranium, plutonium, and thorium, strontium-90, gross alpha/beta, and tritium.<br><br>212 samples from monitoring well MW-4 borehole. Samples were analyzed for VOCs, SVOCs, TAL metals, hexavalent chromium, total uranium, plutonium, and thorium, isotopic uranium, plutonium, and thorium, gross alpha/beta, and tritium.<br><br>14 samples from shallow boreholes in the ISS. Samples were analyzed for isotopic plutonium and gamma spectroscopy. | Determine vertical distribution of contamination at the MWL. Sampling locations were based upon disposal cell location and depth. |

COC = Constituent of concern.
ISS = Interim Storage Site.
MWL = Mixed Waste Landfill.
RCRA = Resource Conservation and Recovery Act.
SVOC = Semivolatile organic compound.
TAL = Target Analyte List.
VOC = Volatile organic compound.

**Table 3a**
**Summary of Data Quality Requirements for the MWL Surface Soil Samples**

| Analytical Requirement | Data Quality Level | RPSD Laboratory Dept. 7713, SNL/NM | General Engineering Laboratories, Inc. Charleston, SC | Quanterra Inc. St. Louis, MO | TMA/Eberline Albuquerque, NM | IT Corp. Laboratory Oak Ridge, TN |
|---|---|---|---|---|---|---|
| 1992 Sampling (102 samples): | | | | | | |
| Tritium | 3 | NA | NA | NA | 92 Samples | 10 Duplicates |
| 1996 Sampling (100 samples): | | | | | | |
| VOCs EPA Method 8260[a] | 3 | NA | NA | 23 Samples 2 Duplicates | NA | NA |
| SVOCs EPA Method 8270[a] | 3 | NA | NA | 23 Samples 2 Duplicates | NA | NA |
| TAL Metals EPA Methods 6010, 7470[a] | 3 | NA | NA | 23 Samples 2 Duplicates | NA | NA |
| Gamma Spec EPA Method 901.1 | 2 | 23 Samples 2 Duplicates | NA | NA | NA | NA |
| 2001 Sampling in the ISS (198 samples): | | | | | | |
| RCRA Metals plus Be and U EPA Method 6010[a] | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |
| VOCs EPA Method 8260[a] | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |
| SVOCs EPA Method 8270[a] | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |
| Gamma Spec EPA Method 901.1[a] | 3 | 9 Samples | 25 Samples 2 Duplicates | NA | NA | NA |
| Gross Alpha/Beta EPA Method 900.0[a] | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |
| Isotopic Plutonium ICP-MS | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |
| Tritium EPA Method 906.0[a] | 3 | NA | 25 Samples 2 Duplicates | NA | NA | NA |

Refer to footnotes at end of table.

## Table 3a (Concluded)
## Summary of Data Quality Requirements for the MWL Surface Soil Samples

| Analytical Requirement | Data Quality Level | RPSD Laboratory Dept. 7713, SNL/NM | General Engineering Laboratories, Inc. Charleston, SC | Quanterra Inc. St. Louis, MO | TMA/Eberline Albuquerque, NM | IT Corp. Laboratory Oak Ridge, TN |
|---|---|---|---|---|---|---|
| 2001 Confirmatory Sampling (67 samples) | | | | | | |
| Gamma Spec EPA Method 901.1[a] | 3 | 21 samples | NA | NA | NA | NA |
| Isotopic Pu ICP-MS | 3 | NA | NA | NA | NA | 46 samples |

[a]EPA (November 1986).
EPA = U.S. Environmental Protection Agency.
Gamma Spec = Gamma Spectroscopy.
ICP-MS = Inductively coupled plasma-mass spectrometry.
ISS = Interim Storage Site.
IT Corp. = IT Corporation.
MWL = Mixed Waste Landfill.
NA = Not applicable.
RCRA = Resource Conservation and Recovery Act.
RPSD = Radiation Protection and Sample Diagnostics.
SNL/NM = Sandia National Laboratories/New Mexico.
SVOC = Semivolatile organic compound.
TAL = Target Analyte List.
TMA = Thermoanalytical Laboratory.
VOC = Volatile organic compound.

**Table 3b**
**Summary of Data Quality Requirements for the MWL Subsurface Borehole Soil Samples**
**(652 samples collected for analysis)**

| Analytical Requirement | Data Quality Level | RPSD Laboratory Dept. 7713, SNL/NM | General Engineering Laboratories, Inc. Charleston, SC | Lockheed Analytical Services Las Vegas, NV |
|---|---|---|---|---|
| VOCs<br>EPA Method 8260[a] | 3 | NA | 88 Samples<br>15 Duplicates | NA |
| SVOCs<br>EPA Method 8270[a] | 3 | NA | 88 Samples<br>15 Duplicates | NA |
| TAL Metals<br>EPA Methods 6010, 7471[a] | 3 | NA | 88 Samples<br>15 Duplicates | NA |
| Isotopic U, Pu, Th<br>LAL-91-SOP-0108[b] | 3 | NA | NA | 88 Samples<br>15 Duplicates |
| Total Radio Strontium<br>LAL-91-SOP-0065[b] and LAL-93-SOP-0196[b] | | | | |
| Gross Alpha/Beta<br>LAL-91-SOP-0061[b] | | | | |
| Tritium<br>LAL-91-SOP-0066[b] | 3 | NA | NA | 105 Samples<br>15 Duplicates |
| Gamma Spec | 2 | 105 Samples<br>15 Duplicates | NA | NA |

[a]EPA (November 1986).
[b]Lockheed Analytical Laboratory (CLP certified) standard operating procedures for radiochemical analyses.

CLP = Contract Laboratory Procedure.
EPA = U.S. Environmental Protection Agency.
Gamma Spec = Gamma Spectroscopy.
MWL = Mixed Waste Landfill.
NA = Not applicable.
RPSD = Radiation Protection Sample Diagnostics.
SNL/NM = Sandia National Laboratories/New Mexico.
SVOC = Semivolatile organic compound.
TAL = Target Analyte List.
VOC = Volatile organic compound.

**Table 3c**
**Summary of Data Quality Requirements for the MWL**
**Subsurface Soil Samples, Monitoring Well MW-4**
**(190 samples collected for analysis)**

| Analytical Requirement | Data Quality Level | RPSD Laboratory Dept. 7713, SNL/NM | Quanterra Inc. Arvada, CO |
|---|---|---|---|
| VOCs<br>EPA Method 8240[a] | 3 | NA | 21 Samples<br>4 Duplicates |
| SVOCs<br>EPA Method 8270[a] | 3 | NA | 22 Samples<br>4 Duplicates |
| TAL Metals<br>EPA Methods 6010, 7471, 7196, 7060, 7740, 7841, 7421[a] | 3 | NA | 22 Samples<br>4 Duplicates |
| Isotopic U, Pu, Th<br>EPA/EMSL[a] | 3 | NA | 22 Samples<br>4 Duplicates |
| Gross Alpha/Beta<br>EPA Method 903.1[a] | 3 | NA | 22 Samples<br>4 Duplicates |
| Tritium<br>EPA Method H-03[a] | 3 | NA | 27 Samples<br>4 Duplicates |
| Gamma Spec | 2 | 26 Samples<br>4 Duplicates | NA |

[a]EPA (November 1986).
EMSL = Environmental Measurements and Standards Laboratory Method.
EPA = U.S. Environmental Protection Agency.
Gamma Spec = Gamma Spectroscopy.
MW = Monitoring well.
MWL = Mixed Waste Landfill.
NA = Not applicable.
RPSD = Radiation Protection Sample Diagnostics.
SNL/NM = Sandia National Laboratories/New Mexico.
SVOC = Semivolatile organic compound.
TAL = Target Analyte List.
VOC = Volatile organic compound.

## III. Determination of Nature, Rate, and Extent of Contamination

### III.1 Introduction

The determination of the nature, rate, and extent of contamination at the MWL was based upon an initial conceptual model developed from historical information, personal interviews, historical photographs, site inspections, and geophysical and radiological surveys. The data quality objectives (DQOs) contained in sampling and analysis plans identify sample locations, sample density, sample depth, and analytical requirements. The analytical data used to assess and characterize the MWL were collected in accordance with the procedures described in sampling and analysis plans and applicable SNL/NM ER OPs.

## III.2 Nature of Contamination

The nature of contamination at the MWL was determined by analytical testing of air, soil, and groundwater samples. Analyses were conducted for VOCs, SVOCs, TAL and RCRA metals, and various radionuclides including plutonium, thorium, uranium, strontium, and tritium. The sampling results are presented in the MWL Phase 1 RFI Report (SNL/NM September 1990) and the MWL Phase 2 RFI Report (Peace et al. September 2002).

It should be noted that this risk assessment is based upon contaminant concentrations obtained from soil sampling conducted at the MWL. The assessment does not consider risk posed by organic, inorganic, or radiological constituents present in the MWL inventory that have not been released into the environment.

## III.3 Rate of Contaminant Migration

The MWL has been inactive since December 1988. The rate of COC migration is dependent predominantly upon site meteorological and surface hydrologic parameters discussed in the MWL Phase 2 RFI Work Plan (SNL/NM March 1993) and the MWL Phase 2 RFI Report (Peace et al. September 2002).

## III.4 Extent of Contamination

Tritium is the primary COC at the MWL and has been a consistent finding at the MWL since environmental monitoring was initiated in 1969. Tritium has been detected in soil to 110 feet below ground surface (bgs), with the greatest tritium activities in surface and near-surface soil in and around the classified area disposal pits. Tritium activities range from 1,100 picocuries (pCi)/gram (g) in surface soil to 207 pCi/g in subsurface soil in the classified area of the MWL.

Plutonium -238 and -239 as well as uranium-238 were detected in ISS surface soil during closure of the facility (SNL/NM January 2002a, SNL/NM January 2002b). The highest plutonium-238 and plutonium-239 activities detected in surface soil were 0.103 and 0.0107 pCi/g, respectively. These activities are slightly above atmospheric fallout levels detected in soil in northern New Mexico (LANL 2000).

## IV. Comparison of Potential COCs to Background Screening Levels

Site history and characterization activities are used to identify potential COCs. The identification of COCs in the soil and the sampling to determine the concentration levels of those COCs across the site are described in the MWL Phase 2 RFI Report (Peace et al. September 2002). Generally, COCs evaluated in this risk assessment included all detected organic and all inorganic COCs for which samples were analyzed. When the detection limit of an organic compound was too high (i.e., could possibly cause an adverse effect to human health or the environment), the compound was retained for further risk analysis.

Nondetected organic constituents not included in this risk assessment were determined to have detection limits low enough to ensure protection of human health and the environment. In order to provide conservatism in this risk assessment, the calculation used only the maximum concentration value of each COC found for the entire site. The SNL/NM maximum background concentration (Dinwiddie September 1997) was selected to provide the background screening levels. Nonradiological COCs for the human health risk assessment also were compared to SNL/NM proposed Subpart S action levels, if appropriate (IT July 1994).

Both radiological and nonradiological soil COCs were evaluated. The nonradiological COCs evaluated in this risk assessment included both organic and inorganic constituents. Chemicals that are essential nutrients, such as iron, magnesium, calcium, potassium, and sodium, were not included in this risk assessment (EPA 1989).

Each remedial alternative is summarized in the following sections. The COC selection criteria is identical for each alternative. However, due to the remedial options, the COCs may vary. For NFA with no ICs, maximum concentrations in MWL soils at all depths were evaluated within the risk assessment. For the remaining alternatives, with the exception of future excavation, the maximum concentrations within the upper five feet (0 to 5 feet bgs) were evaluated in the risk assessments due to ICs that will remain in place for these alternatives. It should be noted that the background screening tables are identical for the NFA with ICs (Alternative I.a), vegetative soil cover (Alternative III.b), and vegetative soil cover with bio-intrusion barrier (Alternative III.c) remedial alternatives. Therefore, the table is presented only once in Section IV.2.

## IV.1 MWL Risk Baseline—NFA with No ICs

Table 4 lists the nonradiological soil COCs for the human health risk assessment and Table 5 lists the nonradiological COCs for the ecological risk assessment at the MWL for this alternative. Table 6 lists the radiological soil COCs for both the human health and ecological risk assessments. All tables provide the associated approved SNL/NM background concentration values (Dinwiddie September 1997). Sections VI.4 and VII.2 discuss the data presented in these tables.

## IV.2 MWL Alternative I.a—NFA with ICs

Table 7 lists the nonradiological soil COCs and Table 8 lists the radiological soil COCs for both the human health and ecological risk assessments at the MWL for this alternative. All tables provide the associated approved SNL/NM background concentration values (Dinwiddie September 1997). Sections VI.4 and VII.2 discuss the data presented in these tables.

## IV.3 MWL Alternatives III.b and c

The CM alternatives all provide significant additional operational cover. Therefore, there are no potential human health or ecological COCs for these alternatives due to the lack of potential exposure pathways.

## IV.4 MWL Alternative V.e—Future Excavation

Table 9 lists the nonradiological soil COCs for the human health risk assessment and Table 10 lists the nonradiological COCs for the ecological risk assessment at the MWL for this

## Table 4
## MWL Risk Baseline—NFA with No ICs
## Nonradiological Soil COCs for Human Health Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| 2-Butanone | 0.0223 J | NA | **NA** | 1[c] | 0.29[c] | No |
| 2-Hexanone | 0.00885 J | NA | **NA** | 6[d] | 1.38[d] | No |
| 4-Methyl-2-pentanone | 0.00757 J | NA | **NA** | 5[e] | 1.19[e] | No |
| Acetone | 0.225 J | NA | **NA** | 0.69[c] | -0.24[c] | No |
| Arsenic | 5.63 | 4.4 | **No** | 44[f] | NA | **Yes** |
| Barium | 808 | 130 | **No** | 170[g] | NA | **Yes** |
| Benzoic acid | 0.068 J | NA | **NA** | 138[h] | 1.87[h] | **Yes** |
| Beryllium | 1.1 | 0.65 | **No** | 19[f] | NA | No |
| Bis(2-ethylhexyl) phthalate | 2.9 | NA | **NA** | 851[h] | 7.6[e] | **Yes** |
| Cadmium | 1.97 | <1 | **No** | 64[f] | NA | **Yes** |
| Chromium VI | 0.23 | 1 | Yes | 16[f] | NA | No |
| Chromium, total | 34.3 | 15.9 | **No** | 16[f] | NA | No |
| Cobalt | 105 | 5.2 | **No** | 10,000[i] | NA | **Yes** |
| Copper | 645 | 15.4 | **No** | 6[f] | NA | No |
| Di-n-butyl phthalate | 0.16 J | NA | **NA** | 6,761[h] | 4.61[e] | **Yes** |
| Di-n-octyl phthalate | 0.13 J | NA | **NA** | 9,334[e] | 5.22[e] | **Yes** |
| Lead | 13.9 | 11.8 | **No** | 49[f] | NA | **Yes** |
| Mercury | 2.11 | <0.1 | **No** | 5,500[f] | NA | **Yes** |
| Methylene chloride | 3.8 | NA | **NA** | 5[c] | 1.25[c] | No |
| Nickel | 97.5 | 11.5 | **No** | 47[f] | NA | **Yes** |
| n-Nitrosodiphenyl-amine | 0.074 J | NA | **NA** | 217[e] | 3.13[e] | **Yes** |
| Phenol | 0.46 | NA | **NA** | 277[h] | 1.46[h] | **Yes** |
| Pyrene | 1.06 | NA | **NA** | 36,300[f] | 5.32[e] | **Yes** |
| Selenium | 0.61 | <1 | **Unknown** | 800[j] | NA | **Yes** |
| Silver | 1.46 | <1 | **No** | 0.5[f] | NA | No |

Refer to footnotes at end of table.

**Table 4 (Concluded)**
**MWL Risk Baseline—NFA with No ICs**
**Nonradiological Soil COCs for Human Health Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| Tetrachloroethene | 0.0054 | NA | **NA** | 49[c] | 2.67[e] | **Yes** |
| Toluene | 0.0204 J | NA | **NA** | 10.7[f] | 2.69[f] | No |
| Trichloroethene | 0.001 J | NA | **NA** | 10.6[f] | 2.29[f] | No |
| Xylenes, total | 0.0178 J | NA | **NA** | 23.4[c] | 1.5[e] | No |
| Zinc | 413 | 62 | **No** | 47[f] | NA | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]Dinwiddie (September 1997), Southwest Test Area.
[b]NMED (March 1998).
[c]BCF and/or Log $K_{ow}$ from Howard (1990).
[d]BCF and/or Log $K_{ow}$ from Howard (1993).
[e]BCF and/or Log $K_{ow}$ from Micromedex (1998).
[f]BCF and/or Log $K_{ow}$ from Yanicak (March 1997).
[g]BCF from Neumann (1976).
[h]BCF and/or Log $K_{ow}$ from Howard (1989).
[i]BCF from Vanderploeg et al. (1975).
[j]BCF from Callahan et al. (1979).
BCF = Bioconcentration factor.
COC = Constituent of concern.
IC = Institutional Control.
J = Estimated concentration.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
NMED = New Mexico Environment Department.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 5**
**MWL Risk Baseline—NFA with No ICs**
**Nonradiological Soil COCs for Ecological Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| Acetone | 0.18 | NA | **NA** | 0.69[c] | -0.24[c] | No |
| Arsenic | 3.7 | 4.4 | Yes | 44[d] | NA | **Yes** |
| Barium | 168 | 130 | **No** | 170[e] | NA | **Yes** |
| Beryllium | 0.65 | 0.65 | Yes | 19[d] | NA | No |
| Bis(2-ethylhexyl) phthalate | 0.073 J | NA | **NA** | 851[f] | 7.6[g] | **Yes** |
| Cadmium | 0.37 J | <1 | **Unknown** | 64[d] | NA | **Yes** |
| Chromium, total | 11.5 | 15.9 | Yes | 16[d] | NA | No |
| Cobalt | 3.8 | 5.2 | Yes | 10,000[h] | NA | **Yes** |
| Copper | 6.8 | 15.4 | Yes | 6[d] | NA | No |
| Di-n-butyl phthalate | 0.16 J | NA | **NA** | 6,761[f] | 4.61[g] | **Yes** |
| Di-n-octyl phthalate | 0.074 J | NA | **NA** | 9,334[g] | 5.22[g] | **Yes** |
| Lead | 7.5 J | 11.8 | Yes | 49[d] | NA | **Yes** |
| Mercury | 0.05[i] | <0.1 | **Unknown** | 5,500[d] | NA | **Yes** |
| Methylene chloride | 0.01 | NA | **NA** | 5[c] | 1.25[c] | No |
| Nickel | 7.7 | 11.5 | Yes | 47[d] | NA | **Yes** |
| Selenium | 0.566 | <1 | **Unknown** | 800[j] | NA | **Yes** |
| Silver | 0.96 J | <1 | **Unknown** | 0.5[d] | NA | No |
| Toluene | 0.002 J | NA | **NA** | 10.7[d] | 2.69[d] | No |
| Zinc | 28.5 | 62 | Yes | 47[d] | NA | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]Dinwiddie (September 1997), Southwest Test Area.
[b]NMED (March 1998).
[c]BCF and/or Log $K_{ow}$ from Howard (1990).
[d]BCF and/or Log $K_{ow}$ from Yanicak (March 1997).
[e]BCF from Neumann (1976).
[f]BCF and/or Log $K_{ow}$ from Howard (1989).
[g]BCF and/or Log $K_{ow}$ from Micromedex (1998).
[h]BCF from Vanderploeg et al. (1975).

**Table 5 (Concluded)**
**MWL Risk Baseline—NFA with No ICs**
**Nonradiological Soil COCs for Ecological Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

[i]Parameter was nondetect. Concentration is one half of detection limit.
[j]BCF from Callahan et al. (1979).
BCF = Bioconcentration factor.
COC = Constituent of concern.
IC = Institutional Control.
J = Estimated concentration.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
NMED = New Mexico Environment Department.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 6**
**MWL Risk Baseline—NFA with No ICs**
**Radiological Soil COCs for Human Health and Ecological Risk Assessments at the MWL with Comparison to the Associated SNL/NM Background Screening Values and BCF**

| COC Name | Maximum Activity (pCi/g) | SNL/NM Background Activity[a] (pCi/g) | Is Maximum COC Activity Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Bioaccumulator? (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|
| Tritium | 1,103[b] | 0.021[c] | **No** | No | No |
| U-238 | 2.41 | 1.4 | **No** | 900[c] | **Yes[d]** |
| Pu-238 | 0.103 | NA | **NA** | 40[e] | **Yes** |
| Pu-239 | 0.0107 | NA | **NA** | 40[e] | **Yes** |

Note: **Bold** indicates COCs that exceed background screening and/or are bioaccumulators.
[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]Peace et al. (September 2002).
[c]Tharp (February 1999).
[d]Baker and Soldat (1992).
[e]Morse and Choppin (1991).
BCF = Bioconcentration factor.
COC = Constituent of concern.
IC = Institutional Control.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
pCi/g = Picocurie(s) per gram.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 7**
**MWL Alternative I.a—NFA with ICs**
**Nonradiological Soil COCs for Human Health and Ecological Risk Assessments at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| Acetone | 0.18 | NA | **NA** | 0.69[c] | -0.24[c] | No |
| Arsenic | 3.7 | 4.4 | Yes | 44[d] | NA | **Yes** |
| Barium | 168 | 130 | **No** | 170[e] | NA | **Yes** |
| Beryllium | 0.65 | 0.65 | Yes | 19[d] | NA | No |
| Bis(2-ethylhexyl) phthalate | 0.073 J | NA | **NA** | 851[f] | 7.6[g] | **Yes** |
| Cadmium | 0.37 J | <1 | **Unknown** | 64[d] | NA | **Yes** |
| Chromium, total | 11.5 | 15.9 | Yes | 16[d] | NA | No |
| Cobalt | 3.8 | 5.2 | Yes | 10,000[h] | NA | **Yes** |
| Copper | 6.8 | 15.4 | Yes | 6[d] | NA | No |
| Di-n-butyl phthalate | 0.16 J | NA | **NA** | 6,761[f] | 4.61[g] | **Yes** |
| Di-n-octyl phthalate | 0.074 J | NA | **NA** | 9,334[f] | 5.22[f] | **Yes** |
| Lead | 7.5 J | 11.8 | Yes | 49[d] | NA | **Yes** |
| Mercury | 0.05[i] | <0.1 | **Unknown** | 5,500[d] | NA | **Yes** |
| Methylene chloride | 0.01 | NA | **NA** | 5[c] | 1.25[c] | No |
| Nickel | 7.7 | 11.5 | Yes | 47[d] | NA | **Yes** |
| Selenium | 0.566 | <1 | **Unknown** | 800[i] | NA | **Yes** |
| Silver | 0.96 J | <1 | **Unknown** | 0.5[d] | NA | No |
| Toluene | 0.002 J | NA | **NA** | 10.7[d] | 2.69[d] | No |
| Zinc | 28.5 | 62 | Yes | 47[d] | NA | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]Dinwiddie (September 1997), Southwest Test Area.
[b]NMED (March 1998).
[c]BCF and/or Log $K_{ow}$ from Howard (1990).
[d]BCF and/or Log $K_{ow}$ from Yanicak (March 1997).
[e]BCF from Neumann (1976).
[f]BCF and/or Log $K_{ow}$ from Howard (1989).
[g]BCF and/or Log $K_{ow}$ from Micromedex (1998).
[h]BCF from Vanderploeg et al. (1975).
[i]BCF from Callahan et al. (1979).

**Table 7 (Concluded)**
**MWL Alternative I.a—NFA with ICs**
**Nonradiological Soil COCs for Human Health and Ecological Risk Assessments at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

BCF = Bioconcentration factor.
COC = Constituent of concern.
IC = Institutional Control.
J = Estimated concentration.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
NMED = New Mexico Environment Department.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 8**
**MWL Alternative I.a—NFA with ICs**
**Radiological Soil COCs for Human Health and Ecological Risk Assessments at the MWL with Comparison to the Associated SNL/NM Background Screening Values and BCF**

| COC Name | Maximum Activity (pCi/g) | SNL/NM Background Activity[a] (pCi/g) | Is Maximum COC Activity Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Bioaccumulator? (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|
| Tritium | 1,103[b] | 0.021[c] | **No** | No | No |
| U-238 | 2.41 | 1.4 | **No** | 900[c] | **Yes**[d] |
| Pu-238 | 0.103 | NA | **NA** | 40[e] | **Yes** |
| Pu-239 | 0.0107 | NA | **NA** | 40[e] | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]Peace et al. (September 2002).
[c]Tharp (February 1999).
[d]Baker and Soldat (1992).
[e]Morse and Choppin (1991).
BCF = Bioconcentration factor.
COC = Constituent of concern.
IC = Institutional Control.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
MWL = Mixed Waste Landfill.
NFA = No Further Action.
pCi/g = Picocurie(s) per gram.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 9**
**MWL Alternative V.e—Future Excavation**
**Nonradiological Soil COCs for Human Health Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| 2-Butanone | 0.0223 J | NA | **NA** | 1[c] | 0.29[c] | No |
| 2-Hexanone | 0.00885 J | NA | **NA** | 6[d] | 1.38[d] | No |
| 4-Methyl-2-pentanone | 0.00757 J | NA | **NA** | 5[e] | 1.19[e] | No |
| Acetone | 0.225 J | NA | **NA** | 0.69[c] | -0.24[c] | No |
| Arsenic | 5.63 | 4.4 | **No** | 44[f] | NA | **Yes** |
| Barium | 808 | 130 | **No** | 170[g] | NA | **Yes** |
| Benzoic acid | 0.068 J | NA | **NA** | 138[h] | 1.87[h] | **Yes** |
| Beryllium | 1.1 | 0.65 | **No** | 19[f] | NA | No |
| Bis(2-ethylhexyl) phthalate | 2.9 | NA | **NA** | 851[h] | 7.6[e] | **Yes** |
| Cadmium | 1.97 | <1 | **No** | 64[f] | NA | **Yes** |
| Chromium VI | 0.23 | 1 | Yes | 16[f] | NA | No |
| Chromium, total | 34.3 | 15.9 | **No** | 16[f] | NA | No |
| Cobalt | 105 | 5.2 | **No** | 10,000[i] | NA | **Yes** |
| Copper | 645 | 15.4 | **No** | 6[f] | NA | No |
| Di-n-butyl phthalate | 0.16 J | NA | **NA** | 6,761[h] | 4.61[e] | **Yes** |
| Di-n-octyl phthalate | 0.13 J | NA | **NA** | 9,334[e] | 5.22[e] | **Yes** |
| Lead | 13.9 | 11.8 | **No** | 49[f] | NA | **Yes** |
| Mercury | 2.11 | <0.1 | **No** | 5,500[f] | NA | **Yes** |
| Methylene chloride | 3.8 | NA | **NA** | 5[c] | 1.25[c] | No |
| Nickel | 97.5 | 11.5 | **No** | 47[f] | NA | **Yes** |
| n-Nitrosodiphenyl-amine | 0.074 J | NA | **NA** | 217[e] | 3.13[e] | **Yes** |
| Phenol | 0.46 | NA | **NA** | 277[h] | 1.46[h] | **Yes** |
| Pyrene | 1.06 | NA | **NA** | 36,300[f] | 5.32[e] | **Yes** |
| Selenium | 0.61 | <1 | **Unknown** | 800[j] | NA | **Yes** |
| Silver | 1.46 | <1 | **No** | 0.5[f] | NA | No |

Refer to footnotes at end of table.

**Table 9 (Concluded)**
**MWL Alternative V.e—Future Excavation**
**Nonradiological Soil COCs for Human Health Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| Tetrachloroethene | 0.0054 | NA | **NA** | 49[c] | 2.67[e] | **Yes** |
| Toluene | 0.0204 J | NA | **NA** | 10.7[f] | 2.69[f] | No |
| Trichloroethene | 0.001 J | NA | **NA** | 10.6[f] | 2.29[f] | No |
| Xylenes, total | 0.0178 J | NA | **NA** | 23.4[c] | 1.5[e] | No |
| Zinc | 413 | 62 | **No** | 47[f] | NA | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]Dinwiddie (September 1997), Southwest Test Area.
[b]NMED (March 1998).
[c]BCF and/or Log $K_{ow}$ from Howard (1990).
[d]BCF and/or Log $K_{ow}$ from Howard (1993).
[e]BCF and/or Log $K_{ow}$ from Micromedex (1998).
[f]BCF and/or Log $K_{ow}$ from Yanicak (March 1997).
[g]BCF from Neumann (1976).
[h]BCF and/or Log $K_{ow}$ from Howard (1989).
[i]BCF from Vanderploeg et al. (1975).
[j]BCF from Callahan et al. (1979).
BCF = Bioconcentration factor.
COC = Constituent of concern.
J = Estimated concentration.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NMED = New Mexico Environment Department.
SNL/NM = Sandia National Laboratories/New Mexico.

**Table 10**
**MWL Alternative V.e—Future Excavation**
**Nonradiological Soil COCs for Ecological Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

| COC Name | Maximum Concentration (mg/kg) | SNL/NM Background Concentration[a] (mg/kg) | Is Maximum COC Concentration Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Log $K_{ow}$ | Bioaccumulator?[b] (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|---|
| Acetone | 0.18 | NA | **NA** | 0.69[c] | -0.24[c] | No |
| Arsenic | 3.7 | 4.4 | Yes | 44[d] | NA | **Yes** |
| Barium | 168 | 130 | **No** | 170[e] | NA | **Yes** |
| Beryllium | 0.65 | 0.65 | Yes | 19[d] | NA | No |
| Bis(2-ethylhexyl) phthalate | 0.073 J | NA | **NA** | 851[f] | 7.6[g] | **Yes** |
| Cadmium | 0.37 J | <1 | **Unknown** | 64[d] | NA | **Yes** |
| Chromium, total | 11.5 | 15.9 | Yes | 16[d] | NA | No |
| Cobalt | 3.8 | 5.2 | Yes | 10,000[h] | NA | **Yes** |
| Copper | 6.8 | 15.4 | Yes | 6[d] | NA | No |
| Di-n-butyl phthalate | 0.16 J | NA | **NA** | 6,761[f] | 4.61[g] | **Yes** |
| Di-n-octyl phthalate | 0.074 J | NA | **NA** | 9,334[g] | 5.22[g] | **Yes** |
| Lead | 7.5 J | 11.8 | Yes | 49[d] | NA | **Yes** |
| Mercury | 0.05[i] | <0.1 | **Unknown** | 5,500[d] | NA | **Yes** |
| Methylene chloride | 0.01 | NA | **NA** | 5[c] | 1.25[c] | No |
| Nickel | 7.7 | 11.5 | Yes | 47[d] | NA | **Yes** |
| Selenium | 0.566 | <1 | **Unknown** | 800[j] | NA | **Yes** |
| Silver | 0.96 J | <1 | **Unknown** | 0.5[d] | NA | No |
| Toluene | 0.002 J | NA | **NA** | 10.7[d] | 2.69[d] | No |
| Zinc | 28.5 | 62 | Yes | 47[d] | NA | **Yes** |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]Dinwiddie (September 1997), Southwest Test Area.
[b]NMED (March 1998).
[c]BCF and/or Log $K_{ow}$ from Howard (1990).
[d]BCF and/or Log $K_{ow}$ from Yanicak (March 1997).
[e]BCF from Neumann (1976).
[f]BCF and/or Log $K_{ow}$ from Howard (1989).
[g]BCF and/or Log $K_{ow}$ from Micromedex (1998).
[h]BCF from Vanderploeg et al. (1975).
[i]BCF from Callahan et al. (1979).

**Table 10 (Concluded)**
**MWL Alternative V.e—Future Excavation**
**Nonradiological Soil COCs for Ecological Risk Assessment at the MWL with Comparison to the Associated SNL/NM Background Screening Values, BCF, and Log $K_{ow}$**

BCF = Bioconcentration factor.
COC = Constituent of concern.
J = Estimated concentration.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NMED = New Mexico Environment Department.
SNL/NM = Sandia National Laboratories/New Mexico.

alternative. Table 11 lists the radiological soil COCs for both the human health and ecological risk assessments. The year 2039 was selected as the target date for future excavation in this risk assessment. All tables provide the associated approved SNL/NM background concentration values (Dinwiddie September 1997). Sections VI.4 and VII.2 discuss the data presented in these tables.

## V. Fate and Transport

The potential for release of COCs to the subsurface soil is directly associated with wastes buried in the MWL disposal cells. COCs may also be released to the surface soil as a result of aboveground storage of waste at the ISS, or through diffusion and vapor transport of tritium. Releases caused by erosion and degradation of the operational cover can also occur.

Wind, surface runoff, and biota are natural mechanisms of COC transport. Wind can transport soil particles with adsorbed COCs (or COCs in particulate form) as suspended dust, capable of dry or wet deposition away from the site. High winds may move larger (sand-sized) particles by saltation. The site is moderately vegetated with ruderals and early successional grasses, and is susceptible to wind and water erosion.

Water percolating through the soil is the primary mechanism for the transport and migration of COCs in the subsurface. Water at the MWL is received as precipitation (rain or occasionally snow). The average annual precipitation in this area is approximately 8 inches (NOAA 1990). Water rarely infiltrates more than a few feet, and typically returns to the atmosphere via evapotranspiration. However, COCs desorbed from the soil particles into the soil solution may be leached into the subsurface soil with this percolation. Extensive field investigations and analytical studies undertaken in TA-3 and at the MWL provide data that address the potential extent of COC migration by this process. Data collected from boreholes, groundwater monitoring wells, and instantaneous profile tests measure saturated and unsaturated zone characteristics and include volumetric water content, saturated and unsaturated hydraulic conductivity, bulk density, and isotopic chloride content. These data are summarized in the MWL Phase 2 RFI report (Peace et al. September 2002). Based upon these data, recharge is negligible and most of the water from precipitation returns to the atmosphere via evapotranspiration.

It has further been estimated that 95 percent of the total rainfall received at SNL/NM is lost through evapotranspiration (Thomson and Smith 1985). This conclusion is supported by the MWL Phase 2 RFI characterization data, which show no evidence of significant water migration past the root zone of plants or the upper 2 feet of soil. Vegetation, although sparse at the site, will increase the rate of water loss from the subsurface soil through transpiration. As water evaporates from the soil surface, it can be expected that the direction of COC movement near the surface may be reversed with capillary rise of the soil water.

Because of the arid nature of the environment at the MWL, characterized by low rainfall and high potential evapotranspiration estimates, recharge to the water table at the MWL is insignificant under current climatic and vegetative conditions (Peace et al. September 2002). Because groundwater beneath this site is approximately 500 feet bgs, the potential for COCs to reach groundwater through the unsaturated zone above the water table is very low.

**Table 11**
**MWL Alternative V.e—Future Excavation**
**Radiological Soil COCs for Human Health and Ecological Risk Assessments at the MWL with Comparison to the Associated SNL/NM Background Screening Values and BCF**

| COC Name | Maximum Activity (pCi/g) | SNL/NM Background Activity[a] (pCi/g) | Is Maximum COC Activity Less Than or Equal to the Applicable SNL/NM Background Screening Value? | BCF (maximum aquatic) | Bioaccumulator? (BCF>40, Log $K_{ow}$>4) |
|---|---|---|---|---|---|
| Am-241 | 3.4E-2 | NA | **NA** | 8,000[b] | No |
| Co-60 | 1.5E+2 | NA | **NA** | NA | **Yes** |
| Cs-137 | 3.9E+3 | 0.664 | **No** | 3,000[b] | No |
| Tritium | 4.3E+3 | 0.021[c] | **No** | No | No |
| Pu-238 | 2.4E-2 | NA | **NA** | 40[d] | **Yes** |
| Pu-239 | 3.6E-2 | NA | **NA** | 40[d] | **Yes** |
| Ra-226 | 1.8E+2 | 2.3 | **No** | No | No |
| Sr-90 | 3.8E+3 | 1.08 | **No** | 600[b] | No |
| Th-232 | 3.0E+1 | 1.01 | **No** | No | No |
| U-238 | 2.8E+2 | 1.4 | **No** | 900[e] | **Yes**[e] |

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.
[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]Yanicak (March 1997).
[c]Tharp (February 1999).
[d]Morse and Choppin (1991).
[e]Baker and Soldat (1992).
BCF = Bioconcentration factor.
COC = Constituent of concern.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
MWL = Mixed Waste Landfill.
NA = Not applicable.
pCi/g = Picocurie(s) per gram.
SNL/NM = Sandia National Laboratories/New Mexico.

COCs that are in the soil solution can enter the food chain via uptake by plant roots. This may be a passive process, but active uptake (i.e., requiring energy expenditure on the part of the plant) or exclusion of some constituents in the soil solution may also take place. COCs taken up by plant roots may be transported to the aboveground tissues which can take up adsorbed constituents directly from the air or by contact with dust particles. Organic constituents in plant tissues may be metabolized or released through volatilization. That which remains in the tissue may be consumed by herbivores or eventually returned to the soil as litter. Aboveground litter is capable of transport by wind until consumed by decomposer organisms in the soil. Constituents in plant tissues that are consumed by herbivores may be either absorbed into tissues or returned to the soil as litter (at the site or transported from the site in the herbivore). The herbivore may be eaten by a carnivore or scavenger and the constituents held in the consumed tissues will repeat the sequence of absorption, metabolization, excretion, and consumption by higher predators, scavengers, and decomposers. The potential for transport of the constituents within the food chain is dependent upon both the mobility of the species that comprise the food chain and the potential for the constituent to be transferred across the links in the food chain.

Degradation of COCs at the MWL may result from biotic or abiotic processes. Inorganic COCs at the MWL are elemental in form and are, therefore, not considered to be degradable. Radiological COCs, however, undergo decay to stable isotopes or radioactive daughter elements. Other transformations of inorganic constituents may include changes in valence (oxidation/reduction reactions) or incorporation into organic forms (e.g., the conversion of selenite or selenate from soil to seleno-amino acids in plants). Degradation processes for organic COCs may include photolysis, hydrolysis, and biotransformation. Photolysis requires light and, therefore, takes place in the air, at the ground surface, or in surface water. Hydrolysis includes chemical transformations in water and may occur in the soil solution. Biotransformation (i.e., transformation caused by plants, animals, and microorganisms) may occur; however, biological activity may be limited by the arid environment at this site.

Table 12 summarizes the fate and transport processes that may occur at the MWL. COCs at this site include a variety of inorganic constituents (e.g., metals and radionuclides) and organic constituents (both volatile and semivolatile) in surface and subsurface soil. Because the topography of the site is relatively flat and the soil is fine-grained, the potential for surface-water transport is low. Because winds in the Albuquerque area can be fairly strong in late winter and early spring, the potential for transport by wind of COCs in surface soil is moderate. In both cases, however, the significance of these transport mechanisms is limited by the fact that the principal releases of COCs (e.g., tritium) occurred to the subsurface soil. Because of the arid nature of the climate at the site, significant movement of water through the subsurface soil is unlikely and migration to groundwater is not expected to occur. The potential for food chain uptake is low because of the small size of the site, the disturbed nature of the habitat, and the depth of the buried waste. In general, transformation of organic constituents will be slow because of the aridity of the environment, and degradation of the inorganic COCs will be insignificant. The decay of radiological COCs is also insignificant because of long half-lives.

**Table 12**
**Summary of Fate and Transport at the MWL**

| Transport and Fate Mechanism | Existence at Site | Significance |
|---|---|---|
| Wind | Yes | Moderate |
| Surface runoff | Yes | Low |
| Migration to groundwater | No | None |
| Food chain uptake | Yes | Low |
| Transformation/degradation | Yes | Low |

MWL = Mixed Waste Landfill.

## VI. Human Health Risk Assessment Analysis

### VI.1 Introduction

Human health risk assessment of this site includes a number of steps that culminate in a quantitative evaluation of the potential adverse human health effects caused by COCs located at the site. The steps to be discussed include the following:

| | |
|---|---|
| Step 1. | Site data are described that provide information on the potential COCs, as well as the relevant physical characteristics and properties of the site. |
| Step 2. | Potential pathways are identified by which a representative population might be exposed to the COCs. |
| Step 3. | The potential intake of these COCs by the representative population is calculated using a tiered approach. The first component of the tiered approach includes two screening procedures. One screening procedure compares the maximum concentration of the COC to an approved SNL/NM maximum background screening value. COCs that are not eliminated during the first screening procedure are subjected to a second screening procedure that compares the maximum concentration of the COC to the SNL/NM proposed Subpart S action level. |
| Step 4. | Toxicological parameters are identified and referenced for COCs that are not eliminated during the screening steps. |
| Step 5. | Potential toxicity effects (specified as a hazard index [HI]) and cancer risks are calculated for nonradiological COCs and background. For radiological COCs, the incremental total effective dose equivalent (TEDE) and incremental estimated cancer risk are calculated by subtracting applicable background concentrations directly from maximum on-site contaminant values. This background subtraction applies only when a radiological COC occurs as contamination and exists as a natural background radionuclide. |
| Step 6. | These values are compared with guidelines established by the EPA, NMED, and DOE to determine whether further evaluation and potential site clean-up are required. Nonradiological COC risk values also are compared to background risk so that an incremental estimated risk may be calculated. |
| Step 7. | Uncertainties relating to the results of the previous steps are addressed. |

### VI.2 Step 1. Site Data

Section I of this risk assessment provides the site description and history for the MWL. Section II provides a comparison of results to DQOs. Section III provides the determination of the nature, rate and extent of contamination.

## VI.3 Step 2. Pathway Identification

The MWL has been designated with a future industrial land use scenario (DOE et al. September 1995). For NFA with no ICs and NFA with ICs, because of the location and characteristics of the potential contaminants, the primary pathways for human exposure are considered to be occupational ingestion of soil for the nonradiological COCs and direct gamma exposure for the radiological COCs. Soil ingestion pathways are included for the radiological COCs as well. The inhalation pathway is included for both the nonradiological and radiological COCs because of the potential to inhale dust and volatiles in the soil. The dermal exposure pathway is considered insignificant in this analysis and, therefore, is not considered further. No intake routes through plant, meat, or milk ingestion are considered appropriate for the industrial land use scenario. However, plant uptake is considered for the residential land use scenario. The conceptual site model (CSM) for NFA with no ICs and NFA with ICs is presented in Figure 1. For the remedial option with additional cover, all pathways are considered minor or do not exist and therefore, no CSM is presented. Under future excavation, all source contamination is assumed to be removed and no CSM is applicable.

**Pathway Identification**

| Nonradiological Constituents | Radiological Constituents |
|---|---|
| Soil ingestion | Soil ingestion |
| Inhalation (dust and volatiles) | Inhalation (dust and volatiles) |
| Plant uptake (residential only) | Plant uptake (residential only) |
| | Direct gamma |

## VI.4 Step 3. COC Screening Procedures

This section discusses Step 3, which includes the two screening procedures. The first screening procedure compares the maximum COC concentration to the approved background screening level. The second screening procedure compares maximum COC concentrations to SNL/NM proposed Subpart S action levels. This second procedure is applied only to COCs that are not eliminated during the first screening procedure.

### VI.4.1 Background Screening Procedure

#### *VI.4.1.1 Methodology*

Maximum concentrations of soil COCs were compared to the approved SNL/NM maximum screening levels for this area (Dinwiddie September 1997), which was selected to provide the background screen in Section IV and to calculate risk attributable to background. Only the COCs detected above SNL/NM background screening levels or COCs that do not have a quantifiable background screening level, were considered further in this risk assessment analysis.

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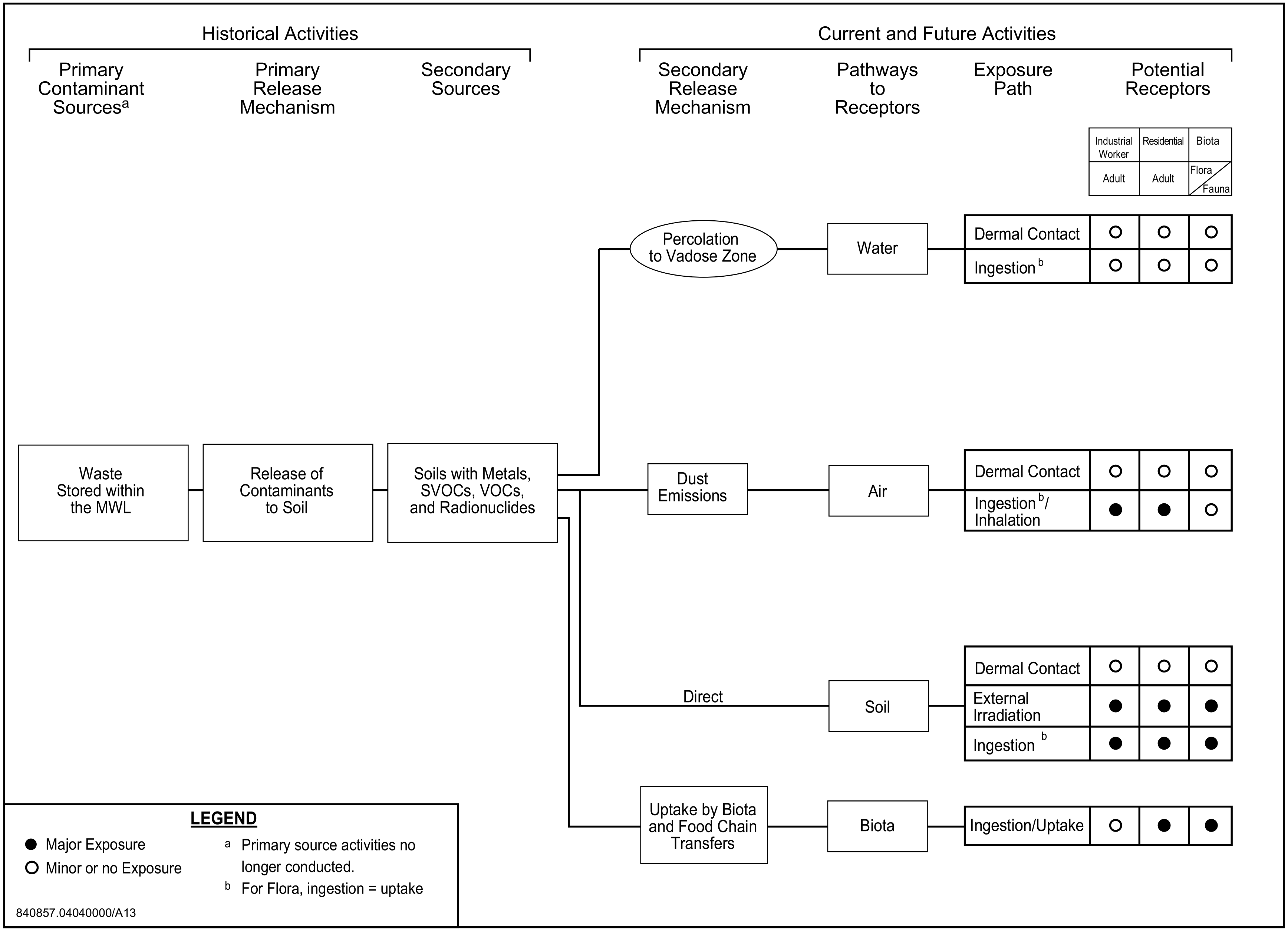


**Figure 1**
**Conceptual Model Flow Diagram for MWL**

For radiological COCs that exceeded the SNL/NM background screening levels, background values were subtracted from the individual maximum radionuclide concentrations. Those that did not exceed these background levels were not carried any further in the risk assessment. This approach is consistent with DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (DOE 1993). Radiological COCs that do not have background screening values and were detected above the analytical minimum detectable activities were carried through the risk assessment at the maximum levels. The resultant radiological COCs remaining after this step are referred to as background-adjusted radiological COCs.

#### *VI.4.1.2 Results for MWL Risk Baseline—NFA with No ICs*

The comparison of the MWL data for nonradiological COCs to SNL/NM approved background values (Dinwiddie September 1997) for the human health risk assessment for this alternative is presented in Tables 4 and 6. Of the nonradiological soil COCs, 12 constituents exhibited maximum measured values greater than the background screening levels (Table 4). One nonradiological COC (selenium) does not have a quantifiable background concentration for comparison. Therefore, it could not be determined whether this COC exceeds background. Sixteen of the COCs are organic constituents that do not have associated background concentrations.

The maximum concentration value for lead is 13.9 milligrams (mg)/kilogram (kg) (Table 4). The EPA intentionally does not provide human health toxicological data on lead; therefore, no risk parameter values could be calculated. However, the NMED guidance for lead screening concentrations for construction and industrial land use scenarios are 750 and 1,500 mg/kg, respectively (Olson and Moats March 2000). The EPA screening guidance value for a residential land use scenario is 400 mg/kg (Laws July 1994). Because the maximum concentration value for lead at this site is less than all the screening values, lead is eliminated from further consideration in this human health risk assessment.

For the radiological COCs, two constituents detected in the soil (tritium and U-238) exhibited maximum activities greater than the background values. Two constituents (Pu-238 and Pu-239) do not have quantified background screening levels; thus, it could not be determined whether these constituents exceed background (Table 6). These radiological constituents were evaluated using the RESRAD code.

#### *VI.4.1.3 Results for MWL Alternative I.a—NFA with ICs*

The comparison of the MWL data to SNL/NM approved background values (Dinwiddie September 1997) for the human health risk assessment of this alternative is presented in Tables 7 and 8. For the nonradiological soil COCs, one constituent (barium) had a maximum measured value greater than its corresponding background screening level (Table 7). Four nonradiological COCs (cadmium, mercury, selenium, and silver) do not have quantifiable background concentrations; therefore, it could not be determined whether these COCs exceed background levels. Six of the COCs are organic constituents that do not have associated background concentrations.

For the radiological COCs, two constituents detected in the soil (tritium and U-238) exhibited maximum activities greater than the background values. Two constituents (Pu-238 and

Pu-239) do not have quantified background screening levels; thus it could not be determined whether these constituents exceed background activities (Table 8). These radiological constituents were evaluated using the RESRAD code.

#### *VI.4.1.4 Results for MWL Alternative V.e—Future Excavation*

The comparison of the MWL data for nonradiological COCs to SNL/NM approved background values (Dinwiddie September 1997) for the human health risk assessment for this alternative is presented in Tables 9 and 11. Of the nonradiological soil COCs, 12 constituents exhibited maximum measured values greater than the background screening levels (Table 9). One nonradiological COC (selenium) does not have a quantifiable background concentration, so it could not be determined whether this COC exceeds background levels. Sixteen of the COCs are organic constituents that do not have associated background concentrations.

The maximum concentration value for lead is 13.9 mg/kg (Table 3). The EPA intentionally does not provide human health toxicological data on lead; therefore, no risk parameter values could be calculated. However, the NMED guidance for lead screening concentrations for construction and industrial land use scenarios are 750 and 1,500 mg/kg, respectively (Olson and Moats March 2000). The EPA screening guidance value for a residential land use scenario is 400 mg/kg (Laws July 1994). Because the maximum concentration value for lead at this site is less than all the screening values, lead is eliminated from further consideration in this human health risk assessment.

For the radiological COCs, seven constituents detected in the soil (Am-241, Cs-137, Ra-226, Sr-90, Th-232, tritium, and U-238) exhibited maximum activities greater than the background values (Table 11). Three radiological constituents (Co-60, Pu-238, and Pu-239) detected in the soil do not have quantified background concentrations, so it could not be determined whether these COCs exceed background activities. These radiological constituents were evaluated using the RESRAD code. The calculated quantity of radiological COCs in the inventory that will be present in the year 2039 is assumed to be uniformly distributed in the 24,486 cubic yards of material designated as waste. No credit is applied for the engineering controls, personal protective equipment (PPE), robotics, respirators or other equipment that might be employed during the excavation. However, this scenario provides a conservative baseline assumption of the potential exposure risk to excavation workers.

### VI.4.2 Subpart S Screening Procedure

#### *VI.4.2.1 Methodology*

The maximum concentrations of nonradiological COCs not eliminated during the background screening process were compared with action levels (IT July 1994) calculated using methods and equations promulgated in the proposed RCRA Subpart S (EPA July 1990) and Risk Assessment Guidance for Superfund (RAGS) (EPA 1989) documentation. Accordingly, all calculations are based upon the assumption that receptor doses from both toxic and potentially carcinogenic compounds result most significantly from the ingestion of contaminated soil. If there were 10 or fewer COCs, and each had a maximum concentration of less than 1/10 the action level, then the site was judged to pose no significant hazard to human health. If there were more than 10 COCs, the Subpart S screening procedure was not performed.

#### *VI.4.2.2 Results*

Because all MWL sample sets contain more than ten COCs retained past the first screening level (including COCs that have no background screening values), the proposed Subpart S screening process was not performed. For each COC not eliminated during the background screening process for the respective MWL remedial alternatives, an individual hazard quotient (HQ) and excess cancer risk value were calculated.

Because radiological COCs do not have predetermined action levels analogous to proposed Subpart S levels, this step in the screening process is not performed for radiological COCs.

### VI.5 Step 4. Identification of Toxicological Parameters

Tables 13 (nonradiological) and 14 (radiological) show the COCs that have been retained in this risk assessment and the corresponding values for the toxicological information available for all the COCs evaluated in the respective remedial alternatives. The toxicological values used in Table 13 were obtained from the Integrated Risk Information System (IRIS) (EPA 1998a), Health Effects Assessment Summary Tables (HEAST) (EPA 1997a), and EPA Region 9 (EPA 1996) and Region 3 (EPA 1997b) databases. Dose conversion factors (DCFs) used in determining the excess TEDE values for the individual pathways were the default values provided in the RESRAD computer code as developed in the following documents:

- For ingestion and inhalation, DCFs are taken from Federal Guidance Report No. 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion” (EPA 1988).

- The DCFs for surface contamination (contamination on the surface of the site) were taken from DOE/EH-0070, “External Dose-Rate Conversion Factors for Calculation of Dose to the Public” (DOE 1988).

- The DCFs for volume contamination (exposure to contamination deeper than the immediate surface of the site) were calculated using the methods discussed in “Dose-Rate Conversion Factors for External Exposure to Photon Emitters in Soil” (*Health Physics* 28:193-205) (Kocher 1983), and ANL/EAIS-8, *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil* (Yu et al. 1993a).

### VI.6 Step 5. Exposure Assessment and Risk Characterization

Section VI.6.1 describes the exposure assessment for this risk assessment. Section VI.6.2 provides the risk characterization, including the HI value and the excess cancer risk, for the potential nonradiological soil COCs and associated background. The incremental TEDE and incremental estimated cancer risk are provided for the background-adjusted radiological COCs for both industrial and residential land uses.

**Table 13**
**Toxicological Parameter Values for the MWL Nonradiological COCs**

| COC Name | $RfD_o$ (mg/kg-day) | Confidence[a] | $RfD_{inh}$ (mg/kg-day) | Confidence[a] | $SF_o$ $(mg/kg\text{-}day)^{-1}$ | $SF_{inh}$ $(mg/kg\text{-}day)^{-1}$ | Cancer Class[b] |
|---|---|---|---|---|---|---|---|
| Arsenic | 3E-4[c] | M | – | – | 1.5E+0[c] | 1.5E+1[c] | A |
| Barium | 7E-2[c] | M | 1.4E-4[d] | – | – | – | – |
| Beryllium | 2E-3[c] | L to M | 5.7E-6[c] | M | – | 8.4E+0[c] | B1 |
| Cadmium | 5E-4[c] | H | 5.7E-5[d] | – | – | 6.3E+0[c] | B1 |
| Chromium, total | 1E+0[c] | L | 5.7E-7[e] | – | – | – | – |
| Cobalt | 6E-2[d] | – | 2.9E-4[d] | – | – | – | – |
| Copper | 3.7E-2[d] | – | – | – | – | – | D |
| Mercury | 3E-4[f] | – | 8.6E-5[c] | M | – | – | D |
| Nickel | 2E-2[c] | M | – | – | – | – | – |
| Selenium | 5E-3[c] | H | – | – | – | – | D |
| Silver | 5E-3[c] | L | – | – | – | – | D |
| Zinc | 3E-1[c] | M | – | – | – | – | D |
| Acetone | 1E-1[c] | L | 1E-1[d] | – | – | – | D |
| Benzoic acid | 4E+0[c] | M | 4E+0[d] | – | – | – | D |
| Bis(2-ethylhexyl) phthalate | 2E-2[d] | – | 2.2E-2[d] | – | 1.4E-2[d] | 1.4E-2[d] | – |
| 2-Butanone | 6E-1[c] | L | 2.9E-1[c] | L | – | – | D |
| Di-n-butyl phthalate | 1E-1[c] | L | 1E-1[d] | – | – | – | D |
| Di-n-octyl phthalate | 2E-2[f] | – | 2E-2[f] | – | – | – | – |
| 2-Hexanone | 4E-2[e] | – | – | – | – | – | – |
| 4-Methyl-2-pentanone | 8E-2[f] | – | 2.3E-2[d] | – | – | – | – |
| Methylene chloride | 6E-2[c] | M | 8.6E-1[f] | – | 7.5E-3[c] | 1.7E-3[c] | B2 |
| n-Nitrosodi-phenylamine | – | – | – | – | 4.9E-3[c] | 4.9E-3[d] | B2 |
| Phenol/Phenolics[g] | 6E-1[c] | L | 6E-1[d] | – | – | – | D |
| Pyrene | 3E-2[c] | L | 3E-2[d] | – | – | – | D |
| Tetrachloroethene | 1E-2[c] | M | 1E-2[d] | – | 5.2E-2[d] | 2E-3[d] | – |
| Toluene | 2E-1[c] | M | 1.1E-1[c] | M | – | – | D |
| Trichloroethene | 6E-3[d] | – | 6E-3[d] | – | 1.1E-2[d] | 6E-3[d] | – |
| Xylenes, total | 2E+0[c] | M | 2E-1[d] | – | – | – | D |

Refer to footnotes at end of table.

## Table 13 (Concluded)
## Toxicological Parameter Values for the MWL Nonradiological COCs

[a]Confidence associated with IRIS (EPA 1998a) database values. Confidence: L = low, M = medium, H = high.
[b]EPA weight-of-evidence classification system for carcinogenicity (EPA 1989) taken from IRIS (EPA 1998a):

A—Human carcinogen.
B1—Probable human carcinogen. Limited human data are available.
B2—Probable human carcinogen. Indicates sufficient evidence in animals and inadequate or no evidence in humans.
D—Not classifiable as to human carcinogenicity.

[c]Toxicological parameter values from IRIS electronic database (EPA 1998a).
[d]Toxicological parameter values from EPA Region 9 electronic database (EPA 1996).
[e]Toxicological parameter values from EPA Region 3 electronic database (EPA 1997b).
[f]Toxicological parameter values from HEAST database (EPA 1997a).
[g]Phenolics does not have toxicological parameter values. Phenol was used as a surrogate.

COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HEAST = Health Effects Assessment Summary Tables.
IRIS = Integrated Risk Information System.
mg/kg-day = Milligram(s) per kilogram per day.
$(mg/kg\text{-}day)^{-1}$ = Per milligram(s) per kilogram per day.
MWL = Mixed Waste Landfill.
$RfD_o$ = Oral chronic reference dose.
$RfD_{inh}$ = Inhalation chronic reference dose.
$SF_o$ = Oral slope factor.
$SF_{inh}$ = Inhalation slope factor.
– = Information not available.

**Table 14**
**Radiological Toxicological Parameter Values for the MWL COCs Obtained from RESRAD Risk Coefficients[a]**

| COC Name | $SF_o$ (1/pCi) | $SF_{inh}$ (1/pCi) | $SF_{ev}$ (g/pCi-yr) | Cancer Class[b] |
|---|---|---|---|---|
| Am-241 | 3.6E-3 | 4.4E-1 | 3.0E-6 | A |
| Co-60 | 2.7E-5 | 2.2E-4 | 2.3E-4 | A |
| Cs-137 | 5.0E-5 | 3.2E-5 | 6.1E-5 | A |
| Tritium | 6.4E-8 | 6.4E-8 | 0.0E+0 | A |
| Pu-238 | 3.2E-3 | 3.9E-1 | 8.6E-8 | A |
| Pu-239 | 3.5E-3 | 4.3E-1 | 3.8E-8 | A |
| Ra-226 | 1.3E-6 | 8.6E-3 | 7.6E-7 | A |
| Sr-90 | 8.1E-4 | 1.3E-3 | 0.0E+0 | A |
| Th-232 | 2.7E-3 | 1.64E+0 | 6.7E-8 | A |
| U-238 | 2.7E-4 | 1.2E-1 | 6.6E-8 | A |

[a]From Yu et al. (1993b).
[b]EPA weight-of-evidence classification system for carcinogenicity (EPA 1989): A—human carcinogen for high dose and high dose rate (i.e., greater than 50 rem per year). For low-level environmental exposures, the carcinogenic effect has not been observed and documented.
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
MWL = Mixed Waste Landfill.
$SF_o$ = Oral (ingestion) slope factor.
$SF_{inh}$ = Inhalation slope factor.
$SF_{ev}$ = External volume exposure slope factor.
1/pCi = One per picocurie.
g/pCi-yr = Gram(s) per picocurie per year.

## VI.6.1 Exposure Assessment

Appendix 1 provides the equations and parameter input values used in calculating intake values and subsequent HI and excess cancer risk values for the individual exposure pathways. The appendix shows parameters for both industrial and residential land use scenarios. The equations for nonradiological COCs are based upon the RAGS (EPA 1989). Parameters are based upon information from the RAGS (EPA 1989), as well as other EPA guidance documents, and reflect the reasonable maximum exposure (RME) approach advocated by the RAGS (EPA 1989). For radiological COCs, the coded equations provided in the RESRAD computer code are used to estimate the incremental TEDE and cancer risk for individual exposure pathways. Further discussion of this process is provided in the *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD* (Yu et al. 1993b).

Although the designated land use scenario is industrial for this site, risk and TEDE values for a residential land use scenario are also presented to provide perspective on the potential risk to human health under the more restrictive land use scenario.

### VI.6.2 Risk Characterization

The following sections present the risk characterizations for each remedial alternative.

#### *VI.6.2.1 MWL Risk Baseline—NFA with No ICs*

Table 15 indicates that for the MWL nonradiological soil COCs, the HI value is 0.07, and the excess cancer risk is 3E-6 for the designated industrial land use scenario. The numbers presented include exposure from soil ingestion and dust and volatile inhalation for the nonradiological soil COCs. Assuming the maximum background concentrations of the MWL associated background constituents, Table 16 indicates that the HI is 0.01 and the excess cancer risk is 2E-6 for the designated industrial land use scenario.

For the radiological COCs under the industrial land use scenario, a TEDE was calculated for both an industrial office worker who spends the majority of his time indoors and an industrial worker who works equal time indoors and outdoors on the site. For this industrial land use scenario, an incremental TEDE of 3.3E-1 millirem per year (mrem/yr) results. In accordance with EPA guidance found in Office of Solid Waste and Emergency Response (OSWER) Directive No. 9200.4-18 (EPA 1997c), an incremental TEDE of 15 mrem/yr is used for the probable land use scenario (industrial in this case); the calculated dose value for the MWL for the industrial land use scenario is well below this guideline. The estimated excess cancer risk is 2.2E-6.

For the residential land use scenario nonradiological soil COCs, the HI value increases to 10, and the excess cancer risk is 9E-5 (Table 15). The numbers presented include exposure from soil ingestion, dust and volatile inhalation, and plant uptake. Although the EPA generally recommends that inhalation not be included in a residential land use scenario (EPA 1991), this pathway is included because of the potential for soil in Albuquerque, New Mexico, to be eroded and, subsequently, for dust to be present in predominantly residential areas. Because of the nature of the local soil, other exposure pathways are not considered (see Appendix 1). Table 16 indicates that for the MWL associated background constituents, the HI is 0.48, and the excess cancer risk is 5E-5.

For the radiological COCs, the incremental TEDE for the residential land use scenario is 9.3 mrem/yr. The guideline being used is an excess TEDE of 75 mrem/yr (SNL/NM February 1998) for a complete loss of IC (residential land use in this case); the calculated dose value for the MWL for the residential land use is well below this guideline. The estimated excess cancer risk is 4.4E-5. The excess cancer risk from the nonradiological COCs and the radiological COCs is not additive, as noted in RAGS (EPA 1989).

The human health risk assessment summarized above is a reasonable worst-case scenario for both current and future risk.

**Table 15**
**MWL Risk Baseline— NFA with No ICs**
**Risk Assessment Values for the MWL Nonradiological Soil COCs**

| COC Name | Maximum Concentration (mg/kg) | Industrial Land Use Scenario[a] | | Residential Land Use Scenario[a] | |
|---|---|---|---|---|---|
| | | HI | Cancer Risk | HI | Cancer Risk |
| Arsenic | 5.63 | 0.02 | 3E-6 | 0.32 | 6E-5 |
| Barium | 808 | 0.01 | – | 0.12 | – |
| Beryllium | 1.1 | 0.00 | 5E-10 | 0.00 | 8E-10 |
| Cadmium | 1.97 | 0.00 | 7E-10 | 1.61 | 1E-9 |
| Chromium, total[b] | 34.3 | 0.01 | – | 0.01 | – |
| Cobalt | 105 | 0.00 | – | 0.03 | – |
| Copper | 645 | 0.02 | – | 3.12 | – |
| Mercury | 2.11 | 0.01 | – | 3.63 | – |
| Nickel | 97.5 | 0.00 | – | 0.14 | – |
| Selenium | 0.61 | 0.00 | – | 0.21 | – |
| Silver | 1.46 | 0.00 | – | 0.06 | – |
| Zinc | 413 | 0.00 | – | 0.75 | – |
| Acetone | 0.225 J | 0.00 | – | 0.04 | – |
| Benzoic acid | 0.068 J | 0.00 | – | 0.00 | – |
| Bis(2-ethylhexyl) phthalate | 2.9 | 0.00 | 1E-8 | 0.00 | 1E-7 |
| 2-Butanone | 0.0223 J | 0.00 | – | 0.00 | – |
| Di-n-butyl phthalate | 0.16 J | 0.00 | – | 0.00 | – |
| Di-n-octyl phthalate | 0.13 J | 0.00 | – | 0.00 | – |
| 2-Hexanone | 0.00885 J | 0.00 | – | 0.00 | – |
| 4-Methyl-2-pentanone | 0.00757 J | 0.00 | – | 0.00 | – |
| Methylene chloride | 3.8 | 0.00 | 3E-7 | 0.15 | 3E-5 |
| n-Nitrosodiphenylamine | 0.074 J | 0.00 | 2E-10 | 0.00 | 3E-8 |
| Phenol | 0.46 | 0.00 | – | 0.00 | – |
| Pyrene | 1.06 | 0.00 | – | 0.00 | – |
| Tetrachloroethene | 0.0054 | 0.00 | 4E-10 | 0.00 | 5E-8 |
| Toluene | 0.0204 J | 0.00 | – | 0.00 | – |
| Trichloroethene | 0.001 J | 0.00 | 1E-10 | 0.00 | 3E-9 |
| Xylenes, total | 0.0178 J | 0.00 | – | 0.00 | – |
| **TOTAL** | | **0.07** | **3E-6** | **10** | **9E-5** |

[a]EPA (1989).
[b]Chromium, total is assumed to be chromium III (most conservative).
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
IC = Institutional Control.
J = Estimated concentration.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NFA = No Further Action.
– = Information not available.

**Table 16**
**MWL Risk Baseline—NFA with No ICs**
**Risk Assessment Values for the MWL Nonradiological Background Soil COCs**

| COC Name | Background Concentration[a] (mg/kg) | Industrial Land Use Scenario[b] | | Residential Land Use Scenario[b] | |
|---|---|---|---|---|---|
| | | HI | Cancer Risk | HI | Cancer Risk |
| Arsenic | 4.4 | 0.01 | 2E-6 | 0.25 | 5E-5 |
| Barium | 130 | 0.00 | – | 0.02 | – |
| Beryllium | 0.65 | 0.00 | 3E-10 | 0.00 | 5E-10 |
| Cadmium | <1 | – | – | – | – |
| Chromium, total | 15.9 | 0.00 | – | 0.01 | – |
| Cobalt | 5.2 | 0.00 | – | 0.00 | – |
| Copper | 15.4 | 0.00 | – | 0.07 | – |
| Mercury | <0.1 | – | – | – | – |
| Nickel | 11.5 | 0.00 | – | 0.02 | – |
| Selenium | <1 | – | – | – | – |
| Silver | <1 | – | – | – | – |
| Zinc | 62 | 0.00 | – | 0.11 | – |
| **TOTAL** | | **0.01** | **2E-6** | **0.48** | **5E-5** |

[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]EPA (1989).
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
IC = Institutional Control.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NFA = No Further Action.
– = Information not available.

### *VI.6.2.2 MWL Alternative I.a—NFA with ICs*

Table 17 indicates that for the MWL nonradiological soil COCs, the HI value is 0.00, and the excess cancer risk is 1E-9 for the designated industrial land use scenario. The numbers presented include exposure from soil ingestion and dust and volatile inhalation for the nonradiological soil COCs. Assuming the maximum background concentrations of the MWL associated background constituents, Table 18 shows an HI of 0.00 and no measurable excess cancer risk for the designated industrial land use scenario.

For the radiological COCs under the industrial land use scenario, a TEDE was calculated for both an industrial office worker who spends the majority of his time indoors and an industrial worker who works equal time indoors and outdoors on the site. For this industrial land use scenario, an incremental TEDE of 3.3E-1 mrem/yr results. In accordance with EPA guidance found in OSWER Directive No. 9200.4-18 (EPA 1997c), an incremental TEDE of 15 mrem/yr is used for the probable land use scenario (industrial in this case); the calculated dose value for the MWL for the industrial land use is well below this guideline. The estimated excess cancer risk is 2.2E-6.

For the residential land use scenario nonradiological soil COCs, the HI value increases to 0.69, and the excess cancer risk is 8E-8 (Table 17). The numbers presented include exposure from soil ingestion, dust and volatile inhalation, and plant uptake. Although EPA (EPA 1991) generally recommends that inhalation not be included in a residential land use scenario, this pathway is included because of the potential for soil in Albuquerque, New Mexico, to be eroded and, subsequently, for dust to be present in predominantly residential areas. Because of the nature of the local soil, other exposure pathways are not considered (see Appendix 1). Table 18 indicates that for the MWL associated background constituents the HI is 0.02 and there is no measurable excess cancer risk.

For the radiological COCs, the incremental TEDE for the residential land use scenario is 9.3 mrem/yr. The guideline being used is an excess TEDE of 75 mrem/yr (SNL/NM February 1998) for a complete loss of IC (residential land use in this case); the calculated dose value for the MWL for the residential land use is well below this guideline. The estimated excess cancer risk is 4.4E-5. The excess cancer risk from the nonradiological COCs and the radiological COCs is not additive, as noted in RAGS (EPA 1989).

The human health risk assessment summarized above is a reasonable worst-case scenario for potential risk during implementation of the remedial alternative and future risk associated with the NFA with ICs alternative. In addition, the NFA with ICs alternative summarizes the current conditions at the site.

### *VI.6.2.3 MWL Alternative III.b—Vegetative Soil Cover*

The vegetative soil cover alternative is similar to the NFA with ICs alternative, except that an additional 5 feet of compacted fill material will have been added to the existing surface. With ICs, the addition of compacted fill material, and the current depth of contamination, the human health pathways will be eliminated for potential nonradiological COCs. Therefore, under this remedial alternative, the nonradiological COC risk is not of concern.

**Table 17**
**MWL Alternative I.a—NFA with ICs**
**Risk Assessment Values for the MWL Nonradiological Soil COCs**

| COC Name | Maximum Concentration (mg/kg) | Industrial Land Use Scenario[a] | | Residential Land Use Scenario[a] | |
|---|---|---|---|---|---|
| | | HI | Cancer Risk | HI | Cancer Risk |
| Barium | 168 | 0.00 | – | 0.03 | – |
| Cadmium | 0.37 J | 0.00 | 1E-10 | 0.30 | 2E-10 |
| Mercury | 0.05[b] | 0.00 | – | 0.09 | – |
| Selenium | 0.566 | 0.00 | – | 0.20 | – |
| Silver | 0.96 J | 0.00 | – | 0.04 | – |
| Acetone | 0.18 | 0.00 | – | 0.03 | – |
| Bis(2-ethylhexyl) phthalate | 0.073 J | 0.00 | 4E-10 | 0.00 | 3E-9 |
| Di-n-butyl phthalate | 0.16 J | 0.00 | – | 0.00 | – |
| Di-n-octyl phthalate | 0.074 J | 0.00 | – | 0.00 | – |
| Methylene chloride | 0.01 | 0.00 | 7E-10 | 0.00 | 8E-8 |
| Toluene | 0.002 J | 0.00 | – | 0.00 | – |
| **TOTAL** | | **0.00** | **1E-9** | **0.69** | **8E-8** |

[a]EPA (1989).
[b]Parameter was nondetect. Concentration is one half the detection limit.
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
IC = Institutional Control.
J = Estimated concentration.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NFA = No Further Action.
– = Information not available.

**Table 18**
**MWL Alternative I.a—NFA with ICs**
**Risk Assessment Values for the MWL Nonradiological**
**Background Soil Constituents**

| COC Name | Background Concentration[a] (mg/kg) | Industrial Land Use Scenario[b] | | Residential Land Use Scenario[b] | |
|---|---|---|---|---|---|
| | | HI | Cancer Risk | HI | Cancer Risk |
| Barium | 130 | 0.00 | – | 0.02 | – |
| Cadmium | <1 | – | – | – | – |
| Mercury | <0.1 | – | – | – | – |
| Selenium | <1 | – | – | – | – |
| Silver | <1 | – | – | – | – |
| **TOTAL** | | **0.00** | **–** | **0.02** | **–** |

[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]EPA (1989).
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
IC = Institutional Control.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NFA = No Further Action.
– = Information not available.

### *VI.6.2.4 MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier*

The vegetative soil cover with a bio-intrusion barrier alternative is similar to the NFA with ICs alternative, except that 3 feet of cobbles and boulders in addition to 5 feet of compacted fill material will be added to the existing surface. With ICs, the addition of the bio-intrusion barrier and compacted fill material, and the current depth of contamination, the human health pathways will be eliminated for potential nonradiological COCs. Therefore, risk from nonradiological COCs under this alternative is not of concern.

For the radiological COCs under the industrial land use scenario, a TEDE was calculated for both an industrial office worker who spends the majority of his time indoors and an industrial worker who works equal time indoors and outdoors on the site. For this industrial land use scenario, an incremental TEDE of 2.4E-5 mrem/yr results. In accordance with EPA guidance found in OSWER Directive No. 9200.4-18 (EPA 1997c), an incremental TEDE of 15 mrem/yr is used for the probable land use scenario (industrial in this case); the calculated dose value for the MWL for the industrial land use is well below this guideline. The estimated excess cancer risk is 3.4E-10.

For the radiological COCs, the incremental TEDE for the residential land use scenario is 1.7E-3 mrem/yr. The guideline being used is an excess TEDE of 75 mrem/yr (SNL/NM February 1998) for a complete loss of IC (residential land use in this case); the calculated dose value for the MWL for the residential land use is well below this guideline. Consequently, the MWL is eligible for unrestricted radiological release because the residential land use scenario results in an incremental TEDE to the on-site receptor of less than 75 mrem/yr. The estimated excess cancer risk is 1.0E-8. The excess cancer risk from the nonradiological COCs and the radiological COCs is not additive, as noted in RAGS (EPA 1989).

The human health risk assessment summarized above for this remedial alternative is a reasonable worst-case scenario for potential risk during implementation of the remedial alternative and future risk associated with the bio-intrusion barrier alternative. Potential occupational injury and fatalities for implementation of the alternative are summarized in Section VIII.

#### *VI.6.2.5 MWL Alternative V.e—Future Excavation*

Table 19 indicates that for the MWL nonradiological soil COCs, the HI value is 0.07, and the excess cancer risk is 3E-6 for the designated industrial land use scenario. The numbers presented include exposure from soil ingestion and dust and volatile inhalation for the nonradiological soil COCs. Assuming the maximum background concentrations of the MWL associated background constituents, Table 20 indicates an HI of 0.01, and excess cancer risk of 2E-6 for the designated industrial land use scenario.

For the radiological COCs under the industrial land use scenario, a TEDE was calculated for both an industrial office worker who spends the majority of his time indoors and an industrial worker who works equal time indoors and outdoors on the site. For this industrial land use scenario, an incremental TEDE of 3.23E+3 mrem/yr results. In accordance with EPA guidance found in OSWER Directive No. 9200.4-18 (EPA 1997c), an incremental TEDE of 15 mrem/yr is used for the probable land use scenario (industrial in this case); the calculated dose value for the MWL for the industrial land use is significantly above this guideline. However, in this instance the applicable guideline is Title 10, Code of Federal Regulations (10 CFR) 835 “Occupational Radiation Protection,” which is 5,000 mrem/year per worker. Another requirement of 10 CFR 835 is to ensure that worker exposures are kept as low as reasonably achievable (ALARA), which would be a significant challenge for excavation work planning. The estimated excess cancer risk is 3.7E-2.

The human health risk assessment summarized above is a reasonable worst-case scenario for potential risk during implementation of this remedial alternative. There is no future risk for the excavation alternative, under the assumption that the MWL will be fully remediated. Potential occupational injury and fatalities for implementation of this alternative are summarized in Section VIII.

### VI.7 Step 6. Comparison of Risk Values to Numerical Guidelines

The following sections present the comparison of risk values to numerical guidelines for the respective remedial alternatives.

The human health risk assessment analysis considered the evaluation of the potential for adverse health effects for both an industrial and residential land use scenario for COCs detected in the soil.

**Table 19**
**MWL Alternative V.e—Future Excavation**
**Risk Assessment Values for the MWL Nonradiological Soil COCs**

| COC Name | Maximum Concentration (mg/kg) | Industrial Land Use Scenario[a] | |
|---|---|---|---|
| | | HI | Cancer Risk |
| Arsenic | 5.63 | 0.02 | 3E-6 |
| Barium | 808 | 0.01 | – |
| Beryllium | 1.1 | 0.00 | 5E-10 |
| Cadmium | 1.97 | 0.00 | 7E-10 |
| Chromium, total[b] | 34.3 | 0.01 | – |
| Cobalt | 105 | 0.00 | – |
| Copper | 645 | 0.02 | – |
| Mercury | 2.11 | 0.01 | – |
| Nickel | 97.5 | 0.00 | – |
| Selenium | 0.61 | 0.00 | – |
| Silver | 1.46 | 0.00 | – |
| Zinc | 413 | 0.00 | – |
| Acetone | 0.225 J | 0.00 | – |
| Benzoic acid | 0.068 J | 0.00 | – |
| Bis(2-ethylhexyl) phthalate | 2.9 | 0.00 | 1E-8 |
| 2-Butanone | 0.0223 J | 0.00 | – |
| Di-n-butyl phthalate | 0.16 J | 0.00 | – |
| Di-n-octyl phthalate | 0.13 J | 0.00 | – |
| 2-Hexanone | 0.00885 J | 0.00 | – |
| 4-Methyl-2-pentanone | 0.00757 J | 0.00 | – |
| Methylene chloride | 3.8 | 0.00 | 3E-7 |
| n-Nitrosodiphenylamine | 0.074 J | 0.00 | 2E-10 |
| Phenol | 0.46 | 0.00 | – |
| Pyrene | 1.06 | 0.00 | – |
| Tetrachloroethene | 0.0054 | 0.00 | 4E-10 |
| Toluene | 0.0204 J | 0.00 | – |
| Trichloroethene | 0.001 J | 0.00 | 1E-10 |
| Xylenes, total | 0.0178 J | 0.00 | – |
| **TOTAL** | | **0.07** | **3E-6** |

[a]EPA (1989).
[b]Chromium, total is assumed to be chromium III (most conservative).
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
J = Estimated concentration.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
– = Information not available.

**Table 20**
**MWL Alternative V.e—Future Excavation**
**Risk Assessment Values for the MWL Nonradiological**
**Background Soil COCs**

| COC Name | Background Concentration[a] (mg/kg) | Industrial Land Use Scenario[b] | |
|---|---|---|---|
| | | HI | Cancer Risk |
| Arsenic | 4.4 | 0.01 | 2E-6 |
| Barium | 130 | 0.00 | – |
| Beryllium | 0.65 | 0.00 | 3E-10 |
| Cadmium | <1 | – | – |
| Chromium, total[c] | 15.9 | 0.00 | – |
| Cobalt | 5.2 | 0.00 | – |
| Copper | 15.4 | 0.00 | – |
| Mercury | <0.1 | – | – |
| Nickel | 11.5 | 0.00 | – |
| Selenium | <1 | – | – |
| Silver | <1 | – | – |
| Zinc | 62 | 0.00 | – |
| **TOTAL** | | **0.01** | **2E-6** |

[a]From Dinwiddie (September 1997), Southwest Test Area.
[b]EPA (1989).
[c]Chromium, total is assumed to be chromium III (most conservative).
COC = Constituent of concern.
EPA = U.S. Environmental Protection Agency.
HI = Hazard index.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
– = Information not available.

For the industrial land use scenario nonradiological soil COCs, the calculated HI ranged from 0.07 for the future excavation and NFA with no ICs to 0.00 for NFA with cover alternatives, significantly less than the numerical guideline of 1 suggested in RAGS (EPA 1989). The excess cancer risk ranged from an estimated 3E-6 for the future excavation and NFA with no ICs to approximately 0.0 for the NFA with cover alternatives. NMED guidance states that cumulative excess lifetime cancer risk must be less than 1E-5 (Bearzi January 2001), thus the excess cancer risk for these alternatives is below the suggested acceptable risk value. This risk assessment also determined risks considering background concentrations of the potential nonradiological COCs for both the industrial and residential land use scenarios. For nonradiological soil COCs, assuming the industrial land use scenario, the HI ranged from 0.01 to 0.00. The estimated excess cancer risk ranged from 2E-6 to no measurable excess cancer risk.

For the radiological COCs under the industrial land use scenario for the various alternatives (with the exception of future excavation), the incremental TEDE ranged from 3.3E-1 to 2.4E-5 mrem/yr, which is less than EPA's numerical guideline of 15 mrem/yr. The EPA weight-of-evidence classification system for carcinogenicity (EPA 1989) states that all radioactive materials are considered to be Class A carcinogens for high dose and high dose rate (i.e., greater than 50 rem per year). However, for low-level environmental exposures, the carcinogenic effect has not been observed and documented. Nevertheless, calculated risks from projected doses are presented for perspective, assuming that low doses and low dose rates produce cancer effects that are linearly extrapolated from high doses and high dose rates.

For the residential land use scenario nonradiological soil COCs, the calculated HI ranged from 10 for the NFA alternative, which is above the numerical guidance, to 0.0 for the NFA with cover alternatives. The excess cancer risk ranged from 9E-5 for NFA with ICs to approximately 0.0 for the NFA with operational cover alternatives. NMED guidance states that cumulative excess lifetime cancer risk must be less than 1E-5 (Bearzi January 2001); thus the excess cancer risk for NFA without ICs is above the suggested acceptable risk value. The HI for associated background for the residential land use scenario ranged from 0.48 to 0.00. The estimated excess cancer risk ranged from 5E-5 to no measurable excess cancer risk.

The incremental TEDE for a residential land use scenario (with the exception of the future excavation alternative) from the radiological components ranged from 9.3 to 1.7E-3 mrem/yr, which is significantly less than the numerical guideline of 75 mrem/yr suggested in SNL/NM's "RESRAD Input Parameter Assumptions and Justification" (SNL/NM February 1998). The estimated excess cancer risk ranged from 4.4E-5 to 1.0E-8. The weight-of-evidence classification system for carcinogenicity (EPA 1989) states that all radioactive materials are considered to be Class A carcinogens for high dose and high dose rate (i.e., greater than 50 rem per year). However, for low-level environmental exposures, the carcinogenic effect has not been observed and documented. Nevertheless, calculated risks from projected doses are presented for perspective, assuming that low doses and low dose rates produce cancer effects that are linearly extrapolated from high doses and high dose rates.

For the radiological COCs under the industrial land use scenario for the future excavation alternative, the incremental TEDE is 3.23E+3 mrem/yr, which is greater than EPA's numerical guideline of 15 mrem/yr. However, in this scenario, the applicable guideline is 5,000 mrem/yr for industrial workers, found in 10 CFR 835, "Occupational Radiation Protection." This assessment does not address the probability of numerous remedial action workers being exposed to radiation during excavation and the requirement of 10 CFR 835 to ensure that worker exposures are maintained ALARA. The incremental estimated excess cancer risk is 3.7E-2. The EPA weight-of-evidence classification system for carcinogenicity (EPA 1989) states that all radioactive materials are considered to be Class A carcinogens for high dose and high dose rate (i.e., greater than 50 rem per year). However, for low-level environmental exposures, the carcinogenic effect has not been observed and documented. Nevertheless, calculated risks from projected doses are presented for perspective, assuming that low doses and low dose rates produce cancer effects that are linearly extrapolated from high doses and high dose rates.

## VI.8 Step 7. Uncertainty Discussion

The determination of the nature, rate, and extent of contamination at the MWL was based upon an initial conceptual model validated with extensive, multimedia sampling. All sampling was implemented in accordance with media-specific sampling and analysis plans, applicable SNL/NM ER OPs, and RFI work plans reviewed and approved by the EPA and/or the NMED. The data collected, based upon sample location, frequency, density, and depth, are representative of the site. The analytical requirements and results satisfy the streamlining approach. Data quality was validated in accordance with SNL/NM procedures and reviewed by outside, independent sources. Consequently, there is little uncertainty associated with the data quality used to perform the risk assessment at the MWL.

Because of the location, history of the site, modeled receptors, and future land use scenario (DOE et al. September 1995), there is low uncertainty in the land use scenario and the potentially affected populations that were considered in this risk assessment analysis. Because the COCs are found in surface and near-surface soil, and because of the location and physical characteristics of the site, there is little uncertainty in the exposure pathways relevant to the analysis.

An RME approach was used to calculate the risk assessment values, which means that the parameter values used in the calculations were conservative and that the calculated intakes are likely overestimated. Maximum values measured of the concentrations of the COCs were used to achieve conservative results.

Table 13 shows the uncertainties (confidence level) in the nonradiological toxicological parameter values. There is a mixture of estimated values and values from the IRIS (EPA 1998a), HEAST (EPA 1997a), EPA Region 9 (EPA 1996) and Region 3 (EPA 1997b) databases. Where values are not provided, information is not available from the IRIS (EPA 1998a), HEAST (EPA 1997a), or the EPA regions (EPA 1996, 1997b). Because of the conservative nature of the RME approach, the uncertainties in the toxicological values are not expected to be of high enough significance to change the conclusion of the risk assessment analysis.

The HI and excess cancer risk values for the nonradiological soil COCs are below the NMED guidelines for the industrial land use scenario under all remedial alternatives. Therefore, considering the conservatism of the analysis, the MWL nonradiological COCs do not pose a threat to human health. For the excavation scenario, maximum concentrations reported during site characterization were assumed to represent the maximum concentrations that would be found during the excavation.

For the radiological COCs, the conclusion from the risk assessment is that the potential effects on human health for both the industrial and residential land use scenarios are within guidelines and represent only a small fraction of the estimated 360 mrem/yr received by the average U.S. population (NCRP 1987), with the exception of the future excavation remedial alternative.

For mobile chemicals, there is the potential for transport to the groundwater and vapor flow to the surface. However, for the MWL both of these pathways are considered to be minor. To account for these uncertainties, a bounding risk analysis was done for potential ingestion of groundwater and inhalation of VOCs.

The only way risk would be significantly impacted would be if the groundwater were impacted at levels for which risk may occur. The bounding risk calculations were done using an established transport model (Risk-Based Corrective Action [RBCA]) (Connor et al. 2000) and the current onsite COCs to determine what COC concentrations in soil would impact groundwater at a given risk level (i.e., HI =1 or Excess Cancer Risk = 1E-5) for onsite occupational receptors. To a lesser extent the COC vapor flow to the surface was evaluated in a similar manner. Note that radionuclides (other than tritium) and metals in subsurface soils were not evaluated for either of the pathways discussed above. They are not particularly mobile and do not volatilize. The following assumptions were made in running the RBCA transport model:

- Maximum COC concentrations were used as the exposure point concentrations
- The modeling assumes an infinite source
- RBCA chemical parameters were used as default parameters, except for the COC toxicity values summarized in Table 13
- RBCA default parameters for the transport modeling were used, except for the site specific parameters summarized in Table 21

Table 22 summarizes the results for the bounding uncertainty assessment. Summarized in Table 22 are the risks based on the transport of the maximum concentrations to groundwater and the surface, and the corresponding COC subsurface soil concentrations that would result in a potential risk for both of these pathways. None of the COCs at their current maximum concentrations resulted in risk for either of the pathways evaluated. In addition, all of the current concentrations of COCs are orders of magnitude below those that would result in risk for either of these minor pathways.

The overall uncertainty in all of the steps in the risk assessment process is considered insignificant with respect to the conclusion reached.

## VI.9 Summary

The MWL contains identified COCs consisting of some organic, inorganic, and radiological constituents. Because of the location of the site on KAFB, the designated land use scenarios, and the nature of the contamination, the potential exposure pathways identified for this site included soil ingestion and dust and volatile inhalation for chemical constituents, and soil ingestion, inhalation of dust and volatiles, and direct gamma exposure for radionuclides. Plant uptake was included as an exposure pathway for the residential land use scenario.

Using conservative assumptions and employing an RME approach to the risk assessment, the calculations for the nonradiological soil COCs indicate that under the industrial land use scenario the HI was significantly less than the accepted numerical guidance from the EPA for all remedial alternatives. The total excess cancer risk is below the acceptable risk value provided by the NMED for an industrial land use (Bearzi January 2001) for all remedial alternatives.

With the exception of the excavation alternative, the incremental TEDE and corresponding estimated cancer risk from the radiological soil COCs are much less than EPA guidance values for both the industrial and residential land use scenarios under all remedial alternatives evaluated.

The uncertainties associated with these calculations are considered small relative to the conservativeness of the risk assessment analysis. It is therefore concluded that the remedial alternatives do not have the potential to significantly affect human health under an industrial land use scenario (with the exception of the future excavation alternative).

**Table 21**
**Site-Specific Data for the MWL RBCA Risk Model**

| Data Needed | Value | Comment/Rationale |
|---|---|---|
| Average soil temperature | 65°F | |
| Depth below grade to top of contamination | 3 to 8 ft | Based on depth to max hits that are the risk drivers and most conservative depth to use. |
| Depth below grade to bottom of contamination | 30 ft | Assumed depth to the bottom of the trench. |
| Depth to Groundwater | 470 ft | Based on measurements from onsite monitor wells. |
| SCS Soil Type or User Defined Soil Vapor Permeability | SM/SC<br>3 to 50 darcies (small scale)<br>50 to 300 darcies (large scale) | Soil type from recent Standard Proctor results and detailed MWL geologic characterization of the local soils.<br>Soil Vapor Permeability data from Phelan Report, September 1993. |
| **Assume soil parameters are equal for all Stratums—backfill and cover material is native material from local area.** | | |
| Soil dry bulk density | 122 pcf or<br>1.95 g/cm$^3$ | From recent Standard Proctor results for the replaceable soils and CAMU spoil pile. Typical as per MWL Research Team. |
| Soil total porosity | 33% | MWL Research Team and supported by 1994 Sitewide Report. |
| Soil water-filled porosity | 6–12% by volume<br>4–7% by weight | Assume this means moisture content. MWL Phase II RFI September 1996. |
| Soil organic carbon fraction | 0.038%<br>539 mg/kg | 0.038% from MWL Phase II RFI September 1996. 539 mg/kg is mean of 27 measurements from 1994 Sitewide Report. |

CAMU = Corrective Action Management Unit.
°F = Degree(s) Fahrenheit.
ft = Foot (feet).
g/cm$^3$ = Gram(s) per cubic centimeter.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
pcf = Pound(s) per cubic foot.
RBCA = Risk-Based Corrective Action.
RCRA = Resource Conservation and Recovery Act.
RFI = RCRA Facility Investigation.
SC = Clayey sands, sand-clay mixtures.
SCS = Soil Classification System.
SM = Silty sands, sand-silt mixtures.
% = Percent.

**Table 22**
**Results of the Bounding Risk Analysis for the MWL**

| COC | Maximum Concentration (mg/kg) | Ingestion of Groundwater | | Inhalation of VOCs | | Resulting Subsurface Soil Concentration (mg/kg) | |
|---|---|---|---|---|---|---|---|
| | | HI | Cancer Risk | HI | Cancer Risk | Ingestion of Groundwater | Inhalation of VOCs |
| Acetone | 2.3E-1 | <1E-15 | NA | 1.7E-4 | NA | >1E+06 | 1.3E+3 |
| Benzoic acid | 6.8E-2 | <1E-15 | NA | 5.9E-9 | NA | >1E+06 | >1E+06 |
| Di-n-butyl phthalate | 1.6E-1 | <1E-15 | NA | 3.6E-10 | NA | >1E+06 | >1E+06 |
| Di-n-octyl phthalate | 1.3E-1 | <1E-15 | NA | 1.5E-9 | NA | >1E+06 | >1E+06 |
| 2-hexanone | 8.9E-3 | <1E-15 | NA | NA | NA | >1E+06 | NA |
| Methyl ethyl ketone | 2.2E-2 | <1E-15 | NA | 6.3E-6 | NA | >1E+06 | 3.6E+3 |
| 4-Methyl-2-pentanone | 7.6E-3 | <1E-15 | NA | 3.1E-5 | NA | >1E+06 | 2.5E+2 |
| Methylene chloride | 3.8E+0 | 1.8E-8 | <1E-15 | 3.6E-4 | 1.8E-7 | >1E+06 | 2.2E+2 |
| Nitrosodimethylamine, n- | 7.4E-2 | NA | <1E-15 | NA | 4.3E-10 | >1E+06 | 1.7E+3 |
| Phenol | 4.6E-1 | <1E-15 | NA | 7.0E-7 | NA | >1E+06 | 6.5E+5 |
| Pyrene | 1.1E+0 | <1E-15 | NA | 3.5E-8 | NA | >1E+06 | >1E+06 |
| Tetrachloroethene | 5.4E-3 | 3.8E-7 | 7.0E-11 | 4.4E-5 | 3.2E-10 | 7.0E+03 | 1.7E+2 |
| Toluene | 2.0E-2 | <1E-15 | NA | 1.4E-5 | NA | >1E+06 | 1.4E+3 |
| Trichloroethene | 1.0E-3 | 6.7E-6 | 1.6E-10 | 1.3E-5 | 1.7E-10 | 6.1E+01 | 5.8E+1 |
| Xylene (mixed isomers) | 1.8E-2 | 7.3E-11 | NA | 7.2E-6 | NA | >1E+06 | 2.5E+3 |

COC = Constituent of concern.
HI = Hazard index.
mg/kg = Milligram(s) per kilogram.
MWL = Mixed Waste Landfill.
NA = Not applicable.
VOC = Volatile organic compound.

# VII. Ecological Risk Assessment

## VII.1 Introduction

This section addresses the ecological risks associated with exposure to constituents of potential ecological concern (COPEC) in soil at the MWL. A component of the NMED Risk-Based Decision Tree (NMED March 1998) is to conduct an ecological screening assessment that corresponds with that presented in EPA's "Ecological Risk Assessment Guidance for Superfund" (EPA 1997d). The current methodology is tiered and contains an initial scoping assessment followed by a more detailed screening assessment. Initial components of NMED's decision tree (a discussion of DQOs, data assessment, and evaluations of bioaccumulation and fate and transport potential) are addressed in Sections II through V of this report. Following the completion of the scoping assessment, a determination is made as to whether a more detailed examination of potential ecological risk is necessary. If such an examination is deemed necessary, the scoping assessment proceeds to a screening assessment, whereby a more quantitative estimate of ecological risk is conducted. Although this assessment incorporates conservatism in the estimation of ecological risks, ecological relevance and professional judgment are also used as recommended by the EPA (EPA 1998b) to ensure that predicted exposures of selected ecological receptors reflect those reasonably expected to occur at the site.

## VII.2 Scoping Assessment

The scoping assessment focuses primarily on the likelihood of exposure of biota at or adjacent to the site to constituents associated with site activities. Included in this section are an evaluation of existing data and a comparison of maximum concentrations detected to background concentrations, evaluation of bioaccumulation potential, and fate and transport potential. A Scoping Risk-Management Decision is included summarizing the scoping results and determining whether further examination of potential ecological impacts is necessary.

### VII.2.1 Data Assessment

As indicated in Section IV (Tables 5 and 6), inorganic constituents in soil at the MWL and the ISS that either exceeded background concentrations or did not have quantified background screening levels were as follows:

- Barium
- Cadmium
- Mercury
- Selenium
- Silver
- Tritium
- Pu-238
- Pu-239
- U-238

Organic analytes that were detected in soil include the following:

- Acetone
- Bis(2-ethylhexyl) phthalate
- Di-n-butyl phthalate
- Di-n-octyl phthalate
- Methylene chloride
- Toluene

### VII.2.2 Bioaccumulation

Among the COPECs listed in Section VII.2.1, the following were considered to have bioaccumulation potential in aquatic environments (Section IV, Tables 5 and 6):

- Barium
- Bis(2-ethylhexyl) phthalate
- Cadmium
- Di-n-butyl phthalate
- Di-n-octyl phthalate
- Mercury
- Selenium
- U-238

It should be noted, however, that as directed by the NMED, bioaccumulation for inorganic constituents is assessed exclusively based upon maximum reported bioconcentration factors (BCFs) for aquatic species (NMED March 1998). Because only aquatic BCFs are used to evaluate the bioaccumulation potential for metals, bioaccumulation in terrestrial species is likely to be overpredicted.

### VII.2.3 Fate and Transport Potential

Section V discusses the potential for the COPECs to migrate from the source of contamination to other media or biota. As noted in Table 12 (Section V), surface-water runoff and food chain uptake are expected to be of low significance as transport mechanisms for COPECs at this site. Because of the depth to groundwater, migration to groundwater is also of low significance. Because of the flat, open terrain and sparse vegetation on the site, the potential for transport of COPECs in the surface soil by wind may be of moderate significance. Degradation/ transformation of COPECs in the soil is expected to be of low significance. The decay of radionuclides is also expected to be of low significance.

### VII.2.4 Scoping Risk-Management Decision

Based upon information gathered through the scoping assessment, it was concluded that complete ecological pathways may be associated with this site and that COPECs also exist at the site. As a consequence, a risk assessment was deemed necessary to predict the potential level of ecological risk associated with the site.

## VII.3 Assessment

As concluded in Section VII.2.4, both complete ecological pathways and COPECs are associated with this site. The risk assessment performed for the site involves a quantitative estimate of current ecological risks using exposure models in association with exposure parameters and toxicity information obtained from the literature. The estimation of potential ecological risks is conservative to ensure that ecological risks are not underpredicted.

Components within the risk assessment include the following:

- Problem Formulation—sets the stage for the evaluation of potential exposure and risk
- Exposure Estimation—provides a quantitative estimate of potential exposure
- Ecological Effects Evaluation—presents benchmarks used to gauge the toxicity of COPECs to specific receptors
- Risk Characterization—characterizes the ecological risk associated with exposure of the receptors to environmental media at the site
- Uncertainty Assessment—discusses uncertainties associated with the estimation of exposure and risk
- Risk Interpretation—evaluates ecological risk in terms of HQs and ecological significance
- Screening Assessment Scientific/Management Decision Point—presents the decision to risk managers based upon the results of the screening assessment

### VII.3.1 Problem Formulation

Problem formulation is the initial stage of the screening assessment that provides the introduction to the risk evaluation process. Components that are addressed in this section include a discussion of ecological pathways and the ecological setting, identification of COPECs, and selection of ecological receptors. The conceptual model, ecological food webs, and ecological endpoints (other components commonly addressed in a screening assessment) are presented in the “Predictive Ecological Risk Assessment Methodology, Environmental Restoration Program, Sandia National Laboratories, New Mexico” (IT July 1998) and are not duplicated here.

### *VII.3.1.1 Ecological Pathways and Setting*

The MWL is located in grassland habitat in the north-central part of TA-3. However, the habitat at this site has been disturbed by excavation and waste burial activities during site operations. The grassland habitat is undergoing restoration through natural succession, and the vegetation is dominated by ruderal and early successional species. Wildlife use of the site is probably limited by the degree of habitat disturbance, although small mammals are known to inhabit the site. No sensitive species are expected to use the site because of the degree of habitat disturbance.

Complete ecological pathways may exist at this site through the exposure of plants and wildlife to COPECs in surface and subsurface soil. Direct uptake of COPECs from soil was assumed to be the major route of exposure for plants, with exposure of plants to wind-blown soil assumed to be minor. Exposure modeling for the wildlife receptors was limited to the food and soil ingestion pathways. Because of the lack of surface water at this site, exposure to COPECs through the ingestion of surface water was considered insignificant. Inhalation and dermal contact were also considered insignificant pathways with respect to ingestion (Sample and Suter 1994). Groundwater is not expected to be affected by COCs at this site and therefore is not considered a pathway for ecological receptors.

### *VII.3.1.2 COPECs*

In order to provide conservatism in this ecological risk assessment, the assessment was based upon the maximum soil concentrations of the COPECs measured in surface and subsurface soil samples. The subsurface samples were limited to depths up to 5 feet bgs. Both radiological and nonradiological COPECs were evaluated. The nonradiological COPECs consisted of inorganic analytes (i.e., metals) and organic analytes that were detected in these soil samples. Inorganic analytes and radionuclides were screened against background concentrations, and those that exceeded the approved SNL/NM background screening levels (Dinwiddie September 1997) for the area were considered to be COPECs. All organic analytes detected were considered to be COPECs for the site. Maximum COPEC concentrations and activities in soil are reported in Tables 5 and 6. Nonradiological inorganic constituents that are essential nutrients, such as iron, magnesium, calcium, potassium, and sodium, were not included in this risk assessment as set forth by the EPA (EPA 1989).

### *VII.3.1.3 Ecological Receptors*

As described in detail in “Predictive Ecological Risk Assessment Methodology, Environmental Restoration Program, Sandia National Laboratories, New Mexico” (IT July 1998), a nonspecific perennial plant was selected as the receptor to represent plant species at the site. Vascular plants are the principal primary producers at the site and are key to the diversity and productivity of the wildlife community associate with the site. The deer mouse (*Peromyscus maniculatus*) and burrowing owl (*Speotyto cunicularia*) were used to represent wildlife use. Because of its opportunistic food habits, the deer mouse was used to represent a mammalian herbivore, omnivore, and insectivore. The burrowing owl was selected as the top predator. The burrowing owl is present at SNL/NM and is designated as a species of management concern by the U.S. Fish and Wildlife Service in Region 2, which includes the state of New Mexico (USFWS September 1995).

## VII.3.2 Exposure Estimation

Direct uptake of COPECs from the soil was considered the only significant route of exposure for terrestrial plants. Exposure modeling for the wildlife receptors was limited to food and soil ingestion pathways. Inhalation and dermal contact were considered insignificant pathways with respect to ingestion (Sample and Suter 1994). Drinking water also was considered an insignificant pathway because of the lack of surface water at this site. The deer mouse was modeled under three dietary regimes: as an herbivore (100 percent of its diet as plant material), as an omnivore (50 percent of its diet as plants and 50 percent as soil invertebrates), and as an insectivore (100 percent of its diet as soil invertebrates). The burrowing owl was modeled as a strict predator on small mammals (100 percent of its diet as deer mice). Because the exposure in the burrowing owl from a diet consisting of equal parts of herbivorous, omnivorous, and insectivorous mice would be equivalent to the exposure consisting of only omnivorous mice, the diet of the burrowing owl was modeled with intake of omnivorous mice only. Both species were modeled with soil ingestion comprising 2 percent of the total dietary intake. Table 23 presents the species-specific factors used in modeling exposures in the wildlife receptors. Justification for use of the factors presented in this table is described in the ecological risk assessment methodology document (IT July 1998).

Although home range is also included in this table, exposures for this risk assessment were modeled using an area use factor of 1.0, implying that all food items and soil ingested come from the site being investigated. The maximum COPEC concentrations from soil samples collected within the upper 5 feet of soil were used to determine conservative estimates of potential exposures and risks to plants and wildlife at this site.

For the radiological dose-rate calculations, the deer mouse was modeled as an herbivore (100 percent of its diet as plants), and the burrowing owl was modeled as a strict predator on small mammals (100 percent of its diet as deer mice). Both were modeled with soil ingestion comprising 2 percent of the total dietary intake. Receptors are exposed to radiation from tritium, U-238, Pu-238 and Pu-239. Internal dose rates to the deer mouse and burrowing owl are approximated using modified dose-rate models from the “Hanford Site Risk Assessment Methodology” (DOE 1995) as presented in the ecological risk assessment methodology document for the SNL/NM ER Program (IT July 1998). Radionuclide-dependent data for the dose-rate calculations were obtained from Baker and Soldat (1992). The internal total-body dose-rate model assumes that a fraction of the radionuclide concentration ingested by a receptor is absorbed by the body and concentrated at the center of a spherical body shape. This provides for a conservative estimate for absorbed dose. This concentrated radiation source at the center of the body of the receptor is assumed to be a “point” source. Radiation emitted from this point source is absorbed by the body tissues to contribute to the absorbed dose.

Table 24 presents the transfer factors used in modeling the concentrations of COPECs through the food chain. Table 25 presents maximum concentrations in soil and derived concentrations in tissues of the various food chain elements that are used to model dietary exposures for each of the wildlife receptors.

**Table 23**
**Exposure Factors for Ecological Receptors at the MWL**

| Receptor Species | Class/Order | Trophic Level | Body Weight[a] (kg) | Food Intake Rate[b] (kg/day) | Dietary Composition[c] | Home Range (acres) |
|---|---|---|---|---|---|---|
| Deer Mouse (*Peromyscus maniculatus*) | Mammalia/ Rodentia | Herbivore | 2.39E-2[d] | 3.72E-3 | Plants: 100% (+ Soil at 2% of intake) | 2.7E-1[e] |
| Deer Mouse (*Peromyscus maniculatus*) | Mammalia/ Rodentia | Omnivore | 2.39E-2[d] | 3.72E-3 | Plants: 50% Invertebrates: 50% (+ Soil at 2% of intake) | 2.7E-1[e] |
| Deer Mouse (*Peromyscus maniculatus*) | Mammalia/ Rodentia | Insectivore | 2.39E-2[d] | 3.72E-3 | Invertebrates: 100% (+ Soil at 2% of intake) | 2.7E-1[e] |
| Burrowing owl (*Speotyto cunicularia*) | Aves/ Strigiformes | Carnivore | 1.55E-1[f] | 1.73E-2 | Rodents: 100% (+ Soil at 2% of intake) | 3.5E+1[g] |

[a]Body weights are in kg wet weight.
[b]Food intake rates are estimated from the allometric equations presented in Nagy (1987). Units are kg dry weight/day.
[c]Dietary compositions are generalized for modeling purposes. Default soil intake value of 2% of food intake.
[d]From Silva and Downing (1995).
[e]From EPA (1993), based upon the average home range measured in semi-arid shrubland in Idaho.
[f]From Dunning (1993).
[g]From Haug et al. (1993).
EPA = U.S. Environmental Protection Agency.
kg = Kilogram(s).
MWL = Mixed Waste Landfill.

**Table 24**
**Transfer Factors Used in Exposure Models for COPECs at the MWL**

| Constituent of Potential Ecological Concern | Soil-to-Plant Transfer Factor | Soil-to-Invertebrate Transfer Factor | Food-to-Muscle Transfer Factor |
|---|---|---|---|
| **Inorganic** | | | |
| Barium | 1.5E-1[a] | 1.0E+0[b] | 2.0E-4[c] |
| Cadmium | 5.5E-1[a] | 6.0E-1[d] | 5.5E-4[a] |
| Mercury | 1.0E+0[c] | 1.0E+0[b] | 2.5E-1[a] |
| Selenium | 5.0E-1[c] | 1.0E+0[b] | 1.0E-1[c] |
| Silver | 1.0E+0[c] | 2.5E-1[d] | 5.0E-3[c] |
| **Organic**[e] | | | |
| Acetone | 5.3E+1 | 1.3E+1 | 1.0E-8 |
| Methylene chloride | 7.3E+0 | 1.5E+1 | 3.6E-7 |
| Toluene | 1.0E+0 | 1.8E+1 | 1.3E-5 |
| Bis(2-ethylhexyl) phthalate | 1.6E-3 | 3.2E+1 | 1.3E+0 |
| Di-n-butyl phthalate | 8.4E-2 | 2.2E+1 | 1.1E-3 |
| Di-n-octyl phthalate | 3.7E-2 | 2.4E+1 | 4.5E-3 |

[a]From Baes et al. (1984).
[b]Default value.
[c]From NCRP (January 1989).
[d]From Stafford et al. (1991).
[e]Soil-to-plant and food-to-muscle transfer factors from equations developed in Travis and Arms (1988). Soil-to-invertebrate transfer factors from equations developed in Connell and Markwell (1990). All three equations based upon relationship of the transfer factor to the Log $K_{ow}$ value of compound.
COPEC = Constituents of potential ecological concern.
$K_{ow}$ = Octanol-water partition coefficient.
Log = Logarithm (base 10).
MWL = Mixed Waste Landfill.
NCRP = National Council on Radiation Protection and Measurements.

**Table 25**
**Media Concentrations[a] for COPECs at the MWL**

| Constituent of Potential Ecological Concern | Soil (maximum) | Plant Foliage[b] | Soil Invertebrate[b] | Deer Mouse Tissues[c] |
|---|---|---|---|---|
| **Inorganic** | | | | |
| Barium | 1.7E+2 | 2.5E+1 | 1.7E+2 | 6.3E-2 |
| Cadmium | 3.7E-1[d] | 2.0E-1 | 2.2E-1 | 3.8E-4 |
| Mercury | 5.0E-2[e] | 5.0E-2 | 5.0E-2 | 4.0E-2 |
| Selenium | 5.7E-1 | 2.8E-1 | 5.7E-1 | 1.4E-1 |
| Silver | 9.6E-1[d] | 9.6E-1 | 2.4E-1 | 9.7E-3 |
| **Organic** | | | | |
| Acetone | 1.8E-1 | 9.6E+0 | 2.3E+0 | 1.9E-7 |
| Methylene chloride | 1.0E-2 | 7.3E-2 | 1.5E-1 | 1.3E-7 |
| Toluene | 2.0E-3[d] | 2.0E-3 | 3.6E-2 | 7.6E-7 |
| Bis(2-ethylhexyl) phthalate | 7.3E-2[d] | 1.1E-4 | 2.3E+0 | 4.7E+0 |
| Di-n-butyl phthalate | 1.6E-1[d] | 1.3E-2 | 3.6E+0 | 6.0E-3 |
| Di-n-octyl phthalate | 7.4E-2[d] | 2.8E-3 | 1.8E+0 | 1.3E-2 |

[a]In milligrams per kilogram. All are based upon dry weight of the media.
[b]Product of the soil concentration and the corresponding transfer factor.
[c]Based upon the deer mouse with an omnivorous diet. Product of the average concentration in food times the food-to-muscle transfer factor times the wet weight-dry weight conversion factor of 3.125 (EPA 1993).
[d]Estimated value
[e]Parameter was nondetect. Concentration is one half of the detection limit.
COPEC = Constituents of potential ecological concern.
EPA = U.S. Environmental Protection Agency.
MWL = Mixed Waste Landfill.

### VII.3.3 Ecological Effects Evaluation

Benchmark toxicity values for the plant and wildlife receptors are presented in Table 26. For plants, the benchmark soil concentrations are based upon the lowest-observed-adverse-effect level (LOAEL). For wildlife, the toxicity benchmarks are based upon the no-observed-adverse-effect level (NOAEL) for chronic oral exposure in a taxonomically similar test species. Sufficient toxicity information was not available to estimate the LOAELs or NOAELs for some COPECs for terrestrial plant life and wildlife receptors, respectively.

The benchmark used for exposure of terrestrial receptors to radiation was 0.1 rad/day. This value has been recommended by the International Atomic Energy Agency (IAEA 1992) for the protection of terrestrial populations. Because plants and insects are less sensitive to radiation than vertebrates (Whicker and Schultz 1982), the dose of 0.1 rad/day should also protect other groups within the terrestrial habitat of the MWL.

**Table 26**
**Toxicity Benchmarks for Ecological Receptors at the MWL**

| Constituent of Potential Ecological Concern | Plant Benchmark[a,b] | Mammalian NOAELs | | | Avian NOAELs | | |
|---|---|---|---|---|---|---|---|
| | | Mammalian Test Species[c,d] | Test Species NOAEL[d,e] | Deer Mouse NOAEL[e,f] | Avian Test Species[d] | Test Species NOAEL[d,e] | Burrowing Owl NOAEL[e,g] |
| **Inorganic** | | | | | | | |
| Barium | 500 | Rat[h] | 5.1 | 10.5 | Chicken | 20.8 | 20.8 |
| Cadmium | 3 | Rat[i] | 1.0 | 1.9 | Mallard | 1.45 | 1.45 |
| Mercury (inorganic) | 0.3 | Mouse | 13.2 | 14.0 | Japanese quail | 0.45 | 0.45 |
| Mercury (organic) | 0.3 | Rat | 0.032 | 0.063 | Mallard | 0.0064 | 0.0064 |
| Selenium | 1 | Rat | 0.20 | 0.39 | Screech owl | 0.44 | 0.44 |
| Silver | 2 | Rat | 17.8[j] | 34.8 | – | – | – |
| **Organic** | | | | | | | |
| Acetone | – | Rat | 10.0 | 19.6 | – | – | – |
| Methylene chloride | – | Rat | 5.85 | 11.4 | – | – | – |
| Toluene | 200 | Mouse | 26 | 27.5 | – | – | – |
| Bis(2-ethylhexyl) phthalate | – | Mouse | 18.3 | 19.4 | Ringed dove | 1.1 | 1.1 |
| Di-n-butyl phthalate | 200 | Mouse | 550 | 582 | Ringed dove | 0.11 | 0.11 |
| Di-n-octyl phthalate | – | Mouse | 79.4[k] | 84.0 | – | – | – |

[a]In milligram(s) per kilogram soil.
[b]From Efroymson et al. (1997).
[c]Body weights (in kilograms) for the NOAEL conversion are as follows: lab mouse, 0.030; lab rat, 0.350 (except where noted).
[d]From Sample et al. (1996), except where noted.
[e]In milligram(s) per kilogram body weight per day.
[f]Based upon NOAEL conversion methodology presented in Sample et al. (1996), using a deer mouse body weight of 0.0239 kilogram and a mammalian scaling factor of 0.25.
[g]Based upon NOAEL conversion methodology presented in Sample et al. (1996). The avian scaling factor of 0.0 was used, making the NOAEL independent of body weight.
[h]Body weight: 0.435 kilogram.
[i]Body weight: 0.303 kilogram.
[j]Based upon a rat LOAEL of 89 milligrams per kilogram per day (EPA 1998a) and an uncertainty factor of 0.2.
[k]Based upon a mouse NOAEL for bis(2-ethylhexyl) phthalate and the ratio of $LD_{50}$ values for bis(2-ethylhexyl) phthalate and di-n-octyl phthalate (Micromedex 1998).

$LD_{50}$ = Acute lethal dose to 50 percent of the test population.
LOAEL = Lowest-observed-adverse-effect level.
MWL = Mixed Waste Landfill.
NOAEL = No-observed-adverse-effect level.
– = Insufficient toxicity data available for risk estimation purposes.

## VII.3.4 Risk Characterization

The following sections provide the risk characterization for the remedial alternatives.

### *VII.3.4.1 MWL NFA Risk Baseline Analysis plus MWL Alternative I.a—NFA with ICs*

Maximum concentrations in soil and estimated dietary exposures were compared to plant and wildlife benchmark values, respectively. Results of these comparisons are presented in Table 27. HQs are used to quantify the comparison with benchmarks for plants and wildlife exposure.

No analytes resulted in HQs exceeding unity for plants, the herbivorous deer mouse, or the burrowing owl. Barium was the only analyte that exhibited HQs greater than unity for the omnivorous and insectivorous deer mouse. HQs for plants could not be determined for acetone, methylene chloride, bis(2-ethylhexyl) phthalate, and di-n-octyl phthalate because of insufficient toxicity information. For the same reason, HQs for the burrowing owl could not be determined for silver, acetone, methylene chloride, toluene, and di-n-octyl phthalate. As directed by the NMED, HIs were calculated for each of the receptors (the HI is the sum of chemical-specific HQs for all pathways for a given receptor). All receptors, except the herbivorous deer mouse, had total HIs greater than unity, with a maximum HI of 2.9E+0 for the insectivorous deer mouse.

Tables 28 and 29 summarize the dose-rate model results for exposure to the radionuclides tritium, Pu-238, Pu-239, and U-238. The total radiation dose rate to the deer mouse was predicted to be 1.6E-3 rad/day and that for the burrowing owl was also predicted to be 1.6E-3 rad/day. The dose rates for the deer mouse and the burrowing owl are considerably less than the benchmark of 0.1 rad/day.

### *VII.3.4.2 MWL Alternatives III.b and III.c—Operational and Vegetative Soil Cover Designs*

The ecological risk assessment process has limited the potential depth of exposure to 5 feet bgs. With the addition of remedial cover for the various alternatives, the depth of COCs in the soil will be greater than 5 feet bgs. Therefore, ecological risk is not evaluated for these alternatives. The NFA alternative summarizes both the current conditions at the site and potential risk during the implementation of the remedial alternatives.

### *VII.3.4.3 MWL Alternative V.e—Future Excavation*

Section VII.3.4.1 summarizes the estimated risk under the future excavation alternative. The risks are the same due to the assumption that maximum concentrations are presented and evaluated for risk in Section VII.3.4.1.

## VII.3.5 Uncertainty Assessment

Many uncertainties are associated with the characterization of ecological risks at the MWL for the NFA alternatives. These uncertainties result from assumptions used in calculating risk that

**Table 27**
**HQs for Ecological Receptors at the MWL**

| Constituent of Potential Ecological Concern | Plant HQ | Deer Mouse HQ (Herbivorous) | Deer Mouse HQ (Omnivorous) | Deer Mouse HQ (Insectivorous) | Burrowing Owl HQ |
|---|---|---|---|---|---|
| **Inorganic** | | | | | |
| Barium | 3.4E-1 | 4.2E-1 | **1.5E+0** | **2.5E+0** | 1.8E-2 |
| Cadmium | 1.2E-1 | 1.7E-2 | 1.8E-2 | 1.9E-2 | 6.0E-4 |
| Mercury (inorganic) | 1.7E-1 | 5.7E-4 | 5.7E-4 | 5.7E-4 | 1.0E-2 |
| Mercury (organic) | 1.7E-1 | 1.3E-1 | 1.3E-1 | 1.3E-1 | 7.1E-1 |
| Selenium | 5.7E-1 | 1.2E-1 | 1.7E-1 | 2.3E-1 | 3.7E-2 |
| Silver | 4.8E-1 | 4.4E-3 | 2.8E-3 | 1.2E-3 | – |
| **Organic** | | | | | |
| Acetone | – | 7.6E-2 | 4.7E-2 | 1.8E-2 | – |
| Methylene chloride | – | 1.0E-3 | 1.5E-3 | 2.1E-3 | – |
| Toluene | 1.0E-5 | 1.1E-5 | 1.1E-4 | 2.0E-4 | – |
| Bis(2-ethylhexyl) phthalate | – | 1.3E-5 | 9.3E-3 | 1.9E-2 | 4.8E-1 |
| Di-n-butyl phthalate | 8.0E-4 | 4.4E-6 | 4.8E-4 | 9.6E-4 | 9.3E-3 |
| Di-n-octyl phthalate | – | 7.8E-6 | 1.6E-3 | 3.3E-3 | – |
| HI[a] | **1.7E+0** | 7.7E-1 | **1.9E+0** | **2.9E+0** | **1.3E+0** |

Note: **Bold** values indicate the HQ or HI exceeds unity.
[a]The HI is the sum of individual HQs using the value for organic mercury as a conservative estimate of the HI.
HI = Hazard index.
HQ = Hazard quotient.
MWL = Mixed Waste Landfill.
– = Insufficient toxicity data available for risk estimation purposes.

**Table 28**
**Internal and External Dose Rates for**
**Deer Mice Exposed to Radionuclides at the MWL and the ISS**

| Radionuclide | Maximum Concentration (pCi/g) | Internal Dose (rad/day) | External Dose (rad/day) | Total Dose (rad/day) |
|---|---|---|---|---|
| Tritium | 1.1E+3 | 1.2E-3 | NA[a] | 1.2E-3 |
| Pu-238 | 0.103 | 2.1E-7 | 1.3E-8 | 2.2E-7 |
| Pu-239 | 0.0107 | 2.05E-8 | 5.3E-10 | 2.1E-8 |
| U-238 | 2.41 | 2.0E-5 | 3.7E-4 | 3.9E-4 |
| **Total** | | | | **1.6E-3** |

[a]NA: External dose from tritium assumed to be insignificant.
ISS = Interim Storage Site.
MWL = Mixed Waste Landfill.
NA = Not applicable.
pCi/g = Picocurie(s) per gram.

**Table 29**
**Internal and External Dose Rates for**
**Burrowing Owls Exposed to Radionuclides at the MWL and the ISS**

| Radionuclide | Maximum Concentration (pCi/g) | Internal Dose (rad/day) | External Dose (rad/day) | Total Dose (rad/day) |
|---|---|---|---|---|
| Tritium | 1.1E+3 | 1.2E-3 | NA[a] | 1.2E-3 |
| Pu-238 | 0.103 | 2.1E-7 | 1.3E-8 | 2.2E-7 |
| Pu-239 | 0.0107 | 2.05E-8 | 5.3E-10 | 2.1E-8 |
| U-238 | 2.41 | 1.0E-5 | 3.7E-4 | 3.8E-4 |
| **Total** | | | | **1.6E-3** |

[a]NA: External dose from tritium assumed to be insignificant.
ISS = Interim Storage Site.
MWL = Mixed Waste Landfill.
NA = Not applicable.
pCi/g = Picocurie(s) per gram.

may overestimate or underestimate true risk presented at a site. For this risk assessment, assumptions are made that are more likely to overestimate exposures and risk rather than to underestimate them. These conservative assumptions are used to be more protective of the ecological resources potentially affected by the site. Conservatisms incorporated into this risk assessment include the use of maximum analyte concentrations measured in soil samples to evaluate risk, the use of wildlife toxicity benchmarks based upon NOAEL values, the incorporation of strict herbivorous and strict insectivorous diets for predicting the extreme HQ values for the deer mouse, and the use of 1.0 as the area use factor for wildlife receptors regardless of seasonal use or home range size. Each of these uncertainties, which are consistent among each of the Solid Waste Management Unit-specific ecological risk assessments, is discussed in greater detail in the uncertainty section of the ecological risk assessment methodology document for the SNL/NM ER Program (IT July 1998).

Uncertainties associated with the estimation of risk to ecological receptors following exposure to tritium, U-238, Pu-238 and Pu-239 are primarily related to those inherent in the radionuclide-specific data. Radionuclide-dependent data are measured values that have their associated errors, which are typically negligible. The dose-rate models used for these calculations are based upon conservative estimates of receptor shape, radiation absorption by body tissues, and intake parameters. The goal is to provide a realistic but conservative estimate of a receptor's exposure to radionuclides in soil, both internally and externally.

In 1997, samples of aboveground plant and small mammal tissues were collected from the MWL and analyzed for inorganic constituents and radionuclides. Although the detection limits for these analyses were too high for quantitation of concentrations in small mammal tissues, the fact that more than 20 small mammals were captured at this site indicates that it supports a viable small mammal community. In the plant tissue samples, most analytes were also below the corresponding detection limits. However, of those that were detected (barium, total chromium, copper, and zinc), only barium is identified as a COPEC within this risk assessment. Barium was measured at lower concentrations than predicted by the risk assessment model by a factor of 4. These results indicate that the effect of conservatism in the risk assessment models are significant for this COPEC.

In the estimation of ecological risk, background concentrations are included as a component of maximum on-site concentrations. As shown in Table 30, conservatisms in the modeling of exposure and risk for barium result in the prediction of risk to the omnivorous and insectivorous deer mice when exposed at background concentrations. For this COPEC, more than 77 percent of the maximum on-site concentration may be associated with background. Therefore, because of the uncertainties associated with exposure and toxicity, it is unlikely that barium, with exposure concentrations largely attributable to background, presents significant ecological risk to either the omnivorous and insectivorous deer mouse.

To assess the potential degree of overestimation caused by the use of the maximum measured soil concentrations in the exposure assessment, average soil concentrations (using full detection limits for nondetections and the maximum value for duplicate samples) were applied. For barium, the 95th upper confidence limit (125 mg/kg) was less than the background value of 130 mg/kg. Thus, for barium, the use of mean soil concentrations reduces the HQs to values less than the HQs derived from background concentrations.

Based upon this uncertainty analysis, ecological risks are very low. HQs greater than unity were initially predicted for barium; however, closer examination of the exposure assumptions

**Table 30**
**HQs for Ecological Receptors Exposed to Background Concentrations at the MWL**

| Constituent of Potential Ecological Concern | Plant HQ | Deer Mouse HQ (Herbivorous) | Deer Mouse HQ (Omnivorous) | Deer Mouse HQ (Insectivorous) | Burrowing Owl HQ |
|---|---|---|---|---|---|
| **Inorganic** | | | | | |
| Barium | 2.6E-1 | 3.3E-1 | **1.1E+0** | **2.0E+0** | 1.4E-2 |
| Cadmium | 1.7E-1 | 2.4E-2 | 2.5E-2 | 2.6E-2 | 8.1E-4 |
| Mercury (inorganic) | 1.7E-1 | 5.7E-4 | 5.7E-4 | 5.7E-4 | 1.0E-2 |
| Mercury (organic) | 1.7E-1 | 1.3E-1 | 1.3E-1 | 1.3E-1 | 7.1E-1 |
| Selenium | 5.0E-1 | 1.0E-1 | 1.5E-1 | 2.0E-1 | 3.3E-2 |
| Silver | 2.5E-1 | 2.3E-3 | 1.4E-3 | 6.0E-4 | – |
| HI[a] | **1.4E+0** | 5.8E-1 | **1.4E+0** | **2.3E+0** | 7.6E-1 |

Note: **Bold** text indicates the HQ or HI exceeds unity.
[a]The HI is the sum of individual HQs using the value for organic mercury as a conservative estimate of the HI.
HI = Hazard index.
HQ = Hazard quotient.
MWL = Mixed Waste Landfill.
– = Insufficient toxicity data available for risk estimation purposes.

revealed an overestimation of risk primarily attributed to exposure concentration and background risk.

### VII.3.6 Risk Interpretation for NFA Risk Baseline Analysis and NFA Alternative with ICs (MWL Alternative I.a)

Ecological risks associated with the MWL were estimated through a screening assessment that incorporated site-specific information when available. Overall, risks to ecological receptors are expected to be very low because predicted risks are based upon exposures to COPECs calculated from the maximum COPEC concentrations measured in soil samples. Predicted risks from exposure to barium were attributed to using these maximum detected values and conservatisms in the risk models. Mean barium concentrations were less than the background screening level. Because the background screening level for barium resulted in a maximum HQ of 2.0, risk from barium is unlikely to be significant. This conclusion is supported by field data indicating the presence of viable populations of small mammals on the site. Based upon this final analysis, ecological risks are very low.

### VII.3.7 Risk Interpretation for Future Excavation Alternative (MWL Alternative V.e)

Section VII.3.6 presents the risk interpretation for the future excavation scenario. The risk interpretation is consistent as for the NFA with and without ICs due to the assumption that risk interpretation from site maximum concentrations are presented and evaluated in Section VII.3.6.

## VIII. Transportation and Remediation Injuries and Fatalities

The following sections assess the potential injuries and fatalities that may occur during implementation of the remedial alternatives being evaluated for the MWL.

### VIII.1 Methodology and Scenarios for Transportation Injuries and Fatalities

To evaluate risk, three components must be defined: scenarios, likelihood, and consequence. Scenarios consist of one basic failure event followed by subsequent failures that lead to some undesirable outcome. Likelihood describes how often the scenario is expected to occur and may be expressed as a probability, which is an expression of the belief that something will or will not occur. Probability is a unitless number between zero and one. Likelihood may also be expressed as a frequency (e.g., accidents per mile). The final component of risk is consequence, the undesired results of the scenario. To evaluate consequences, the source term (what is released, how much, and what form it takes) must be defined, and, for release scenarios, dispersion of the source term must be predicted. However, for this evaluation only the direct impact of potential transportation accidents will be evaluated (i.e., injuries and fatalities). Chemical or radionuclide exposure and risk are not quantified. Only vehicle-related consequences that include traffic injuries and fatalities are quantified.

The input parameters used in the risk assessment can be broadly divided into three categories:

- Cargo-specific parameters—These parameters include the characteristics of the cargo (e.g., the number of shipments), and the radionuclides and chemicals in the soil (not quantified).

- Route-specific parameters—These parameters include traffic and population characteristics for the transport route (e.g., accident rate, injury and fatality rates, vehicle count rate, length of the route, and population density). National average rates will be used to evaluate injury and fatality rates.

- Scenario-specific parameters—These parameters include a number of variables that are generally independent of the cargo transported and the route taken (e.g., the number of people in vehicles, the average speed of vehicles, etc.).

### VIII.1.1 CMS Transportation Alternatives

Six CMs have been evaluated in the transportation risk analysis. These include:

- MWL Risk Baseline—NFA with No ICs
- MWL Alternative I.a—NFA with ICs
- MWL Alternative III.a—Bio-Intrusion Barrier
- MWL Alternative III.b—Vegetative Soil Cover
- MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier
- MWL Alternative V.e—Future Excavation

Each scenario includes unique transportation requirements to complete the remedial actions based upon the volume of soil to be imported or removed, and the distance of vehicle travel.

### VIII.1.2 Transportation Risk Assumptions

The following assumptions were also used to calculate the transportation risk:

- The total number of shipments is based upon the volume of soil transported by dump truck (assumed to be 20 cubic yards). The number of dump truck loads assumed for each alternative is summarized below:

  - MWL Risk Baseline—NFA with No ICs: No on-site activities

  - MWL Alternative 1.a—NFA with ICs: 305 loads of sub-grade soil from the borrow pit west of the Corrective Action Management Unit (CAMU)

  - MWL Alternative III.b—Vegetative Soil Cover: 800 loads of sub-grade soil from the borrow pit west of the CAMU, and 110 loads of top soil from borrow pit west of the MWL

  - MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier: 800 loads of sub-grade soil from the borrow pit west of the CAMU, 110 loads of top soil from borrow pit west of the MWL, and 440 loads of cobble from the off-site east mountain gravel pit

  - MWL Alternative V.e—Future Excavation: 1,175 loads of excavated waste moved to on-site waste processing facility, 5,900 loads of re-deposited soil to be compacted (1,300 loads from off site)

- The total distance used to calculate injuries and fatalities due to traffic accidents is based upon a roundtrip. The total distance traveled for each location is summarized below:

  - Sub-grade soil from the borrow pit west of the CAMU—4 miles roundtrip

  - Top soil from borrow pit west of the MWL—0.5 miles roundtrip

  - Cobble from the off-site east mountain gravel pit—30 miles roundtrip

  - Excavated waste shipped off site (Nevada Test Site)—1,650 miles roundtrip

  - Risk of accident injury per vehicle 100 million vehicle miles traveled is 15 (national average for large trucks [DOT 2002])

  - Risk of accident fatality per vehicle 100 million vehicle miles traveled is 0.4 (national average for large trucks [DOT 2002])

### VIII.1.3 Methodology for Remediation Injuries and Fatalities

Evaluation of human health risk as a result of remediation activities is very similar in concept to the determination of risk for transportation activities. The three components described in the transportation methodology (i.e., scenarios, likelihood, and consequence) must be defined with respect to the activities performed, and the risk is a product of probability and consequence.

Nonchemical-related worker risk can be determined from accident statistics related to specific industries from the U.S. Department of Labor (DOL) and other sources. For the activities that would be performed at the MWL, the DOL industrial labor classification of construction was used to estimate the injury and fatality rates per man-hour. From the classification and unit risk information gained from DOL statistics (DOL 2002), risk models were constructed using the assumption that there is a linear relationship between total effort in man-hours and risk.

### VIII.1.4 Remediation Risk Assumptions

System definition includes the determination of factors that characterize the working environment. The following assumptions were used to calculate the remediation risk for both human health injury and fatality to workers:

- Worker exposures to chemicals and radionuclides under normal operating conditions would be controlled under established procedures that require doses to be kept ALARA

- Risk of occupational injury per full-time employee (FTE) of excavation (construction labor classification) is 3.7 x $10^{-2}$ (BLS/DOL 2002)

- Risk of occupational injury per FTE of maintenance (engineer labor classification) is 7.0 x $10^{-3}$ (BLS/DOL 2002)

- Risk of occupational fatality per FTE of excavation (construction labor classification) is 1.78 x $10^{-4}$ (BLS/DOL 2002)

- Worker hour estimates for the remedial options include the following:

  - NFA with no ICs—No addition effort

  - NFA with ICs—900 technician and scientist hours per year for 30 years for surveillance and maintenance

  - Vegetative Cover—900 technician and scientist hours per year for 30 years for surveillance and maintenance, 15 people for 3 months (9,000 hours) assuming 10-hour days for construction operations

  - Vegetative Cover with Bio-Intrusion Barrier—900 technician and scientist hours per year for 30 years for surveillance and maintenance, 15 people for 4 months (12,000 hours) assuming 10-hour days for construction operations

  - Future Excavation—25 people for 24 months (120,000 hours) assuming 10-hour days for construction operations

All excavation and soil handling workers are assumed to don PPE. Therefore, radionuclide and chemical risks are not considered. However, for the excavation scenario, the workers will be exposed to penetrating gamma radiation, and this exposure should be considered as well. Potential individual worker exposure during excavation is discussed in Section VI.6.2.6. The dose to an individual worker is 3.23E+3 with associated risk of 3.7E-2. Multiplying this times the 50 person months project for excavation, this becomes 1.6E+5 mrem (total), with an associated risk of 1.85.

### VIII.1.5 Transportation/Remediation Assessment Results

The results of the analysis are summarized in Table 31. Included in this summary is the predicted number of injuries and fatalities for both potential transportation and remedial activities for each of the alternatives evaluated in the MWL CMS.

## IX. Conclusions

Results of the risk analysis indicate that, regardless of transport method or remedial alternative, transportation and remediation risk to the public and transport crew is the dominant source of risk for the CM alternatives, particularly vehicle-related deaths and injuries. Remediation risk is directly related to the amount of soil to be excavated or used as fill/cover. Due to the fact that

**Table 31**
**Summary of Transportation and Remediation Injuries and Fatalities for the MWL CMS**

| Corrective Measure Alternative | Transportation | | Remediation | |
|---|---|---|---|---|
| | Injuries | Fatalities | Injuries | Fatalities |
| MWL Risk Baseline—NFA with No ICs | No Transportation Risk | | No Remediation Risk | |
| MWL Alternative I.a—NFA with ICs | 1.8E-2 | 4.9E-4 | 9.5E-2 | 2.4E-3 |
| MWL Alternative III.b—Vegetative Soil Cover | 4.9E-2 | 1.3E-3 | 2.6E-1 | 3.2E-3 |
| MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier | 2.5E-1 | 6.6E-3 | 3.2E-1 | 3.5E-3 |
| MWL Alternative V.e—Future Excavation | 8.8E-1 | 2.3E-1 | 2.2E+0 | 1.1E-2 |

CMS = Corrective Measures Study.
IC = Institutional Control.
NFA = No Further Action.
MWL = Mixed Waste Landfill.

the remediation/transportation risk is the major component of risk determined by this analysis, cost and regulatory considerations, rather than risk associated with receptors' exposure to contamination, should be the deciding factors for the selection of CMS alternatives. In summary, the injuries and fatalities due to transportation and remediation far exceed the risks of chemical or radionuclide exposure during excavation of the MWL (Table 32).

**Table 32**
**Summary of the MWL CMS Alternatives Risk Results**

| Alternatives | Human Health (IND) | | Ecological | | Transportation and Remediation Total Predicted Injuries and Fatalities | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Transportation | | Remediation | |
| | Non-Radiological | Radiological | Non-Radiological | Radiological (rad/day) | Injuries | Fatalities | Injuries | Fatalities |
| MWL Risk Baseline—NFA with No ICs | HI = 0.07<br>CR = 3E-6 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | No Transportation Risk | | No Remediation Risk | |
| MWL Alternative I.a—NFA with ICs | HI = 0.00<br>CR = 1E-9 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | 0.018 | 0.00049 | 0.095 | 0.0024 |
| MWL Alternative III.b—Vegetative Soil Cover | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.049 | 0.0013 | 0.26 | 0.0032 |
| MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.25 | 0.0066 | 0.32 | 0.0035 |
| MWL Alternative V.e—Future Excavation | HI = 0.07<br>CR = 3E-6 | TEDE = 3.23E3 mrem/yr<br>CR = 3.7E-2 | NA | NA | 0.88 | 0.23 | 2.26 | 0.011 |

CMS = Corrective Measures Study.
CR = Cancer risk.
HI = Hazard index.
HQ = Hazard quotient.
IC = Institutional Control.
IND = Industrial.
mrem/yr = Millirem per year.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
TEDE = Total Effective Dose Equivalent.

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# APPENDIX 1
## EXPOSURE PATHWAY DISCUSSION FOR CHEMICAL AND RADIONUCLIDE CONTAMINATION

Introduction

Sandia National Laboratories/New Mexico (SNL/NM) uses a default set of exposure routes and associated default parameter values developed for each future land use designation being considered for SNL/NM Environmental Restoration (ER) Project sites. This default set of exposure scenarios and parameter values are invoked for risk assessments unless site-specific information suggests other parameter values. Because many SNL/NM solid waste management units (SWMUs) have similar types of contamination and physical settings, SNL/NM believes that the risk assessment analyses at these sites can be similar. A default set of exposure scenarios and parameter values facilitates the risk assessments and subsequent review.

The default exposure routes and parameter values used are those that SNL/NM views as resulting in a Reasonable Maximum Exposure (RME) value. Subject to comments and recommendations by the U.S. Environmental Protection Agency (EPA) Region VI and New Mexico Environment Department (NMED), SNL/NM will use these default exposure routes and parameter values in future risk assessments.

At SNL/NM, all SWMUs exist within the boundaries of the Kirtland Air Force Base. Approximately 240 potential waste and release sites have been identified where hazardous, radiological, or mixed materials may have been released to the environment. Evaluation and characterization activities have occurred at all of these sites to varying degrees. Among other documents, the SNL/NM ER draft Environmental Assessment (DOE 1996) presents a summary of the hydrogeology of the sites, the biological resources present and proposed land use scenarios for the SNL/NM SWMUs. At this time, all SNL/NM SWMUs have been tentatively designated for either industrial or recreational future land use. The NMED has also requested that risk calculations be performed based upon a residential land use scenario. All three land use scenarios will be addressed in this document.

The SNL/NM ER Project has screened the potential exposure routes and identified default parameter values to be used for calculating potential intake and subsequent hazard index (HI), excess cancer risk and dose values. The EPA (EPA 1989a) provides a summary of exposure routes that could potentially be of significance at a specific waste site. These potential exposure routes consist of:

- Ingestion of contaminated drinking water
- Ingestion of contaminated soil
- Ingestion of contaminated fish and shellfish
- Ingestion of contaminated fruits and vegetables
- Ingestion of contaminated meat, eggs, and dairy products

- Ingestion of contaminated surface water while swimming

- Dermal contact with chemicals in water

- Dermal contact with chemicals in soil

- Inhalation of airborne compounds (vapor phase or particulate)

- External exposure to penetrating radiation (immersion in contaminated air; immersion in contaminated water; and exposure from ground surfaces with photon-emitting radionuclides)

Based upon the location of the SNL/NM SWMUs and the characteristics of the surface and subsurface at the sites, we have evaluated these potential exposure routes for different land use scenarios to determine which should be considered in risk assessment analyses (the last exposure route is pertinent to radionuclides only). At SNL/NM SWMUs, there is currently no consumption of fish, shellfish, fruits, vegetables, meat, eggs, or dairy products that originate on site. Additionally, no potential for swimming in surface water is present due to the high-desert environmental conditions. As documented in the RESRAD computer code manual (ANL 1993), risks resulting from immersion in contaminated air or water are not significant compared to risks from other radiation exposure routes.

For the industrial and recreational land use scenarios, SNL/NM ER has, therefore, excluded the following four potential exposure routes from further risk assessment evaluations at any SNL/NM SWMU:

- Ingestion of contaminated fish and shellfish
- Ingestion of contaminated fruits and vegetables
- Ingestion of contaminated meat, eggs, and dairy products
- Ingestion of contaminated surface water while swimming

That part of the exposure pathway for radionuclides related to immersion in contaminated air or water is also eliminated.

For the residential land use scenario, we will include ingestion of contaminated fruits and vegetables because of the potential for residential gardening.

Based upon this evaluation, for future risk assessments the exposure routes that will be considered are shown in Table 1. Dermal contact is included as a potential nonradiological organic constituents exposure pathway in all land use scenarios. However, the potential for dermal exposure to inorganic constituents is not considered significant and will not be included. In general, the dermal exposure pathway is generally considered not to be significant relative to water ingestion and soil ingestion pathways but will be considered for organic components. Because of the lack of toxicological parameter values for this pathway, the inclusion of this exposure pathway into risk assessment calculations may not be possible and may be part of the uncertainty analysis for a site where dermal contact is potentially applicable.

**Table 1**
**Exposure Pathways Considered for Various Land Use Scenarios**

| Industrial | Recreational | Residential |
|---|---|---|
| Ingestion of contaminated drinking water | Ingestion of contaminated drinking water | Ingestion of contaminated drinking water |
| Ingestion of contaminated soil | Ingestion of contaminated soil | Ingestion of contaminated soil |
| Inhalation of airborne compounds (vapor phase or particulate) | Inhalation of airborne compounds (vapor phase or particulate) | Inhalation of airborne compounds (vapor phase or particulate) |
| Dermal contact (nonradiological organic constituents only) | Dermal contact (nonradiological organic constituents only) | Dermal contact (nonradiological organic constituents only) |
| External exposure to penetrating radiation from ground surfaces | External exposure to penetrating radiation from ground surfaces | Ingestion of fruits and vegetables |
| | | External exposure to penetrating radiation from ground surfaces |

Equations and Default Parameter Values for Identified Exposure Routes

In general, SNL/NM expects that ingestion of compounds in drinking water and soil will be the more significant exposure routes for chemicals; external exposure to radiation may also be significant for radionuclides. All of the above routes will, however, be considered for their appropriate land use scenarios. The general equation for calculating potential intakes via these routes is shown below. The equations are from the Risk Assessment Guidance for Superfund (RAGS): Volume 1 (EPA 1989a, 1991). These general equations also apply to calculating potential intakes for radionuclides. A more in-depth discussion of the equations used in performing radiological pathway analyses with the RESRAD code may be found in the RESRAD Manual (ANL 1993). RESRAD is the only code designated by the U.S. Department of Energy (DOE) in DOE Order 5400.5 for the evaluation of radioactively contaminated sites (DOE 1993). The Nuclear Regulatory Commission (NRC) has approved the use of RESRAD for dose evaluation by licensees involved in decommissioning, NRC staff evaluation of waste disposal requests, and dose evaluation of sites being reviewed by NRC staff. RESRAD has been applied to more than 300 sites in the U.S. and other countries. EPA Science Advisory Board reviewed the RESRAD model. EPA used RESRAD in their rulemaking on radiation site cleanup regulations. RESRAD code has been verified, undergone several benchmarking analyses, and been included in the International Atomic Energy Agency's VAMP and BIOMOVS II projects to compare environmental transport models.

Also shown are the default values SNL/NM ER will use in RME risk assessment calculations for industrial, recreational, and residential land use scenarios, based upon EPA and other governmental agency guidance. The pathways and values for chemical contaminants are discussed first, followed by those for radionuclide contaminants. Certain site-specific input parameters have been pre-established by agreement between SNL and NMED (SNL/NM February 1998). RESRAD input parameters that are left as the default values provided with the code are not discussed. Further information relating to these parameters may be found in the RESRAD Manual (ANL 1993) or by directly accessing the RESRAD websites at: http://web.ead.anl.gov/resrad/home2/ or http://web.ead.anl.gov/resrad/documents/.

Generic Equation for Calculation of Risk Parameter Values

The equation used to calculate the risk parameter values (i.e., hazard quotients/HI, excess cancer risk, or radiation total effective dose equivalent [TEDE] [dose]) is similar for all exposure pathways and is given by:

Risk (or Dose) = Intake x Toxicity Effect (either carcinogenic, noncarcinogenic, or radiological)

$$= C \times (CR \times EFD/BW/AT) \times \text{Toxicity Effect} \quad (1)$$

where

C = contaminant concentration (site specific)
CR = contact rate for the exposure pathway
EFD = exposure frequency and duration
BW = body weight of average exposure individual
AT = time over which exposure is averaged.

For nonradiological constituents of concern (COCs), the total risk/dose (either cancer risk or HI) is the sum of the risks/doses for all of the site-specific exposure pathways and contaminants. For radionuclides, the calculated radiation exposure, expressed as TEDE is compared directly to the exposure guidelines of 15 millirem per year (mrem/year) for industrial and recreational future use and 75 mrem/year for the unlikely event that institutional control of the site is lost and the site is used for residential purposes (EPA 1997).

The evaluation of the carcinogenic health hazard produces a quantitative estimate for excess cancer risk resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of the quantitative estimate with the potentially acceptable risk of 1E-5 for nonradiological carcinogens. The evaluation of the noncarcinogenic health hazard produces a quantitative estimate (i.e., the HI) for the toxicity resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of this quantitative estimate with the EPA standard HI of unity (1). The evaluation of the health hazard due to radioactive compounds produces a quantitative estimate of doses resulting from the COCs present at the site. This estimated dose can be used to calculate an assumed risk. However, this calculated risk is presented for illustration purposes only, not to determine compliance with regulations.

The specific equations used for the individual exposure pathways can be found in RAGS (EPA 1989a) and are outlined below. The RESRAD Manual (ANL 1993) describes similar equations for the calculation of radiological exposures.

A receptor can ingest soil or dust directly by working in the contaminated soil. Indirect ingestion can occur from sources such as unwashed hands introducing contaminated soil to food that is then eaten. An estimate of intake from ingesting soil will be calculated as follows:

$$I_s = \frac{C_s * IR * CF * EF * ED}{BW * AT}$$

where:

$I_s$ = Intake of contaminant from soil ingestion (milligrams [mg]/kilogram [kg]/day)
$C_s$ = Chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (1E-6 kg/mg)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Soil Inhalation

A receptor can inhale soil or dust directly by working in the contaminated soil. An estimate of intake from inhaling soil will be calculated as follows (EPA 1989b):

$$I_s = \frac{C_s * IR * EF * ED * \left( 1/VF + 1/PEF \right)}{BW * AT}$$

where:

$I_s$ = Intake of contaminant from soil inhalation (mg/kg/day)
$C_s$ = Chemical concentration in soil (mg/kg)
IR = Inhalation rate (cubic meters [$m^3$]/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
VF = soil-to-air volatilization factor ($m^3$/kg)
PEF = particulate emission factor ($m^3$/kg)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Groundwater Ingestion

A receptor can ingest water by drinking it or through using household water for cooking. An estimate of intake from ingesting water will be calculated as follows (EPA 1989b):

$$I_w = \frac{C_w * IR * EF * ED}{BW * AT}$$

where:

$I_w$ = Intake of contaminant from water ingestion (mg/kg/day)
$C_w$ = Chemical concentration in water (mg/liter [L])
IR = Ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Groundwater Inhalation

The amount of a constituent taken into the body via exposure to volatilization from showering or other household water uses will be evaluated using the concentration of the constituent in the water source (EPA 1991 and 1992). An estimate of intake from volatile inhalation from groundwater will be calculated as follows (EPA 1991):

$$I_w = \frac{C_w * K * IR_i * EF * ED}{BW * AT}$$

where:

- $I_w$ = Intake of volatile in water from inhalation (mg/kg/day)
- $C_w$ = Chemical concentration in water (mg/L)
- K = volatilization factor (0.5 L/m$^3$)
- $IR_i$ = Inhalation rate (m$^3$/day)
- EF = Exposure frequency (days/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged—days)

For volatile compounds, volatilization from groundwater can be an important exposure pathway from showering and other household uses of groundwater. This exposure pathway will only be evaluated for organic chemicals with a Henry's Law constant greater than 1 X $10^{-5}$ and with a molecular weight of 200 grams/mole or less (EPA 1991).

Vegetable and Fruit Ingestion

A receptor may ingest contaminated vegetables and fruits. This pathway is only applicable to the residential land-use scenario. An estimate of intake from ingesting vegetables and fruits will be calculated as follows (EPA 1989b):

$$I_f = \frac{C_f * IR * FI * EF * ED}{BW * AT}$$

where:

- $I_f$ = Intake of contaminant from food ingestion (mg/kg/day)
- $C_f$ = Chemical concentration in food (mg/kg)
- IR = Ingestion rate (kg/meal)
- FI = Fraction ingested from contaminated source (unitless)
- EF = Exposure frequency (meals/year)
- ED = Exposure duration (years)
- BW = Body weight (kg)
- AT = Averaging time (period over which exposure is averaged—days)

Tables 2 and 3 show the default parameter values suggested for use by SNL/NM at SWMUs, based upon the selected land use scenarios for nonradiological and radiological COCs, respectively. References are given at the end of the table indicating the source for the chosen parameter values. SNL/NM uses default values that are consistent with both regulatory guidance and the RME approach. Therefore, the values chosen will, in general, provide a conservative estimate of the actual risk parameter. These parameter values are suggested for use for the various exposure pathways, based upon the assumption that a particular site has no unusual characteristics that contradict the default assumptions. For sites for which the assumptions are not valid, the parameter values will be modified and documented.

## Summary

SNL/NM will use the described default exposure routes and parameter values in risk assessments at sites that have an industrial, recreational, or residential future land use scenario. There are no current residential land use designations at SNL/NM ER sites, but NMED has requested this scenario to be considered to provide perspective of the risk under the more restrictive land use scenario. For sites designated as industrial or recreational land use, SNL/NM will provide risk parameter values based upon a residential land use scenario to indicate the effects of data uncertainty on risk value calculations or in order to potentially mitigate the need for institutional controls or restrictions on SNL/NM ER sites. The parameter values are based upon EPA guidance and supplemented by information from other government sources. The values are generally consistent with those proposed by Los Alamos National Laboratory for use in their Environmental Restoration Program, with a few minor variations. If these exposure routes and parameters are acceptable, SNL/NM will use them in risk assessments for all sites where the assumptions are consistent with site-specific conditions. All deviations will be documented.

**Table 2**
**Default Nonradiological Exposure Parameter Values for Various Land Use Scenarios**

| Parameter | Industrial | Recreational | Residential |
|---|---|---|---|
| **General Exposure Parameters** | | | |
| Exposure frequency | 8 hr/day for 250 day/yr | 4 hr/wk for 52 wk/yr | 350 day/yr |
| Exposure duration (yr) | 25[a,b] | 30[a,b] | 30[a,b] |
| Body weight (kg) | 70[a,b] | 70 adult[a,b]<br>15 child | 70 adult[a,b]<br>15 child |
| Averaging Time (days)<br>for carcinogenic compounds<br>(= 70 yr x 365 day/yr)<br>for noncarcinogenic compounds<br>(= ED x 365 day/yr) | <br>25,550[a]<br><br>9,125 | <br>25,550[a]<br><br>10,950 | <br>25,550[a]<br><br>10,950 |
| **Soil Ingestion Pathway** | | | |
| Ingestion rate | 100 mg/day[c] | 200 mg/day child<br>100 mg/day adult | 200 mg/day child<br>100 mg/day adult |
| **Inhalation Pathway** | | | |
| Inhalation rate ($m^3$/yr) | 5,000[a,b] | 260 | 7,000[a,b] |
| Volatilization factor ($m^3$/kg) | chemical specific | chemical specific | chemical specific |
| Particulate emission factor ($m^3$/kg) | 1.32E9[a] | 1.32E9[a] | 1.32E9[a] |
| **Water Ingestion Pathway** | | | |
| Ingestion rate (liter/day) | 2[a,b] | 2[a,b] | 2[a,b] |
| **Food Ingestion Pathway** | | | |
| Ingestion rate (kg/yr) | NA | NA | 138[b] |
| Fraction ingested | NA | NA | 0.25[b] |
| **Dermal Pathway** | | | |
| Surface area in water ($m^2$) | 2[b,d] | 2[b,d] | 2[b,d] |
| Surface area in soil ($m^2$) | 0.53[b,d] | 0.53[b,d] | 0.53[b,d] |
| Permeability coefficient | chemical specific | chemical specific | chemical specific |

[a]Risk Assessment Guidance for Superfund, Vol. 1, Part B (EPA 1991).
[b]Exposure Factors Handbook (EPA 1989b).
[c]EPA Region VI guidance (EPA 1996).
[d]Dermal Exposure Assessment (EPA 1992).
ED = Exposure duration.
EPA = U.S. Environmental Protection Agency.
hr = Hour(s).
kg = Kilogram(s).
m = Meter(s).
mg = Milligram(s).
NA = Not available.
wk = Week(s).
yr = Year(s).

**Table 3**
**Default Radiological Exposure Parameter Values for Various Land Use Scenarios**

| Parameter | Industrial | Recreational | Residential |
|---|---|---|---|
| **General Exposure Parameters** | | | |
| Exposure frequency | 8 hr/day for 250 day/yr | 4 hr/wk for 52 wk/yr | 365 day/yr |
| Exposure duration (yr) | 25[a,b] | 30[a,b] | 30[a,b] |
| Body weight (kg) | 70 adult[a,b] | 70 adult[a,b] | 70 adult[a,b] |
| **Soil Ingestion Pathway** | | | |
| Ingestion rate | 100 mg/day[c] | 100 mg/day[c] | 100 mg/day[c] |
| Averaging Time (days) (= 30 yr x 365 day/yr) | 10,950[d] | 10,950[d] | 10,950[d] |
| **Inhalation Pathway** | | | |
| Inhalation rate ($m^3$/yr) | 7300[d,e] | 10,950[e] | 7300[d,e] |
| Mass loading for inhalation g/$m^3$ | 1.36 E-5[d] | 1.36 E-5 [d] | 1.36 E-5 [d] |
| **Food Ingestion Pathway** | | | |
| Ingestion rate, leafy vegetables (kg/yr) | NA | NA | 16.5[c] |
| Ingestion rate, fruits, non-leafy vegetables & grain (kg/yr) | NA | NA | 101.8[b] |
| Fraction ingested | NA | NA | 0.25[b,d] |

[a]Risk Assessment Guidance for Superfund, Vol. 1, Part B (EPA 1991).
[b]Exposure Factors Handbook (EPA 1989b).
[c]EPA Region VI guidance (EPA 1996).
[d]For radionuclides, RESRAD (ANL, 1993).
[e]SNL/NM (February 1998).
EPA = U.S. Environmental Protection Agency.
g = Gram(s).
hr = Hour(s).
kg = Kilogram(s).
m = Meter(s).
mg = Milligram(s).
NA = Not applicable.
wk = Week(s).
yr = Year(s).

References

ANL, see Argonne National Laboratory.

Argonne National Laboratory (ANL), 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD*, Version 5.0, ANL/EAD/LD-2, Argonne National Laboratory, Argonne, IL.

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# APPENDIX F

## New Mexico Environment Department Notice of Deficiency Comments with DOE/Sandia National Laboratories' Responses

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**Sandia National Laboratories**
**Albuquerque, New Mexico**
**December 19, 2003**

**Environmental Restoration Project**
**Responses to New Mexico Environment Department**
**NOTICE OF DEFICIENCY**
**for the**
**Mixed Waste Landfill: Corrective Measures Study Report, May 2003**
**EPA ID#: 5890110518**
**HWB-SNL-01-025**

## INTRODUCTION

This document responds to a Notice of Deficiency (NOD) received from the State of New Mexico Environment Department (NMED) regarding the Sandia National Laboratories Mixed Waste Landfill (MWL) Corrective Measures Study Report (SNL/NM May 2003). The NOD was issued in a letter from the NMED to the U.S. Department of Energy (DOE) on November 5, 2003 (Martin, November 5, 2003).

This document provides the NMED NOD comments and DOE/Sandia National Laboratories (SNL) responses provided in *italics* on a separate line following "*DOE/SNL Response.*" Responses to general comments begin on page 1. Responses to specific comments begin on page 2.

Additional supporting data for DOE/SNL responses are included as attachments where designated. Attachment A presents figures from the MWL Corrective Measures Study Report that have been revised at the request of the NMED. Attachment B presents tables from the MWL Corrective Measures Study Report that have been revised at the request of the NMED. Revised text in each table is shown in *italics*.

## NMED General Comments

The following general comments do not require a response. They are included herein to express the opinions of the New Mexico Environment Department (NMED, or Department) and for the benefit of the administrative record.

1. It is clear from the text of the Mixed Waste Landfill (MWL) Corrective Measures Study (CMS) Report that the U. S. Department of Energy (DOE)/Sandia National Laboratories (SNL) has the view that RCRA cover systems are inferior to evapotranspiration caps (ET caps). The NMED does not share this point of view. In the short term, there is ample evidence that RCRA covers will outperform ET caps. For the long term, there is no compelling evidence that a well-constructed RCRA cap made of modern materials is likely to fail simply because part of it would be constructed of man-made materials or fine-grain soil (clay). Additionally, not all RCRA cap variations contain fine-grain soil barriers.

Regardless, the NMED recognizes that ET caps are adequate for some sites, subject to certain geologic and climatological conditions. Modeling submitted with the ET cap design for the MWL, and modeling done for Kirtland Air Force Base's (KAFB's) Landfills 1, 2, and 8 indicate that ET caps should provide acceptable performance for landfills situated at both SNL/NM and KAFB. The only reason not to install a RCRA cover system is that an ET cap is expected to provide acceptable performance at a lower cost.

2. Regarding the No Further Action (NFA) alternative, the NMED is unlikely to accept the operational cover because of the lack of documentation on its design, expected performance, the materials that it is constructed of, and the lack of construction quality data. Although there is some historical evidence that the operational cover meets corrective action objectives #1, 3, and 4, there are also uncertainties concerning whether this will remain true in the future. Additionally, the lack of construction and design documentation does not provide confidence to the NMED that corrective action objective #2 can be met in the future.

3. Actual monitoring and post-closure care requirements for the MWL will be negotiated later with the NMED, and will depend on the remedy selected by the Department.

4. The NMED reserves all rights with respect to any enforcement authority the Department may have with respect to radionuclides.

## NMED Specific Comments

Below are specific comments, most which require a response. Comments not requiring a response are included herein to express the opinions of the NMED and for the benefit of the administrative record.

1. Page 48, 2nd paragraph, Health and Safety -- This paragraph says that excavation and characterization present moderate health and safety concerns, and the risk to site workers is ranked medium. This seems to be inconsistent with the language in the first paragraph of Section 3.2.11.1 (page 47), which states "This alternative poses little exposure risk to site workers, the public, and wildlife". The latter suggests that the risk to site workers should be changed from "medium" to "low". Provide an explanation as to which risk level is correct in the DOE/SNL's opinion.

*<u>DOE/SNL Response</u>: Page 48, 2nd paragraph, Health and Safety -- This paragraph refers to MWL Alternative V.e—Future Excavation, which includes hazards from excavation and characterization machinery, heat stress, pressure hazards, noise, and ergonomic work strain. DOE/SNL considers the risk to site workers from construction and characterization hazards as medium. Section 3.2.11.1, page 47, refers to Corrective Action Objective No. 1, radiological dose to site workers, representative members of the public, radon emissions, and radiological dose to wildlife. DOE/SNL believes there is little exposure risk because total radionuclide activity will have decayed to safer levels.*

2. Page 48, Section 3.2.11.3, Cost -- The cost for disposal has not been included as it should be. Given that costs are given as present value, the cost today for disposal of waste should have been included. For simplicity, the NMED suggests using the cost for disposal included in the landfill excavation scenario presented in Appendix H, which is in the range of $122,000,000. Provide a disposal cost for this remedial alternative.

*<u>DOE/SNL Response</u>: An estimated cost for transportation and disposal of waste for MWL Alternative V.e—Future Excavation is $168,525,120. This estimate is consistent with transportation and disposal costs used for Alternative V.b—Complete Excavation with Off-site Disposal and assumes all soils will be returned to the excavation as backfill. The text in Section 3.2.11.3 has been revised to state, "Direct capital costs for the Future Excavation alternative are $235,603,841. Costs for shipment of waste to an off-site, licensed disposal facility are included."*

3. Page 51, Section 4.1, first bullet below 1st paragraph -- Clarify whether institutional controls (ICs) will include monitoring for durations as much as 100 years, given that 30 and 70 year time periods are used elsewhere in the document.

*<u>DOE/SNL Response</u>: The actual monitoring and post-closure care requirements for the MWL will be negotiated with the NMED, and will depend on the remedy selected. The 30-, 70- and 100-year time periods used in the document are planning tools. According to NRC 10 CFR 61, 100 years is the longest period of time that active ICs can be relied upon. The 30-year time period used to calculate long-term monitoring costs is based on*

*a RACER code limitation. The 70-year time period (Table 4-1) is based on a DOE planning horizon for Long-Term Stewardship.*

4. Page 61, Section 4.3.4, first paragraph -- see specific comment #2.

<u>DOE/SNL Response</u>*: An estimated cost for transportation and disposal of waste for MWL Alternative V.e—Future Excavation is $168,525,120. This estimate is consistent with transportation and disposal costs used for Alternative V.b—Complete Excavation with Off-site Disposal, and assumes all excavated soils will be returned to the excavation as backfill. See response to Specific Comment No. 2.*

5. Page 62, Section 4.3.4.2, first sentence -- Note that mixed and hazardous waste may require treatment before disposal to meet the land disposal restrictions in 20.4.1.800 NMAC incorporating 40 CFR Part 268. No response is required.

<u>DOE/SNL Response</u>*: Comment acknowledged.*

6. Page 63, Section 4.3.4.4 -- Although excavation may take only an estimated two years, the design and construction of support facilities, which must precede excavation, will likely take several additional years. This is demonstrated in Appendix H for the excavation scenario described in that appendix. Please provide an estimate of the total project duration for the future excavation scenario.

<u>DOE/SNL Response</u>*: The design and construction of support facilities, which precede excavation, will take three to five years. Excavation will require an additional 2 years. Total project duration for the future excavation scenario is estimated to be five to seven years.*

7. Page 63, Section 4.3.4.5, 2nd sentence -- The language in this sentence is poor and implies that there will be no costs for waste disposal for future excavation. Provide clarification.

<u>DOE/SNL Response</u>*: Section 4.3.4.5 has been revised to state the following, " Capital costs for MWL Alternative V.e—Future Excavation are $325,704,159, including waste disposal costs. Because there are no operations and maintenance costs for Alternative V.e, operations and maintenance costs are not included in the estimate."*

8. Page 65, Section 5, first paragraph following the four bullets -- See general comment #2. No response is required.

<u>DOE/SNL Response:</u> *Comment acknowledged.*

9. Page 65, Section 5, 2nd paragraph following the four bullets -- The text states "This selection is based on years of dialogue with the NMED and the public in determining the best approach for closure of the site." Clarify whether the CMS added value to this conclusion.

*DOE/SNL Response: The CMS added value to the remedy selection process by verifying (through the formal CMS process) the results of earlier studies by DOE/SNL. These earlier studies identified that NFA with ICs and MWL Alternative III.b —Vegetative Soil Cover were the best alternatives for the MWL (SNL/NM 1996; SNL/NM 1999).*

10. Figures 1-3 and 1-4. There is a dashed line in both figures separating the northern and southern halves of the unclassified area. In Figure 1-3, the dashed line presumably represents part of the MWL perimeter according to the legend. In Figure 1-4, it represents a fence. Provide clarification.

*DOE/SNL Response: The dashed lines in Figures 1-3 and 1-4 represent MWL fencing. The outermost dashed line represents perimeter fencing. The legend in Figure 1-3 has been revised for clarification.*

11. Figures 3-1 through 3-7. All of these figures do not include a scale. Resubmit the figures with the appropriate scales included. The addition of an arrow to indicate the north direction on each figure should also be included for the benefit of the public.

*DOE/SNL Response: An appropriate scale and a north arrow will be added to Figures 3-1 through 3-7.*

12. Table 2-1, "NFA" corrective measure, "Comments" block at bottom of table -- See general comment #2. No response is required.

*DOE/SNL Response: Comment acknowledged.*

13. Table 2-1, "ICs" corrective measure, "Long-term Surveillance and Maintenance" technology description, column on "Responsiveness to Corrective Action Objectives" -- For reasons explained in general comment #2 above, the NMED's opinion is that this column should contain the ranking of "no" instead of "yes". No response is required.

*DOE/SNL Response: Comment acknowledged.*

14. Table 2-1, "Containment" corrective measure, "Structural Barriers" technology description, column on "Performance" -- the NMED agrees that the long-term performance of this technology can be poor if proper maintenance is not being conducted. The NMED disagrees with the first sentence in the "Comments" block in that structural barriers such as concrete and asphalt can easily meet corrective action objectives #2 and #3, provided that such barriers are well maintained. However, in the case of the MWL, the Department would prefer a remedial alternative that will require as little maintenance as possible. Thus, no response is required.

*DOE/SNL Response: Comment acknowledged.*

15. Table 2-1, "Containment" corrective measure, "RCRA Subtitle C Cap" technology description, column on "Performance" -- For reasons stated in general comment # 1

above, the NMED believes strongly that the performance of a RCRA cap should be ranked as least as high as an ET cap. Thus, DOE/SNL should consider changing the performance ranking from "Fair" to "Good", and resubmitting this page of Table 2-1.

<u>DOE/SNL Response</u>: *DOE/SNL spent a considerable amount of time researching and evaluating the performance of RCRA Subtitle C Caps vs. the performance of Vegetative soil covers and considered changing the performance ranking of a RCRA Subtitle C Cap from "Fair" to "Good". However, based on the body of scientific evidence cited in the literature, DOE/SNL decided that the performance of a RCRA Subtitle C Cap should not be ranked as high as a vegetative soil cover in arid and semi-arid environments of the southwestern U.S.*

*DOE/SNL agree that the short-term performance of a RCRA Subtitle C Cap is comparable to vegetative soil covers assuming identical construction quality assurance (CQA) and construction quality control (CQC). However, the phrase "short-term" is not defined in the regulations. DOE/SNL believe that the long-term performance of a RCRA Subtitle C Cap is highly questionable and suspect based on the use of synthetic materials and complex, multi-layer designs.*

16. Table 2-1, "Containment" corrective measure, "Bio-Intrusion Barrier" technology description -- A bio-intrusion barrier alone would not likely be accepted by the NMED as a remedial alternative. It may be accepted in combination with another technology. No response is required.

<u>DOE/SNL Response</u>: *Comment acknowledged.*

17. Tables 2-1, technology descriptions for "Complete Excavation" and "Partial Excavation" with either "Above-Ground Retrievable Storage" or "Offsite Disposal", "Comments" blocks for all four cases -- NMED agrees that these technologies are problematic with regard to meeting corrective action objective #1 in the short term. However, these technologies, in the long term, are responsive to corrective action objective #1 (assuming in the cases for partial excavation that this is also true for a technology applied to the unclassified portion of the landfill). Resubmit these pages of Table 2-1 with language stating that objective # 1 will be met in the long term; include also language that corrective objective #1 will not be met in the short term as currently indicated.

<u>DOE/SNL Response</u>: *Comment acknowledged. Technology descriptions in Table 2-1 regarding Complete Excavation and Partial Excavation with either Above-Ground Retrievable Storage or Off-Site Disposal have been changed to state, "This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term."*

18. Table 2-2, "Long-Term Surveillance and Maintenance" technology column -- the column for "Responsiveness to Corrective Action Objectives" -- For reasons stated in

general comment #2, the NMED believes that this column should be changed from "yes" to "no". No response is required.

*<u>DOE/SNL Response:</u> Comment acknowledged.*

19. Table 2-2, “RCRA Subtitle C Cap” technology column -- the column for “Performance” -- see specific comment #15.

*<u>DOE/SNL Response</u>: Comment acknowledged. See response to Specific Comment No. 15.*

20. Table 3-1, Alternatives V.a and V.b -- State the reasons why long-term monitoring, maintenance, and access controls will be required for these complete excavation scenarios.

*<u>DOE/SNL Response</u>: Long-term monitoring, maintenance, and access controls will not be required for MWL Alternatives V.a and V.b. In addition, long-term monitoring and maintenance will not be required for MWL Alternatives V.c and V.d because exposure and migration risks will have been significantly reduced. However, access controls will be required for MWL Alternatives V.c and V.d. Table 3-1 has been revised accordingly.*

21. Table 3-4, alternatives III.d and III.e -- See general comment #1 above. For the limit migration of contaminants to ground water column, NMED believes that the rankings of "No" should be changed to "Yes", and that the text should explain that the RCRA cap alternatives were not given further evaluation in Chapter 4 because they cost more than ET caps. No response is required.

*<u>DOE/SNL Response:</u> Comment acknowledged.*

22. Table 3-4, alternatives V.a to V.d -- SNL/DOE should indicate in a footnote in the table that their failure in meeting the corrective action objective of “minimize exposure to workers, the public, and wildlife” is limited to the short-term because of the increased exposure during the excavation phases. In the long-term, these alternatives can meet this corrective action objective. Make this change and resubmit the table.

*<u>DOE/SNL Response</u>: A footnote has been added to Table 3-4 for MWL Alternatives V.a to V.d stating, "This alternative's failure in meeting Corrective Action Objective 1 is limited to the short term because of the increased exposure during excavation. In the long term, this alternative meets Corrective Action Objective 1 in minimizing exposure to workers, the public, and wildlife."*

23. Table 3-4, alternative V.e, column for “Worker Health and Safety Risk” -- See specific comment # 1.

*<u>DOE/SNL Response:</u> Comment acknowledged. See response to Specific Comment No. 1.*

24. Table 4-1, extent of long-term monitoring -- Clarify whether DOE/SNL really intend to monitor ground water for 70 years, or whether this duration of monitoring is just being assumed for the purpose of calculating costs and for suggested post-closure activities. See also general comment #3.

*DOE/SNL Response:* *The actual monitoring and post-closure care requirements for the MWL will be negotiated with the NMED, and will depend on the remedy selected. The 70-year time period (Table 4-1) is based on a DOE planning horizon for Long-Term Stewardship. DOE/SNL intend to monitor groundwater for as long as monitoring is warranted.*

25. Table 4-1, Short term reduction in existing risks, future excavation alternative -- The risk assessments assume that the levels of radiological and chemical constituents will be similar to those detected during the RCRA Facility Investigation (RFI). Although the nonradiological risk would be difficult to estimate without further information, the health risk due to chemicals could be much higher than that corresponding to the levels of contaminants detected at the landfill during the RFI. The same applies to radiological constituents, which already show a high level of risk in the future excavation scenario. No response is required.

*DOE/SNL Response:* *Comment acknowledged.*

26. Table 4-1, "Cost", "Future Excavation" alternative -- change the table to include disposal costs and resubmit. See specific comment #2.

*DOE/SNL Response:* *MWL Alternative V.e—Future Excavation in Table 4-1 has been revised to include waste disposal costs. Table 4-1 has also been revised to clarify issues raised in Specific comment No. 32 regarding reduction in toxicity, mobility, and volume of waste.*

27. Table 4-2, "Ecological (Rad) and Transportation and Remediation Injuries and Fatalities" -- include the units of measure and resubmit the table.

*DOE/SNL Response:* *The units for "Ecological Rad" are Rad/day. Injuries and fatalities are unitless. These are total predicted numbers of injuries and fatalities based on the remedial option.*

28. Table 4-3, alternative V.e, under direct costs, include the cost of disposal and correct accordingly the total cost (last column). See specific comment #2.

*DOE/SNL Response:* *Table 4-3, MWL Alternative V.e—Future Excavation has been revised to include the cost of waste disposal.*

29. Appendix B -- For the category of monitoring, for each cost summary report, it is not clear what the costs are for each type of monitoring. Provide clarification.

*DOE/SNL Response:* *The costs for each type of monitoring are summarized in the attached Table 29a. Additional details on the monitoring costs are included in the Technology Cost Detail reports in Appendix C of the CMS.*

30. With regard to the information presented in Chapter 4 (and associated appendices), please provide the following information in table format:

A. For each remedial alternative, indicate the type, frequency, and duration of monitoring assumed for the purposes of calculating costs.

*DOE/SNL Response:* *The type, frequency, and duration of monitoring assumed for each remedial alternative for the purposes of calculating costs are shown in the attached Table 30a. Monitoring at the site may continue for many years; however, because of software limitations, monitoring costs for only 30 years were assumed in the cost estimates, with the exception of MWL Alternative V.e—Future Excavation.*

B. Using total costs (directs plus markups), breakout the costs of monitoring, surveillance, and maintenance for each remedial alternative. Escalate the costs for each type of monitoring/surveillance/maintenance for a period of 30 years (or 70 or 100 years) using an average inflation rate of 4% per year (or justify and use another rate). Report also the difference between the escalated costs and their present value.

*DOE/SNL Response:* The attached *Table 30b breaks out the costs of monitoring and surveillance and maintenance for each remedial alternative. Escalated costs for each type of monitoring, surveillance and maintenance are provided for all alternatives. A 30-year monitoring period is assumed for all alternatives except for MWL Alternative V.e—Future Excavation. Future excavation assumes a monitoring period from 2006 until the hypothetical excavation date (2040).*

*Escalation factors are provided by the RACER cost-estimating program, and are the latest Office of Management and Budget Calculation, as published by the Department of Defense Comptroller. Escalation factors vary from year to year. For example, in RACER, the escalation from 2001 to 2002 is 1.0272; from 2002 to 2003 it is 1.0198; and from 2003 to 2004 it is 1.0216. Escalation includes inflation; however, the inflation component of the rates published by the comptroller is not extractable from the RACER program, but may be obtained from the comptroller for the rates published in 2001.*

**Table 29a. Monitoring costs and details for the various alternatives.**

| Type of Monitoring | Direct Cost | Markups | Total Cost | Duration | Period | Frequency[1] | Proposed Alternatives | Monitoring Details |
|---|---|---|---|---|---|---|---|---|
| Groundwater, Soil, Vegetation, and Air | $864,012 | $494,492 | $1,358,504 | 30 years | 2007 through 2036 | Annually | NFA with Institutional Controls<br>Bio-Intrusion Barrier<br>Vegetative Soil Cover<br>Vegetative Soil Cover with Bio-Intrusion Barrier<br>RCRA Subtitle C Cap<br>RCRA Subtitle C Cap with Bio-Intrusion Barrier<br>Future Excavation | Groundwater may be analyzed for tritium, gross alpha/beta activity, gamma spectroscopy, target analyte list metals, volatile organic compounds, nitrate, major ions, and alkalinity. Soil may be analyzed for tritium and gamma spectroscopy. Vegetation may be analyzed for tritium and gamma spectroscopy. Air may be analyzed for tritium, gamma spectroscopy, and gross alpha/beta. |
| Long-Term Surveillance and Maintenance | $70,115 | $98,629 | $168,744 | 30 years | 2007 through 2036 | Quarterly | NFA with Institutional Controls<br>Bio-Intrusion Barrier<br>Vegetative Soil Cover<br>Vegetative Soil Cover with Bio-Intrusion Barrier<br>RCRA Subtitle C Cap<br>RCRA Subtitle C Cap with Bio-Intrusion Barrier<br>Future Excavation | Surveillance and maintenance activities may include seeding, mulching, grading, erosion control, signage, and fencing |
| Vadose Zone Monitoring | $328,260 | $261,249 | $589,509 | 30 years | 2007 through 2036 | Annually | Bio-Intrusion Barrier<br>Vegetative Soil Cover<br>Vegetative Soil Cover with Bio-Intrusion Barrier<br>RCRA Subtitle C Cap<br>RCRA Subtitle C Cap with Bio-Intrusion Barrier<br>Future Excavation | Vadose zone monitoring may consist of Flexible Liner Underground Technologies (FLUTe) and neutron moisture content monitoring. The Vadose FLUTe systems may have 5 access ports, installed at increments of 50 ft to a total depth of 250 ft bgs. The ports may be sampled annually for tritium and volatile organic compounds. Neutron probe access holes may be monitored annually for moisture content. More frequent sampling may be advantageous during the first two years of monitoring to establish baseline vadose zone conditions. These additional costs are not included. |

## Table 29a. Monitoring costs and details for the various alternatives (con't).

| Type of Monitoring | Direct Cost | Markups | Total Cost | Duration | Period | Frequency[1] | Proposed Alternatives | Monitoring Details[1] |
|---|---|---|---|---|---|---|---|---|
| Groundwater, Soil, Vegetation, and Air | $115,202 | $65,932 | $181,134 | 4 years | 2037 through 2040 | Annually | Future Excavation | Groundwater may be analyzed for tritium, gross alpha/beta activity, gamma spectroscopy, target analyte list metals, volatile organic compounds, nitrate, major ions, and alkalinity. Soil may be analyzed for tritium and gamma spectroscopy. Vegetation may be analyzed for tritium and gamma spectroscopy. Air may be analyzed for tritium, gamma spectroscopy, and gross alpha/beta. |
| Long-Term Surveillance and Maintenance | $9,349 | $12,964 | $22,313 | 4 years | 2037 through 2040 | Quarterly | Future Excavation | Surveillance and maintenance activities may include seeding, mulching, grading, erosion control, signage, and fencing |
| Vadose Zone Monitoring | $43,768 | $34,826 | $78,594 | 4 years | 2037 through 2040 | Annually | Future Excavation | Vadose zone monitoring may consist of Flexible Liner Underground Technologies (FLUTe) and neutron moisture content monitoring. The Vadose FLUTe systems may have 5 access ports, installed at increments of 50 ft to a total depth of 250 ft bgs. The ports may be sampled annually for tritium and volatile organic compounds. Neutron probe access holes may be monitored annually for moisture content. |

[1]The actual monitoring and post-closure care requirements for the MWL will be negotiated with the NMED, and will depend on the remedy selected

**Table 30a. Type, frequency, and duration of monitoring assumed for the purposes of calculating costs in the MWL CMS.**

| General Corrective Measure | Alternative | Description | Monitoring Type | | | | | | | | | | Surveillance and Maintenance[6] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Groundwater[1] | | Soil[2] | | Vegetation[3] | | Air[4] | | Vadose Zone[5] | | | |
| | | | Frequency | Duration | Frequency | Duration | Frequency | Duration | Frequency | Duration | Frequency | Duration | Frequency | Duration |
| | I.a | NFA with ICs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | None | NA | Quarterly | 30 yrs |
| Containment | III.a | Bio-Intrusion Barrier | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Quarterly | 30 yrs |
| | III.b | Vegetative Soil Cover | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Quarterly | 30 yrs |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Quarterly | 30 yrs |
| | III.d | RCRA Subtitle C Cap | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Quarterly | 30 yrs |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Annually | 30 yrs | Quarterly | 30 yrs |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | none | NA | none | NA | none | NA | none | NA | none | NA | none | NA |
| | V.b | Complete Excavation with Off-Site Disposal | none | NA | none | NA | none | NA | none | NA | none | NA | none | NA |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | none | NA | none | NA | none | NA | none | NA | none | NA | none | NA |
| | V.d | Partial Excavation with Off-Site Disposal | none | NA | none | NA | none | NA | none | NA | none | NA | none | NA |
| | V.e | Future Excavation | Annually | Until Excavation[7] | Annually | Until Excavation[7] | Annually | Until Excavation[7] | Annually | Until Excavation[7] | Annually | Until Excavation[7] | Quarterly | Until Excavation[7] |

[1]Groundwater samples may be analyzed for tritium, gross alpha/beta, gamma spectroscopy, TAL metals, VOCs, nitrate, major ions, and alkalinity.
[2]Soil samples may be analyzed for tritium and gamma spectroscopy.
[3]Vegetation samples may be analyzed for tritium and gamma spectroscopy.
[4]Air samples may be analyzed for tritium, gamma spectroscopy, and gross alpha/beta.
[5]Vadose zone monitoring may be conducted for moisture content (by neutron logging), tritium, and VOCs.
[6]Surveillance and maintenance activities may include seeding, mulching, grading, erosion control, signage, and fencing.
[7]Assumes a hypothetical excavation date 50 years after closure of the landfill, i.e., 2040.

NA - Not Applicable

**Table 30b. Escalated costs for monitoring and surveillance and maintenance for each of the MWL alternatives.**

| General Corrective Measure | Alternative | Description | Monitoring Costs[1] | | | Surveillance and Maintenance Costs[2] | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total Cost | Escalated Cost[3,4] | Cost Difference | Total Cost | Escalated Cost[3,4] | Cost Difference |
| | I.a | NFA with ICs | $1,370,839 | $2,099,928 | $729,089 | $169,825 | $260,153 | $90,328 |
| Containment | III.a | Bio-Intrusion Barrier | $1,948,013 | $2,984,023 | $1,036,010 | $168,744 | $258,501 | $89,757 |
| | III.b | Vegetative Soil Cover | $1,948,013 | $2,984,023 | $1,036,010 | $168,744 | $258,501 | $89,757 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | $1,948,013 | $2,984,023 | $1,036,010 | $168,744 | $258,501 | $89,757 |
| | III.d | RCRA Subtitle C Cap | $1,948,013 | $2,984,023 | $1,036,010 | $168,744 | $258,501 | $89,757 |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | $1,948,013 | $2,984,023 | $1,036,010 | $168,744 | $258,501 | $89,757 |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | $0 | $0 | $0 | $0 | $0 | $0 |
| | V.b | Complete Excavation with Off-Site Disposal | $0 | $0 | $0 | $0 | $0 | $0 |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | $0 | $0 | $0 | $0 | $0 | $0 |
| | V.d | Partial Excavation with Off-Site Disposal | $0 | $0 | $0 | $0 | $0 | $0 |
| | V.e | Future Excavation | $2,207,741 | $3,501,778 | $1,294,037 | $191,057 | $302,980 | $111,923 |

[1]Monitoring costs are for groundwater monitoring, soil sampling, vegetation sampling, air sampling, and vadose zone monitoring. Monitoring costs do not include the cost of the vadose zone monitoring system, which will cost an estimated $228,457 in current dollars.

[2]Surveillance and maintenance costs include costs for seeding, mulching, grading, erosion control, signage, and fencing.

[3]Escalated costs are based on a 30-year monitoring period for all alternatives except for MWL Alternative V.e--Future Excavation. Escalation for Future Excavation assumes monitoring and surveillance and maintenance will continue until excavation (hypothetically, 50 years after landfill closure, i.e. in 2040).

[4]Escalation factors were provided by the RACER cost estimating program, and are the latest Office of Management and Budget Calculation, as published by the Department of Defense Comptroller.

C. Using total costs (directs plus markups), calculate the cost per square foot (in $\$/ft^2$) of each warehouse and support building for each remedial alternative in today's dollars. Show your calculations separately.

*DOE/SNL Response:* *The cost per square foot of warehouses and support buildings for each remedial alternative is shown in the attached Table 30c.*

D. Using total costs (directs plus markups), calculate the cost per mile (in $/mile) of all roads that would need to be constructed for each remedial alternative in today's dollars. Show your calculations separately.

*DOE/SNL Response: The attached Table 30d presents costs per mile for roads to be constructed for each alternative.*

*Note: Comments 31 through 47 in the NMED NOD refer to Appendix H in the original Mixed Waste Landfill Corrective Measures Study Report (May 2003). Appendix H contained an independently derived cost estimate for MWL Alternative V.b—Complete Excavation with Off-Site Disposal. This alternative was eliminated through the CMS process because it did not meet Corrective Action Objectives. Because MWL Alternative V.b—Complete Excavation with Off-Site Disposal was not selected as one of the four candidate alternatives for detailed evaluation in Chapter 4, Appendix H and Comments 31 through 47 are not included in this document.*

48. Appendix I, Section IV, Page I-12, last paragraph of section, third sentence stating "However, due to remedial options, the COC's may vary." -- This statement and the rest of the paragraph would be more clear with some additional explanatory text. Provide further explanation on how constituents of concern were selected.

*DOE/SNL Response: The COC selection criteria are summarized in the previous paragraphs of this section. This includes a background screen for inorganics and all detected organics. The sentence "However, due to remedial options, the COC's may vary." is in reference to depth consideration for potential exposure of the remedial options. The referenced paragraph has been revised with the following; "For NFA with no ICs, maximum concentrations in MWL soils at all depths were evaluated within the risk assessment. For the remaining alternatives (with the exception of future excavation), the maximum concentrations within the upper five feet (0 to 5 ft bgs) were evaluated in the risk assessments due to institutional controls that will remain in place for these alternatives."*

49. Appendix I, Page I-42, Section VI.6.2.2 -- Provide an explanation as to what ICs are implemented for this alternative. Make it clear how these ICs would then cause less risk than that calculated for the "NFA without ICs" alternative (compare Tables 16 and 17). Explain why the list of COC's is different in Tables 16 and 17 (see specific comment #48).

**Table 30c. Cost per square foot of warehouses and support buildings for all remedial alternatives**

| | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area ($ft^2$) | Total Cost ($\$/ft^2$) |
|---|---|---|---|---|---|---|
| **Alternative V.a - Complete Excavation with Aboveground Retrievable Storage - Option A** | UnClassified Soil Storage Warehouse 1 | High Bay Warehouse | $20,778,390 | $29,400,000 | 569,999 | $51.58 |
| | UnClassified Soil Storage Warehouse 2 | High Bay Warehouse | $20,778,390 | $29,400,000 | 569,999 | $51.58 |
| | UnClassified Soil Storage Warehouse 3 | High Bay Warehouse | $20,778,390 | $29,400,000 | 569,999 | $51.58 |
| | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Classified Soil Storage Warehouse 2 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $684,704 | $927,000 | 5,286 | $175.37 |

| | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area ($ft^2$) | Total Cost ($\$/ft^2$) |
|---|---|---|---|---|---|---|
| **Alternative V.a - Complete Excavation with Aboveground Retrievable Storage - Option B** | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $294,423 | $398,610 | 2,273 | $175.37 |

| | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area ($ft^2$) | Total Cost ($\$/ft^2$) |
|---|---|---|---|---|---|---|
| **Alternative V.b - Complete Excavation with Off-Site Disposal - Option A** | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $294,423 | $398,610 | 2,273 | $175.37 |

**Table 30c. Cost per square foot of warehouses and support buildings for all remedial alternatives (Con't)**

| Alternative | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area (ft²) | Total Cost ($/ft²) |
|---|---|---|---|---|---|---|
| **Alternative V.b - Complete Excavation with Off-Site Disposal - Option B** | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Unclassified Waste Storage Warehouse | High Bay Warehouse | $21,114,374 | $29,875,000 | 569,999 | $52.41 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $294,423 | $398,610 | 2,273 | $175.37 |

| Alternative | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area (ft²) | Total Cost ($/ft²) |
|---|---|---|---|---|---|---|
| **Alternative V.c - Partial Excavation with Aboveground Retrievable Storage - Option A** | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Classified Soil Storage Warehouse 2 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $294,423 | $398,610 | 2,273 | $175.37 |

| Alternative | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area (ft²) | Total Cost ($/ft²) |
|---|---|---|---|---|---|---|
| **Alternative V.c - Partial Excavation with Aboveground Retrievable Storage - Option B** | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $198,564 | $268,830 | 1,533 | $175.37 |

| Alternative | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area (ft²) | Total Cost ($/ft²) |
|---|---|---|---|---|---|---|
| **Alternative V.d - Partial Excavation with Off-Site Disposal - Option A** | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | MWL Storage Facility Office | General Administrative Facility | $95,859 | $129,780 | 740 | $175.37 |

**Table 30c. Cost per square foot of warehouses and support buildings for all remedial alternatives (Con't)**

| Alternative V.d - Partial Excavation with Off-Site Disposal - Option B | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area ($ft^2$) | Total Cost ($\$/ft^2$) |
|---|---|---|---|---|---|---|
| | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | MWL Storage Facility Office | General Administrative Facility | $95,859 | $129,780 | 740 | $175.37 |

| Alternative V.e - Future Excavation | Facility | Model Type | Facility Direct Cost | Facility Total Cost | Area ($ft^2$) | Total Cost ($\$/ft^2$) |
|---|---|---|---|---|---|---|
| | Classified Soil Storage Warehouse 1 | High Bay Warehouse | $17,563,199 | $24,850,000 | 477,803 | $52.01 |
| | Classified Waste Storage Warehouse | High Bay Warehouse | $5,080,123 | $7,188,000 | 103,459 | $69.48 |
| | MWL Storage Facility Office | General Administrative Facility | $198,564 | $268,830 | 1,533 | $175.37 |

Note: All costs are in today's dollars.

**Table 30d. Costs per mile of roads to be constructed for each remedial alternative.**

| General Corrective Measure | Alternative | Description | Road Length (Miles) | Total Cost[1] of Roads | Cost per Mile ($) | Cost per Linear Ft ($) |
|---|---|---|---|---|---|---|
| | I.a | NFA with ICs | 1.92 | $126,211 | $65,849 | $12.47 |
| Containment[2] | III.a | Bio-Intrusion Barrier | 1.92 | $122,554 | $63,941 | $12.11 |
| | III.b | Vegetative Soil Cover | 1.92 | $122,554 | $63,941 | $12.11 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | 1.92 | $122,554 | $63,941 | $12.11 |
| | III.d | RCRA Subtitle C Cap | 1.92 | $122,554 | $63,941 | $12.11 |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | 1.92 | $122,554 | $63,941 | $12.11 |
| Excavation[3] | V.a | Complete Excavation with Aboveground Retrievable Storage | 3.08 | $713,069 | $231,550 | $43.85 |
| | | Complete Excavation with Aboveground Retrievable Storage | 1.36 | $314,908 | $231,550 | $43.85 |
| | V.b | Complete Excavation with Off-Site Disposal | 1.36 | $314,908 | $231,550 | $43.85 |
| | | Complete Excavation with Off-Site Disposal | 1.36 | $314,908 | $231,550 | $43.85 |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | 1.33 | $307,962 | $231,550 | $43.85 |
| | | Partial Excavation with Aboveground Retrievable Storage | 1.00 | $231,550 | $231,550 | $43.85 |
| | V.d | Partial Excavation with Off-Site Disposal | 0.75 | $173,663 | $231,550 | $43.85 |
| | | Partial Excavation with Off-Site Disposal | 0.75 | $173,663 | $231,550 | $43.85 |
| | V.e | Future Excavation | 1.00 | $231,550 | $231,550 | $43.85 |

[1]Total cost = direct cost plus markups

[2]Road costs for the NFA and Containment alternatives were determined by RACER, and are for a one-lane crowned dirt road from the MWL south to the clean soil piles located west of the Corrective Action Management Unit.

[3]Road costs for the Excavation alternatives were determined by PACES, and are for a 2-lane crowned asphalt road from the landfill to the various high-bay warehouses.

*<u>DOE/SNL Response:</u> The risk summary provided in Section VI.6.2.2 is MWL Alternative 1.a - NFA with ICs. As described in the main text, this includes maintaining long-term monitoring, surveillance and maintenance, and access controls. Therefore, the contamination depth was limited to 0 to 5 feet bgs. Note that for the other NFA with ICs alternatives, additional cover is proposed and the risks are zero due to the lack of potential exposure pathways (i.e., the waste will be greater than 5 feet bgs). For NFA with no ICs, all depths were evaluated and therefore, the COC list is different and leads to greater calculated risk (refer to Section IV for more detail on the COC selection criteria).*

## References


Martin, S. (New Mexico Environment Department), letter to K.L Boardman (U.S. Department of Energy) and P.B. Davies (Sandia National Laboratories), "Notice of Deficiency: Mixed Waste Landfill Corrective Measures Study Report, May 2003, Sandia National Laboratories," EPA ID#5890110518, HWB-SNL-01-025, November 5, 2003.

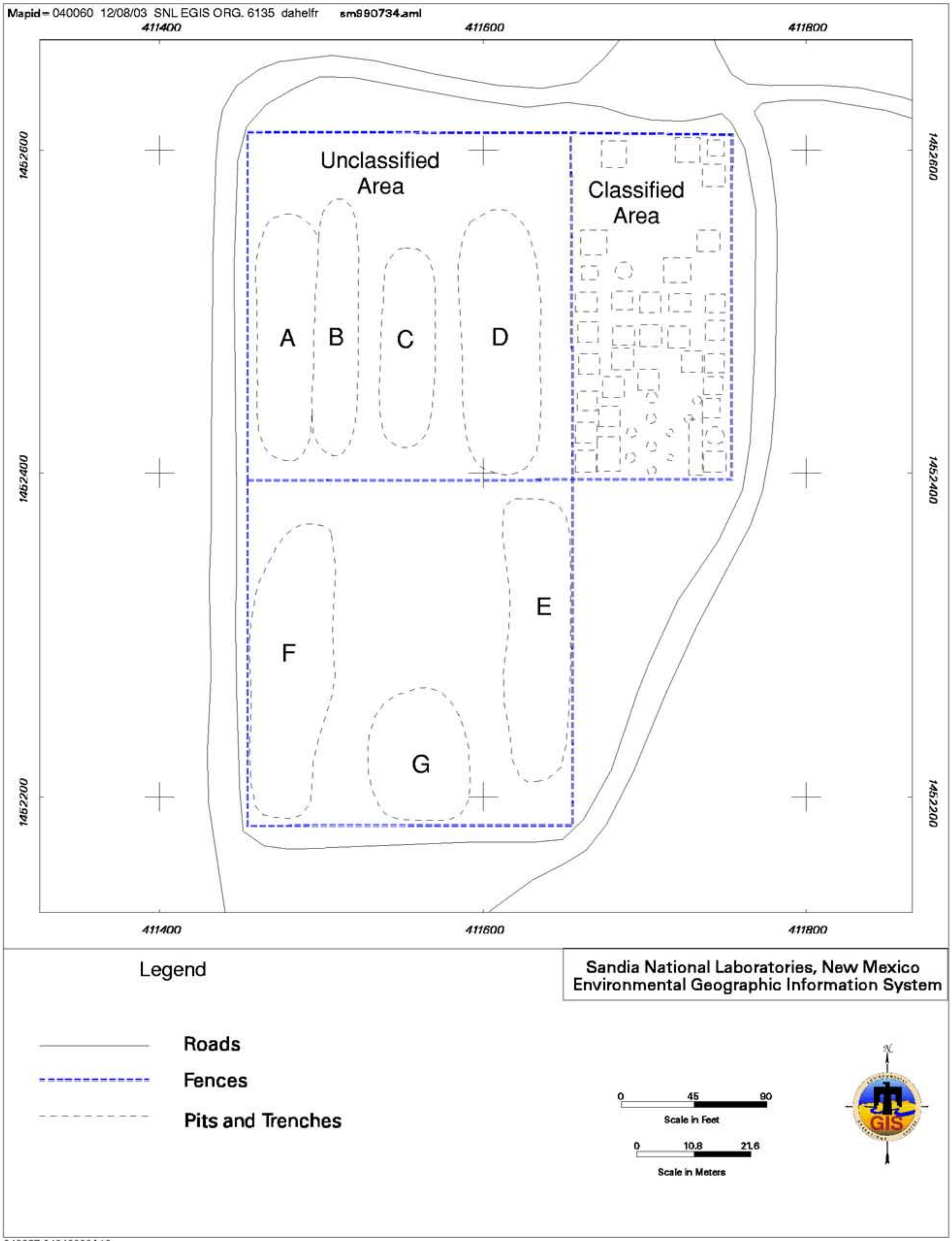
Sandia National Laboratories/New Mexico (SNL/NM), 1996, "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, NM". Sandia National Laboratories Dept. 7585: Environmental Restoration for Landfills and Test Areas, Albuquerque, NM 87185. Prepared for the US DOE. under contract DE-AC04-94AL85000.

Sandia National Laboratories/New Mexico (SNL/NM), September, 1999, "Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, New Mexico", prepared for US DOE by Sandia National Laboratories Environmental Restoration Project, Albuquerque, New Mexico, September 23, 1999.

Sandia National Laboratories/New Mexico (SNL/NM), May 2003, "Mixed Waste Landfill Corrective Measures Study Final Report, Sandia National Laboratories/New Mexico", prepared for US DOE by Sandia National Laboratories Environmental Restoration Project, Albuquerque, New Mexico, May 2003.

# ATTACHMENT A

**Revised Figures**
**From the**
**Mixed Waste Landfill**
**Corrective Measures Study**




840857.04040000A10

**Figure 1-3**
**Map of the Mixed Waste Landfill**

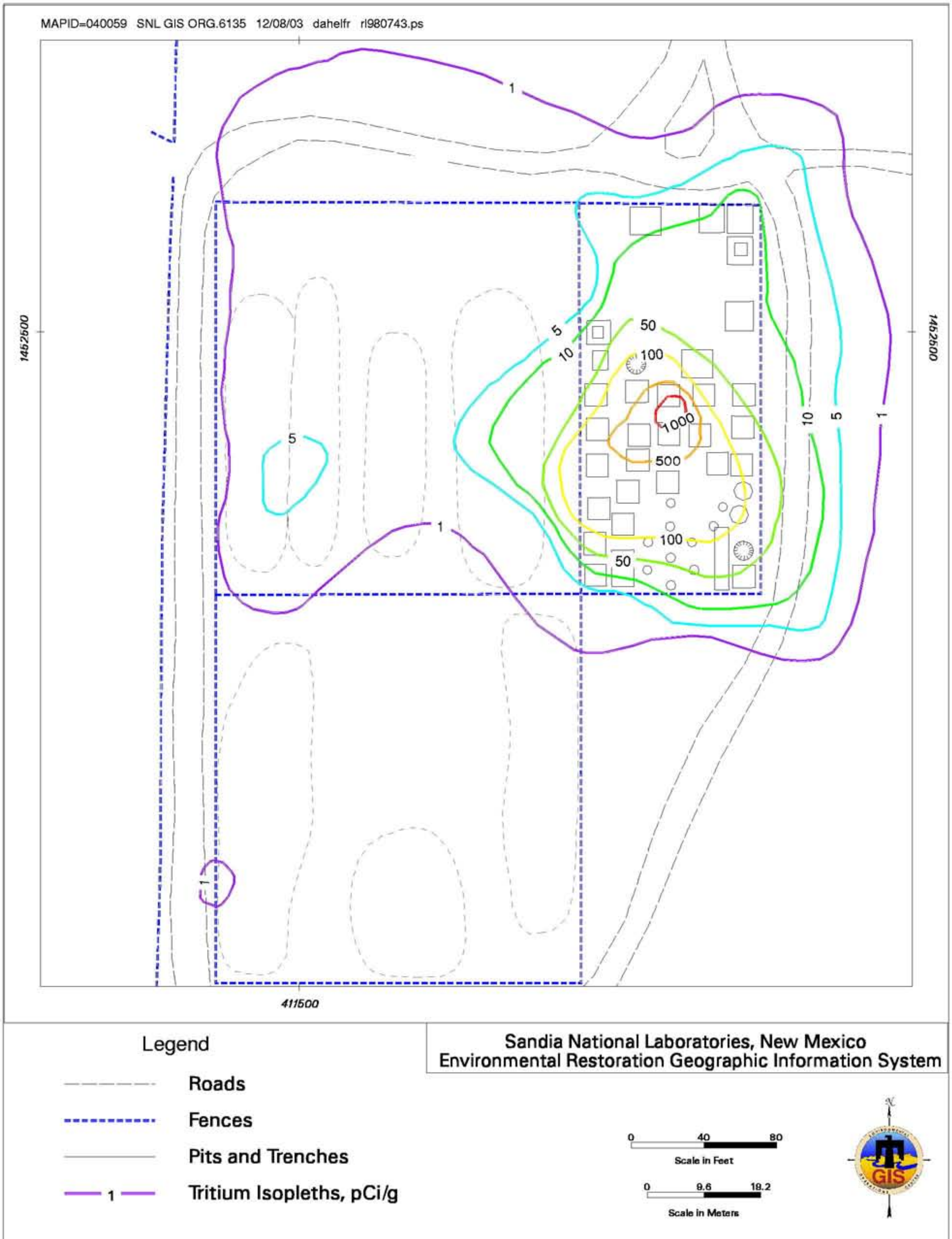
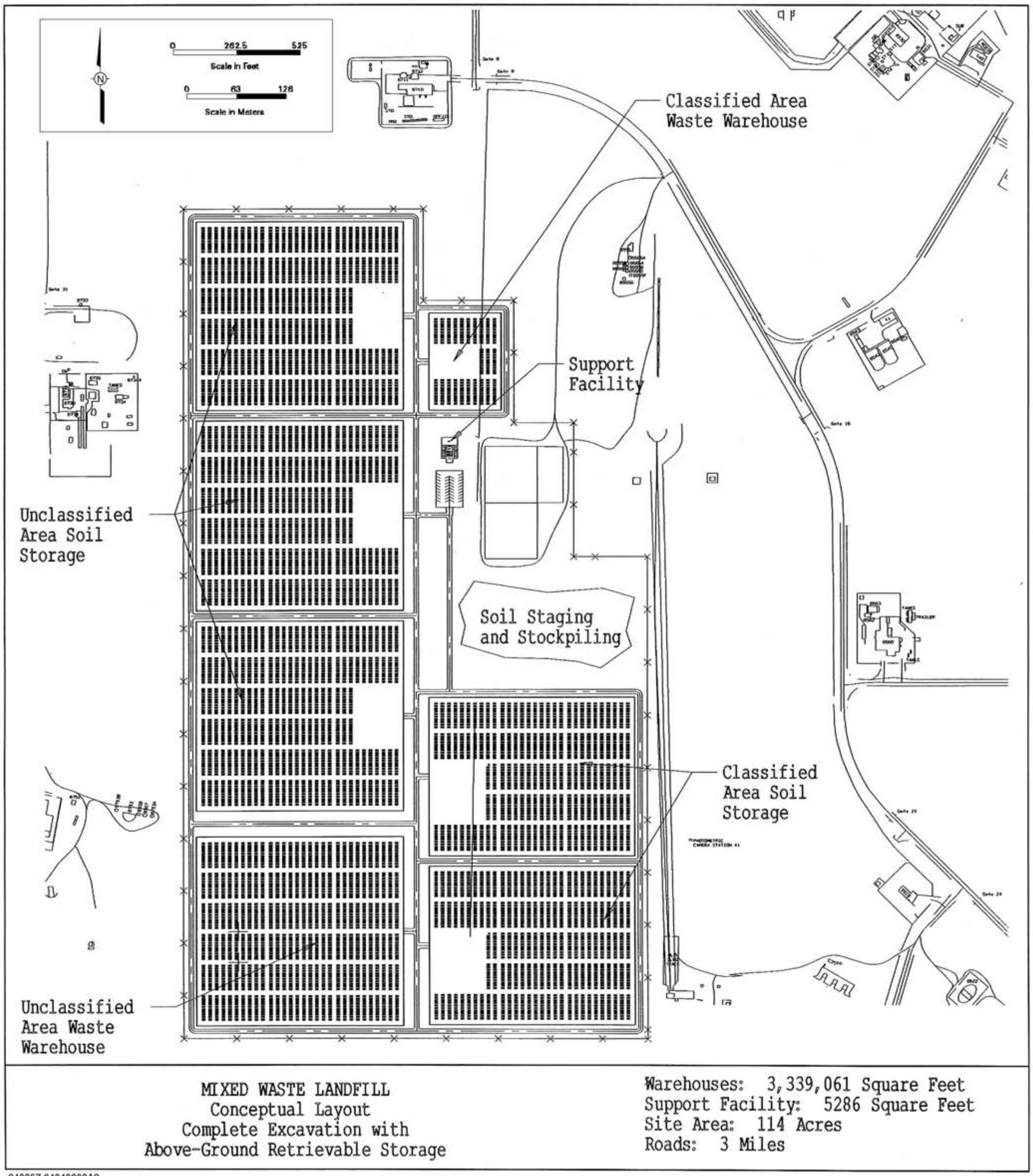



**Figure 1-4**
**Tritium in Surface Soil Soils at the Mixed Waste Landfill (1993)**




840857.04040000A2

**Figure 3-1 Completed Excavation with Aboveground Retrievable Storage**

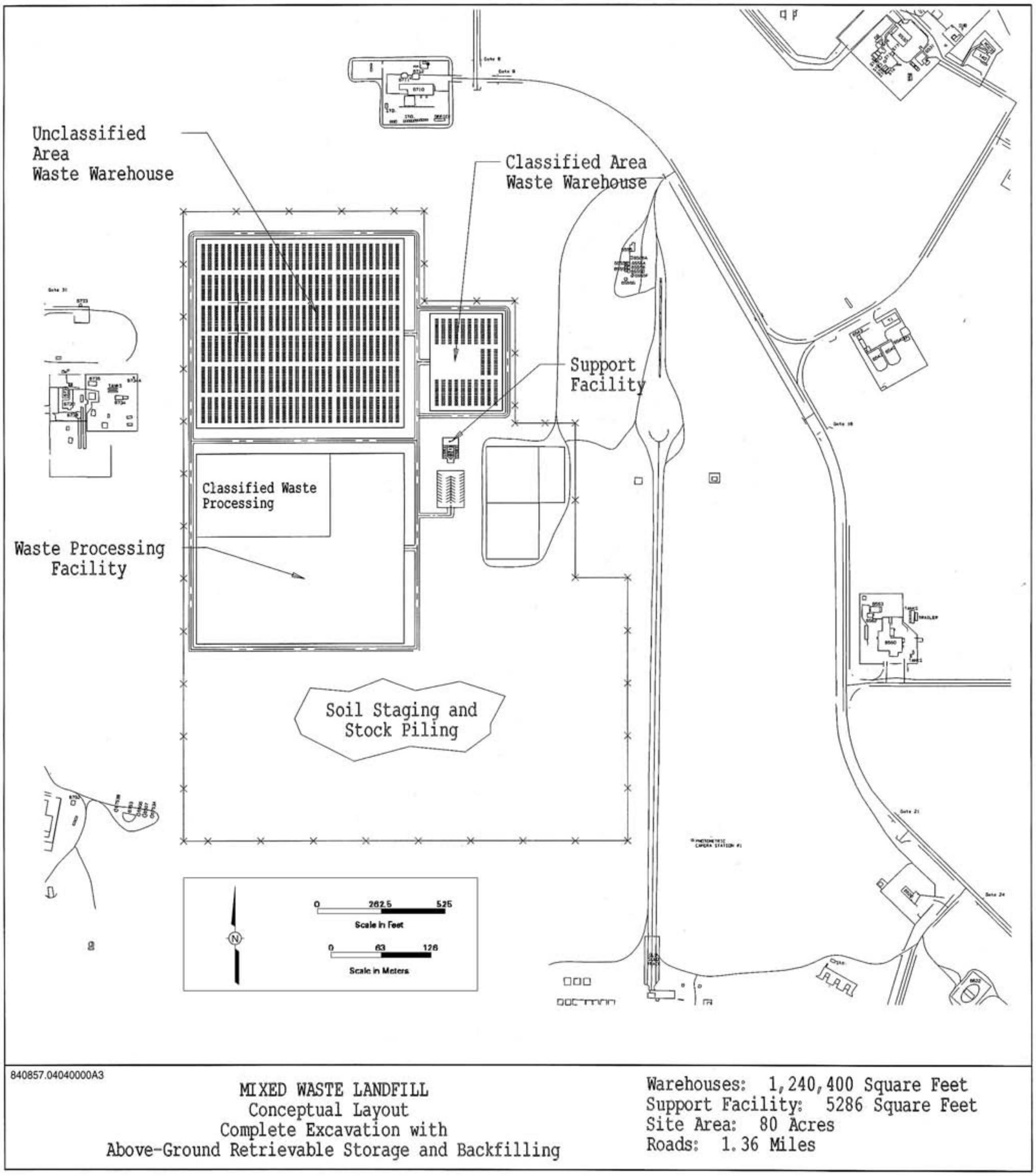
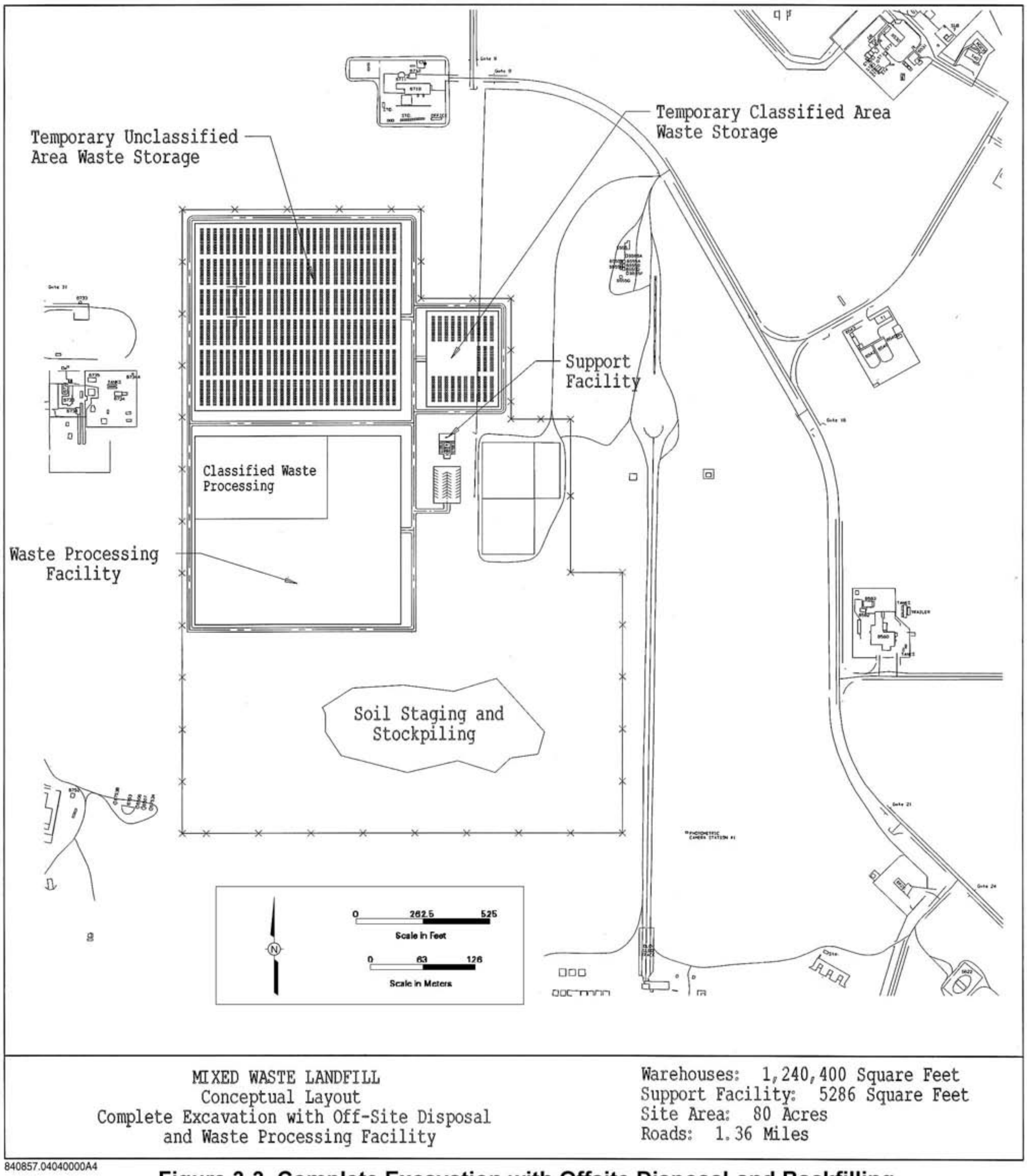
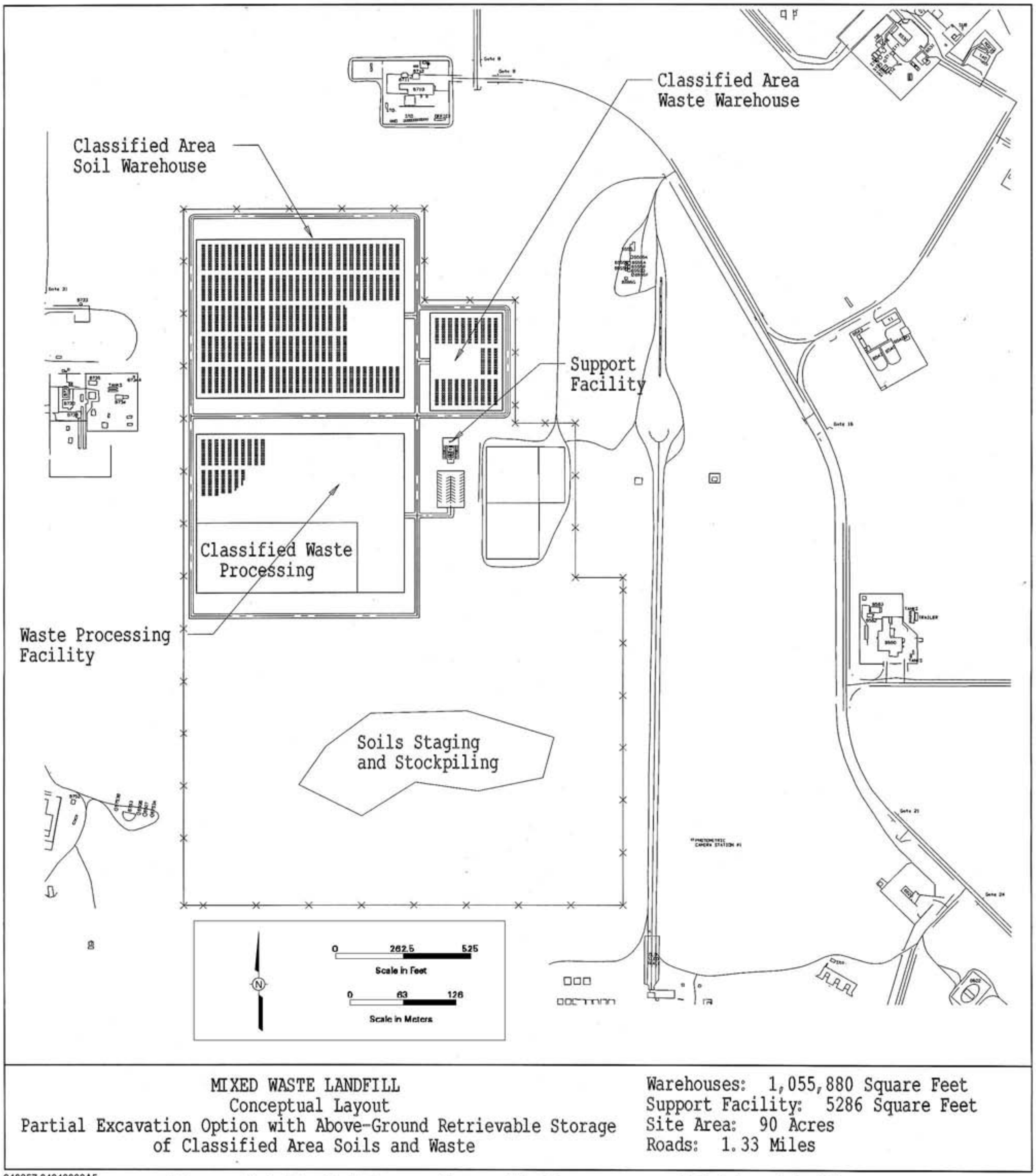



**Figure 3-2 Complete Excavation with Aboveground Retrievable Storage and Backfilling**



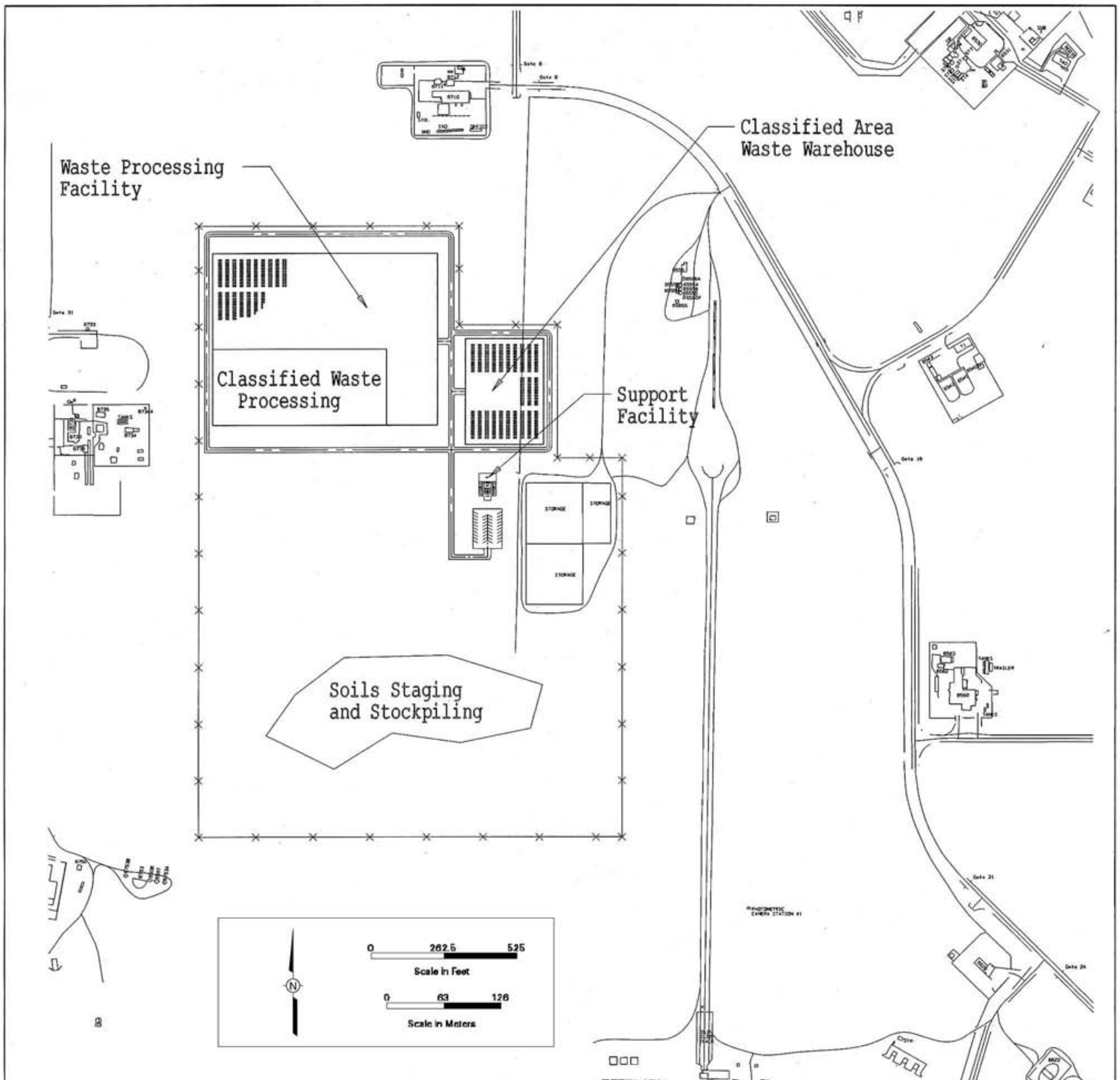
840857.04040000A4

**Figure 3-3 Complete Excavation with Offsite Disposal and Backfilling**




840857.04040000A5

**Figure 3-4 Partial Excavation with Aboveground Retrievable Storage**

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MIXED WASTE LANDFILL
Conceptual Layout
Partial Excavation with Aboveground Retrievable Storage
of Classified Area Waste and Backfilling

Warehouses: 579,140 Square Feet
Support Facility: 5286 Square Feet
Site Area: 66.75 Acres
Roads: 1 Mile

**Figure 3-5 Partial Excavation with Aboveground Retrievable Storage and Backfilling**

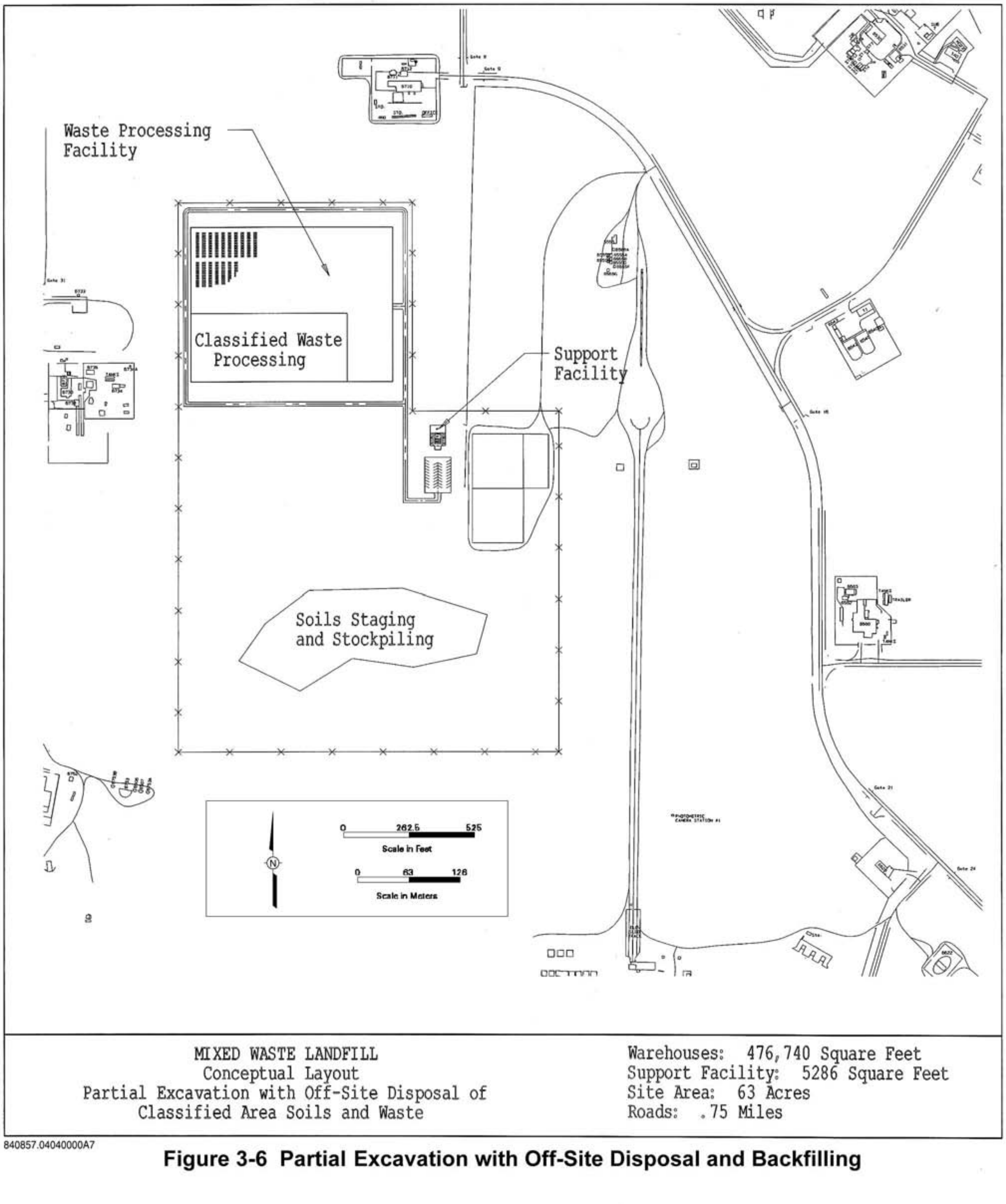


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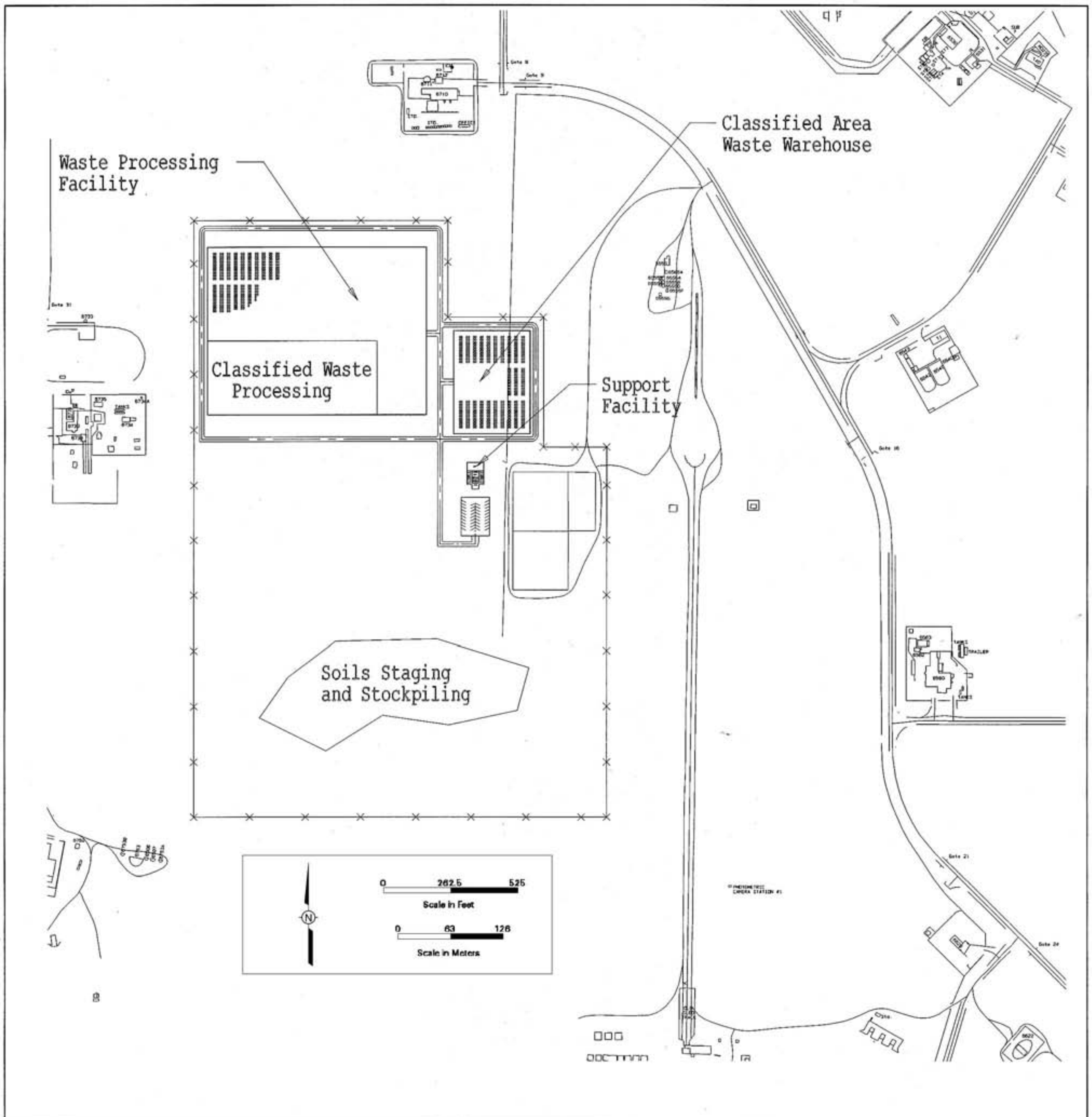
**Figure 3-6 Partial Excavation with Off-Site Disposal and Backfilling**




MIXED WASTE LANDFILL
Conceptual Layout
Future Partial Excavation with Aboveground Retrievable Storage of Classified Area Waste and Backfilling

Warehouses: 579,140 Square Feet
Support Facility: 5286 Square Feet
Site Area: 66.75 Acres
Roads: 1 Mile

840857.04040000A8

**Figure 3-7 Future Excavation**

# ATTACHMENT B

**Revised Tables**
**From the**
**Mixed Waste Landfill**
**Corrective Measures Study**

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Excavation/ Storage/ Treatment/ Disposal | Complete Excavation with Aboveground, Retrievable Storage: This technology would involve complete excavation of the MWL and permanent storage of wastes in an on-site, aboveground, retrievable storage facility. This technology would require on-site capabilities for removal, shielding, handling, characterization, repackaging, transport, and storage of radioactive and mixed waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. *This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term.* Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and aboveground retrievable storage would require the construction of secure, high-bay warehouses to stockpile, process, store, and monitor waste. Regulations would limit the duration and storage of hazardous and mixed waste, and pretreatment of waste may be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. | | | | |

Refer to footnotes at end of table.

## Table 2-1 (Continued)
## Description and Evaluation of General Corrective Measures

| Corrective Measure | Technology Description | Technology Evaluation | | |
|---|---|---|---|---|
| | | Responsive to Corrective Action Objectives | Implementability | Performance |
| Excavation/ Storage/ Treatment/ Disposal | Complete Excavation with Off-Site Disposal: This technology would involve complete excavation of the MWL and shipment of wastes to a licensed, off-site facility. This technology would require on-site capabilities for removal, shielding and handling, and temporary on-site facilities for characterization, pretreatment, and repackaging prior to shipment and disposal of the waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. *This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term.* Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and off-site disposal would require the construction of secure, high-bay warehouses to stockpile, process, package, store, and ship waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment of waste, including demilitarization of classified waste, may be required before shipment. Transportation of waste to an off-site facility may pose DOT and public health concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. | | | | |

Refer to footnotes at end of table.

## Table 2-1 (Continued)
## Description and Evaluation of General Corrective Measures

| Corrective Measure | Technology Description | Technology Evaluation: Responsive to Corrective Action Objectives | Technology Evaluation: Implementability | Technology Evaluation: Performance |
|---|---|---|---|---|
| Excavation/ Storage/ Treatment/ Disposal | Partial Excavation with Aboveground Retrievable Storage: This technology would involve excavation of the classified area of the MWL and permanent storage of wastes in an on-site, aboveground, retrievable storage facility. The classified area was selected because it contains various radioactive sources, tritium, uranium, and activation and fission products. This technology would require on-site capabilities for removal, shielding, handling, characterization, repackaging, transport, and storage of radioactive and mixed waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. *This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term.* Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and aboveground retrievable storage would require the construction of secure, high-bay warehouses to stockpile, process, store, and monitor waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment of waste would be required before permanent storage. It is likely that some waste would need to be shipped off site for treatment and disposal. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization. | | | | |

Refer to footnotes at end of table.

**Table 2-1 (Continued)**
**Description and Evaluation of General Corrective Measures**

| Corrective Measure | Technology Description | Technology Evaluation: Responsive to Corrective Action Objectives | Technology Evaluation: Implementability | Technology Evaluation: Performance |
|---|---|---|---|---|
| Excavation/ Storage/ Treatment/ Disposal | Partial Excavation with Off-Site Disposal: This technology would involve excavation of the classified area of the MWL and shipment of wastes to a licensed, off-site facility for disposal. The classified area was selected because it contains radioactive sources, tritium, activation products, and wastes that pose national security concerns. This technology would require on-site capabilities for removal, shielding, handling, and temporary on-site facilities for characterization, pretreatment, and repackaging prior to shipment and disposal of the waste. | Yes | Yes | Good |
| Comments | | | | |
| This technology is directly responsive to Corrective Action Objectives 2, 3, and 4. *This technology is not responsive to Corrective Action Objective 1 in the short term; however, it is responsive to Corrective Action Objective 1 in the long term.* Excavation involves extensive intrusive activity and direct exposure of site workers to radioactive materials. This technology is technically and administratively implementable. Appropriate time, distance, and shielding to protect site workers would require the use of remote handling and/or robotic equipment. Fugitive emissions generated from excavation activities may pose significant health risks to site workers and the public. Excavation and off-site disposal would require the construction of secure, high-bay warehouses to stockpile, process, package, store, and ship waste. Regulations would limit the duration of storage of hazardous and mixed waste, and pretreatment, including demilitarization of classified waste, may be required before shipment. Transportation of waste to an off-site facility must be in compliance with DOT regulations. As with other radioactive waste shipments, such transportation may raise public concerns. The acceptance of waste by an off-site disposal facility may be limited by pretreatment requirements and/or facility-specific waste acceptance criteria. The unclassified area of the landfill would require additional technology for remediation such as containment or stabilization. | | | | |

Refer to footnotes at end of table.

## Table 3-1
## Development of Corrective Measures Alternatives for the MWL

| General Corrective Measure | Alternative | Description | Technology: NFA | Long-Term Monitoring | Long-Term Surveillance & Maintenance | Long-Term Access Controls | Vegetative Soil Cover | RCRA Subtitle C Cap | Bio-Intrusion Barrier | Complete Excavation with Aboveground Retrievable Storage | Complete Excavation with Off-Site Disposal | Partial Excavation with Aboveground Retrievable Storage | Partial Excavation with Off-Site Disposal | Future Excavation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I.a | NFA with ICs | X | X | X | X | | | | | | | | |
| Containment | III.a | Bio-Intrusion Barrier | | X | X | X | | | X | | | | | |
| | III.b | Vegetative Soil Cover | | X | X | X | X | | | | | | | |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | | X | X | X | X | | X | | | | | |
| | III.d | RCRA Subtitle C Cap | | X | X | X | | X | | | | | | |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | | X | X | X | | X | X | | | | | |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | | | | | | | | X | | | | |
| | V.b | Complete Excavation with Off-Site Disposal | | | | | | | | | X | | | |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | | | | X | | | | | | X | | |
| | V.d | Partial Excavation with Off-Site Disposal | | | | X | | | | | | | X | |
| | V.e | Future Excavation | | X | X | X | | | | | | | | X |

IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act

**Table 3-2**
**Estimated Direct Costs for MWL Corrective Measures Alternatives**

| General Corrective Measure | Alternative | Description | Direct Cost |
|---|---|---|---|
| | I.a | NFA with ICs | $1,082,143 |
| Containment | III.a | Bio-Intrusion Barrier | $2,201,668 |
| | III.b | Vegetative Soil Cover | $1,953,501 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | $2,527,007 |
| | III.d | RCRA Subtitle C Cap | $2,850,872 |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | $3,636,474 |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage—Option A | $545,620,660 |
| | | Complete Excavation with Aboveground Retrievable Storage—Option B | $416,018,751 |
| | V.b | Complete Excavation with Off-Site Disposal—Option A | $702,088,516 |
| | | Complete Excavation with Off-Site Disposal—Option B | $579,110,303 |
| | V.c | Partial Excavation with Aboveground Retrievable Storage—Option A | $139,718,215 |
| | | Partial Excavation with Aboveground Retrievable Storage—Option B | $103,569,857 |
| | V.d | Partial Excavation with Off-Site Disposal—Option A | $157,360,724 |
| | | Partial Excavation with Off-Site Disposal—Option B | $116,638,183 |
| | V.e | Future Excavation | *$211,544,567* |

IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act

## Table 3-3
## Cost Breakdown for Individual Excavation Alternatives

| Alternative | Description | Cost of Excavation, Characterization, and Transportation | Cost of Aboveground Retrievable Storage Facility and/or Waste Processing Facility | Total Direct Cost |
|---|---|---|---|---|
| V.a | Complete Excavation with Aboveground Retrievable Storage—Option A | $420,059,569 | $125,561,091 | $545,620,660 |
| | Complete Excavation with Aboveground Retrievable Storage—Option B | $367,196,113 | $48,822,638 | $416,018,751 |
| V.b | Complete Excavation with Off-Site Disposal—Option A | $653,265,878 | $48,822,638 | $702,088,516 |
| | Complete Excavation with Off-Site Disposal—Option B | $530,287,665 | $48,822,638 | $579,110,303 |
| V.c | Partial Excavation with Aboveground Retrievable Storage—Option A | $97,997,927 | $41,720,288 | $139,718,215 |
| | Partial Excavation with Aboveground Retrievable Storage—Option B | $79,510,583 | $24,059,274 | $103,569,857 |
| V.d | Partial Excavation with Off-Site Disposal—Option A | $138,479,388 | $18,881,336 | $157,360,724 |
| | Partial Excavation with Off-Site Disposal—Option B | $97,756,847 | $18,881,336 | $116,638,183 |
| V.e | Future Excavation | *$211,544,567* | $24,059,274 | *$235,603,841* |

## Table 3-4
## Summary of Development of Corrective Measures Alternatives for the MWL (Chapter 3.0)

| General Corrective Measure | Alternative | Description | Effectiveness at Meeting Corrective Action Objectives: Minimize Exposure to Workers, the Public, and Wildlife | Limit Migration of Contaminants to Groundwater | Minimize Biological Intrusion into Waste | Prevent or Limit Human Intrusion | Implementability: Constructability Concerns | Worker Health and Safety Risk | Maintenance Requirements | Evaluation Summary |
|---|---|---|---|---|---|---|---|---|---|---|
| | I.a | NFA with ICs | Yes | Yes | Yes | Yes | Insignificant | Low | Minimal | Suitable |
| Containment | III.a | Bio-Intrusion Barrier | Yes | No | Yes | Yes | Minimal | Low | Minimal | Unsuitable |
| | III.b | Vegetative Soil Cover | Yes | Yes | Yes | Yes | Minimal | Low | Minimal | Suitable |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | Yes | Yes | Yes | Yes | Minimal | Low | Minimal | Suitable |
| | III.d | RCRA Subtitle C Cap | Yes | No | Yes | Yes | Moderate | Low | Moderate | Unsuitable |
| | III.e | RCRA Subtitle C Cap with Bio-Intrusion Barrier | Yes | No | Yes | Yes | Moderate | Low | Moderate | Unsuitable |
| Excavation | V.a | Complete Excavation with Aboveground Retrievable Storage | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.b | Complete Excavation with Off-Site Disposal | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.c | Partial Excavation with Aboveground Retrievable Storage | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.d | Partial Excavation with Off-Site Disposal | No[a] | Yes | Yes | Yes | Significant | High | Moderate | Unsuitable |
| | V.e | Future Excavation | Yes | Yes | Yes | Yes | Significant | Medium | Moderate | Suitable |

IC Institutional Controls
MWL Mixed Waste Landfill
NFA No Further Action
RCRA Resource Conservation and Recovery Act

[a]*This alternative's failure in meeting Corrective Action Objective 1 is limited to the short term because of the increased exposure during excavation. In the long term, this alternative meets Corrective Action Objective 1 in minimizing exposure to workers, the public, and wildlife.*

**Table 4-1**
**Summary Evaluation of MWL Candidate Corrective Measures Alternatives**

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| **Long-Term Reliability and Effectiveness** | | | | |
| Magnitude of Remaining Risk(s) after Implementation of the Alternative | Nonrad: HI = 0.00; excess cancer risk = 1E-9; risk below NMED guidelines.<br><br>Rad: TEDE = 3.3E-1 mrem/yr; excess cancer risk = 2.2E-6; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 2.4E-5 mrem/yr; excess cancer risk = 3.4E-10; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 2.4E-5 mrem/yr; excess cancer risk = 3.4E-10; below EPA guidelines.<br><br>Ecorisk less than NMED guidelines.<br><br>Risk would decrease with time due to radioactive decay. Risk would increase if erosion or intrusion occurs should ICs be relinquished. | Nonrad: HI = 0.00; excess cancer risk ≈ 0.00; risk below NMED guidelines.<br><br>Rad: TEDE = 0.00 mrem/yr; excess cancer risk = 0; below EPA guidelines.<br><br>Ecorisk approximately 0.<br><br>Risk approaches 0 assuming COCs are removed to background screening levels. |
| Extent of Long-Term Monitoring | Minimum of 70 years. The operational cover will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | Minimum of 70 years. The vegetative soil cover will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | Minimum of 70 years. The vegetative cover with bio-intrusion barrier will be monitored and maintained to prevent ponding and intrusion of deep-rooted plants and promote surface runoff and growth of native vegetation. ICs will include environmental monitoring, site surveillance and maintenance, access controls, and groundwater and tritium monitoring. | No monitoring required after excavation. |
| Uncertainties Associated with Leaving Waste in Place | Low | Low | Low | NA – No waste left in place. |

Refer to footnotes at end of table.

**Table 4-1 (Continued)**
**Summary Evaluation of MWL Candidate Corrective Measures Alternatives**

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| Potential for Failure of Alternative | Very Low | Very Low | Very Low | NA – No waste left in place. |
| **Reduction in Toxicity, Mobility, and Volume** | | | | |
| Reduction in Toxicity | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | No reduction other than natural radioactive decay. Reduction of radiological toxicity can be achieved only by the passage of time. | Relative to the landfill, toxicity will be reduced. Relative to the waste, no reduction other than natural radioactive decay. |
| Reduction in Mobility | Minimal bio-intrusion, human access, and inadvertent human intrusion protection. | Minimized by limiting water infiltration, bio-intrusion, human access, and inadvertent human intrusion. | Minimized by limiting water infiltration, bio-intrusion, human access, and inadvertent human intrusion. | Eliminated by removal of waste from landfill disposal cells. |
| Reduction in Volume | None | None | None | Potential increase in volume |
| **Short-Term Effectiveness** | | | | |
| Short-Term Reduction in Existing Risk(s) | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE unchanged.<br><br>Ecorisk unchanged. | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE reduced by 3.3E-1 mrem/yr; excess cancer risk reduced by 2.2E-6.<br><br>Ecorisk reduced. | Nonrad:<br>Incremental HI = 0.07.<br>Incremental excess cancer risk = 3.31E-6.<br>Risk below NMED guidelines<br><br>Rad:<br>TEDE reduced by 3.3E-1 mrem/yr; excess cancer risk reduced by 2.2E-6.<br><br>Ecorisk reduced. | Nonrad:<br>None (assumes maximum concentrations reported during characterization).<br>Risk below NMED guidelines.<br><br>Rad:<br>TEDE increased by 3.23E+3 mrem/yr; excess cancer risk increased by 3.7E-2.<br><br>Ecorisk unchanged. |
| Time Needed to Achieve Reduction in Risk(s) | 1 month | 4 months | 4 months | 2 years (excavation only) |

Refer to footnotes at end of table.

## Table 4-1 (Concluded)
## Summary Evaluation of MWL Candidate Corrective Measures Alternatives

| Evaluation Criteria | MWL I.a<br>NFA with ICs | MWL III.b<br>Vegetative Soil Cover | MWL III.c<br>Vegetative Soil Cover with Bio-Intrusion Barrier | MWL V.e<br>Future Excavation |
|---|---|---|---|---|
| Short-Term Risk(S) Posed to Site Workers, the Community, and the Environment During Implementation of the Alternative | Transportation:<br>Injuries: 1.8E-2<br>Fatalities: 4.9E-4<br><br>Implementation:<br>Injuries: 9.5E-2<br>Fatalities: 2.4E-3 | Transportation:<br>Injuries: 4.9E-2<br>Fatalities: 1.3E-3<br><br>Implementation:<br>Injuries: 2.6E-1<br>Fatalities: 3.2E-3 | Transportation:<br>Injuries: 2.5E-1<br>Fatalities: 6.6E-3<br><br>Implementation:<br>Injuries: 3.2E-1<br>Fatalities: 3.5E-3 | Transportation:<br>Injuries: 8.8E-1<br>Fatalities: 2.3E-1<br><br>Implementation:<br>Injuries: 2.2E+0<br>Fatalities: 1.1E-2 |
| **Implementability** | | | | |
| Availability of Materials, Equipment, and Contractors | Readily available | Readily available | Readily available | Readily available |
| Technical and Administrative Difficulties | None. Addition of soil presents minimal concerns. | None. Addition of compacted fill presents minimal concerns. | None. Addition of compacted fill and the barrier present moderate concerns. | Significant. Excavation and characterization activities present significant concerns. |
| Permits and Approvals | Air quality | Air quality | Air quality | Digging, rad worker, waste storage, waste treatment, air quality |
| **Cost** | | | | |
| Capital and Operation and Maintenance Costs (Net Present Value) | $1,772,882 | $4,335,274 | $7,096,859 | *$325,704,159* |

COC Contaminant of concern.
Ecorisk Ecological risk
EPA U.S. Environmental Protection Agency
HI Hazard Index
IC Institutional Controls
mrem/yr Millirem(s) per year
MWL Mixed Waste Landfill
NA Not applicable
NFA No Further Action
NMED New Mexico Environment Department
Rad Radiological
TEDE Total Effective Dose Equivalent

**Table 4-2**
**Summary of the MWL CMS Alternatives Risk Results**

| Alternatives | Human Health (IND) | | Ecological | | Transportation and Remediation Total Predicted Injuries and Fatalities | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Transportation | | Remediation | |
| | Nonrad | Rad | Nonrad | Rad (rad/day) | Injuries | Fatalities | Injuries | Fatalities |
| MWL Risk Baseline—NFA with No ICs | HI = 0.07<br>CR = 3E-6 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | No Transportation Risk | | No Remediation Risk | |
| MWL–Ia. NFA with ICs | HI = 0.00<br>CR = 1E-9 | TEDE = 3.3E-1 mrem/yr<br>CR = 2.2E-6 | No HQ exceedence after uncertainty addressed | Mouse = 1.6E-3<br>Owl = 1.6E-3 | 0.018 | 0.00049 | 0.095 | 0.0024 |
| MWL–IIIb. Vegetative Soil Cover | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.049 | 0.0013 | 0.26 | 0.0032 |
| MWL–IIIc. Vegetative Soil Cover with Bio-Intrusion Barrier | HI = 0.00<br>CR ≈ 0.00 | TEDE = 2.4E-5 mrem/yr<br>CR = 3.4E-10 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.25 | 0.0066 | 0.32 | 0.0035 |
| MWL–V.e Future Excavation | HI = 0.07<br>CR = 3E-6 | TEDE = 3.23E3 mrem/yr<br>CR = 3.7E-2 | HQ ≈ 0.00 | HI ≈ 0.00 | 0.88 | 0.023 | 2.22 | 0.011 |

CMS Corrective Measures Study
CR Cancer Risk
HI Hazard Index
HQ Hazard Quotient
IC Institutional Controls
IND Industrial
mrem/yr Millirem(s) per year
MWL Mixed Waste Landfill
NFA No Further Action
Rad Radiological
TEDE Total Effective Dose Equivalent

## Table 4-3
## Detailed Cost Breakdowns for Candidate Corrective Measures Alternatives, Including Capital Costs, Operation and Maintenance Costs, Administrative Costs, and Escalation

| General Corrective Measure | Alternative | Description | Cost Component | Cost Breakdown | | |
|---|---|---|---|---|---|---|
| | | | | Direct Cost[a] | Markups[b] | Total Cost |
| NFA | I.a | NFA with ICs | Capital Cost[c] | $1,082,143 | $690,739 | $1,772,882 |
| | | | Operations & Maintenance[d] | $0 | $0 | $0 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $1,772,882 |
| Containment | III.b | Vegetative Soil Cover | Capital Cost[c] | $1,953,501 | $1,525,040 | $3,478,541 |
| | | | Operations & Maintenance[d] | $309,301 | $547,432 | $856,733 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $4,335,274 |
| | III.c | Vegetative Soil Cover with Bio-Intrusion Barrier | Capital Cost[c] | $2,527,007 | $1,959,816 | $4,486,823 |
| | | | Operations & Maintenance[d] | $849,300 | $1,760,736 | $2,610,036 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $7,096,859 |
| Excavation | V.e | Future Excavation | Capital Cost[c] | *$235,603,841* | *$ 90,100,318* | *$325,704,159* |
| | | | Operations & Maintenance[d] | $0 | $0 | $0 |
| | | | Total Cost[e] (Net Present Value) | NA | NA | $325,704,159 |

[a]Direct costs include material, labor, and equipment used to implement the alternative.
[b]Markups are all costs other than direct costs that do not contribute to the alternative, and include SNL/NM's administrative costs (loads) and contingency allowances.
[c]Capital costs include construction and installation costs, equipment costs, and indirect costs such as engineering costs, legal fees, permitting fees, and startup and shakedown costs.
[d]Operation and maintenance costs are estimated for 30 years only, and include operating labor and materials costs, maintenance labor and materials costs, replacement costs, utilities, monitoring and reporting costs, administrative costs, and indirect costs.
[e]Total costs are based upon net present value, and do not include escalation.

IC Institutional Controls
NA Not applicable
NFA No Further Action
SNL/NM Sandia National Laboratories/New Mexico

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