Sandia National Laboratories/New Mexico

MIXED WASTE LANDFILL
Corrective Measures Study
Final Report
Sandia National Laboratories/ New Mexico

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Environmental
Restoration
Project

United States Department of Energy
Office of Kirtland Site Operations

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Executive Summary

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 6,300 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(s)
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 includes 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 condition, 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 2,842 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 2,000 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 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 6,300 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). Tritium activity was greatest within the upper 30 feet of the soil profile. 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 (Peace et al. September 2002) to thoroughly investigate environmental impacts associated with disposal activities at the MWL. 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 identified at the MWL during the Phase 2 RFI 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 surface and subsurface soil have been found to be anomalously high at KAFB/SNL/NM (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 1,100 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 0.294 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 8.5×10^{-6} millirems (mrem)/yr. The effective dose equivalent exposure to off-site receptors from tritium air emissions from the MWL is 1.1×10^{-5} mrem/yr, which is greater than the dose to an on-site receptor because an off-site receptor is 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 groundwater or as air emissions 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 are 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 constructability 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 potential 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 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 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 developing and evaluating 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 43 years has been minimal. The existing operational cover has performed quite well in the natural environment of the semiarid 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 management and 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) constructability, 2) site worker health and safety, and 3) site maintenance requirements.

The constructability 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

This criterion addresses the cost evaluation 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, cost detail, and cost over time reports generated by RACER for alternative development are provided in Appendices B, C, and D, respectively. Cost summary details for the aboveground retrievable storage facility are provided in Appendix E. Additional cost details are provided in Appendix F. Costs for remote handling and/or robotic excavation of the classified area are provided in Appendix G. 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 directly 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

Constructability. 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 constructability 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

Constructability. 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 constructability 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 semiarid 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

Constructability. 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 constructability 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 for 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

Constructability. 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 semiarid 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

Constructability. 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

Constructability. 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, but 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

Constructability. 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 G). 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, but 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

Constructability. 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 G). 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, but 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

Constructability. 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 G). 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. 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, but 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

Constructability. 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 G). 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 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. 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

Constructability. 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 $72,512,261. Costs for aboveground retrievable storage of waste and/or shipment of waste to an off-site, licensed facility for disposal are not included. These costs are unknown at this time but may be comparable to costs provided for previous excavation alternatives. 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. Even though excavation alternatives V.a, V.b, V.c, and V.d developed in Chapter 3.0 were not retained for detailed evaluation in Chapter 4.0, an excavation alternative is evaluated in detail in Appendix H because of public interest.

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. An additional Alternative, V.b, Complete Excavation with Off-Site Disposal, received the same detailed evaluation even though it failed Chapter 3.0 development criteria. This evaluation was conducted because of public interest and is provided in Appendix H.

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 criteria 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 I.

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 I.

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 1,000 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 I.

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 constructability 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 east mesa 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 I.

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 1,000 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 I.

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 constructability 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 I.

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 1,000 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 I.

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 constructability 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. Disposition of waste is not determined in this evaluation because future waste disposal alternatives are unknown. 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 I.

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 I.

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. 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 the Future Excavation alternative are $106,209,085. There are no operations and maintenance or waste disposition costs for future excavation. 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, for both the number of site workers and 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 IC, 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 semiarid 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 insure 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.

6. References

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