APPENDIX I

Risk Assessment for the MWL

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THE MIXED WASTE LANDFILL: RISK ASSESSMENT REPORT

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

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

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

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

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

I. Site Description and History

SNL/NM is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico. The MWL, located 3.5 miles south of SNL/NM's central facilities and 5 miles southeast of Albuquerque International Sunport,

is a fenced, 2.6-acre compound in the north-central portion of TA-3. The elevation is 5,381 feet above mean sea level.

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

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

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

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

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

A Phase 1 RCRA Facility Investigation (RFI) was conducted in 1989 and 1990 to determine whether a release of contaminants had occurred at the site and to begin characterizing the nature and extent of possible releases. The Phase 1 investigation indicated that tritium was the primary constituent of concern (COC). No organic contaminants were identified. A Phase 2 RFI was initiated in 1992 to thoroughly determine the source of contamination, define the nature

and extent of the contamination, identify potential transport pathways for contaminants, evaluate potential risks posed by the levels of contamination identified, and recommend remedial action, if warranted, for the landfill.

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

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

I.1 MWL Groundwater Data

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

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

I.2 ISS Sampling and Closure

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

In March 2001, soil sampling was conducted as part of the formal closure process for the ISS under the direction of NMED. Soil samples were collected at 25 locations across the ISS and analyzed for RCRA metals, VOCs, SVOCs, and radionuclides. Sampling results indicated the

presence of low activities of plutonium-238 and -239, as well as uranium-238 in one area of the ISS.

II. Data Quality Objectives

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

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

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

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

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

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

Table 1
SNL/NM ER OPs Applicable to the MWL

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

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

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

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

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

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

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

Refer to footnotes at end of table.

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

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

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

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

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

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

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

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

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

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

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

III.1 Introduction

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

III.2 Nature of Contamination

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

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

III.3 Rate of Contaminant Migration

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

III.4 Extent of Contamination

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

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

IV. Comparison of Potential COCs to Background Screening Levels

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

Nondetected organic constituents not included in this risk assessment were determined to have detection limits low enough to ensure protection of human health and the environment. In order to provide conservatism in this risk assessment, the calculation used only the maximum

concentration value of each COC found for the entire site. The SNL/NM maximum background concentration (Dinwiddie September 1997) was selected to provide the background screening levels. Nonradiological COCs for the human health risk assessment also were compared to SNL/NM proposed Subpart S action levels, if appropriate (IT July 1994).

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

Each remedial alternative is summarized in the following sections. The COC selection criteria is identical for each alternative. However, due to the remedial options, the COCs may vary. For NFA with no IC, COC contamination at all depths was evaluated. For the remaining alternatives, with the exception of future excavation, a potential depth of COC contamination was limited to 0 to 5 feet bgs. It should be noted that the background screening tables are identical for the NFA with IC (Alternative I.a), vegetative soil cover (Alternative III.b), and vegetative soil cover with bio-intrusion barrier (Alternative III.c) remedial alternatives. Therefore, the table is presented only once in Section IV.2.

IV.1 MWL Risk Baseline—NFA with No IC

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

IV.2 MWL Alternative I.a—NFA with IC

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

IV.3 MWL Alternatives III.b and c

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

IV.4 MWL Alternative V.e—Future Excavation

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

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

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

Refer to footnotes at end of table.

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

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

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.

[a]Dinwiddie (September 1997), Southwest Test Area.

[b]NMED (March 1998).

[c]BCF and/or Log K_{ow} from Howard (1990).

[d]BCF and/or Log K_{ow} from Howard (1993).

[e]BCF and/or Log K_{ow} from Micromedex (1998).

[f]BCF and/or Log K_{ow} from Yanicak (March 1997).

[g]BCF from Neumann (1976).

[h]BCF and/or Log K_{ow} from Howard (1989).

[i]BCF from Vanderploeg et al. (1975).

[j]BCF from Callahan et al. (1979).

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

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

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

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

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

[i]Parameter was nondetect. Concentration is one half of detection limit.
[j]BCF from Callahan et al. (1979).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Refer to footnotes at end of table.

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

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

Note: **Bold** indicates COCs that exceed background screening values and/or are bioaccumulators.

[a]Dinwiddie (September 1997), Southwest Test Area.

[b]NMED (March 1998).

[c]BCF and/or Log K_{ow} from Howard (1990).

[d]BCF and/or Log K_{ow} from Howard (1993).

[e]BCF and/or Log K_{ow} from Micromedex (1998).

[f]BCF and/or Log K_{ow} from Yanicak (March 1997).

[g]BCF from Neumann (1976).

[h]BCF and/or Log K_{ow} from Howard (1989).

[i]BCF from Vanderploeg et al. (1975).

[j]BCF from Callahan et al. (1979).

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

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

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

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

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

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

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

V. Fate and Transport

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

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

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

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

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

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

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

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

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

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

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

Table 12
Summary of Fate and Transport at the MWL

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

MWL = Mixed Waste Landfill.

VI. Human Health Risk Assessment Analysis

VI.1 Introduction

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

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

VI.2 Step 1. Site Data

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

VI.3 Step 2. Pathway Identification

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

Pathway Identification

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

VI.4 Step 3. COC Screening Procedures

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

VI.4.1 Background Screening Procedure

VI.4.1.1 Methodology

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

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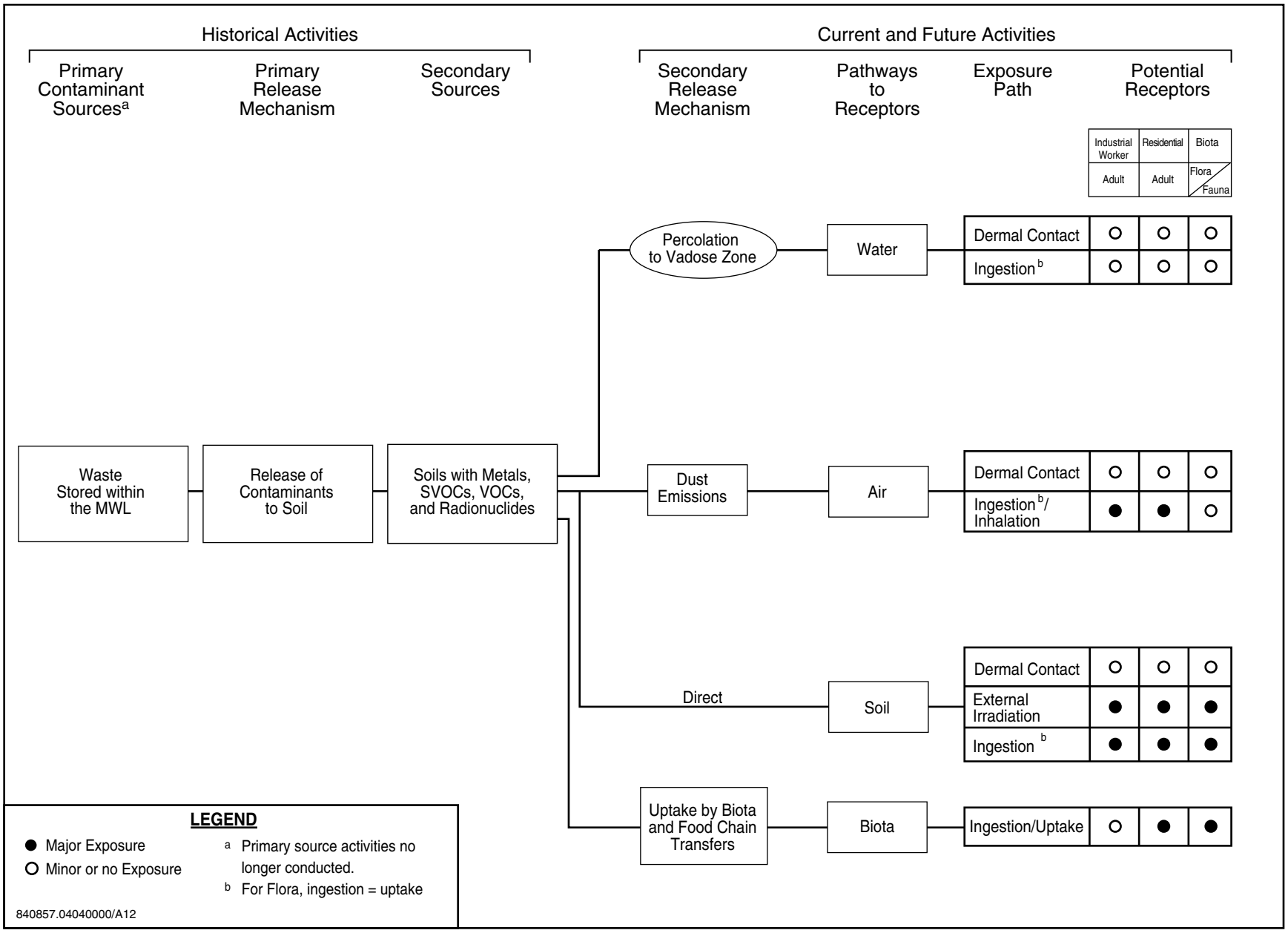

Figure 1
Conceptual Model Flow Diagram for MWL

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

VI.4.1.2 Results for MWL Risk Baseline—NFA with No IC

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

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

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

VI.4.1.3 Results for MWL Alternative I.a—NFA with IC

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

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

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

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

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

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

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

VI.4.2 Subpart S Screening Procedure

VI.4.2.1 Methodology

The maximum concentrations of nonradiological COCs not eliminated during the background screening process were compared with action levels (IT July 1994) calculated using methods and equations promulgated in the proposed RCRA Subpart S (EPA July 1990) and Risk Assessment Guidance for Superfund (RAGS) (EPA 1989) documentation. Accordingly, all calculations are based upon the assumption that receptor doses from both toxic and potentially carcinogenic compounds result most significantly from the ingestion of contaminated soil. If there were 10 or fewer COCs, and each had a maximum concentration of less than 1/10 the

action level, then the site was judged to pose no significant hazard to human health. If there were more than 10 COCs, the Subpart S screening procedure was not performed.

VI.4.2.2 Results

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

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

VI.5 Step 4. Identification of Toxicological Parameters

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

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

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

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

VI.6 Step 5. Exposure Assessment and Risk Characterization

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

Table 13
Toxicological Parameter Values for the MWL Nonradiological COCs

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

Refer to footnotes at end of table.

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

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

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

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

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

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

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

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

VI.6.1 Exposure Assessment

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

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

VI.6.2 Risk Characterization

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

VI.6.2.1 MWL Risk Baseline—NFA with No IC

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

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

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

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

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

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

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

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

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

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

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

VI.6.2.2 MWL Alternative I.a—NFA with IC

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

For the radiological COCs, the incremental TEDE for the residential land use scenario is 1.7E-3 mrem/yr. The guideline being used is an excess TEDE of 75 mrem/yr (SNL/NM February 1998) for a complete loss of IC (residential land use in this case); the calculated dose value for the MWL for the residential land use is well below this guideline. Consequently, the MWL is eligible for unrestricted radiological release because the residential land use scenario

results in an incremental TEDE to the on-site receptor of less than 75 mrem/yr. The estimated excess cancer risk is 1.0E-8. The excess cancer risk from the nonradiological COCs and the radiological COCs is not additive, as noted in RAGS (EPA 1989).

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

VI.6.2.5 MWL Alternative V.e—Future Excavation

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

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

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

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

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

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

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

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

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

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

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

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

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

For the radiological COCs under the industrial land use scenario for the various alternatives (with the exception of future excavation), the incremental TEDE ranged from 3.3E-1 to 2.4E-5 mrem/yr, which is less than EPA's numerical guideline of 15 mrem/yr. The EPA weight-of-evidence classification system for carcinogenicity (EPA 1989) states that all radioactive materials are considered to be Class A carcinogens for high dose and high dose

rate (i.e., greater than 50 rem per year). However, for low-level environmental exposures, the carcinogenic effect has not been observed and documented. Nevertheless, calculated risks from projected doses are presented for perspective, assuming that low doses and low dose rates produce cancer effects that are linearly extrapolated from high doses and high dose rates.

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

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

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

VI.8 Step 7. Uncertainty Discussion

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

validated in accordance with SNL/NM procedures and reviewed by outside, independent sources. Consequently, there is little uncertainty associated with the data quality used to perform the risk assessment at the MWL.

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

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

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

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

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

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

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

mobile and do not volatilize. The following assumptions were made in running the RBCA transport model:

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

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

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

VI.9 Summary

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

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

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

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

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

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

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

Table 22
Results of the Bounding Risk Analysis for the MWL

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

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

VII. Ecological Risk Assessment

VII.1 Introduction

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

VII.2 Scoping Assessment

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

VII.2.1 Data Assessment

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

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

Organic analytes that were detected in soil include the following:

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

VII.2.2 Bioaccumulation

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

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

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

VII.2.3 Fate and Transport Potential

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

VII.2.4 Scoping Risk-Management Decision

Based upon information gathered through the scoping assessment, it was concluded that complete ecological pathways may be associated with this site and that COPECs also exist at

the site. As a consequence, a risk assessment was deemed necessary to predict the potential level of ecological risk associated with the site.

VII.3 Assessment

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

Components within the risk assessment include the following:

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

VII.3.1 Problem Formulation

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

VII.3.1.1 Ecological Pathways and Setting

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

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

VII.3.1.2 COPECs

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

VII.3.1.3 Ecological Receptors

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

VII.3.2 Exposure Estimation

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

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

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

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

Table 23
Exposure Factors for Ecological Receptors at the MWL

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

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

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

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

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

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

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

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

VII.3.3 Ecological Effects Evaluation

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

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

Table 26
Toxicity Benchmarks for Ecological Receptors at the MWL

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

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

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

VII.3.4 Risk Characterization

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

VII.3.4.1 MWL NFA Risk Baseline Analysis plus MWL Alternative I.a—NFA with IC

Maximum concentrations in soil and estimated dietary exposures were compared to plant and wildlife benchmark values, respectively. Results of these comparisons are presented in Table 27. HQs are used to quantify the comparison with benchmarks for plants and wildlife exposure.

No analytes resulted in HQs exceeding unity for plants, the herbivorous deer mouse, or the burrowing owl. Barium was the only analyte that exhibited HQs greater than unity for the omnivorous and insectivorous deer mouse. HQs for plants could not be determined for acetone, methylene chloride, bis(2-ethylhexyl) phthalate, and di-n-octyl phthalate because of insufficient toxicity information. For the same reason, HQs for the burrowing owl could not be determined for silver, acetone, methylene chloride, toluene, and di-n-octyl phthalate. As directed by the NMED, HIs were calculated for each of the receptors (the HI is the sum of chemical-specific HQs for all pathways for a given receptor). All receptors, except the herbivorous deer mouse, had total HIs greater than unity, with a maximum HI of 2.9E+0 for the insectivorous deer mouse.

Tables 28 and 29 summarize the dose-rate model results for exposure to the radionuclides tritium, Pu-238, Pu-239, and U-238. The total radiation dose rate to the deer mouse was predicted to be 1.6E-3 rad/day and that for the burrowing owl was also predicted to be 1.6E-3 rad/day. The dose rates for the deer mouse and the burrowing owl are considerably less than the benchmark of 0.1 rad/day.

VII.3.4.2 MWL Alternatives III.b and III.c—Operational and Vegetative Soil Cover Designs

The ecological risk assessment process has limited the potential depth of exposure to 5 feet bgs. With the addition of remedial cover for the various alternatives, the depth of COCs in the soil will be greater than 5 feet bgs. Therefore, ecological risk is not evaluated for these alternatives. The NFA alternative summarizes both the current conditions at the site and potential risk during the implementation of the remedial alternatives.

VII.3.4.3 MWL Alternative V.e—Future Excavation

Section VII.3.4.1 summarizes the estimated risk under the future excavation alternative. The risks are the same due to the assumption that maximum concentrations are presented and evaluated for risk in Section VII.3.4.1.

VII.3.5 Uncertainty Assessment

Many uncertainties are associated with the characterization of ecological risks at the MWL for the NFA alternatives. These uncertainties result from assumptions used in calculating risk that

Table 27
HQs for Ecological Receptors at the MWL

Constituent of Potential Ecological Concern	Plant HQ	Deer Mouse HQ (Herbivorous)	Deer Mouse HQ (Omnivorous)	Deer Mouse HQ (Insectivorous)	Burrowing Owl HQ
Inorganic					
Barium	3.4E-1	4.2E-1	**1.5E+0**	**2.5E+0**	1.8E-2
Cadmium	1.2E-1	1.7E-2	1.8E-2	1.9E-2	6.0E-4
Mercury (inorganic)	1.7E-1	5.7E-4	5.7E-4	5.7E-4	1.0E-2
Mercury (organic)	1.7E-1	1.3E-1	1.3E-1	1.3E-1	7.1E-1
Selenium	5.7E-1	1.2E-1	1.7E-1	2.3E-1	3.7E-2
Silver	4.8E-1	4.4E-3	2.8E-3	1.2E-3	–
Organic					
Acetone	–	7.6E-2	4.7E-2	1.8E-2	–
Methylene chloride	–	1.0E-3	1.5E-3	2.1E-3	–
Toluene	1.0E-5	1.1E-5	1.1E-4	2.0E-4	–
Bis(2-ethylhexyl) phthalate	–	1.3E-5	9.3E-3	1.9E-2	4.8E-1
Di-n-butyl phthalate	8.0E-4	4.4E-6	4.8E-4	9.6E-4	9.3E-3
Di-n-octyl phthalate	–	7.8E-6	1.6E-3	3.3E-3	–
HI[a]	**1.7E+0**	7.7E-1	**1.9E+0**	**2.9E+0**	**1.3E+0**

Note: **Bold** values indicate the HQ or HI exceeds unity.
[a]The HI is the sum of individual HQs using the value for organic mercury as a conservative estimate of the HI.
HI = Hazard index.
HQ = Hazard quotient.
MWL = Mixed Waste Landfill.
– = Insufficient toxicity data available for risk estimation purposes.

Table 28
Internal and External Dose Rates for
Deer Mice Exposed to Radionuclides at the MWL and the ISS

Radionuclide	Maximum Concentration (pCi/g)	Internal Dose (rad/day)	External Dose (rad/day)	Total Dose (rad/day)
Tritium	1.1E+3	1.2E-3	NA[a]	1.2E-3
Pu-238	0.103	2.1E-7	1.3E-8	2.2E-7
Pu-239	0.0107	2.05E-8	5.3E-10	2.1E-8
U-238	2.41	2.0E-5	3.7E-4	3.9E-4
Total				**1.6E-3**

[a]NA: External dose from tritium assumed to be insignificant.
ISS = Interim Storage Site.
MWL = Mixed Waste Landfill.
NA = Not applicable.
pCi/g = Picocurie(s) per gram.

Table 29
Internal and External Dose Rates for
Burrowing Owls Exposed to Radionuclides at the MWL and the ISS

Radionuclide	Maximum Concentration (pCi/g)	Internal Dose (rad/day)	External Dose (rad/day)	Total Dose (rad/day)
Tritium	1.1E+3	1.2E-3	NA[a]	1.2E-3
Pu-238	0.103	2.1E-7	1.3E-8	2.2E-7
Pu-239	0.0107	2.05E-8	5.3E-10	2.1E-8
U-238	2.41	1.0E-5	3.7E-4	3.8E-4
Total				**1.6E-3**

[a]NA: External dose from tritium assumed to be insignificant.
ISS = Interim Storage Site.
MWL = Mixed Waste Landfill.
NA = Not applicable.
pCi/g = Picocurie(s) per gram.

may overestimate or underestimate true risk presented at a site. For this risk assessment, assumptions are made that are more likely to overestimate exposures and risk rather than to underestimate them. These conservative assumptions are used to be more protective of the ecological resources potentially affected by the site. Conservatisms incorporated into this risk assessment include the use of maximum analyte concentrations measured in soil samples to evaluate risk, the use of wildlife toxicity benchmarks based upon NOAEL values, the incorporation of strict herbivorous and strict insectivorous diets for predicting the extreme HQ values for the deer mouse, and the use of 1.0 as the area use factor for wildlife receptors regardless of seasonal use or home range size. Each of these uncertainties, which are consistent among each of the Solid Waste Management Unit-specific ecological risk assessments, is discussed in greater detail in the uncertainty section of the ecological risk assessment methodology document for the SNL/NM ER Program (IT July 1998).

Uncertainties associated with the estimation of risk to ecological receptors following exposure to tritium, U-238, Pu-238 and Pu-239 are primarily related to those inherent in the radionuclide-specific data. Radionuclide-dependent data are measured values that have their associated errors, which are typically negligible. The dose-rate models used for these calculations are based upon conservative estimates of receptor shape, radiation absorption by body tissues, and intake parameters. The goal is to provide a realistic but conservative estimate of a receptor's exposure to radionuclides in soil, both internally and externally.

In 1997, samples of aboveground plant and small mammal tissues were collected from the MWL and analyzed for inorganic constituents and radionuclides. Although the detection limits for these analyses were too high for quantitation of concentrations in small mammal tissues, the fact that more than 20 small mammals were captured at this site indicates that it supports a viable small mammal community. In the plant tissue samples, most analytes were also below the corresponding detection limits. However, of those that were detected (barium, total chromium, copper, and zinc), only barium is identified as a COPEC within this risk assessment. Barium was measured at lower concentrations than predicted by the risk assessment model by a factor of 4. These results indicate that the effect of conservatism in the risk assessment models are significant for this COPEC.

In the estimation of ecological risk, background concentrations are included as a component of maximum on-site concentrations. As shown in Table 30, conservatisms in the modeling of exposure and risk for barium result in the prediction of risk to the omnivorous and insectivorous deer mice when exposed at background concentrations. For this COPEC, more than 77 percent of the maximum on-site concentration may be associated with background. Therefore, because of the uncertainties associated with exposure and toxicity, it is unlikely that barium, with exposure concentrations largely attributable to background, presents significant ecological risk to either the omnivorous and insectivorous deer mouse.

To assess the potential degree of overestimation caused by the use of the maximum measured soil concentrations in the exposure assessment, average soil concentrations (using full detection limits for nondetections and the maximum value for duplicate samples) were applied. For barium, the 95th upper confidence limit (125 mg/kg) was less than the background value of 130 mg/kg. Thus, for barium, the use of mean soil concentrations reduces the HQs to values less than the HQs derived from background concentrations.

Based upon this uncertainty analysis, ecological risks are very low. HQs greater than unity were initially predicted for barium; however, closer examination of the exposure assumptions

Table 30
HQs for Ecological Receptors Exposed to Background Concentrations at the MWL

Constituent of Potential Ecological Concern	Plant HQ	Deer Mouse HQ (Herbivorous)	Deer Mouse HQ (Omnivorous)	Deer Mouse HQ (Insectivorous)	Burrowing Owl HQ
Inorganic					
Barium	2.6E-1	3.3E-1	**1.1E+0**	**2.0E+0**	1.4E-2
Cadmium	1.7E-1	2.4E-2	2.5E-2	2.6E-2	8.1E-4
Mercury (inorganic)	1.7E-1	5.7E-4	5.7E-4	5.7E-4	1.0E-2
Mercury (organic)	1.7E-1	1.3E-1	1.3E-1	1.3E-1	7.1E-1
Selenium	5.0E-1	1.0E-1	1.5E-1	2.0E-1	3.3E-2
Silver	2.5E-1	2.3E-3	1.4E-3	6.0E-4	–
HI[a]	**1.4E+0**	5.8E-1	**1.4E+0**	**2.3E+0**	7.6E-1

Note: **Bold** text indicates the HQ or HI exceeds unity.
[a]The HI is the sum of individual HQs using the value for organic mercury as a conservative estimate of the HI.
HI = Hazard index.
HQ = Hazard quotient.
MWL = Mixed Waste Landfill.
– = Insufficient toxicity data available for risk estimation purposes.

revealed an overestimation of risk primarily attributed to exposure concentration and background risk.

VII.3.6 Risk Interpretation for NFA Risk Baseline Analysis and NFA Alternative with IC (MWL Alternative I.a)

Ecological risks associated with the MWL were estimated through a screening assessment that incorporated site-specific information when available. Overall, risks to ecological receptors are expected to be very low because predicted risks are based upon exposures to COPECs calculated from the maximum COPEC concentrations measured in soil samples. Predicted risks from exposure to barium were attributed to using these maximum detected values and conservatisms in the risk models. Mean barium concentrations were less than the background screening level. Because the background screening level for barium resulted in a maximum HQ of 2.0, risk from barium is unlikely to be significant. This conclusion is supported by field data indicating the presence of viable populations of small mammals on the site. Based upon this final analysis, ecological risks are very low.

VII.3.7 Risk Interpretation for Future Excavation Alternative (MWL Alternative V.e)

Section VII.3.6 presents the risk interpretation for the future excavation scenario. The risk interpretation is consistent as for the NFA with and without ICs due to the assumption that risk interpretation from site maximum concentrations are presented and evaluated in Section VII.3.6.

VIII. Transportation and Remediation Injuries and Fatalities

The following sections assess the potential injuries and fatalities that may occur during implementation of the remedial alternatives being evaluated for the MWL.

VIII.1 Methodology and Scenarios for Transportation Injuries and Fatalities

To evaluate risk, three components must be defined: scenarios, likelihood, and consequence. Scenarios consist of one basic failure event followed by subsequent failures that lead to some undesirable outcome. Likelihood describes how often the scenario is expected to occur and may be expressed as a probability, which is an expression of the belief that something will or will not occur. Probability is a unitless number between zero and one. Likelihood may also be expressed as a frequency (e.g., accidents per mile). The final component of risk is consequence, the undesired results of the scenario. To evaluate consequences, the source term (what is released, how much, and what form it takes) must be defined, and, for release scenarios, dispersion of the source term must be predicted. However, for this evaluation only the direct impact of potential transportation accidents will be evaluated (i.e., injuries and fatalities). Chemical or radionuclide exposure and risk are not quantified. Only vehicle-related consequences that include traffic injuries and fatalities are quantified.

The input parameters used in the risk assessment can be broadly divided into three categories:

- Cargo-specific parameters—These parameters include the characteristics of the cargo (e.g., the number of shipments), and the radionuclides and chemicals in the soil (not quantified).

- Route-specific parameters—These parameters include traffic and population characteristics for the transport route (e.g., accident rate, injury and fatality rates, vehicle count rate, length of the route, and population density). National average rates will be used to evaluate injury and fatality rates.

- Scenario-specific parameters—These parameters include a number of variables that are generally independent of the cargo transported and the route taken (e.g., the number of people in vehicles, the average speed of vehicles, etc.).

VIII.1.1 CMS Transportation Alternatives

- Six CMs have been evaluated in the transportation risk analysis. These include:
- MWL Risk Baseline—NFA with No IC
- MWL Alternative I.a—NFA with IC
- MWL Alternative III.a—Bio-Intrusion Barrier
- MWL Alternative III.b—Vegetative Soil Cover
- MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier
- MWL Alternative V.e—Future Excavation

Each scenario includes unique transportation requirements to complete the remedial actions based upon the volume of soil to be imported or removed, and the distance of vehicle travel.

VIII.1.2 Transportation Risk Assumptions

The following assumptions were also used to calculate the transportation risk:

- The total number of shipments is based upon the volume of soil transported by dump truck (assumed to be 20 cubic yards). The number of dump truck loads assumed for each alternative is summarized below:

  - MWL Risk Baseline—NFA with No IC: No on-site activities

  - MWL Alternative 1.a—NFA with IC: 305 loads of sub-grade soil from the borrow pit west of the Corrective Action Management Unit (CAMU)

  - MWL Alternative III.b—Vegetative Soil Cover: 800 loads of sub-grade soil from the borrow pit west of the CAMU, and 110 loads of top soil from borrow pit west of the MWL

  - MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier: 800 loads of sub-grade soil from the borrow pit west of the CAMU, 110 loads of

top soil from borrow pit west of the MWL, and 440 loads of cobble from the off-site east mountain gravel pit

- MWL Alternative V.e—Future Excavation: 1,175 loads of excavated waste moved to on-site waste processing facility, 5,900 loads of re-deposited soil to be compacted (1,300 loads from off site)

- The total distance used to calculate injuries and fatalities due to traffic accidents is based upon a roundtrip. The total distance traveled for each location is summarized below:

  - Sub-grade soil from the borrow pit west of the CAMU—4 miles roundtrip
  - Top soil from borrow pit west of the MWL—0.5 miles roundtrip
  - Cobble from the off-site east mountain gravel pit—30 miles roundtrip
  - Excavated waste shipped off site (Nevada Test Site)—1,650 miles roundtrip
  - Risk of accident injury per vehicle 100 million vehicle miles traveled is 15 (national average for large trucks [DOT 2002])
  - Risk of accident fatality per vehicle 100 million vehicle miles traveled is 0.4 (national average for large trucks [DOT 2002])

VIII.1.3 Methodology for Remediation Injuries and Fatalities

Evaluation of human health risk as a result of remediation activities is very similar in concept to the determination of risk for transportation activities. The three components described in the transportation methodology (i.e., scenarios, likelihood, and consequence) must be defined with respect to the activities performed, and the risk is a product of probability and consequence.

Nonchemical-related worker risk can be determined from accident statistics related to specific industries from the U.S. Department of Labor (DOL) and other sources. For the activities that would be performed at the MWL, the DOL industrial labor classification of construction was used to estimate the injury and fatality rates per man-hour. From the classification and unit risk information gained from DOL statistics (DOL 2002), risk models were constructed using the assumption that there is a linear relationship between total effort in man-hours and risk.

VIII.1.4 Remediation Risk Assumptions

System definition includes the determination of factors that characterize the working environment. The following assumptions were used to calculate the remediation risk for both human health injury and fatality to workers:

- Worker exposures to chemicals and radionuclides under normal operating conditions would be controlled under established procedures that require doses to be kept ALARA

- Risk of occupational injury per full-time employee (FTE) of excavation (construction labor classification) is 3.7×10^{-2} (BLS/DOL 2002)
- Risk of occupational injury per FTE of maintenance (engineer labor classification) is 7.0×10^{-3} (BLS/DOL 2002)
- Risk of occupational fatality per FTE of excavation (construction labor classification) is 1.78×10^{-4} (BLS/DOL 2002)
- Worker hour estimates for the remedial options include the following:
  - NFA with no IC—No addition effort
  - NFA with IC—900 technician and scientist hours per year for 30 years for surveillance and maintenance
  - Vegetative Cover—900 technician and scientist hours per year for 30 years for surveillance and maintenance, 15 people for 3 months (9,000 hours) assuming 10-hour days for construction operations
  - Vegetative Cover with Bio-Intrusion Barrier—900 technician and scientist hours per year for 30 years for surveillance and maintenance, 15 people for 4 months (12,000 hours) assuming 10-hour days for construction operations
  - Future Excavation—25 people for 24 months (120,000 hours) assuming 10-hour days for construction operations

All excavation and soil handling workers are assumed to don PPE. Therefore, radionuclide and chemical risks are not considered. However, for the excavation scenario, the workers will be exposed to penetrating gamma radiation, and this exposure should be considered as well. Potential individual worker exposure during excavation is discussed in Section VI.6.2.6. The dose to an individual worker is 3.23E+3 with associated risk of 3.7E-2. Multiplying this times the 50 person months project for excavation, this becomes 1.6E+5 mrem (total), with an associated risk of 1.85.

VIII.1.5 Transportation/Remediation Assessment Results

The results of the analysis are summarized in Table 31. Included in this summary is the predicted number of injuries and fatalities for both potential transportation and remedial activities for each of the alternatives evaluated in the MWL CMS.

IX. Conclusions

Results of the risk analysis indicate that, regardless of transport method or remedial alternative, transportation and remediation risk to the public and transport crew is the dominant source of risk for the CM alternatives, particularly vehicle-related deaths and injuries. Remediation risk is directly related to the amount of soil to be excavated or used as fill/cover. Due to the fact that

Table 31
Summary of Transportation and Remediation Injuries and Fatalities for the MWL CMS

Corrective Measure Alternative	Transportation		Remedial Operations	
	Injuries	Fatalities	Injuries	Fatalities
MWL Risk Baseline—NFA with No IC	No Transportation Risk		No Remediation Risk	
MWL Alternative I.a—NFA with IC	1.8E-2	4.9E-4	9.5E-2	2.4E-3
MWL Alternative III.b—Vegetative Soil Cover	4.9E-2	1.3E-3	2.6E-1	3.2E-3
MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier	2.5E-1	6.6E-3	3.2E-1	3.5E-3
MWL Alternative V.e—Future Excavation	8.8E-1	2.3E-1	2.2E+0	1.1E-2

CMS = Corrective Measures Study.
IC = Institutional Control.
NFA = No Further Action.
MWL = Mixed Waste Landfill.

the remediation/transportation risk is the major component of risk determined by this analysis, cost and regulatory considerations, rather than risk associated with receptors' exposure to contamination, should be the deciding factors for the selection of CMS alternatives. In summary, the injuries and fatalities due to transportation and remediation far exceed the risks of chemical or radionuclide exposure during excavation of the MWL (Table 32).

Table 32
Summary of the MWL CMS Alternatives Risk Results

Alternatives	Human Health (IND)		Ecological		Transportation and Remediation Injuries and Fatalities			
					Transportation		Remedial Operations	
	Non-Radiological	Radiological	Non-Radiological	Radiological (rad/day)	Injuries	Fatalities	Injuries	Fatalities
MWL Risk Baseline—NFA with No IC	HI = 0.07 CR = 3E-6	TEDE = 3.3E-1 mrem/yr CR = 2.2E-6	No HQ exceedence after uncertainty addressed	Mouse = 1.6E-3 Owl = 1.6E-3	No Transportation Risk		No Remediation Risk	
MWL Alternative I.a—NFA with IC	HI = 0.00 CR = 1E-9	TEDE = 3.3E-1 mrem/yr CR = 2.2E-6	No HQ exceedence after uncertainty addressed	Mouse = 1.6E-3 Owl = 1.6E-3	0.018	0.00049	0.095	0.0024
MWL Alternative III.b—Vegetative Soil Cover	HI = 0.00 CR ≈ 0.00	TEDE = 2.4E-5 mrem/yr CR = 3.4E-10	HQ ≈ 0.00	HI ≈ 0.00	0.049	0.0013	0.26	0.0032
MWL Alternative III.c—Vegetative Soil Cover with Bio-Intrusion Barrier	HI = 0.00 CR ≈ 0.00	TEDE = 2.4E-5 mrem/yr CR = 3.4E-10	HQ ≈ 0.00	HI ≈ 0.00	0.25	0.0066	0.32	0.0035
MWL Alternative V.e—Future Excavation	HI = 0.07 CR = 3E-6	TEDE = 3.23E3 mrem/yr CR = 3.7E-2	NA	NA	0.88	0.23	2.26	0.011

CMS = Corrective Measures Study.
CR = Cancer risk.
HI = Hazard index.
HQ = Hazard quotient.
IC = Institutional Control.
IND = Industrial.
mrem/yr = Millirem per year.
MWL = Mixed Waste Landfill.
NA = Not applicable.
NFA = No Further Action.
TEDE = Total Effective Dose Equivalent.

X. References

Baes, III, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor, 1984. "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture," ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Baker, D.A., and J.K. Soldat, 1992. "Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment," PNL-8150, Pacific Northwest Laboratory, Richland, Washington.

Bearzi, J.P. (New Mexico Environment Department), January 2001. Memorandum to RCRA-Regulated Facilities, "Risk-Based Screening Levels for RCRA Corrective Action Sites in New Mexico," Hazardous Waste Bureau, New Mexico Environment Department, Santa Fe, New Mexico. January 23, 2001.

BLS, see Bureau of Labor Statistics.

Bureau of Labor Statistics, see U.S. Department of Transportation (DOT), 2002.

Callahan, M.A., M.W. Slimak, N.W. Gabel, I.P. May, C.F. Fowler, J.R. Freed, P. Jennings, R.L. Durfee, F.C. Whitmore, B. Maestri, W.R. Mabey, B.R. Holt, and C. Gould, 1979, "Water-Related Environmental Fate of 129 Priority Pollutants," EPA-440/4-79-029, Office of Water and Waste Management, Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Connell, D.W., and R.D. Markwell, 1990. "Bioaccumulation in Soil to Earthworm System," *Chemosphere*, Vol. 20, pp. 91-100.

Connor, J.A., R.L. Bowers, J.P. Nevin, and R.T. Fisher, 2000. "Software Guidance Manual for RBCA Tool Kit for Chemical Releases," Groundwater Services, Inc., Houston, Texas.

Dinwiddie, R.S. (New Mexico Environment Department), September 1997. Letter to M.J. Zamorski (U.S. Department of Energy), "Request for Supplemental Information: Background Concentrations Report, SNL/KAFB." September 24, 1997.

DOE, see U.S. Department of Energy.

DOL, see U.S. Department of Labor.

DOT, see U.S. Department of Transportation.

Dunning, J.B., 1993. *CRC Handbook of Avian Body Masses*, CRC Press, Boca Raton, Florida.

Efroymson, R.A, M.E. Will, G.W. Suter II, and A.C Wooten, 1997. "Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision," ES/ER/TM-85/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

EPA, see U.S. Environmental Protection Agency.

Goering, T.J., G.M. Haggerty, D.V Hart, and J.L. Peace, December 2002. "Mixed Waste Landfill Groundwater Report, 1990 through 2001," Draft SAND Report SAND2002-XXXX (currently in review), prepared for the U.S. Department of Energy by Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico (Contract DE-AC04-94AL85000).

Haug, E.A., B.A. Millsap, and M.S. Martell, 1993. "*Speotyto cunicularia* Burrowing Owl," *in* A. Poole and F. Gill (eds.), *The Birds of North America*, No. 61, The Academy of Natural Sciences of Philadelphia.

Howard, P.H., 1989. Vol. 1: "Large Production and Priority Pollutants," *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*, Lewis Publishers, Inc., Chelsea, Michigan.

Howard, P.H., 1990. Vol. II: "Solvents," *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*, Lewis Publishers, Inc., Chelsea, Michigan.

Howard, P.H., 1993. Vol. IV: "Solvents 2," *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*, Lewis Publishers, Inc., Chelsea, Michigan.

IAEA, see International Atomic Energy Agency.

International Atomic Energy Agency (IAEA), 1992. "Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards," *Technical Report Series* No. 332, International Atomic Energy Agency, Vienna, Austria.

IT Corporation (IT), July 1994. "Report of Generic Action Level Assistance for the Sandia National Laboratories/New Mexico Environmental Restoration Program," IT Corporation, Albuquerque, New Mexico.

IT Corporation (IT), July 1998. "Predictive Ecological Risk Assessment Methodology, Environmental Restoration Program, Sandia National Laboratories, New Mexico," IT Corporation, Albuquerque, New Mexico.

IT, see IT Corporation.

Kocher, D.C. 1983. "Dose-Rate Conversion Factors for External Exposure to Photon Emitters in Soil," *Health Physics,* Vol. 28, pp. 193–205.

LANL, see Los Alamos National Laboratory.

Laws, E. (U.S. Environmental Protection Agency), July 1994. Memorandum to Region Administrators I-X, "Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities," U.S. Environmental Protection Agency, Washington, D.C. July 14, 1994.

Los Alamos National Laboratory (LANL), 2000. "Environmental Surveillance at Los Alamos during 2000," LA-13861-ENV, Los Alamos National Laboratory, Los Alamos, New Mexico.

Micromedex, Inc., 1998. "Registry of Toxic Effects of Chemical Substances (RTECS)," Hazardous Substances Databank.

Morse, J.W., and G.R. Choppin, 1991. The Chemistry of Transuranic Elements in Natural Waters. *Reviews in Aquatic Sciences* 4:1-22 *in* Eisler 1994.

Nagy, K.A., 1987. "Field Metabolic Rate and Food Requirement Scaling in Mammals and Birds," *Ecological Monographs*, Vol. 57, No. 2, pp. 111–128.

National Council on Radiation Protection and Measurements (NCRP), 1987. "Exposure of the Population in the United States and Canada from Natural Background Radiation," National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP), January 1989. "Screening Techniques for Determining Compliance with Environmental Standards: Releases of Radionuclides to the Atmosphere," NCRP Commentary No. 3, Rev. January 1989, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Oceanographic and Atmospheric Administration (NOAA), 1990. Local Climatological Data, Annual Summary with Comparative Data, Albuquerque, New Mexico.

NCRP, see National Council on Radiation Protection and Measurements.

Neumann, G., 1976. "Concentration Factors for Stable Metals and Radionuclides in Fish, Mussels and Crustaceans—a Literature Survey," Report 85-04-24, National Swedish Environmental Protection Board.

New Mexico Environment Department (NMED), March 1998. "RPMP Document Requirement Guide," RCRA Permits Management Program, Hazardous and Radioactive Materials Bureau, New Mexico Environment Department, Santa Fe, New Mexico.

NMED, see New Mexico Environment Department

NOAA, see National Oceanographic and Atmospheric Administration.

Olson, K., and W. Moats (New Mexico Environment Department), March 2000. Memorandum to File, "Proposed ER Site 8 Cleanup Levels," Hazardous and Radioactive Materials Bureau, New Mexico Environment Department, Santa Fe, New Mexico.

Peace, J.L, T.J. Goering, and M.D. McVey, September 2002. "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico." SAND Report SAND2002-2997, prepared for the U.S. Department of Energy by Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico (Contract DE-AC04-94AL85000).

Sample, B.E., and G.W. Suter II, 1994. "Estimating Exposure of Terrestrial Wildlife to Contaminants," ES/ER/TM-125, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sample, B.E., D.M. Opresko, and G.W. Suter II, 1996. "Toxicological Benchmarks for Wildlife: 1996 Revision," ES/ER/TM-86/R3, Risk Assessment Program, Health Sciences Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sandia National Laboratories/New Mexico (SNL/NM), September 1990. "Report of the Phase 1 RCRA Facility Investigation of the Mixed Waste Landfill," Environmental Impact and Restoration Division, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM), March 1993. "Phase 2 RCRA Facility Investigation Work Plan for the Mixed Waste Landfill," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM), May 1994, *Data Flow*, Administrative Operating Procedure (AOP 94-27), Sandia National Laboratories/New Mexico, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM), November 1994. "Comment Responses to U.S. Environmental Protection Agency Notice of Deficiency," Mixed Waste Landfill Phase 2 RFI Work Plan, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM), February 1998. "RESRAD Input Parameter Assumptions and Justification," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM), June 1998. "Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996" Volumes 1 and 2. Prepared for the U.S. Department of Energy by Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, June 15, 1998.

Sandia National Laboratories/New Mexico (SNL/NM), January 2000. "Data Validation Procedure for Chemical and Radiochemical Data (AOP 00-003) Rev. 0," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM) January 2002a. "RCRA Closure Report for the SNL/NM Interim Storage Site (ISS)," Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories/New Mexico (SNL/NM) January 2002b. "ISS: Risk Screening Assessment Report," Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Silva, M., and J.A. Downing, 1995. *CRC Handbook of Mammalian Body Masses*, CRC Press, Boca Raton, Florida.

SNL/NM, See Sandia National Laboratories, New Mexico.

Stafford, E.A., J.W. Simmers, R.G. Rhett, and C.P. Brown, 1991. "Interim Report: Collation and Interpretation of Data for Times Beach Confined Disposal Facility, Buffalo, New York," *Miscellaneous Paper* D-91-17, U.S. Army Corps of Engineers, Buffalo, New York.

Tharp, T. (Sandia National Laboratories/New Mexico), February 1999. Memorandum to F.B. Nimick (Sandia National Laboratories/New Mexico), "Tritium Background Data Statistical Analysis for Site-Wide Surface Soils." Sandia National Laboratories, Albuquerque, New Mexico. February 25, 1999.

Thomson, B.M. and G.J. Smith, 1985. "Investigation of Groundwater Contamination Potential at Sandia National Laboratories, Albuquerque, New Mexico," *In Proceedings of the Fifth DOE Environmental Protection Information Meeting*, Albuquerque, New Mexico, November 6-8, 1984, CONF-841187, pp. 531–540.

Travis, C.C., and A.D. Arms, 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetables," *Environmental Science and Technology*, Vol. 22, No. 3, pp. 271–274.

U.S. Department of Energy (DOE), 1988. "External Dose-Rate Conversion Factors for Calculation of Dose to the Public," DOE/EH-0070, Assistant Secretary for Environment, Safety and Health, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1993. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1995. "Hanford Site Risk Assessment Methodology," DOE/RL-91-45 (Rev. 3), U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy, U.S. Air Force, and U.S. Forest Service, September 1995. "Workbook: Future Use Management Area 2," prepared by the Future Use Logistics and Support Working Group in cooperation with the U.S. Department of Energy Affiliates, the U.S. Air Force, and the U.S. Forest Service.

U.S. Fish and Wildlife Service (USFWS), September 1995. "Migratory Nongame Birds of Management Concern in the United States: The 1995 List," Office of Migratory Bird Management, U.S. Fish and Wildlife Service, Washington, D.C.

U.S. Department of Labor (DOL), 2002. *Occupational Injuries and Illnesses in the United States by Industry 2000*. Internet Version. Washington, DC.

U.S. Department of Transportation (DOT), 2002. *Safety Facts 2000, A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. Internet Version. Washington, DC.

U.S. Environmental Protection Agency (EPA), November 1986. "Test Methods for Evaluating Solid Waste," 3rd ed., Update 3, SW-846, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1988. Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1989. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual," EPA/540-1089/002, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), July 1990. "Corrective Action for Solid Waste Management Units (SWMU) at Hazardous Waste Management Facilities, Proposed Rule," *Federal Register*, Vol. 55, Title 40, Parts 264, 265, 270, and 271.

U.S. Environmental Protection Agency (EPA), 1991. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B)," Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1993. *Wildlife Exposure Factors Handbook*, Vol. I," EPA/600/R-93/187a, U.S. Environmental Protection Agency, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1996. "Region 9 Preliminary Remediation Goals (PRGs) 1996," electronic database maintained by Region 9, U.S. Environmental Protection Agency, San Francisco, California.

U.S. Environmental Protection Agency (EPA), 1997a. "Health Effects Assessment Summary Tables (HEAST), FY 1997 Update," EPA-540-R-97-036, Office of Research and Development and Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C..

U.S. Environmental Protection Agency (EPA), 1997b. "Risk-Based Concentration Table," electronic database maintained by Region 3, U.S. Environmental Protection Agency, Philadelphia, Pennsylvania.

U.S. Environmental Protection Agency (EPA), 1997c. "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," OSWER Directive No. 9200.4-18, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1997d. "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risks," Interim Final, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1998a. Integrated Risk Information System (IRIS) electronic database, maintained by the U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA), 1998b. "Guidelines for Ecological Risk Assessment," EPA/630/R-95/002F, U.S. Environmental Protection Agency, Washington, D.C.

USFWS, see U.S. Fish and Wildlife Service.

Vanderploeg, H.A., D.C. Parzyck, W.H. Wilcox, J.R. Kercher, and S.V. Kaye, 1975. "Bioaccumulation Factors for Radionuclides in Freshwater Biota," ORNL-5002, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Whicker, F.W., and V. Schultz, 1982. *Radioecology: Nuclear Energy and the Environment*, Volume II, CRC Press, Boca Raton, Florida.

Yanicak, S. (Oversight Bureau, New Mexico Environment Department), March 1997. Letter to M. Johansen (DOE/AIP/POC Los Alamos National Laboratory), (Tentative) list of constituents of potential ecological concern (COPECs) which are considered to be bioconcentrators and/or biomagnifiers. March 3, 1997.

Yu, C., C. Loureiro, J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia, and E. Faillace, 1993a. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, ANL/EAIS-8, Argonne National Laboratory, Argonne, Illinois.

Yu, C., A.J. Zielen, J.-J. Cheng, Y.C. Yuan, L.G. Jones, D.J. LePoire, Y.Y. Wang, C.O. Loureiro, E. Gnanapragasam, E. Faillace, A. Wallo III, W.A. Williams, and H. Peterson, 1993b. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD,* Version 5.0. Environmental Assessment Division, Argonne National Laboratory, Argonne, Illinois.

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APPENDIX 1
EXPOSURE PATHWAY DISCUSSION FOR CHEMICAL AND RADIONUCLIDE CONTAMINATION

Introduction

Sandia National Laboratories/New Mexico (SNL/NM) uses a default set of exposure routes and associated default parameter values developed for each future land use designation being considered for SNL/NM Environmental Restoration (ER) Project sites. This default set of exposure scenarios and parameter values are invoked for risk assessments unless site-specific information suggests other parameter values. Because many SNL/NM solid waste management units (SWMUs) have similar types of contamination and physical settings, SNL/NM believes that the risk assessment analyses at these sites can be similar. A default set of exposure scenarios and parameter values facilitates the risk assessments and subsequent review.

The default exposure routes and parameter values used are those that SNL/NM views as resulting in a Reasonable Maximum Exposure (RME) value. Subject to comments and recommendations by the U.S. Environmental Protection Agency (EPA) Region VI and New Mexico Environment Department (NMED), SNL/NM will use these default exposure routes and parameter values in future risk assessments.

At SNL/NM, all SWMUs exist within the boundaries of the Kirtland Air Force Base. Approximately 240 potential waste and release sites have been identified where hazardous, radiological, or mixed materials may have been released to the environment. Evaluation and characterization activities have occurred at all of these sites to varying degrees. Among other documents, the SNL/NM ER draft Environmental Assessment (DOE 1996) presents a summary of the hydrogeology of the sites, the biological resources present and proposed land use scenarios for the SNL/NM SWMUs. At this time, all SNL/NM SWMUs have been tentatively designated for either industrial or recreational future land use. The NMED has also requested that risk calculations be performed based upon a residential land use scenario. All three land use scenarios will be addressed in this document.

The SNL/NM ER Project has screened the potential exposure routes and identified default parameter values to be used for calculating potential intake and subsequent hazard index (HI), excess cancer risk and dose values. The EPA (EPA 1989a) provides a summary of exposure routes that could potentially be of significance at a specific waste site. These potential exposure routes consist of:

- Ingestion of contaminated drinking water
- Ingestion of contaminated soil
- Ingestion of contaminated fish and shellfish
- Ingestion of contaminated fruits and vegetables
- Ingestion of contaminated meat, eggs, and dairy products

- Ingestion of contaminated surface water while swimming
- Dermal contact with chemicals in water
- Dermal contact with chemicals in soil
- Inhalation of airborne compounds (vapor phase or particulate)
- External exposure to penetrating radiation (immersion in contaminated air; immersion in contaminated water; and exposure from ground surfaces with photon-emitting radionuclides)

Based upon the location of the SNL/NM SWMUs and the characteristics of the surface and subsurface at the sites, we have evaluated these potential exposure routes for different land use scenarios to determine which should be considered in risk assessment analyses (the last exposure route is pertinent to radionuclides only). At SNL/NM SWMUs, there is currently no consumption of fish, shellfish, fruits, vegetables, meat, eggs, or dairy products that originate on site. Additionally, no potential for swimming in surface water is present due to the high-desert environmental conditions. As documented in the RESRAD computer code manual (ANL 1993), risks resulting from immersion in contaminated air or water are not significant compared to risks from other radiation exposure routes.

For the industrial and recreational land use scenarios, SNL/NM ER has, therefore, excluded the following four potential exposure routes from further risk assessment evaluations at any SNL/NM SWMU:

- Ingestion of contaminated fish and shellfish
- Ingestion of contaminated fruits and vegetables
- Ingestion of contaminated meat, eggs, and dairy products
- Ingestion of contaminated surface water while swimming

That part of the exposure pathway for radionuclides related to immersion in contaminated air or water is also eliminated.

For the residential land use scenario, we will include ingestion of contaminated fruits and vegetables because of the potential for residential gardening.

Based upon this evaluation, for future risk assessments the exposure routes that will be considered are shown in Table 1. Dermal contact is included as a potential nonradiological organic constituents exposure pathway in all land use scenarios. However, the potential for dermal exposure to inorganic constituents is not considered significant and will not be included. In general, the dermal exposure pathway is generally considered not to be significant relative to water ingestion and soil ingestion pathways but will be considered for organic components. Because of the lack of toxicological parameter values for this pathway, the inclusion of this exposure pathway into risk assessment calculations may not be possible and may be part of the uncertainty analysis for a site where dermal contact is potentially applicable.

Table 1
Exposure Pathways Considered for Various Land Use Scenarios

Industrial	Recreational	Residential
Ingestion of contaminated drinking water	Ingestion of contaminated drinking water	Ingestion of contaminated drinking water
Ingestion of contaminated soil	Ingestion of contaminated soil	Ingestion of contaminated soil
Inhalation of airborne compounds (vapor phase or particulate)	Inhalation of airborne compounds (vapor phase or particulate)	Inhalation of airborne compounds (vapor phase or particulate)
Dermal contact (nonradiological organic constituents only)	Dermal contact (nonradiological organic constituents only)	Dermal contact (nonradiological organic constituents only)
External exposure to penetrating radiation from ground surfaces	External exposure to penetrating radiation from ground surfaces	Ingestion of fruits and vegetables
		External exposure to penetrating radiation from ground surfaces

Equations and Default Parameter Values for Identified Exposure Routes

In general, SNL/NM expects that ingestion of compounds in drinking water and soil will be the more significant exposure routes for chemicals; external exposure to radiation may also be significant for radionuclides. All of the above routes will, however, be considered for their appropriate land use scenarios. The general equation for calculating potential intakes via these routes is shown below. The equations are from the Risk Assessment Guidance for Superfund (RAGS): Volume 1 (EPA 1989a, 1991). These general equations also apply to calculating potential intakes for radionuclides. A more in-depth discussion of the equations used in performing radiological pathway analyses with the RESRAD code may be found in the RESRAD Manual (ANL 1993). RESRAD is the only code designated by the U.S. Department of Energy (DOE) in DOE Order 5400.5 for the evaluation of radioactively contaminated sites (DOE 1993). The Nuclear Regulatory Commission (NRC) has approved the use of RESRAD for dose evaluation by licensees involved in decommissioning, NRC staff evaluation of waste disposal requests, and dose evaluation of sites being reviewed by NRC staff. RESRAD has been applied to more than 300 sites in the U.S. and other countries. EPA Science Advisory Board reviewed the RESRAD model. EPA used RESRAD in their rulemaking on radiation site cleanup regulations. RESRAD code has been verified, undergone several benchmarking analyses, and been included in the International Atomic Energy Agency's VAMP and BIOMOVS II projects to compare environmental transport models.

Also shown are the default values SNL/NM ER will use in RME risk assessment calculations for industrial, recreational, and residential land use scenarios, based upon EPA and other governmental agency guidance. The pathways and values for chemical contaminants are discussed first, followed by those for radionuclide contaminants. Certain site-specific input parameters have been pre-established by agreement between SNL and NMED (SNL/NM February 1998). RESRAD input parameters that are left as the default values provided with the code are not discussed. Further information relating to these parameters may be found in the RESRAD Manual (ANL 1993) or by directly accessing the RESRAD websites at: http://web.ead.anl.gov/resrad/home2/ or http://web.ead.anl.gov/resrad/documents/.

Generic Equation for Calculation of Risk Parameter Values

The equation used to calculate the risk parameter values (i.e., hazard quotients/HI, excess cancer risk, or radiation total effective dose equivalent [TEDE] [dose]) is similar for all exposure pathways and is given by:

Risk (or Dose) = Intake x Toxicity Effect (either carcinogenic, noncarcinogenic, or radiological)

$$= C \times (CR \times EFD/BW/AT) \times \text{Toxicity Effect} \quad (1)$$

where

C = contaminant concentration (site specific)
CR = contact rate for the exposure pathway
EFD = exposure frequency and duration
BW = body weight of average exposure individual
AT = time over which exposure is averaged.

For nonradiological constituents of concern (COCs), the total risk/dose (either cancer risk or HI) is the sum of the risks/doses for all of the site-specific exposure pathways and contaminants. For radionuclides, the calculated radiation exposure, expressed as TEDE is compared directly to the exposure guidelines of 15 millirem per year (mrem/year) for industrial and recreational future use and 75 mrem/year for the unlikely event that institutional control of the site is lost and the site is used for residential purposes (EPA 1997).

The evaluation of the carcinogenic health hazard produces a quantitative estimate for excess cancer risk resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of the quantitative estimate with the potentially acceptable risk of 1E-5 for nonradiological carcinogens. The evaluation of the noncarcinogenic health hazard produces a quantitative estimate (i.e., the HI) for the toxicity resulting from the COCs present at the site. This estimate is evaluated for determination of further action by comparison of this quantitative estimate with the EPA standard HI of unity (1). The evaluation of the health hazard due to radioactive compounds produces a quantitative estimate of doses resulting from the COCs present at the site. This estimated dose can be used to calculate an assumed risk. However, this calculated risk is presented for illustration purposes only, not to determine compliance with regulations.

The specific equations used for the individual exposure pathways can be found in RAGS (EPA 1989a) and are outlined below. The RESRAD Manual (ANL 1993) describes similar equations for the calculation of radiological exposures.

A receptor can ingest soil or dust directly by working in the contaminated soil. Indirect ingestion can occur from sources such as unwashed hands introducing contaminated soil to food that is then eaten. An estimate of intake from ingesting soil will be calculated as follows:

$$I_s = \frac{C_s * IR * CF * EF * ED}{BW * AT}$$

where:

I_s = Intake of contaminant from soil ingestion (milligrams [mg]/kilogram [kg]/day)
C_s = Chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (1E-6 kg/mg)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Soil Inhalation

A receptor can inhale soil or dust directly by working in the contaminated soil. An estimate of intake from inhaling soil will be calculated as follows (EPA 1989b):

$$I_s = \frac{C_s * IR * EF * ED * \left(1/VF + 1/PEF\right)}{BW * AT}$$

where:

I_s = Intake of contaminant from soil inhalation (mg/kg/day)
C_s = Chemical concentration in soil (mg/kg)
IR = Inhalation rate (cubic meters [m^3]/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
VF = soil-to-air volatilization factor (m^3/kg)
PEF = particulate emission factor (m^3/kg)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Groundwater Ingestion

A receptor can ingest water by drinking it or through using household water for cooking. An estimate of intake from ingesting water will be calculated as follows (EPA 1989b):

$$I_w = \frac{C_w * IR * EF * ED}{BW * AT}$$

where:

I_w = Intake of contaminant from water ingestion (mg/kg/day)
C_w = Chemical concentration in water (mg/liter [L])
IR = Ingestion rate (L/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Groundwater Inhalation

The amount of a constituent taken into the body via exposure to volatilization from showering or other household water uses will be evaluated using the concentration of the constituent in the water source (EPA 1991 and 1992). An estimate of intake from volatile inhalation from groundwater will be calculated as follows (EPA 1991):

$$I_w = \frac{C_w * K * IR_i * EF * ED}{BW * AT}$$

where:

I_w = Intake of volatile in water from inhalation (mg/kg/day)
C_w = Chemical concentration in water (mg/L)
K = volatilization factor (0.5 L/m^3)
IR_i = Inhalation rate (m^3/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

For volatile compounds, volatilization from groundwater can be an important exposure pathway from showering and other household uses of groundwater. This exposure pathway will only be evaluated for organic chemicals with a Henry's Law constant greater than 1 X 10^{-5} and with a molecular weight of 200 grams/mole or less (EPA 1991).

Vegetable and Fruit Ingestion

A receptor may ingest contaminated vegetables and fruits. This pathway is only applicable to the residential land-use scenario. An estimate of intake from ingesting vegetables and fruits will be calculated as follows (EPA 1989b):

$$I_f = \frac{C_f * IR * FI * EF * ED}{BW * AT}$$

where:

I_f = Intake of contaminant from food ingestion (mg/kg/day)
C_f = Chemical concentration in food (mg/kg)
IR = Ingestion rate (kg/meal)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (meals/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged—days)

Tables 2 and 3 show the default parameter values suggested for use by SNL/NM at SWMUs, based upon the selected land use scenarios for nonradiological and radiological COCs, respectively. References are given at the end of the table indicating the source for the chosen

parameter values. SNL/NM uses default values that are consistent with both regulatory guidance and the RME approach. Therefore, the values chosen will, in general, provide a conservative estimate of the actual risk parameter. These parameter values are suggested for use for the various exposure pathways, based upon the assumption that a particular site has no unusual characteristics that contradict the default assumptions. For sites for which the assumptions are not valid, the parameter values will be modified and documented.

Summary

SNL/NM will use the described default exposure routes and parameter values in risk assessments at sites that have an industrial, recreational, or residential future land use scenario. There are no current residential land use designations at SNL/NM ER sites, but NMED has requested this scenario to be considered to provide perspective of the risk under the more restrictive land use scenario. For sites designated as industrial or recreational land use, SNL/NM will provide risk parameter values based upon a residential land use scenario to indicate the effects of data uncertainty on risk value calculations or in order to potentially mitigate the need for institutional controls or restrictions on SNL/NM ER sites. The parameter values are based upon EPA guidance and supplemented by information from other government sources. The values are generally consistent with those proposed by Los Alamos National Laboratory for use in their Environmental Restoration Program, with a few minor variations. If these exposure routes and parameters are acceptable, SNL/NM will use them in risk assessments for all sites where the assumptions are consistent with site-specific conditions. All deviations will be documented.

Table 2
Default Nonradiological Exposure Parameter Values for Various Land Use Scenarios

Parameter	Industrial	Recreational	Residential
General Exposure Parameters			
Exposure frequency	8 hr/day for 250 day/yr	4 hr/wk for 52 wk/yr	350 day/yr
Exposure duration (yr)	25[a,b]	30[a,b]	30[a,b]
Body weight (kg)	70[a,b]	70 adult[a,b] 15 child	70 adult[a,b] 15 child
Averaging Time (days) for carcinogenic compounds (= 70 yr x 365 day/yr) for noncarcinogenic compounds (= ED x 365 day/yr)	25,550[a] 9,125	25,550[a] 10,950	25,550[a] 10,950
Soil Ingestion Pathway			
Ingestion rate	100 mg/day[c]	200 mg/day child 100 mg/day adult	200 mg/day child 100 mg/day adult
Inhalation Pathway			
Inhalation rate (m^3/yr)	5,000[a,b]	260	7,000[a,b]
Volatilization factor (m^3/kg)	chemical specific	chemical specific	chemical specific
Particulate emission factor (m^3/kg)	1.32E9[a]	1.32E9[a]	1.32E9[a]
Water Ingestion Pathway			
Ingestion rate (liter/day)	2[a,b]	2[a,b]	2[a,b]
Food Ingestion Pathway			
Ingestion rate (kg/yr)	NA	NA	138[b]
Fraction ingested	NA	NA	0.25[b]
Dermal Pathway			
Surface area in water (m^2)	2[b,d]	2[b,d]	2[b,d]
Surface area in soil (m^2)	0.53[b,d]	0.53[b,d]	0.53[b,d]
Permeability coefficient	chemical specific	chemical specific	chemical specific

[a]Risk Assessment Guidance for Superfund, Vol. 1, Part B (EPA 1991).
[b]Exposure Factors Handbook (EPA 1989b).
[c]EPA Region VI guidance (EPA 1996).
[d]Dermal Exposure Assessment (EPA 1992).
ED = Exposure duration.
EPA = U.S. Environmental Protection Agency.
hr = Hour(s).
kg = Kilogram(s).
m = Meter(s).
mg = Milligram(s).
NA = Not available.
wk = Week(s).
yr = Year(s).

Table 3
Default Radiological Exposure Parameter Values for Various Land Use Scenarios

Parameter	Industrial	Recreational	Residential
General Exposure Parameters			
Exposure frequency	8 hr/day for 250 day/yr	4 hr/wk for 52 wk/yr	365 day/yr
Exposure duration (yr)	25[a,b]	30[a,b]	30[a,b]
Body weight (kg)	70 adult[a,b]	70 adult[a,b]	70 adult[a,b]
Soil Ingestion Pathway			
Ingestion rate	100 mg/day[c]	100 mg/day[c]	100 mg/day[c]
Averaging Time (days) (= 30 yr x 365 day/yr)	10,950[d]	10,950[d]	10,950[d]
Inhalation Pathway			
Inhalation rate (m^3/yr)	7300[d,e]	10,950[e]	7300[d,e]
Mass loading for inhalation g/m^3	1.36 E-5[d]	1.36 E-5 [d]	1.36 E-5 [d]
Food Ingestion Pathway			
Ingestion rate, leafy vegetables (kg/yr)	NA	NA	16.5[c]
Ingestion rate, fruits, non-leafy vegetables & grain (kg/yr)	NA	NA	101.8[b]
Fraction ingested	NA	NA	0.25[b,d]

[a]Risk Assessment Guidance for Superfund, Vol. 1, Part B (EPA 1991).
[b]Exposure Factors Handbook (EPA 1989b).
[c]EPA Region VI guidance (EPA 1996).
[d]For radionuclides, RESRAD (ANL, 1993).
[e]SNL/NM (February 1998).
EPA = U.S. Environmental Protection Agency.
g = Gram(s).
hr = Hour(s).
kg = Kilogram(s).
m = Meter(s).
mg = Milligram(s).
NA = Not applicable.
wk = Week(s).
yr = Year(s).

References

ANL, see Argonne National Laboratory.

Argonne National Laboratory (ANL), 1993. *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD*, Version 5.0, ANL/EAD/LD-2, Argonne National Laboratory, Argonne, IL.

DOE, see U.S. Department of Energy.

EPA, see U.S. Environmental Protection Agency.

Sandia National Laboratories/New Mexico (SNL/NM), February 1998. "RESRAD Input Parameter Assumptions and Justification," Sandia National Laboratories/New Mexico Environmental Restoration Project, Albuquerque, New Mexico.

U.S. Department of Energy (DOE), 1993. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1996. "Environmental Assessment of the Environmental Restoration Project at Sandia National Laboratories/New Mexico," U.S. Department of Energy, Kirtland Area Office.

U.S. Environmental Protection Agency (EPA), 1989a. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual," EPA/540-1089/002, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1989b. *Exposure Factors Handbook*, EPA/600/8-89/043, U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1991. "Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B)," EPA/540/R-92/003, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1992. "Dermal Exposure Assessment: Principles and Applications," EPA/600/8-91/011B, Office of Research and Development, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1996. "Soil Screening Guidance: Technical Background Document," EPA/540/1295/128, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1997. (OSWER No. 9200.4-18) *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, U.S. EPA Office of Radiation and Indoor Air, Washington D.C, August 1997.