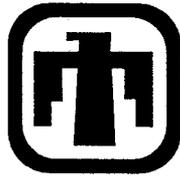


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Sandia National Laboratories

Results of the Liquid Waste Disposal System
RCRA Facility Investigation
Sandia National Laboratories
Albuquerque, New Mexico

September 1995

Environmental Restoration Project



United States Department of Energy
Albuquerque Operations Office

SNL 1234



**RESULTS OF THE LIQUID WASTE DISPOSAL SYSTEM
RCRA FACILITY INVESTIGATION
SANDIA NATIONAL LABORATORIES, ALBUQUERQUE, NEW MEXICO**

September 1995

Prepared by

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EXECUTIVE SUMMARY

Background

A significant portion of the nuclear design and engineering work performed at Sandia National Laboratories/New Mexico (SNL/NM) was conducted in Technical Area V (TA-V). The Liquid Waste Disposal System (LWDS) was designed to receive, monitor, and discharge radioactive effluent from the Sandia Experimental Reactor Facility (SERF) in TA-V. The LWDS consists of three holding tanks and an associated pumping system (Environmental Restoration [ER] Site 52), a drainfield (ER Site 5), and two surface impoundments (ER Site 4).

Starting in 1963, radioactive discharges drained to the holding tanks where they were monitored and then pumped into the drainfield. The discharge water washed away the soil near the drainfield. In 1967, the drainfield collapsed and would no longer accept water. Discharges were then directed into the impoundments. Radioactive discharges continued until 1971 when the SERF was decommissioned. From 1963 until 1971, the system received approximately 19 million gallons of waste water contaminated with approximately 35 curies of radionuclides. Nonradioactive discharges to the surface impoundments continued until 1992. Possible contaminants for all LWDS sites include radionuclides from the discharge of reactor cooling water, organic solvents/heavy metals from various industrial processes in TA-V, and polychlorinated biphenyls (from an unknown source in the LWDS surface impoundments only). Presently, the LWDS holding tanks discharge to a new TA-V Liquid Effluent Control System.

Investigation Work Plan

The LWDS investigation was performed in accordance with the *Liquid Waste Disposal System RCRA Facility Investigation Work Plan* (hereafter the "LWDS RFI work plan"). The investigation included collecting 80 surface soil samples and performing geophysical tests in the LWDS surface impoundments, drilling 16 boreholes, performing an internal investigation of the LWDS holding tanks and associated piping, and installing and sampling ground-water monitor wells at the LWDS surface impoundments and drainfield.

The LWDS RFI work plan has four basic objectives:

1. Define the nature and extent of contamination at each of the ER sites that comprise the LWDS,
2. Identify potential contaminant transport pathways,
3. Evaluate potential risks posed by the levels of contamination identified at the LWDS, and
4. Provide guidance for selecting remedial alternatives at the site, if necessary.

Data Evaluation

Data collected during the RCRA Facility Investigation (RFI) were evaluated several ways. Initially, a constituent population was statistically compared to natural background

using EPA-approved methods. Any constituent of concern failing the statistical comparison was further analyzed for its spatial distribution. Contamination at the LWDS demonstrated a strong spatial correlation with the discharge points, and the combination of statistical techniques with the use of process history provides a robust analysis. Constituents that failed the statistical comparison to background and showed a strong spatial correlation were identified as contaminants.

After a constituent was identified as a contaminant, the sample population was compared to RCRA proposed action levels and, in most cases, studied in a detailed risk assessment. A computer model developed by SNL/NM, called the Probabilistic Risk Evaluation and Characterization Investigation System (*Précis*), was used. The basic risk assessment methodology defined by the U.S. Environmental Protection Agency (EPA, 1989) has been modified to include a quantitative uncertainty analysis technique. The probabilistic risk assessment methodology is ideal for quantitatively assessing uncertainty. Site-specific sections list assumptions from the risk assessment methodology that relate to future land use and exposure unit definitions.

Results and Recommendations

In summary, contamination was detected at all three sites. Contamination levels are low, in most cases barely discernible above background, and are limited to the near surface of the LWDS surface impoundments, the vicinity of the LWDS drainfield, and inside the LWDS holding tanks. A detailed analysis of these contamination levels has been completed, and No Further Action is recommended for all three sites.

Trichloroethene and its degradation products are present in LWDS drainfield ground-water monitor well LWDS-MW1. These chemicals have not been detected in any LWDS ER sites and are most likely from another source area in TA-V. Further investigations of TA-V ground-water issues continue under the TA-III/V RCRA Facility Investigation.

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
API	American Petroleum Institute
COCs	constituents of concern
CSAMT	Controlled Source Audiofrequency Magnetotellurics
CWL	Chemical Waste Landfill
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FID	flame ionization detector
FOP	Field Operating Procedure
GR	gamma ray
GM	Geiger Müller
HCF	Hot Cell Facility
HERMES	High-Energy Radiation Megavolt Electron Source
HI	hazard index
HSWA	Hazardous and Solid Waste Amendments
ICR	incremental lifetime cancer risk
KAFB	Kirtland Air Force Base
KS	Kolmogorov-Smirnov (test)
LECS	Liquid Effluent Control System
LWDS	Liquid Waste Disposal System
MCL	maximum concentration limit
MEK	methyl ethyl ketone
MWL	Mixed Waste Landfill
N	neutron
NFA	No Further Action
NPDES	National Pollutant Discharge Elimination System
OU	Operable Unit
OVA	organic vapor analyzer
PCB	polychlorinated biphenyl
POTW	publicly-owned treatment works
Précis	Probabilistic Risk Evaluation and Characterization Investigation System
PVC	polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RPD	relative percent difference
SERF	Sandia Engineering Reactor Facility
SNL/NM	Sandia National Laboratories/New Mexico
SVOC	semi-volatile organic compound
SWHC	Site-Wide Hydrogeologic Characterization (Project)
SWMU	solid waste management unit
TA	Technical Area
TAL	target analyte list
TCE	trichloroethene
TPH	total petroleum hydrocarbons

TSP	trisodium phosphate
TTO	total toxic organics
USAF	U.S. Air Force
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
WRS	Wilcoxon Rank Sum (test)

bgl	below ground level
Ci	curie
cm	centimeter
cps	counts per second
°F	Fahrenheit degree
ft	foot
ft ²	square feet
ft/mi	feet per mile
g	gram
gal	gallon
gm/cc	grams per cubic centimeter
K _{sat}	saturated conductivity
in.	inch
m	meter
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mi	mile
mph	miles per hour
mrem/yr	millirem per year
msl	mean sea level
pCi/g	picocuries per gram
pCi/L	picocuries per liter
ppb	parts per billion
ppm	parts per million
s	second
yd	yard

Approximate Conversion Factors For Selected SI (Metric) Units

Multiply SI (Metric) Unit	By	To Obtain U.S. Customary Unit
Cubic Meters (m ³)	35	Cubic feet (ft ³)
Centimeters (cm)	0.39	Inches (in.)
Meters (m)	3.3	Feet (ft)
Kilometers (km)	0.62	Miles (mi)
Square kilometers (km ²)	0.39	Square miles (mi ²)
Hectares (ha)	2.5	Acres
Liters (L)	0.26	Gallons (gal)
Grams (g)	0.035	Ounces (oz)
Kilograms (kg)	2.2	Pounds (lb)
Micrograms per gram (μg/g)	1	Parts per million (ppm)
Milligrams per liter (mg/L)	1	Parts per million (ppm)
Celsius (°C)	9/5 + 32	Fahrenheit (°F)

1.0 INTRODUCTION

1.1 Site Background

A significant portion of the nuclear design and engineering work performed at Sandia National Laboratories/New Mexico (SNL/NM) was conducted in Technical Area V (TA-V). The Sandia Engineering Reactor Facility (SERF) located in TA-V consisted of a main reactor and experimental facilities housed in Buildings 6580 and 6581, and support facilities housed in Buildings 6582 and 6583 (Figure 1-1). Operation of these facilities resulted in the generation of industrial waste water, some of which contained low concentrations of radionuclides. The Liquid Waste Disposal System (LWDS) received and managed this waste water.

The LWDS consists of three holding tanks and the associated pumping system (Environmental Restoration [ER] Site 52), a drainfield (ER Site 5), and two surface impoundments (ER Site 4) (Figure 1-1). The LWDS received liquid effluent from the main reactor, experimental facilities, and support facilities in TA-V. The holding tanks received liquid effluent from the SERF during that facility's entire period of operation from 1962 to 1971. The drainfield was used from 1963 to 1967; it collapsed in 1967 and was replaced with the two surface impoundments. The impoundments were used to receive radioactive waste water from 1967 to 1971. Since 1971, the holding tanks have received nonradioactive waste water from the Hot Cell Facility (HCF) housed in Building 6580. The nonradioactive waste water was discharged to the impoundments until October 1992. Currently, the holding tanks drain to a new Liquid Effluent Control System (LECS). The LECS receives and holds all TA-V process water for sampling prior to discharge to the City of Albuquerque publicly-owned treatment works (POTW).

1.2 RFI Work Plan Overview and Objectives

All LWDS work has been performed in accordance with the *Liquid Waste Disposal System RCRA Facility Investigation Work Plan* (hereafter the "LWDS RFI work plan") approved by the U.S. Environmental Protection Agency (EPA), Region VI in 1994 (SNL, 1994a). The LWDS RFI work plan outlined an investigation strategy that included:

- Collecting surface soil samples at the LWDS surface impoundments;
- Performing surface geophysical tests at the LWDS surface impoundments;
- Drilling and sampling boreholes at the LWDS surface impoundments, drainfield, and holding tanks;

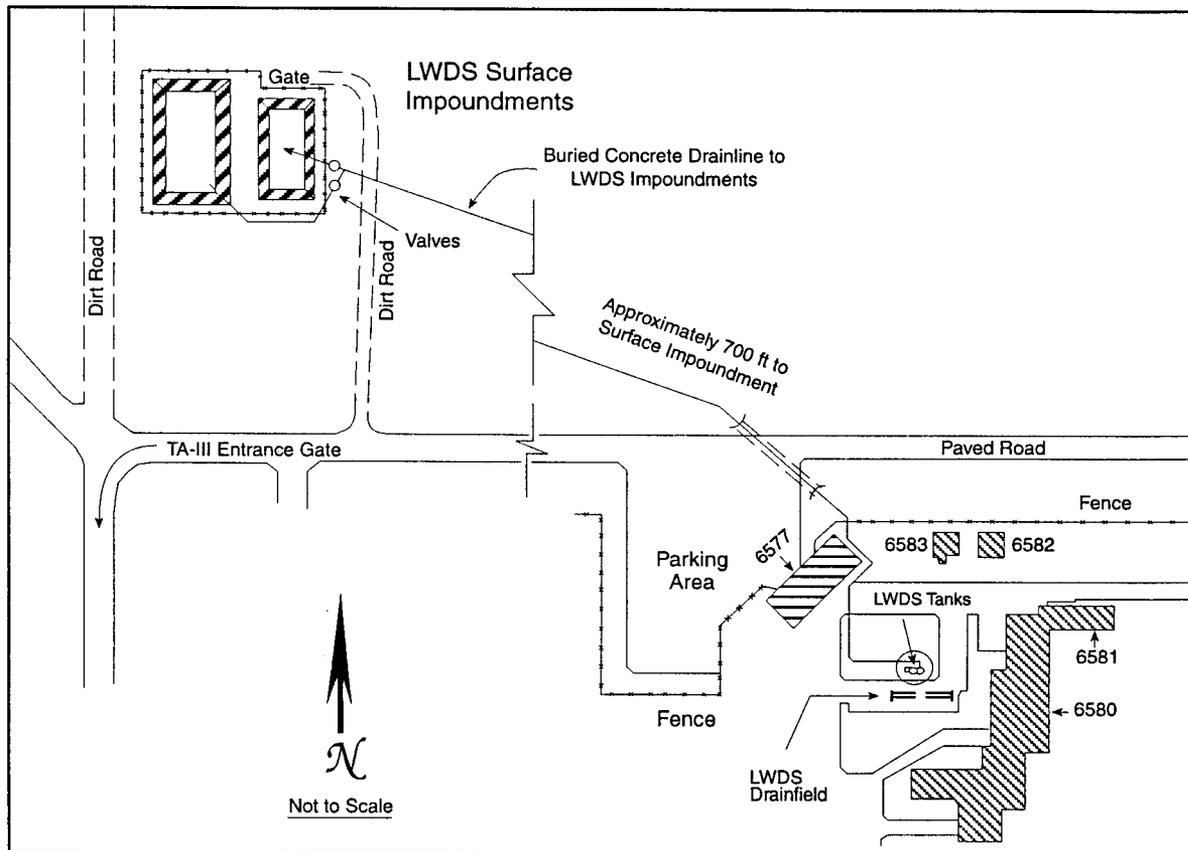


Figure 1-1. Liquid Waste Disposal System Site Map

- Performing an investigation of the LWDS holding tanks internal contents and associated piping; and
- Installing and sampling ground-water monitoring wells at the LWDS surface impoundments and drainfield.

The LWDS RFI work plan also described data analysis methods, including a comparison to background and health-based cleanup concentrations and activities.

In summary, there were four overall objectives of the LWDS RFI work plan:

1. Define the nature and extent of contamination at each of the three LWDS ER sites;
2. Identify potential contaminant transport pathways;
3. Evaluate potential risks posed by the levels of contamination identified, if present; and
4. Provide guidance for remedial alternatives at the sites, if necessary.

2.0 ENVIRONMENTAL SETTING

2.1 Climate

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

The average annual precipitation for the Albuquerque area is 8.54 in. The average monthly precipitation ranges from a minimum of less than 0.5 in. in the winter months to approximately 1.5 in. in the summer months. Mean annual snowfall in the Albuquerque area is approximately 11 in. Summer precipitation, particularly July through August, is usually in the form of heavy thundershowers that typically last less than 1 hour at any given location (Williams, 1986). Average annual pan evaporation at Albuquerque International Sunport weather station 224 is 89 in. (U.S. National Weather Service, 1982).

Under normal conditions, wind speeds seldom exceed 32 mph and are generally less than 8 mph (Bonzon et al., 1974). Strong winds, often accompanied by blowing dust, occur mostly in late winter and early spring. During these months, the prevailing surface winds are from the east. Rapid nighttime ground cooling produces strong temperature inversions and strong drainage winds down the Tijeras Canyon.

2.2 Surface Features

Cultural Surface Features

The LWDS holding tanks and drainfield are located within TA-V. TA-V, which encompasses approximately 23 acres, contains approximately 20 permanent structures and 30 temporary buildings and trailers. The LWDS holding tanks and drainfield were constructed below grade; as such, the only visible surface features are the accesses to holding tanks 2 and 4, and the tank vents.

The surface impoundments are located approximately 1000 ft northwest of TA-V (Figure 1-1). Except for monitor well LWDS-MW2, no permanent structures exist at the surface impoundments. The surface impoundments also were constructed below grade.

Impoundment 1 is approximately 8100 ft² with dimensions of 65 ft by 125 ft by 12 ft deep. Impoundment 2 is approximately 9400 ft² with dimensions of 102 ft by 92 ft by 20 ft deep. The original size may have changed slightly as a result of sidewall erosion and the subsequent deposition of the eroded soil on the impoundment floors.

The *Technical Areas 3 and 5 RCRA Facility Investigation Work Plan* describes other TA-V facilities in further detail (SNL, 1993).

Natural Surface Features

The LWDS is approximately 4 mi west of the Manzano Mountains and 7 mi east of the Rio Grande. Elevations at the LWDS range from 5400 ft above sea level at the surface impoundments to 5440 ft above sea level near the holding tanks. The immediate vicinity is a gently sloping plain.

2.3 Surface Water

Surface water is rarely present in the LWDS vicinity. During large rainstorms, surface water may pond in depressions that remain after grading operations within TA-V. After the storms, the ponds evaporate quickly.

2.4 Geology

2.4.1 Regional Geology

The Albuquerque-Belen structural basin is one of the largest north-south trending basins in the Rio Grande trough. The basin is a compound graben measuring 90 mi long and 30 mi wide, bordered by uplifted fault blocks to the east and west (Bjorklund and Maxwell, 1961). The eastern boundary is marked by the Sandia, Manzanita, and Manzano mountains. The western side of the basin is bounded by the Lucero uplift, with the Ladron Mountains to the south and minor physiographic relief to the northwest.

Erosion from the surrounding highlands has filled the Albuquerque basin with up to 9000 ft of sediments. This sequence of sediments, the Santa Fe Group Formation, consists of debris flows and channel, flood plain, and aeolian deposits. The Santa Fe Group thins toward the basin edges and is truncated by the bounding uplifts. The Miocene- and Pliocene-age Santa Fe Group sediments are interbedded with Tertiary and Quaternary basalts and pyroclastics, and are overlain in places by the Pliocene Ortiz gravel deposits and Rio Grande fluvial deposits (Bjorklund and Maxwell, 1961).

2.4.2 Local Geology

From August 1992 to May 1993, the U.S. Geological Survey (USGS) collected lithologic and hydrogeologic data beneath the LWDS during drilling operations. Information was collected from 16 boreholes and 2 ground-water monitor wells.

The sediments underlying the LWDS facility consist of alluvial fan deposits derived from the Manzanitas to the east. On a local scale, alluvial fan deposits are characterized by great internal variability, and detailed correlations are not feasible. On a larger scale, however, general trends can be observed laterally and vertically.

The borehole geophysical logs provide a continuous, normalized indirect measurement of the relative amount of "fines" in the sediment via the gamma-ray (GR) and neutron (N) curves. The GR log measures the natural radioactivity emitted primarily from the potassium-40 of the clays and the potassium feldspars. Increasing GR response (in counts per second) generally indicates an increasing percentage of fine sediments. The N log measures the relative concentration of the hydrogen (H) ion of water in the sediment, and because many clays contain chemically bound H in their crystal lattices, a decreasing N response generally indicates an increasing percentage of clayey sediments. Below the water table, the N becomes "saturated" and cannot be used for lithologic control. The generally increasing GR and decreasing N readings downward in both LWDS-MW1 and LWDS-MW2 wells (Figures 2-1 and 2-2) indicate the decrease with depth in average sediment grain size.

Continuous core was collected and described for LWDS-MW1 and soil samples were collected for grain-size analysis and saturated conductivity (K_{sat}) at 20-ft intervals. The results of these measurements and lithologic descriptions indicate that coarse-grained sediments dominate the upper section and that grain size decreases downward to approximately 490 ft and support the interpretation of the geophysical logs. The top of the section is dominated by high-energy episodic debris flows that deposited coarse-grained loads near the head of an alluvial fan derived from the eroding mountains to the east. As depth increases, the lithology indicates a more tranquil depositional environment at the toe of the alluvial fan. This lithologic variation is consistent with the regional depositional pattern of coarser material deposited over fine material

LWDS-MW1

Geophysical Logs USGS

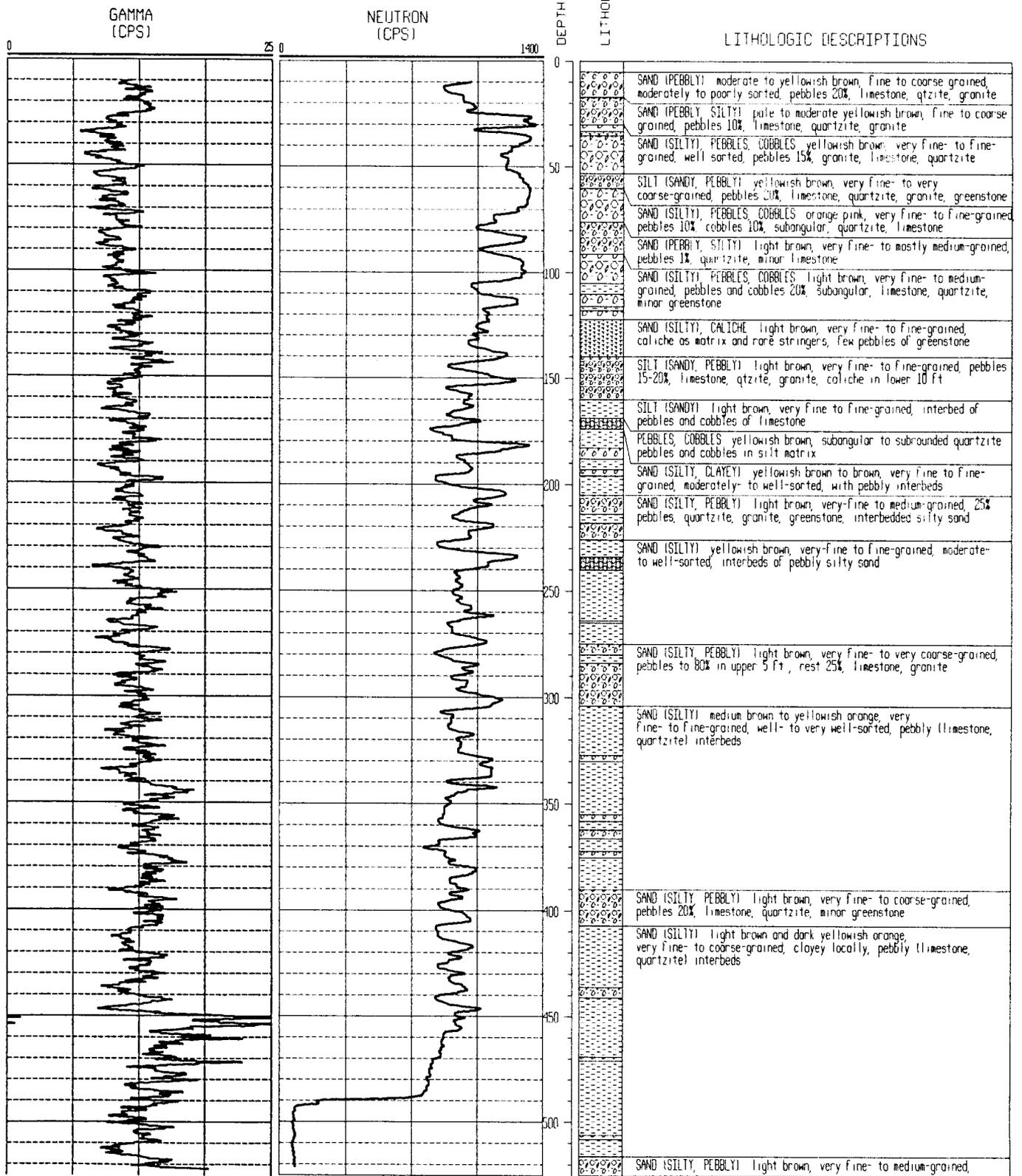


Figure 2-1. LWDS-MW1 Geophysical and Lithologic Log

LWDS-MW2

Geophysical Logs USGS

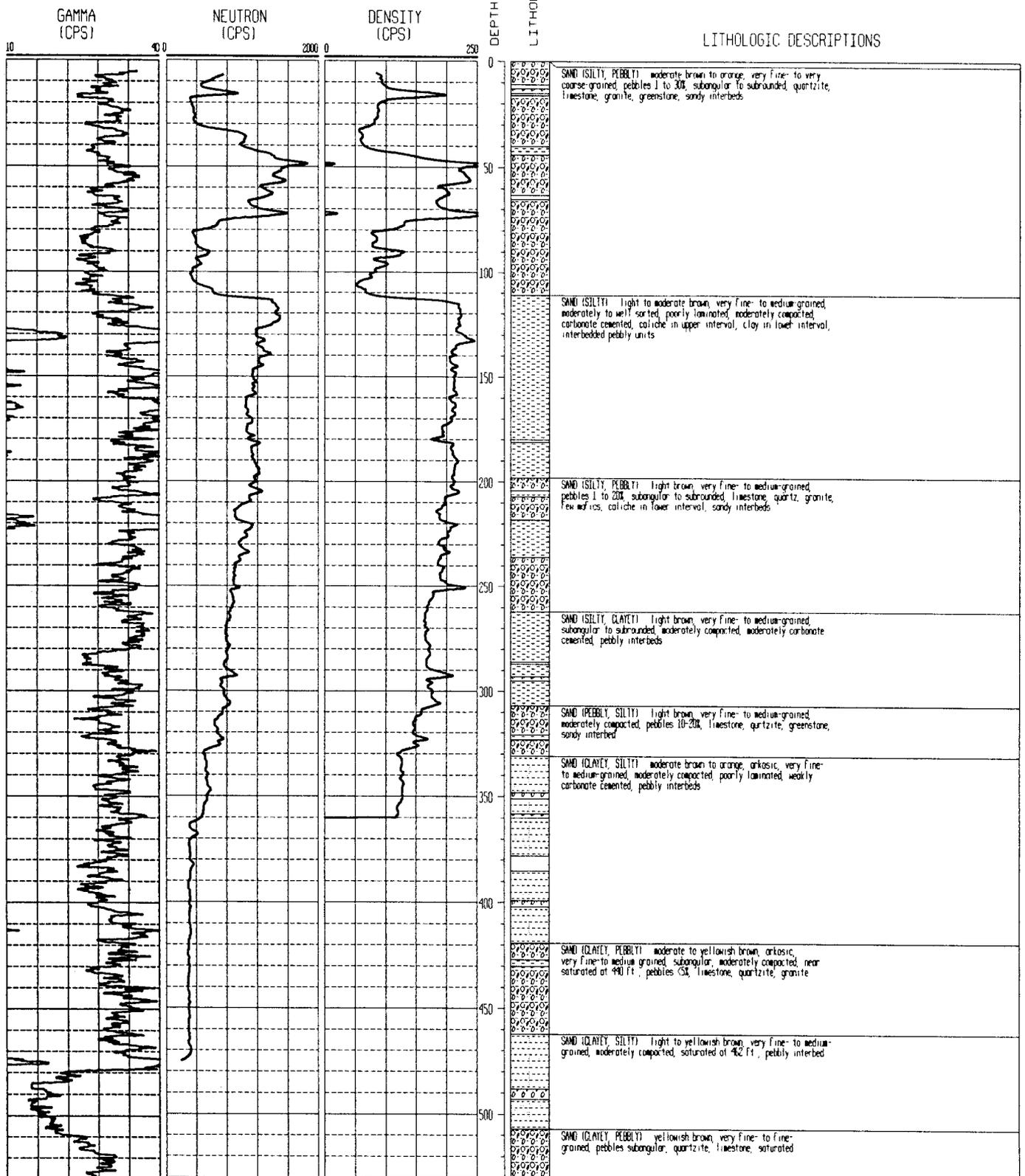


Figure 2-2. LWDS-MW2 Geophysical and Lithologic Log

over time. Below 490 ft, the grain size and K_{sat} increases slightly, possibly suggesting a new sequence. The alluvial fan package in LWDS-MW2 appears similar. Below approximately 480 ft, the GR readings diminish, suggesting the same coarsening seen below 490 ft in LWDS-MW1.

Petrographic analysis was performed with seven samples collected from LWDS-MW1. The samples were collected at selected points from archived core to represent the different layers defined in lithologic and geophysical logs. This analysis showed that mineralogy plays no significant role in the vertical variation in K_{sat} . The general decrease in K_{sat} downward is the result of a decrease in average grain size.

2.5 Hydrogeology

The Rio Grande, located 8 mi to the west, flows in a southerly direction and is the primary surface drainage feature in the Albuquerque-Belen basin. In the basin, the ground-water system is controlled by the Rio Grande and its flood plain, tributary inflow, mountain front runoff, and recharge.

The principal aquifer in the area occurs in the unconsolidated and semiconsolidated sands, gravels, silts, and clays of the Santa Fe Group Formation. The aquifer is generally unconfined, although semiconfined conditions may exist locally because of discontinuous, lenticular silt and clay-rich deposits.

Beneath Kirtland Air Force Base (KAFB), the regional aquifer generally flows toward the Rio Grande at an average gradient of approximately 10 ft/mi; however, local perturbations in the water table are caused by municipal wells as well as lithologic and structural heterogeneity. Before extensive development of the regional aquifer by the City of Albuquerque and KAFB, the predominant ground-water flow direction in the SNL/KAFB area was west-southwest (Bjorklund and Maxwell, 1961); however, municipal pumping by the City of Albuquerque and KAFB has substantially affected the natural ground-water flow regime (Reeder et al., 1967; Kues, 1987). The KAFB production wells have a substantial effect on the hydraulic gradient in the area, creating a cone of depression in the potentiometric surface in the northern portion of KAFB. USGS projections indicate that, by the end of the century, the water table in the Albuquerque area will drop an estimated 30 to 50 ft from 1989 levels (Reeder et al., 1967).

The primary source of ground water in the LWDS area is found primarily in the unconsolidated and semiconsolidated sedimentary deposits of the basin-fill aquifer. A relatively thick unsaturated zone of approximately 460 ft overlies this aquifer. The basin-fill aquifer underlying the LWDS site is recharged primarily by inflow from the mountain areas to the east. Recharge resulting from direct infiltration of precipitation is minor due to the high evaporation, low precipitation rates, and an extensive vadose zone.

3.0 DATA EVALUATION

Data collected during the LWDS investigation were evaluated several ways. Constituents of concern (COCs) are those contaminants that have been identified as possibly being released at a site. Analytical data were examined to determine whether each COC is actually present at the site as a contaminant. This involved a statistical comparison to background coupled with an examination of the spatial distribution of the constituent. Initially, a constituent's concentrations were compared to natural background using EPA-approved methods, as described in Section 3.2.4. Any COC failing the statistical comparison to background (i.e., could not be proven to be within background with 95 percent confidence) was further examined for spatial distribution. Contamination at the LWDS was proven to have a strong spatial correlation to the discharge points in the drainfield and impoundments. COCs that failed the statistical comparison to background and showed a strong spatial correlation were identified as contaminants.

After a constituent is identified as a contaminant, the sample population is compared to EPA action levels and, in most cases, studied in a detailed transport and risk assessment. A SNL/NM-developed computer program, Probabilistic Risk Evaluation and Characterization Investigation System (*Précis*) (Knowlton, 1994), analyzed all contaminants for a particular site (organic compounds, radionuclides, and RCRA metals). The following sections describe this process in greater detail.

3.1 Summary of Quality Assurance/Quality Control Activities

All field activities performed at the LWDS during the implementation of the LWDS RFI work plan (SNL, 1994a) followed strict Quality Assurance/Quality Control (QA/QC) protocols. These protocols in part comprise the collection of 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 RFI investigation.

The QA/QC samples proved to be invaluable during the evaluation of the analytical results. This was particularly germane when reviewing the analytical data for volatile organic compounds (VOCs). Throughout the investigation, common laboratory contaminants including methylene chloride, methyl ethyl ketone (MEK), and acetone

were consistently identified in both the field samples and the QC samples. The consistent presence of these constituents in method blanks and trip blanks suggests that they are attributable to laboratory contamination. Accordingly, low levels of VOC results for these analytes were not considered indicative of organic contamination.

QA/QC procedures employed during this investigation also included verification and validation of the analytical results according to guidelines from AOP94-27 (SNL, 1994b). This verification includes reviewing sample holding times, equipment rinsate, method and trip blank results, and comparing duplicate samples. Some analytical results for individual parameters were out of compliance with respect to one or more of these criteria. Chromium-VI was especially problematic due to the 1-day holding time which could not be met by the off-site laboratory. Table 3-1 identifies those analytes and associated samples evaluated as being out of compliance with programmatic and regulatory requirements. There were relatively few noncompliances, so that the overall integrity of the data package is not expected to be affected.

3.2 Statistical Analysis of Background

As part of the Site-Wide Hydrogeologic Characterization (SWHC) Project, a statistical analysis of the background population was performed. The methodology and analysis results are summarized in the remainder of this section, and are presented in greater detail in the report entitled *Background Concentrations of Constituents of Concern to the Sandia National Laboratories/New Mexico Environmental Restoration Project Phase II: Interim Report*, dated October 1994 (IT, 1994a). The purpose of the SWHC Project investigation was to determine the background concentrations for constituents that occur naturally at SNL/NM, including metals and radionuclides. This investigation included compiling analytical data from samples collected during ER activities at SNL/NM. These data were culled; all samples that were contaminated or had elevated detection limits were removed. The data distribution was then determined, and depending upon the distribution, either a 95-percent upper tolerance limit (UTL) or a nonparametric 95th-percentile value was calculated.

As required in the LWDS RFI work plan, a site-specific background study was also conducted at the LWDS. Sixteen surface-soil background and one duplicate surface-soil sample were collected from an area located northeast of the LWDS surface impoundments. A 50-ft by 50-ft grid was established in this area, situated approximately 1000 ft upwind. Sample collection procedures were identical to those used in the

Table 3-1
Analytes and Associated Samples in Noncompliance

Parameter	Test Method	Sample Type	Number in Noncompliance	Total Samples	Percent in Noncompliance	QC Flag ^a
Cadmium	6010 ^b	Field, Duplicate	2	392	0.5	D
Chromium	6010 ^b	Field, Duplicate	8	392	2.1	D
Cobalt-60	Gamma Spectroscopy	Field, Duplicate	4	391	1.0	D
Copper	6010 ^b	Field, Duplicate	14	381	3.7	D
Iron	6010 ^b	Field, Duplicate	4	385	1.0	D
Lead	6010 ^b	Field, Duplicate	4	45	8.9	D
Lead	7421 ^b	Field, Duplicate	4	399	1.0	D
Lead-212	Gamma Spectroscopy	Field, Duplicate	8	525	1.5	D
Lead-214	Gamma Spectroscopy	Field, Duplicate	2	525	0.3	D
Manganese	6010 ^b	Field, Duplicate	4	392	1.0	D
Nickel	6010 ^b	Field, Duplicate	4	392	1.0	D
Potassium	6010 ^b	Field, Duplicate	4	392	1.0	D
Potassium-40	Gamma Spectroscopy	Field, Duplicate	2	525	0.3	D
Radium-226	Gamma Spectroscopy	Field, Duplicate	2	525	0.3	D
Radium-228	Gamma Spectroscopy	Field, Duplicate	4	525	0.6	D
Silver	6010 ^b	Field, Duplicate	2	392	0.5	D
Sodium	6010 ^b	Field, Duplicate	2	392	0.5	D
Thallium-208	Gamma Spectroscopy	Field, Duplicate	6	525	1.1	D
Thorium-228	Gamma Spectroscopy	Field, Duplicate	4	525	0.6	D
Thorium-232	Gamma Spectroscopy	Field, Duplicate	2	525	0.3	D
Tritium	EPA H-01 ^b	Field, Duplicate	20	386	5.2	D
Vanadium	6010 ^b	Field, Duplicate	4	392	1.0	D
Zinc	6010 ^b	Field, Duplicate	4	392	1.0	D
			114			

^a D denotes the sample is outside the relative percent difference (RPD) range. H1 denotes missed holding time for analysis. H2 denotes missed holding time for extraction or analysis.

^b Reference: U.S. Environmental Protection Agency (EPA), 1986, "Test Methods for Evaluating Solid Waste," Volume IA: "Laboratory Manual Physical/Chemical Methods," SW-846, Third Edition, EPA, Office of Solid Waste and Emergency Response, Washington, DC (November 1986).

Table 3-1
Analytes and Associated Samples in Noncompliance (Concluded)

Parameter	Test Method	Sample Type	Number in Noncompliance	Total Samples	Percent in Noncompliance	QC Flag ^a
VOCs	8240 ^b	Field	2	505	0.3	H1
Chromium-VI	7196 ^b	Field, Duplicate	86	86	100	H1
Mercury	7471 ^b	Field, Duplicate	20	394	5.0	H1
			108			
SVOCs	8270 ^b	Field, Duplicate	34	452	7.5	H2
			34			

^a D denotes the sample is outside the relative percent difference (RPD) range. H1 denotes missed holding time for analysis. H2 denotes missed holding time for extraction or analysis.

^b Reference: U.S. Environmental Protection Agency (EPA), 1986, "Test Methods for Evaluating Solid Waste," Volume IA: "Laboratory Manual Physical/Chemical Methods," SW-846, Third Edition, EPA, Office of Solid Waste and Emergency Response, Washington, DC (November 1986).

Note: VOCs = volatile organic compounds; SVOCs = semi-volatile organic compounds.

surface sampling conducted at the impoundments. The LWDS background data were included in the SWHC Project effort; the LWDS background populations were within SWHC background. However, the SWHC Project-determined background populations were used for data evaluation in this report, rather than the LWDS background data, for several reasons.

- The data sets were much larger;
- The SWHC Project approach was developed to be consistent with current EPA guidance, and the report has been submitted to the EPA; and
- The LWDS background soil samples did not replicate the lithologic range exhibited by the LWDS ER sites.

Advantages of using the site-wide approach included lower cost, greater efficiency, a larger database of individual analyses, and the development of consistent values for the entire facility. Potential disadvantages of the site-wide approach are that it may yield a broader range of values for each COC than is directly pertinent to the LWDS, and it may not be statistically valid if several distinct populations (e.g., from different lithologies) are included in the data set. The latter is addressed by separately checking each data set for multiple populations.

3.2.1 Background Metals in Soil

Seven of the fourteen metals identified in soil samples (barium, beryllium, cadmium, total chromium, copper, nickel, and zinc) were lognormally distributed and therefore analyzed using standard parametric statistical methods consistent with EPA-recommended protocol. No data exist for mercury, tin, or zirconium. Lead, chromium-VI, silver, and total uranium were analyzed using nonparametric methods either because the final working data set possessed a high percentage of nondetect values, or because the distribution was multimodal. Table 3-2 summarizes all critical statistical parameters determined for each constituent. In each case, either a 95-percent UTL (normal or lognormal distribution) or a 95th percentile (nonparametric distribution) was calculated. Several concentration values were rejected a priori for being approximately three to four times greater than the next highest value. Very few additional outliers were identified in the working data sets.

Table 3-2
Summary of Background Concentrations for Metals in Soil
(adapted from IT, 1994a)

Analyte	Original Number of Samples	Number of Detects	Number of Rejected Samples	Distribution Type	Range (mg/kg)	Sample Size	Geometric Mean (mg/kg)	Median (mg/kg)	95% Upper Tolerance Limit (mg/kg)	95th Percentile (mg/kg)
Barium	964	951	169	Lognormal	0.13–730	795	55.76	68.20	398.1	N/A
Beryllium	436	408	103	Lognormal	0.1–1.1	331	0.317	0.33	0.8	N/A
Cadmium	914	209	738	Lognormal	0.1–8.5	176	0.411	0.50	3.5	N/A
Total Chromium	1016	994	18	Lognormal	0.01–58.1	998	5.71	5.70	22.9	N/A
Chromium-VI	118	53	7	Unknown ^a	<detection limit (<0.02)	111	<detection limit (<0.02)	<detection limit (<0.02)	N/A	<detection limit (<0.02)
Copper	407	404	15	Lognormal	1.0–29.0	392	6.179	6.20	16.7	N/A
Lead	738	438	48	Nonparametric	1.0–110.0	690	4.575	4.40	N/A	15.0
Mercury	0	0	0	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A
Nickel	407	397	4	Lognormal	1.0–30.9	403	6.283	6.30	15.4	N/A
Silver	972	236	725	Nonparametric	0.05–10.0	247	0.741	1.0	N/A	4.0
Zinc	161	161	3	Lognormal	8.3–59.9	158	22.15	21.0	46.7	N/A
Zirconium	0	0	0	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A

^a Constituents of concern are of unknown distribution type because data are either unusable or nonexistent.

Note: mg/kg = milligrams per kilogram; N/A = Not applicable.

Numerous points representing suspected barium contamination at TA-II were deleted from the overall barium data set, despite the fact that they were not determined to be outliers. This action was justified because barium disposal occurred at the site and the probability plot indicated the presence of two distinct populations. Moreover, an independent statistical background study (IT, 1993) concluded that the observed second population of barium is likely due to anthropogenic activities.

Metal concentration ranges were similar for surface and subsurface data; however, surface-sampling coverage was generally better, resulting in a higher range of values. Better coverage results in a greater observed data range because of the approximately lognormal distribution of the metals; however, total chromium has a higher median at the surface, whereas the other metals for which data are now available (barium, beryllium, cadmium, copper, lead, nickel, total uranium, silver, and zinc) have higher values in the subsurface. With the exception of zinc, the differences between median values for the surface and the subsurface data are minor. Furthermore, the observed variability in the data may be attributable to grain-size differences of the individual samples.

3.2.2 Background Radionuclides in Soil

Eleven of the nineteen naturally-occurring radionuclides (bismuth-212, bismuth-214, cesium-137, cobalt-60, lead-210, radium-224, radium-228, strontium-90, uranium-234, uranium-235, and uranium-238) were analyzed using nonparametric methods because they are either multimodally distributed or have too few detects. Six of the remaining eight radionuclides are either approximately normally distributed (potassium-40) or approximately lognormally distributed (lead-212, lead-214, radium-226, thorium-232, and thorium-234) and were analyzed using standard parametric statistical methods. No background data are available for radon or tritium.

Table 3-3 summarizes all critical statistical parameters determined for each radionuclide COC. In each case, either a 95-percent UTL (normal or lognormal distribution) or a 95th percentile (nonparametric distribution) was calculated. Whereas a few points were rejected a priori, few additional outliers were identified in any of the radionuclide data sets. TA-V consistently has a greater observed range and higher median values for radionuclides than do the other areas. Some high values for cesium-137 in soil collected from TA-V were identified on the distribution plots and were subsequently rejected from the overall data set as suspected contamination.

Table 3-3
Summary of Background Concentrations for Radionuclides in Soil
(adapted from IT, 1994a)

Analyte	Original Number of Samples	Number of Detects	Number of Rejected Samples	Distribution Type	Range (pCi/g)	Sample Size	Geometric Mean (pCi/g)	Median (pCi/g)	95th Upper Tolerance Limit (pCi/g)	95th Percentile (pCi/g)
Bismuth-212	324	17	307	Nonparametric	0.414–2.7	17	1.1055	1.0	N/A	2.7
Bismuth-214	340	321	19	Nonparametric	0.27–1.4	321	0.648	0.6	N/A	0.8
Cesium-137 (Surface) (Subsurface)	802 N/A N/A	561 N/A N/A	26 N/A N/A	N/A Nonparametric Unknown ^a	N/A 0.004–10.1 <detection limit (<0.0686)	N/A 604 172	N/A 0.200 <detection limit (<0.0686)	N/A 0.2495 <detection limit (<0.0686)	N/A N/A N/A	N/A 0.92 <detection limit (<0.0686)
Cobalt-60	321	11	74	Unknown ^a	<detection limit (<0.0418)	247	<detection limit (<0.0418)	<detection limit (<0.0418)		<detection limit (<0.0418)
Lead-210 ^b	338	40	292	Nonparametric	0.3–12.0	46	2.26838	2.835	N/A	6.8
Lead-212 ^b	323	233	90	Lognormal	0.1–1.4	233	0.49689	0.5	1.1	N/A
Lead-214 ^b	249	241	9	Lognormal	0.29–1.13	240	0.549	0.56	0.9	N/A
Potassium-40	722	720	4	Normal	0.192–31.0	718	15.889	16.4	25.34	N/A
Radium-224	24	24	0	Nonparametric	0.43–0.97	24	0.6747	0.655	N/A	0.968
Radium-226	368	53	314	Lognormal	0.5–2.09	54	0.713	0.590	1.9	N/A
Radium-228	24	24	0	Nonparametric	0.45–1.05	24	0.695	0.630	N/A	1.05
Radon	0	0	0	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A
Strontium-90	54	45	9	Nonparametric	0.032–1.85	45	0.2528	0.2883	N/A	0.77
Thorium-232	136	136	0	Lognormal	0.23–1.20	136	0.7971	0.810	1.3	N/A
Thorium-234	365	52	330	Lognormal	0.324–3.0	35	0.7796	0.71	2.9	N/A
Tritium	0	0	0	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A
Uranium-234	4	4	0	Nonparametric	0.8–1.0	4	0.897	0.9	N/A	1.0
Uranium-235	95	21	75	Nonparametric	0.05–0.18	20	0.1198	0.1235	N/A	0.17
Uranium-238	223	206	17	Nonparametric	0.0033–2.065	206	0.506	0.763	N/A	1.1

^a Constituents of concern are of unknown distribution type because data are either unusable or nonexistent.
^b These constituents are not listed as constituents of concern in Table A-1 of Appendix A for this media.
Note: pCi/g = picocuries per gram; N/A = Not applicable.

Several COCs are part of the naturally-occurring uranium-decay series. Because total uranium (Section 3.2.1) and its isotopes are apparently bimodally distributed, the daughter products might also be bimodally distributed. Some COCs show bimodal distribution; however, in a few cases (lead-212, lead-214, radium-226, thorium-232, and thorium-234) the use of standard statistical methods showed approximately lognormally distributed COCs. Except for potassium-40, most of the radionuclides are closer to lognormal than normal distribution type as evidenced by the probability plots.

Several radionuclides showed a broader range of values at the surface than in the subsurface. The reason for this difference is twofold: (1) there were more samples collected for the surface data set, so a greater total number of high values would be expected from the lognormal distribution seen for some of the COCs; and (2) several of the COCs that have been deposited as atmospheric fallout from global nuclear weapons testing are readily adsorbed onto soil and may not have yet reached the subsurface. In that event, however, those COCs associated with atmospheric fallout should be evenly distributed across SNL/NM as well as off-site. For some COCs (e.g., cesium-137 and potassium-40) no significant difference is observed between off-site and on-site localities and/or between on-site localities.

3.2.3 Metals and Nitrates in Ground Water

Background analyses for ground water were performed on a regional basis, rather than by individual area. Due to insufficient data, no statistical analysis was performed with respect to depth.

Of the 14 COCs assessed for ground water, only barium and nitrate had a sufficient number of detects to apply standard statistical methods to characterize the distributions. Where possible, either a UTL (lognormal distribution) or a 95th percentile (nonparametric distribution) was calculated and is tentatively proposed as the background value for the appropriate regions. Table 3-4 summarizes the geometric means, medians, ranges, sample sizes, and UTLs or 95th percentiles. Although most COCs in ground water appear to be approximately lognormally distributed, nonparametric analyses were required for cadmium, total chromium, and lead because of the high proportion of nondetect values. Sufficient data are available for barium, total chromium, and lead to calculate a 95th percentile that is above the stated detection limit of the analyses. Cadmium, nickel, and silver have sufficient data to confirm that the geometric means, medians, and the 95th percentiles are below the detection

Table 3-4
Summary of Background Concentrations for Metals and Nitrate plus Nitrite in Ground Water
(adapted from IT, 1994a)

Analyte	Original Number of Samples	Number of Detects	Number of Rejected Samples	Distribution Type	Range (mg/L)	Sample Size	Geometric Mean (mg/L)	Median (mg/L)	95th Upper Tolerance Limit (mg/L)	95th Percentile (mg/L)
Barium	272	75	197	Lognormal	0.001–1.3	91	0.056	0.07	N/A	1.0
Beryllium	52	0	51	Unknown ^a	<detection limit (<0.002)	1	<detection limit (<0.002)	<detection limit (<0.002)	N/A	N/A
Cadmium	220	1	161	Nonparametric	0.0025–0.017	59	<detection limit (<0.005)	<detection limit (<0.005)	N/A	<detection limit (<0.005)
Total Chromium	476	13	386	Nonparametric	0.0005–1.6	90	0.006	0.01	N/A	0.25
Chromium-VI	78	0	78	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A
Copper	52	0	50	Unknown ^a	N/A	2	N/A	N/A	N/A	N/A
Lead	223	4	163	Nonparametric	0.02–0.92	60	0.023	0.02	N/A	0.04
Nickel	98	0	52	Unknown ^a	<detection limit (<0.04)	46	<detection limit (<0.04)	<detection limit (<0.04)	N/A	N/A
Nitrate + Nitrite	131	69	62	Lognormal	1.0–17.0	69	2.881	3.0	12.1	N/A
Silver	213	0	155	Unknown ^a	<detection limit (<0.01)	58	<detection limit (<0.01)	<detection limit (<0.01)	N/A	N/A
Tin	28	0	28	Unknown ^a	N/A	0	N/A	N/A	N/A	N/A
Zinc	111	0	107	Unknown ^a	<detection limit (<0.02)	4	<detection limit (<0.02)	<detection limit (<0.02)	N/A	<detection limit (<0.02)

^a Constituents of concern are of unknown distribution type because data are either unusable or nonexistent.
Note: mg/L = milligrams per liter; N/A = not applicable.

limits of analyses for the entire sampling area. Sufficient data are currently unavailable to determine background values for beryllium, chromium-VI, copper, mercury, tin, zinc, and zirconium; however, sufficient data exist to calculate a regional UTL for both barium and nitrate plus nitrite.

3.2.4 Methodology for the Statistical Comparison of Site-Sampling Results to Background

Several EPA-approved statistical tests were used to compare soil analytical data to background levels. The following sections describe these tests and list the relative strengths of each.

3.2.4.1 *Wilcoxon Rank Sum Test*

The Wilcoxon Rank Sum (WRS) test is performed by ordering all observations from background and the potentially contaminated site according to their magnitude and then assigning a rank from lowest to highest. The ranks in the potentially contaminated area are summed and compared to a table of critical values to determine whether the site is contaminated.

The WRS test is a nonparametric test more powerful than the Quantile test (described below) in determining whether the potentially contaminated area has concentrations uniformly higher than background (EPA, 1992). However, the WRS test allows for fewer less-than measurements than the Quantile test. As a general rule, the WRS test should be avoided if more than 40 percent of the measurements in the potentially contaminated area or background are nondetects. All soil analytical data were subjected to the WRS test in this analysis, although the test power was greatly reduced when the nondetect percent was greater than 40.

3.2.4.2 *Quantile Test*

The Quantile test is performed by separating background data and individual site data. The data are then ordered from highest to lowest. The number of background and individual site data points are calculated. The number of data points for background and the selected potentially contaminated site is then compared to a table that identifies how many of the highest measurements must come from the potentially contaminated site versus background to indicate contamination.

The Quantile test is a nonparametric test that has more power than the WRS test to detect when only a small portion of the remediated site has not been completely cleaned up. Also, the Quantile test can be used even when a fairly large proportion of the measurements is below the limit of detection (EPA, 1992).

3.2.4.3 Hot-Measurement Comparison (Upper Tolerance Limit) Calculation

The hot-measurement comparison consists of comparing each measurement from the potentially contaminated area with an upper-limit concentration value. This upper-limit concentration value is such that any measurement from the potentially contaminated area that is equal to or greater than this value indicates an area of relatively high concentrations that must be further investigated (EPA, 1992). Concentrations exceeding the upper-limit value may indicate inappropriate sample collection, handling, or analysis procedures, or actual contamination.

The upper-limit concentration value was calculated in the SWHC Project background study based on the 95th percentile for nonparametric data and the 95th UTL for parametric data.

3.2.4.4 Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov (KS) test calls for two independent samples and tests the null hypothesis that the two samples come from identical distributions. This is achieved through the calculation and comparison of the cumulative distribution functions for each sample (Steel and Torrie, 1980). The maximum numerical difference between the two calculated values is compared to tables of critical values. If the data do not support the null hypothesis, it is concluded that the two samples are from different populations. The test is also sensitive to differences in variance, since it is a test of the equality of distributions rather than of specific parameters.

The KS test is a nonparametric test that can be used to evaluate the fit of any distribution. In general, the KS test is considered more powerful than alternative goodness-of-fit chi-square tests. The three general limitations are (1) the method is computationally complex; (2) it requires large sample sizes for greatest power (i.e., 50 or more); and (3) the parameters of the hypothesized distribution (e.g., mean and variance

of a normal distribution) are assumed to be known (Gibbons, 1994). Lilliefors (1967, 1969) generalized the test to the case of a normal or lognormal distribution with unknown mean and variance, although the method is still computationally complex and requires large samples.

The KS test was applied to soil data from all LWDS sites, but the test results are not further discussed in Section 4.0. The test analyzes distributions and is comparatively less powerful if the sampled population is not grossly contaminated.

3.2.4.5 Student's T-Test

The t-test is a parametric test that compares the means of two samples. To use the t-test statistic, both sampled populations must be approximately normally (or lognormally) distributed with approximately equal population variances, and the random samples must be selected independently of each other.

The equations and methodology for applying the t-test are explained in most statistics books, including McClave and Dietrich (1982) and Mendenhall (1975).

3.3 Resource Conservation and Recovery Act Action Levels

Action levels are concentrations of various parameters in soil, water, or air above which a corrective measure study for the facility could be warranted. These levels are determined to be indicators to protect human health and the environment. For air, surface soils, ground water, and surface water, generic action levels were estimated using assumptions outlined in RCRA (40 CFR 264) proposed Subpart S. The use of action levels allows a quick evaluation of the risk associated with the sampled concentrations of contaminants. In the case of the LWDS holding tanks, this evaluation indicated that the site should be proposed for No Further Action. For the other two LWDS ER sites, the comparison to proposed Subpart S action levels was inconclusive and a site-specific risk assessment was performed.

3.4 Contaminant Fate and Transport/Risk Assessment

All contaminants at the surface impoundments and drainfield were evaluated in a site-specific risk assessment. After a constituent was determined to be anthropogenic, the *entire* sampled population was used in the site-specific risk assessment, including concentrations within natural background levels.

The computer model developed by SNL/NM, *Précis*, was used (Knowlton, 1994). The basic risk assessment methodology defined by the EPA (1989) has been modified to include a quantitative uncertainty analysis technique. Initially, the SNL/NM risk assessment employs relatively simple process models to describe transport processes and conservative distributions of input parameters. If more detailed site-specific analysis is required, the preliminary risk assessment may be modified to include more rigorous analytical or numerical process models to describe transport processes. The probabilistic risk assessment methodology is ideal for quantitatively assessing uncertainty. Site-specific sections (Sections 4.2 and 4.3) list the risk assessment results, and Annexes I and II contain further details relating to future land use and exposure unit definitions.

3.5 Development of Conclusions and Recommendations

Ultimately, data for each site were evaluated to determine the adequacy of site characterization and to assess the risk each site poses to human health and the environment. This evaluation addressed the need for any potential future actions and the site disposition.

4.0 SITE-SPECIFIC RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

4.1 ER Site 52 Holding Tanks

The RCRA Facility Assessment (RFA) performed in 1987 identified Solid Waste Management Unit (SWMU) 98 as a holding tank for radioactive waste water discharged from the "TA-V hot cell lab and lab drains" for temporary storage (EPA, 1987). ER Project Site 52 contains SWMU 98 and also includes two other holding tanks within the same system (Figure 4-1). The LWDS holding tanks were designed to receive liquid wastes from the SERF main reactor, experimental facilities, and support facilities located in buildings 6580, 6581, 6582, and 6583. The reactor operated from 1962 to 1971. The tanks received liquid wastes from the SERF during this entire period. Potential COCs from this waste stream include radioactive wastes in the coolant water, and organic solvents and radiochemicals from the support facilities. The primary sources of radioactivity in the liquid wastes were the short-lived activation products of the coolant water and water impurities.

A series of two concrete tanks and one steel tank served as holding tanks for the liquid waste to allow short-lived radionuclides to decay before discharge to the drainfield and/or surface impoundments. Before each discharge, the liquid was thoroughly mixed and monitored for total radioactivity and fission products. The presence of fission products would have indicated a leaking fuel element. If fission products were detected, ion exchange through resin beds was to have been performed on the liquid waste, and the resins were to have been drummed for disposal. However, trace concentrations of fission products were sometimes released without ion exchange having taken place. For example, according to the SERF disposal logs, cesium-137 was occasionally detected in the discharge.

Tanks 1 and 2 were installed in 1963 and have volumes of 2000 and 6000 gal (Figure 4-2). Tank 1, directly above Tank 2, is concrete and measures 9 ft by 10 ft by 3 ft deep. Tank 2 is concrete and measures 16 ft by 10 ft by 5 ft deep (Figure 4-2).

Scaled engineering drawings show Tank 1 is buried at a depth of 17.5 ft and Tank 2 is buried at 22 ft (depth to the top of the tank). One manhole contains a pump and provides access to Tank 2. The tank access has a floor grating, is equipped with a 110-volt outlet, and is closed at the surface by a manhole cover. A third tank, referred

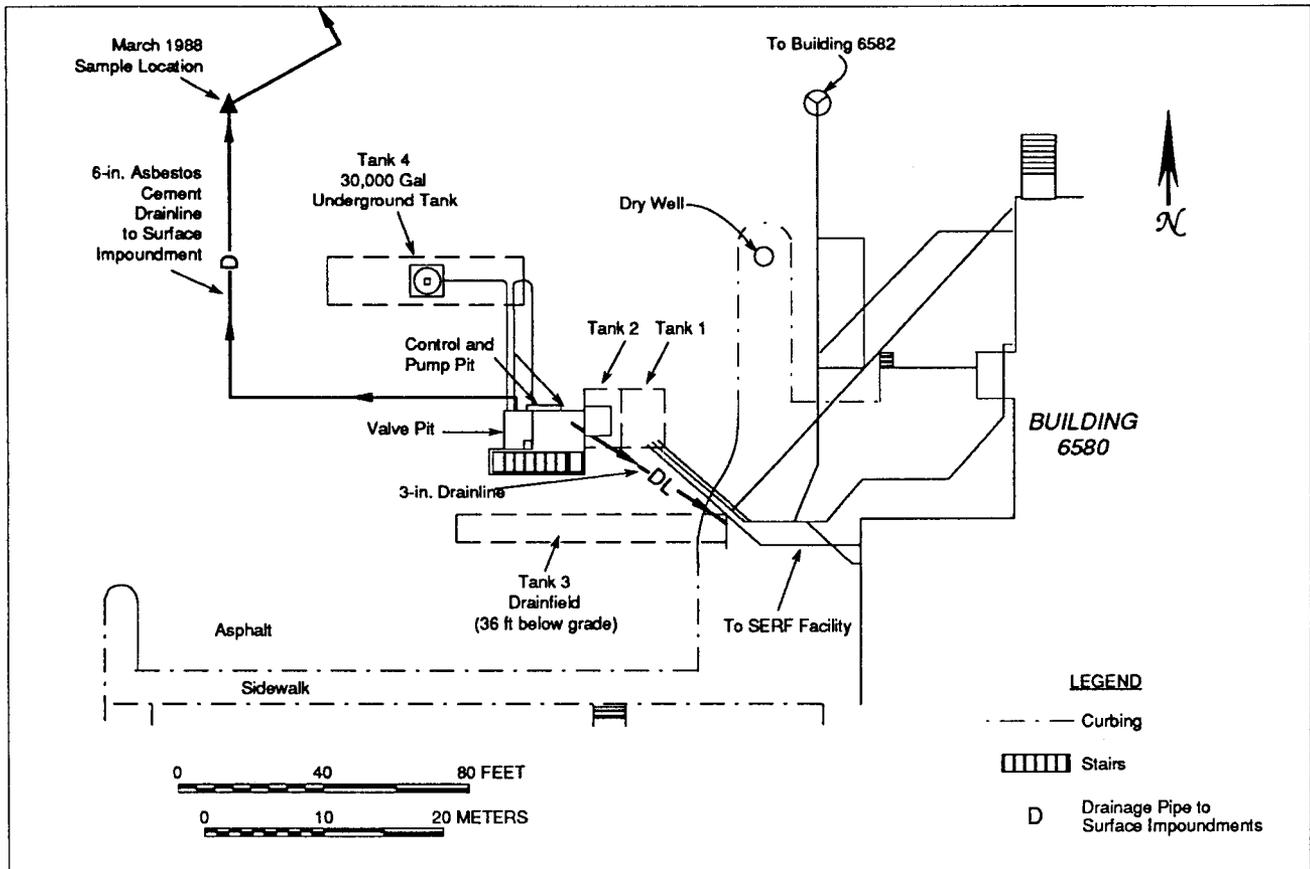


Figure 4-1. LWDS Holding Tanks Plan View

to as Tank 4, was installed in 1968 to increase holding capacity. (The LWDS drainfield, discussed in Section 4.2, has been referred to as Tank 3.) Tank 4 is steel, has a capacity of 30,000 gal, and is buried at a depth of 7 ft (depth to the top of the tank). The drain connections to this tank are fully manual, and no records of any use of this tank have been found.

The SERF was decommissioned in 1971 and is no longer in operation. Building 6580 was converted into the Hot Cell Facility (HCF); the floor drains and laboratory sinks in the HCF still connect to the holding tanks. The HCF personnel routinely work with irradiated fuel-rod material that produces a spectrum of fission products, including transuranic material. The sinks are used for hand-washing by personnel in the HCF, and the floor drains receive the water used to mop the floors. Radioactive material that has inadvertently escaped from the hot cells could possibly enter the LWDS through these floor drains. Since the decommissioning of the SERF in 1971, nonradioactive discharges from various buildings in TA-V have continued to drain to the holding tanks.

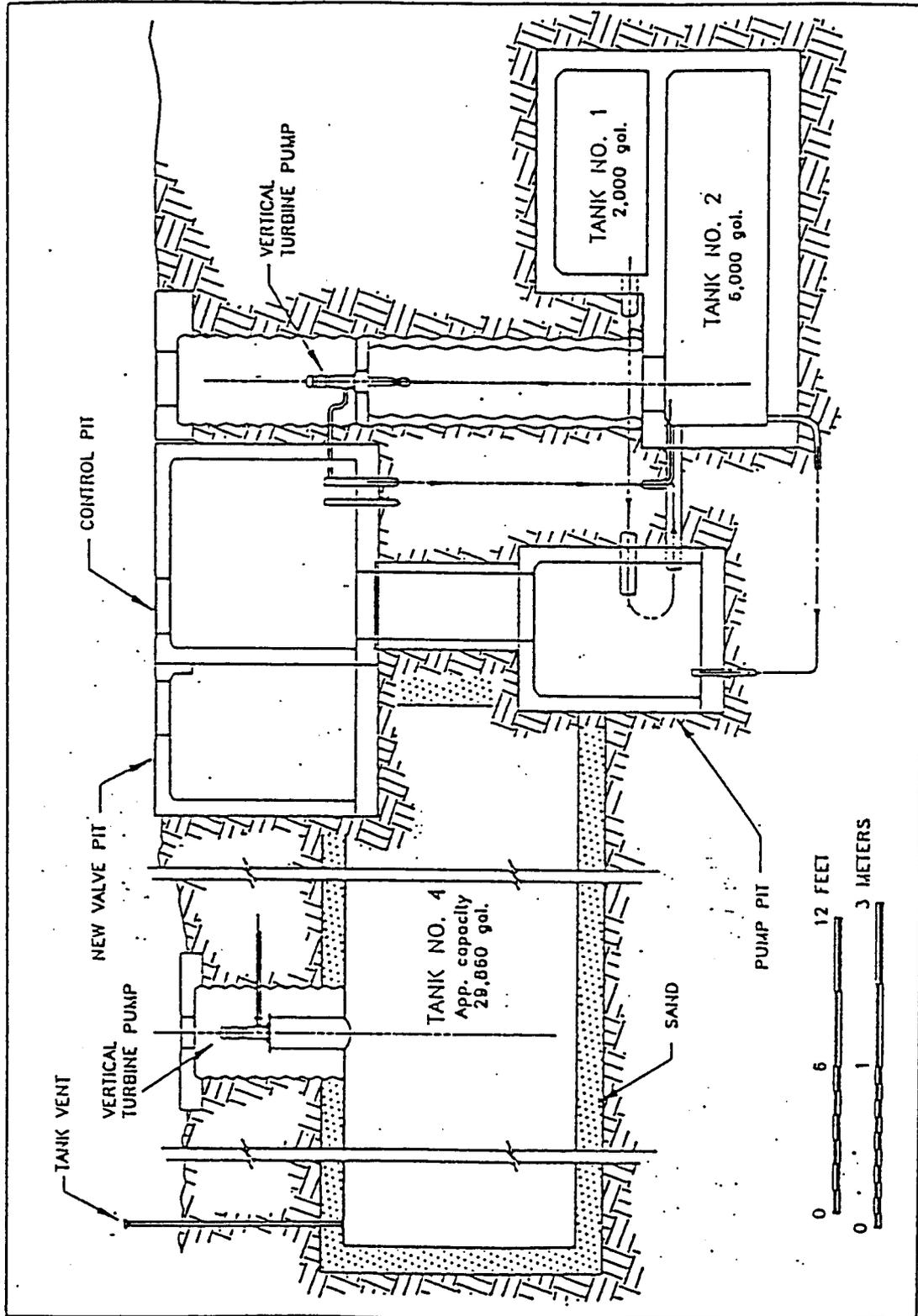


Figure 4-2. LWDS Holding Tanks Profile

The tanks were periodically pumped to the surface impoundments until October 1992, when the U.S. Department of Energy (DOE) ordered that all discharges to the impoundments be stopped. Thereafter, the tanks were pumped intermittently (approximately every one to four months), discharging approximately 4600 gal of water each time. During this time, no logs were maintained to record the frequency of operation and activity measurement.

Recently, increased attention to these discharges has resulted in improved operating practices and considerably fewer discharges to the holding tanks (e.g., as of October 1993, the tanks had not been pumped for almost ten months).

In 1994, a Liquid Effluent Control System (LECS) was constructed to manage all future TA-V liquid discharges. The LECS receives all process water from TA-V, including liquids previously discharged to the holding tanks. This system allows for the water to be held and sampled prior to discharging it to the City of Albuquerque publicly-owned treatment works (POTW). The LECS connects into the LWDS downstream from the holding tanks, in effect leaving the tanks in service indefinitely.

4.1.1 Contamination Sources

The three holding tanks and their piping are the potential sources of contamination for this SWMU (ER Site 52). These tanks were investigated for any signs of leakage to the underlying soil. Because these tanks are not currently scheduled for removal, an internal investigation of the tank contents was conducted. This investigation was intended to evaluate the tank contents as a potential source for spreading contamination to the surrounding soil in the future and to aid in determining the acceptability of leaving the tanks in service.

4.1.2 Field Investigation

Internal Contamination

Internal investigation of the holding tanks consisted of content sampling for Tanks 2 and 4. The LWDS RFI work plan sampling plan was based on the tanks' construction and the discharge history of the system. (Figure 4-2 shows the vertical profile of the holding tank.) Tank 1 is inaccessible for direct sampling. Effluent from TA-V support buildings enters Tank 1 and then flows directly to Tank 2 where it collects. Contamination levels are assumed to be uniform between Tanks 1 and 2 based on the discharge flow path and recirculation of the tank contents.

Internal pipe contamination was investigated by collecting swipe samples, obtained by excavating a pit at a pipe joint and disassembling the joint (see Figure 4-3). A 90-degree joint coupling in the pipe was chosen because of the likelihood of particulates becoming lodged at this location. This location also represents an original section of pipe, rather than a section installed in the 1980s to reroute the drainline for the new TA-V access Building 6577. After the pipe was disassembled, swipe samples were collected from the inside. A soil sample and duplicate were collected immediately beneath the disassembled joint. The pipe was reassembled upon completion of sampling and the excavation was backfilled and compacted. The swipe samples were counted on-site at the TA-V Dosimetry Laboratory.

Subsurface Soil

In September 1992, three angled boreholes (LWDS-BH6, 7, and 8) were drilled at the holding tanks (Figure 4-3). In general, field procedures were identical to those described in Appendix A. These boreholes were sampled at approximately 5-ft intervals along the angled borehole to 50 ft and soil samples were analyzed for tritium, gamma-emitting radionuclides, volatile and semi-volatile organic compounds, and metals using the methods described in Appendix B. Soil analysis conducted at an off-site laboratory did not reveal the presence of volatile organic contamination; however, low levels of organic vapors were detected with field screening instruments between 30 ft and 43 ft in Borehole 7. The suspected presence of organic solvents resulted in a high likelihood of creating mixed waste with continued investigation. Subsurface investigation at the LWDS holding tanks was postponed due to a DOE-imposed moratorium on generating mixed waste.

The exact nature of the organic contamination was not determined. Extensive gas chromatograph analyses were performed to "fingerprint" the organics but the results were inconclusive. The analyses did not compare well with known organic contaminants or with a sample of the nearby High-Energy Radiation Megavolt Electron Source (HERMES) oil-contaminated soil. Preliminary gas chromatograph analyses indicated the presence of a complex of heavy organic compounds, typical of a petroleum product. Such a release would not be expected from the LWDS tanks, a conclusion strengthened by the absence of other known holding tank contaminants such as radionuclides. Because the tanks are located in a highly industrial area with several known fuel and oil releases, contamination from another source was suspected. At that time, the LWDS

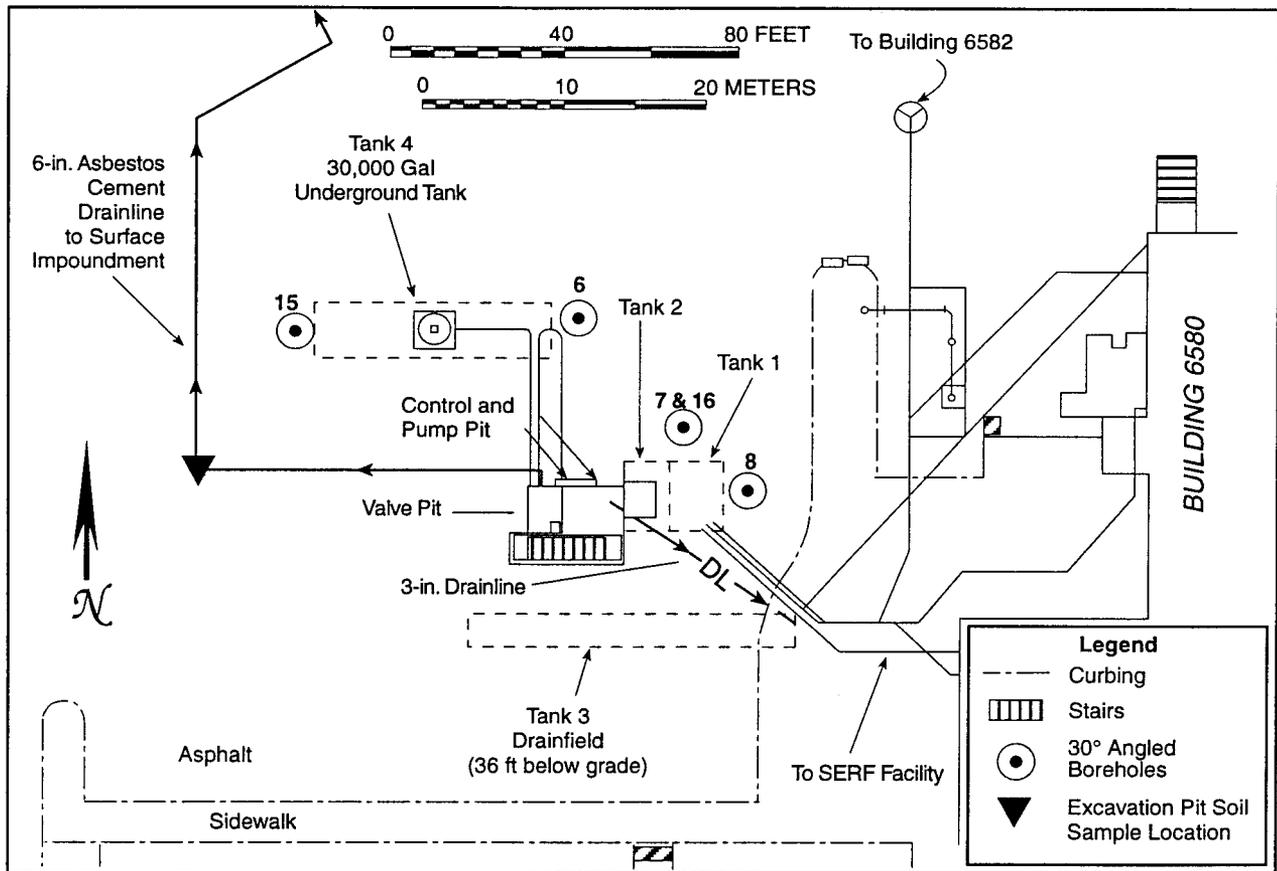


Figure 4-3. LWDS Holding Tanks Sample Location Map

drainfield (ER Site 4) and HERMES (ER Site 36), located approximately 30 ft south and 200 ft east, were strong candidates as sources of the contamination.

The holding tank subsurface investigation resumed in March 1994. Permission to generate mixed waste had been received from DOE and organic contamination was suspected from either the LWDS drainfield or the HERMES oil site. Borehole 15 (Figure 4-3) was completed coincident with the entire subsurface investigation of the LWDS drainfield (see Section 4.2). Borehole 15 was also sampled at approximately 5-ft intervals. Contrary to expectations, no organic contamination was found in the LWDS

drainfield or in Borehole 15. At this point, the subsurface soil investigation of the holding tanks, as originally scoped, had been completed, but no source for the contaminants found in Borehole 7 had been identified. Borehole 16 (Figure 4-3) was added to the investigation. Borehole 16 was located adjacent to the original Borehole 7 and drilled to 50 ft. No contamination was detected.

The organic vapors detected in Borehole 7 are now believed to be associated with soil vapor from the nearby HERMES site (ER Site 36). Thousands of gallons of oil were released to the soil at the HERMES site. This oil is believed to be impacting the ground water, approximately 500 ft below. Although gas chromatography and mass spectrometry (GC/MS) results for Borehole 7 did not compare well with known HERMES oil, only the lighter constituents traveling in the vapor phase away from the concentrated product may have been encountered.

4.1.3 Nature and Extent of Contamination

Internal Contamination

The internal tank sampling results identified the presence of several solvents and radionuclides slightly above the detection limit (IT, 1992). Table 4-1 summarizes the detected constituents. Although *soil* action levels were exceeded, these contaminant levels were measured inside the tanks; there is no evidence of gross leakage to the soil (see Section 4.1.2 on subsurface soil contamination). Industrial waste waters containing these levels of RCRA-regulated constituents are acceptable for discharge to the City of Albuquerque POTW. These data are representative of a typical process-water waste stream and also are representative of future discharges to the holding tanks. Based on the results of the internal sampling, no further internal sampling is needed and continued operation of the tanks as part of the LECS will not pose a threat to human health or the environment.

The holding tank drainline was disassembled and swiped on January 24, 1994, as described in Section 4.1.2. The investigation results are presented in an IT report (IT, 1994b). In summary, no contamination was detected in or beneath the drainline.

Subsurface Soil

The soil sample collected in the internal-pipe-contamination excavation did not show contamination.

Table 4-1
Holding Tank Internal Sampling Results

Contaminant	Highest Detected Level	NPDES Discharge Limit ^a
Dichloroethane	160 µg/L	5,000 µg/L of Total Toxic Organics (TTO)
Trichloroethene	28 µg/L	5,000 µg/L TTO
Lead	58 µg/L	3,200 µg/L
Mercury	3.9 µg/L	100 µg/L
Gross Alpha ^b	None detected	Not established
Gross Beta ^b	300 pCi/L	Not established
Cobalt-60 ^b	80 pCi/L	12.5 x 10 ⁴ pCi/L
Cesium-137 ^b	520 pCi/L	7.5 x 10 ⁴ pCi/L
^a Reference: City of Albuquerque, Public Works Department, <i>Sewer Use and Waste Water Control Ordinance, Chapter VIII, Article IX</i> , 1990. ^b Radioactive contamination was detected only in Tank 4, which is not planned for continued use in the Liquid Effluent Control System. Note: NPDES = National Pollutant Discharge Elimination System; µg/L = micrograms per liter; g/L = grams per liter; pCi/L = picocuries per liter.		

Table 4-2 summarizes the evaluation of soil analyses conducted below the holding tanks. All analytical results were determined to indicate a lack of contamination (as discussed in Section 3.0), with the exception of the 15-ft sample from Borehole 15. This sample contained slightly elevated levels of four metals. This grouping, although suspicious, does not necessarily indicate tank leakage. These metals were not detected at high levels in the holding tanks and no increased soil moisture was detected in Borehole 15 at any depth. Elevated concentrations of these metals were not noted in deeper samples. All values were close to background levels and in a purely statistical analysis would have been evaluated as statistical outliers, except that they were located together. Their common grouping may indicate corrosion products of the Tank 4 metal. This sample location is also very close to the tank bottom which is at approximately 16 ft below ground level (bgl). Except for beryllium, all soil analytical results are well below 40 CFR 264, proposed Subpart S, soil action levels (Table 4-3). Beryllium was detected at a concentration of 1.2 milligrams per kilogram (mg/kg), which is slightly above background range for this area.

Table 4-2
Statistical Comparison of Site 52 to Background

Parameter	Distribution Type	T- Test		Wilcoxon	Quantile	Upper Tolerance Limit (UTL)	Maximum Concentration	Spatial	ER Site 52 Contaminant
		= Variance	≠ Variance						
Barium	Lognormal	Pass	Fail	Pass	Pass	398.1 (mg/kg)	412 (mg/kg)	Pass	No
Beryllium	Lognormal	Pass	Pass	Pass	Pass	.79 (mg/kg)	1.2 (mg/kg)	Fail	Yes
Cadmium	Lognormal	Pass	Pass	Pass	Pass	3.5 (mg/kg)	1.3 (mg/kg)	Pass	No
Chromium	Lognormal	Fail	Fail	Fail	Pass	22.9 (mg/kg)	28.2 (mg/kg)	Pass	No
Copper	Lognormal	Fail	Fail	Fail	Pass	16.7 (mg/kg)	18.4 (mg/kg)	Fail	Yes
Lead	Nonparametric	N/A	N/A	Pass	Pass	15 (mg/kg)	10.2 (mg/kg)	Pass	No
Nickel	Lognormal	Pass	Fail	Pass	Pass	15.4 (mg/kg)	15.5 (mg/kg)	Fail	Yes
Zinc	Lognormal	Pass	Pass	Pass	Pass	46.7 (mg/kg)	47.3 (mg/kg)	Fail	Yes
Bismuth-212	Nonparametric	Pass	Pass	Pass	Pass	2.7 (pCi/g)	1.5 (pCi/g)	Pass	No
Bismuth-214	Nonparametric	N/A	N/A	Pass	Pass	0.8 (pCi/g)	1 (pCi/g)	Pass	No
Cesium-137	Nonparametric	N/A	N/A	Pass	Pass	Not detected	.093 (pCi/g)	Pass	No
Cobalt-60 ^a	N/A	N/A	N/A	N/A	N/A	Not detected	Not detected	Pass	No
Lead-212	Lognormal	Pass	Pass	Pass	Pass	1.1 (pCi/g)	1 (pCi/g)	Pass	No
Lead-214	Lognormal	Pass	Pass	Pass	Pass	.9 (pCi/g)	1.2 (pCi/g)	Pass	No
Potassium-40	Normal	Pass	Pass	Pass	Pass	25.3 (pCi/g)	19 (pCi/g)	Pass	No
Radium-226	Lognormal	N/A	N/A	Pass	Pass	2.1 (pCi/g)	2.14 (pCi/g)	Pass	No
Radium-228	Nonparametric	N/A	N/A	Pass	Pass	1.1 (pCi/g)	1.3 (pCi/g)	Pass	No
Thorium-232	Lognormal	Pass	Pass	Pass	Pass	1.26 (pCi/g)	1.3 (pCi/g)	Pass	No

^a Not naturally occurring.

Note: mg/kg = milligrams per kilogram; N/A = not applicable; pCi/g = picocuries per gram.

"Fail" indicates that the parameter was judged as a site contaminant by the particular statistical test.

Table 4-3
Holding Tank Soil Contaminant Summary

Parameter	Maximum Concentration (mg/kg)	Background ^a (mg/kg)	Soil Action Levels ^b (mg/kg)
Beryllium	1.2	0.79	0.2
Copper	18.4	16.7	None
Nickel	15.5	15.4	2000
Zinc	47.3	46.7	20000

^a95th upper tolerance limit (UTL) or percentile.
^b40 CFR 264, proposed Subpart S.
 Note: bgl = below ground level; mg/kg = milligrams per kilogram.

4.1.4 Risk Assessment

The beryllium value of 1.2 mg/kg is six times the 40 CFR 264, proposed Subpart S, soil action level. This result would normally trigger further action; however, no other beryllium concentrations at this site, including four samples from deeper in Borehole 15, approach the background UTL. Thus, the single aberrant value has been judged to be a statistical outlier and is not considered to be indicative of contamination.

The comparison to proposed Subpart S action levels for the other constituents was as follows. No organic or radioactive contamination was detected in the soils. Copper, nickel, and zinc concentrations detected in the soil did not exceed proposed Subpart S action levels (Table 4-3). Accordingly, there is no need for a detailed site risk assessment.

4.1.5 Summary and Conclusions

As demonstrated in Section 4.1.3, the holding tanks contain some contamination, but the existing levels are considerably below City of Albuquerque POTW discharge limits. The low moisture of the underlying soil indicates little or no leakage from the tanks, which was further substantiated by soil sampling data. Allowing for the possibility of future leakage, the tanks still pose no significant threat because:

1. The waste water contained very low concentrations of contaminants;
2. The depth to ground water is approximately 490 ft; and

3. The effluent will be monitored as part of the LECS operations to ensure that any increases in contaminant levels are investigated and mitigated.

The requirements for determination of No Further Action are contained in the Hazardous and Solid Waste Amendments (HSWA) Module of the RCRA Part B permit:

. . . This permit modification application must contain information demonstrating that there are no releases of hazardous waste including hazardous constituents from a particular SWMU at the facility that pose threats to human health and/or the environment, . . .

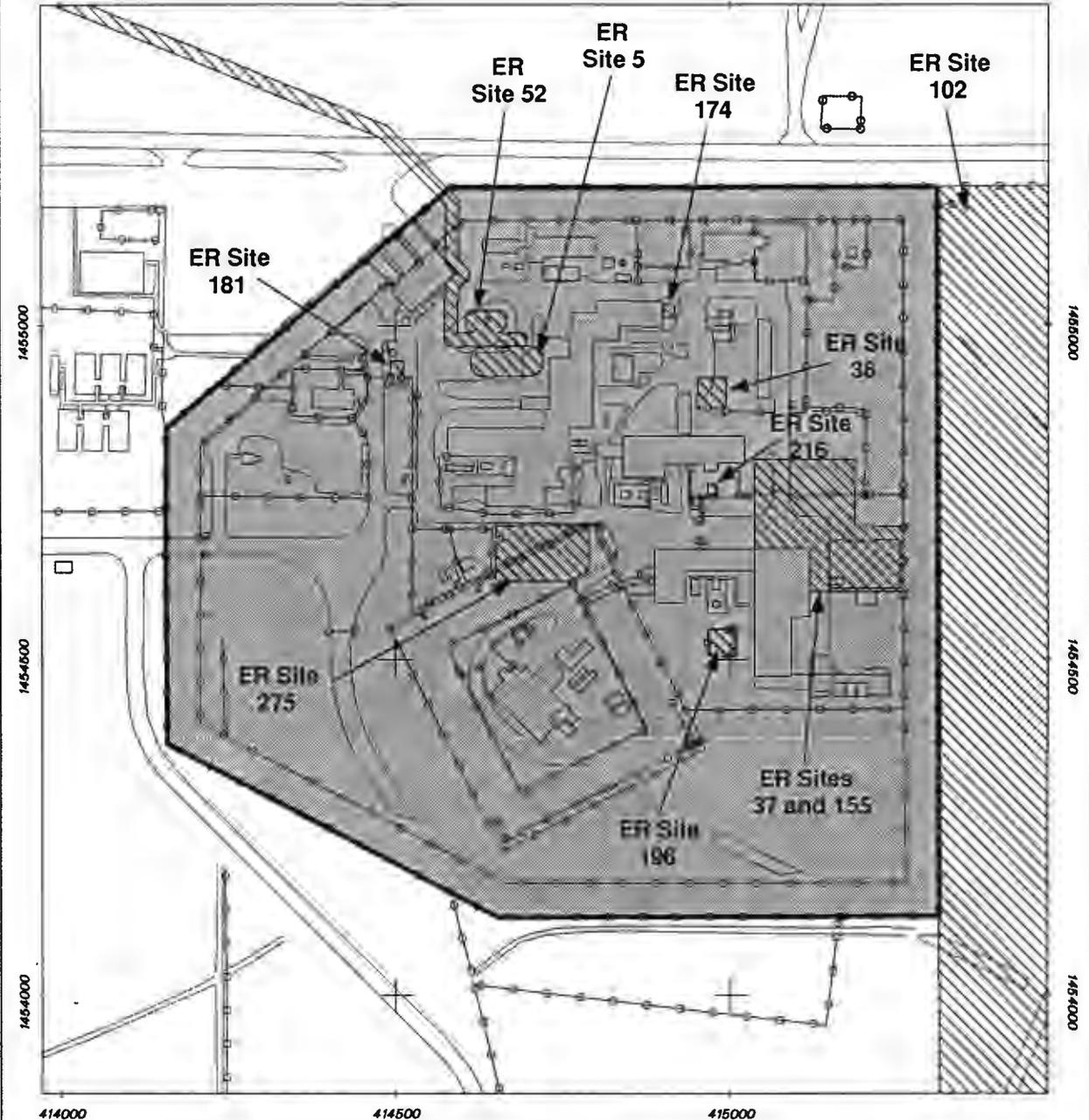
This risk-based proposal contains information needed to make the No Further Action determination. No organic or radioactive contamination was detected in soil beneath the holding tanks (Section 4.1.3). Metal contamination may exist, but all concentrations are at or near background levels and are well below 40 CFR 264, proposed Subpart S, soil action levels, or both. Accordingly, under the RCRA corrective action process, No Further Action is proposed for the LWDS holding tanks.

4.2 ER Site 5 LWDS Drainfield

Site 5, the LWDS drainfield, was designed to receive liquid wastes discharged from the LWDS holding tanks. The RFA performed in 1987 (EPA, 1987) designated this site as SWMUs 16 and 17, describing them as two separate clay seepage pits. However, the RFA is in error, as only one pit, or drainfield, exists. The below-grade drainfield was operational from 1963 to when it collapsed in 1967. According to health physics personnel working then, the collapse was viewed as a sinking of the overlying pavement. The drainfield operation was well understood at the time and the action taken (construction of the lagoons) suggests that its capacity to receive water was expected to be limited. No evidence of an overflow or spill, which would have occurred in the Building 6580 basement, has been found. The last recorded discharge occurred on May 11, 1967. The LWDS drainfield is buried approximately 30 ft deep and is located approximately 30 ft south of the LWDS holding tanks. The reported capacity of the drainfield is approximately 12,000 gal.

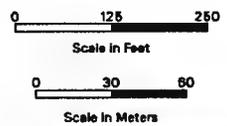
4.2.1 Contamination Sources

TA-V has a long history of industrial activity. A total of ten ER sites has been identified (Figure 4-4). The only verified source of contamination in the LWDS drainfield is the



Legend

-  Buildings
-  Roadways
-  Fences
-  Technical Area V
-  ER Sites



Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System

Figure 4-4. Environmental Restoration Sites Located Within Technical Area V

discharge from the LWDS holding tanks. This discharge entered the drainfield at the east end and infiltrated the surrounding soil.

Several other sources in the immediate area may contribute to soil contamination at the drainfield. Contaminant release to the soil column has been identified at three adjacent sites (181, 36, and 275). Site 181 originally contained a fuel-oil underground storage tank. This tank was found to be leaking upon its removal; approximately 27 cubic yards of stained soil were excavated. Later, two boreholes drilled nearby measured total petroleum hydrocarbon (TPH) contamination to a depth of approximately 30 ft. Site 36 (HERMES oil spill) contained a series of five 35,000-gal USTs that pumped dielectric oil in a closed-loop system to the HERMES facility. Thousands of gallons of oil were released to the subsurface, extending to a total depth of approximately 280 ft and impacting the ground water below. As manufactured, the oil reportedly contained no hazardous constituents (e.g., polychlorinated biphenyls [PCBs] or VOCs), but it is unknown whether such constituents might have entered the system at a later date. Site 275 (TA-V seepage pits) is a new site added during the drainfield investigation. This site processed most of the process and septic water from TA-V.

4.2.2 Field Investigation

Boreholes

Four soil boreholes were installed at the LWDS drainfield. Figure 4-5 shows the borehole locations and depths. The boreholes were completed in March 1994 with a Barber 70E drill rig using the rotasonic method. In general, field procedures were identical to those described in Appendix A. After retrieval, the soil core was screened for the presence of organic and radiological constituents. Soil samples were then collected from the core at intervals dictated by the LWDS RFI work plan (SNL, 1994a) and submitted to an off-site laboratory for tritium, gamma-emitting radionuclides, volatile and semi-volatile organic compounds, and metals for analysis using the methods described in Appendix B. Section 4.2.3 summarizes the analysis results.

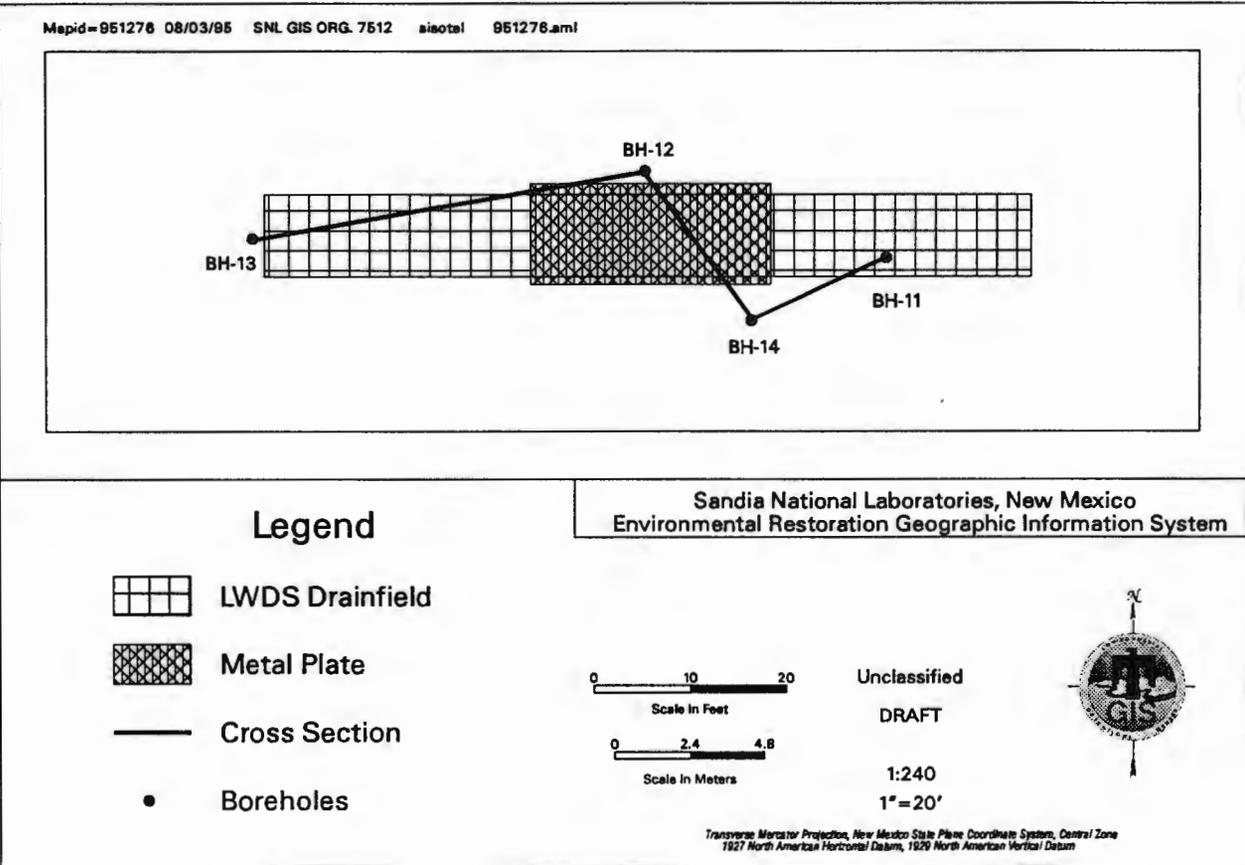


Figure 4-5. LWDS Drainfield Borehole Locations

Five borings were originally proposed to investigate the drainfield. One borehole could not be installed because a large metal plate covers the midsection of the drainfield. Figure 4-5 shows the approximate location of the plate. Three attempts were made to complete the borehole planned for the middle of the drainfield. Each attempt met complete refusal at the exact depth of 27 ft. The refusal was rather dramatic, with the pitch of the sonic head changing drastically. The sonic head energy was diverted from the tip of the core barrel to the outside drive casing and within seconds the sonic core barrel welded itself to the casing. Based on the symptoms described above, the lead driller attributed the problem to the presence of a metal plate and the borehole was aborted.

Monitor Well Installation

The first attempt to install a drainfield monitoring well occurred in September 1992. The pilot borehole was continuously cored using the rotasonic drilling method and field procedures described in Appendix A. Refusal was encountered at 167 ft and the borehole was subsequently backfilled with volclay.

A second attempt to install a drainfield monitor well began in April 1993, with a more capable drill rig. The borehole, located approximately 10 ft east of the initial attempt (Figure 4-6), was drilled with a combination of rotasonic, air rotary, and cable-tool drive methods to a total depth of 525 ft bgl. The monitor well is constructed of 4.5-in.-diameter Schedule 80 polyvinyl chloride (PVC) pipe. The screened interval extends from 500 to 515 ft bgl. The monitor well was developed in July 1993.

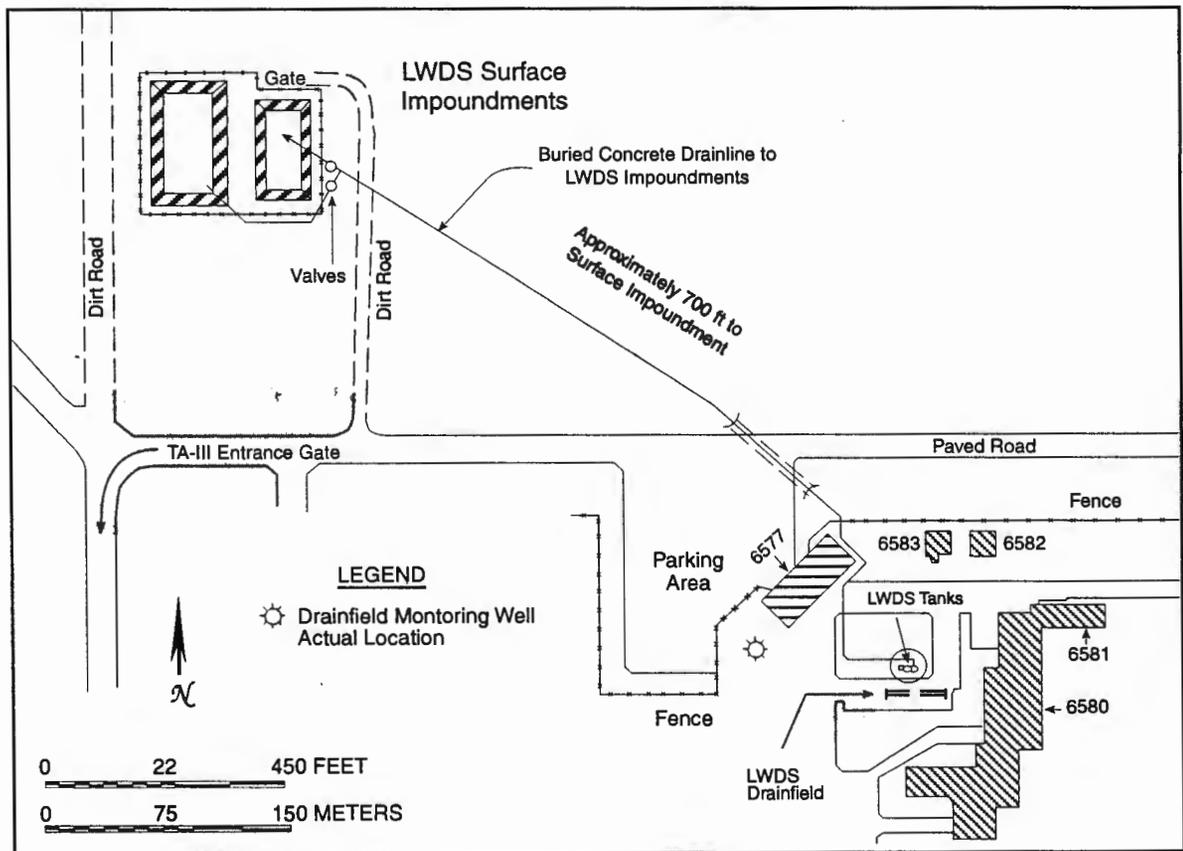


Figure 4-6. LWDS Site Map Showing Drainfield Monitoring Well Location

Ground-Water Sampling

Beginning in November 1993, quarterly ground-water samples were collected from well LWDS-MW1 with a Bennet™ piston pump. Ground-water sampling was performed in accordance with procedures in the *LWDS Ground-Water Monitoring Project Site-Specific Sampling Plan*, (IT, 1994c). With the exception noted below, analysis procedures followed those described in Appendix B.

Ground-water samples collected from well LWDS-MW1 were initially analyzed for VOCs by EPA Method 8240, which includes both GC/MS analyses. This test method typically has a quantitation limit of 5 micrograms per liter ($\mu\text{g/L}$) or parts per billion (ppb). Historically, this analytical method has been preferred because the presence of organic constituents is verified by a second analytical instrument. Following the identification of trichloroethene (TCE) in well LWDS-MW1 in early 1994, SNL/NM switched to EPA Method 8010. This test method utilizes GC, verifies sample constituents by duplicate analysis, and has a detection limit of 0.5 ppb.

4.2.3 Nature and Extent of Contamination

A review of the analytical results indicates soil contamination from several metals, radionuclides, and toluene. The contamination is limited to the drainfield and the surrounding soil, and no contamination has been detected below 45 ft. Organic contaminants, principally TCE, are present in levels above federal maximum concentration limits (MCLs) in the drainfield monitor well. The LWDS drainfield has been ruled out as the source of this contamination due to the absence of TCE at the site. The TA-V seepage pits have been identified as a potential source of ground-water contamination. Investigation of the ground-water contamination at the new ER site will continue under the TA-III/V RFI.

Toluene was detected four times in the drainfield, with the highest concentration of 51 ppb identified at 65 ft bgl in BH-11. In all cases, toluene was also detected in the associated trip blank and is suspected to be laboratory contamination. The highest toluene results slightly exceeded ten times the detected blank value, thus toluene was included in the risk assessment.

Metals

Table 4-4 summarizes the evaluation of metal contamination at the drainfield. Five metals were identified as contaminants: beryllium, cadmium, chromium, copper, and zinc. These metals are limited to the drainfield and adjacent soil. No contamination was

SI No. 2.

Table 4-4
Statistical Comparison of Site 5 to Background

Parameter	Distribution	T- Test		Wilcoxon	Quantile	Upper Tolerance Limit (UTL)	Maximum Concentration	Spatial	Site 5 Contaminant
		= Variance	≠ Variance						
Barium	Lognormal	Pass	Pass	Pass	Pass	398.1 (mg/kg)	258 (mg/kg)	Pass	No
Beryllium	Lognormal	Fail	Fail	Fail	Pass	.79 (mg/kg)	1 (mg/kg)	Fail	Yes
Cadmium	Lognormal	Pass	Pass	Pass	Pass	3.5 (mg/kg)	51.1 (mg/kg)	Fail	Yes
Chromium	Lognormal	Fail	Fail	Fail	Pass	22.9 (mg/kg)	42.4 (mg/kg)	Fail	Yes
Copper	Lognormal	Fail	Fail	Fail	Pass	16.7 (mg/kg)	24.2 (mg/kg)	Fail	Yes
Lead	Nonparametric	N/A	N/A	Pass	Pass	15 (mg/kg)	14 (mg/kg)	Pass	No
Nickel	Lognormal	Pass	Pass	Pass	Pass	15.4 (mg/kg)	13.7 (mg/kg)	Pass	No
Zinc	Lognormal	Pass	Pass	Pass	Pass	46.7 (mg/kg)	67.3 (mg/kg)	Fail	Yes
Bismuth-212	Nonparametric	Pass	Pass	Pass	Pass	2.7 (pCi/g)	1.3 (pCi/g)	Pass	No
Bismuth-214	Nonparametric	N/A	N/A	Pass	Pass	0.8 (pCi/g)	.84 (pCi/g)	Pass	No
Cesium-137	Nonparametric	N/A	N/A	Pass	Pass	0.9 (pCi/g)	.14 (pCi/g)	Fail	Yes
Cobalt-60 ^a	N/A	N/A	N/A	N/A	N/A	N/A	0.15 (pCi/g)	Fail	Yes
Lead-212	Lognormal	Fail	Fail	Fail	Pass	1.1 (pCi/g)	1.1 (pCi/g)	Pass	No
Lead-214	Lognormal	Fail	Fail	Fail	Pass	Not Detected	1 (pCi/g)	Pass	No
Potassium-40	Normal	Pass	Pass	Pass	Pass	25.3 (pCi/g)	19 (pCi/g)	Pass	No
Radium-226	Lognormal	N/A	N/A	Pass	Pass	2.1 (pCi/g)	2.25 (pCi/g)	Pass	No
Radium-228	Nonparametric	N/A	N/A	Pass	Pass	1.1 (pCi/g)	1.1 (pCi/g)	Pass	No
Thorium-232	Lognormal	Pass	Pass	Pass	Pass	1.26 (pCi/g)	1.1 (pCi/g)	Pass	No

^a Not naturally occurring.

Note: mg/kg = milligrams per kilogram; pCi/g = picocuries per gram.

"Fail" indicates that the parameter was judged as a site contaminant by the particular statistical test.

may come con d to UTL
Cross-section

detected below 45 ft bgl. Figures 4-7 through 4-9 show the contaminant concentration contours for cadmium, beryllium, and chromium.

No contamination contours are provided for zinc. The sample distribution pattern for this constituent did not correspond with other identified contaminants; however, zinc was included in the risk assessment because the one high value was located directly beneath the drainfield in Borehole 12 and exceeded the background zinc UTL.

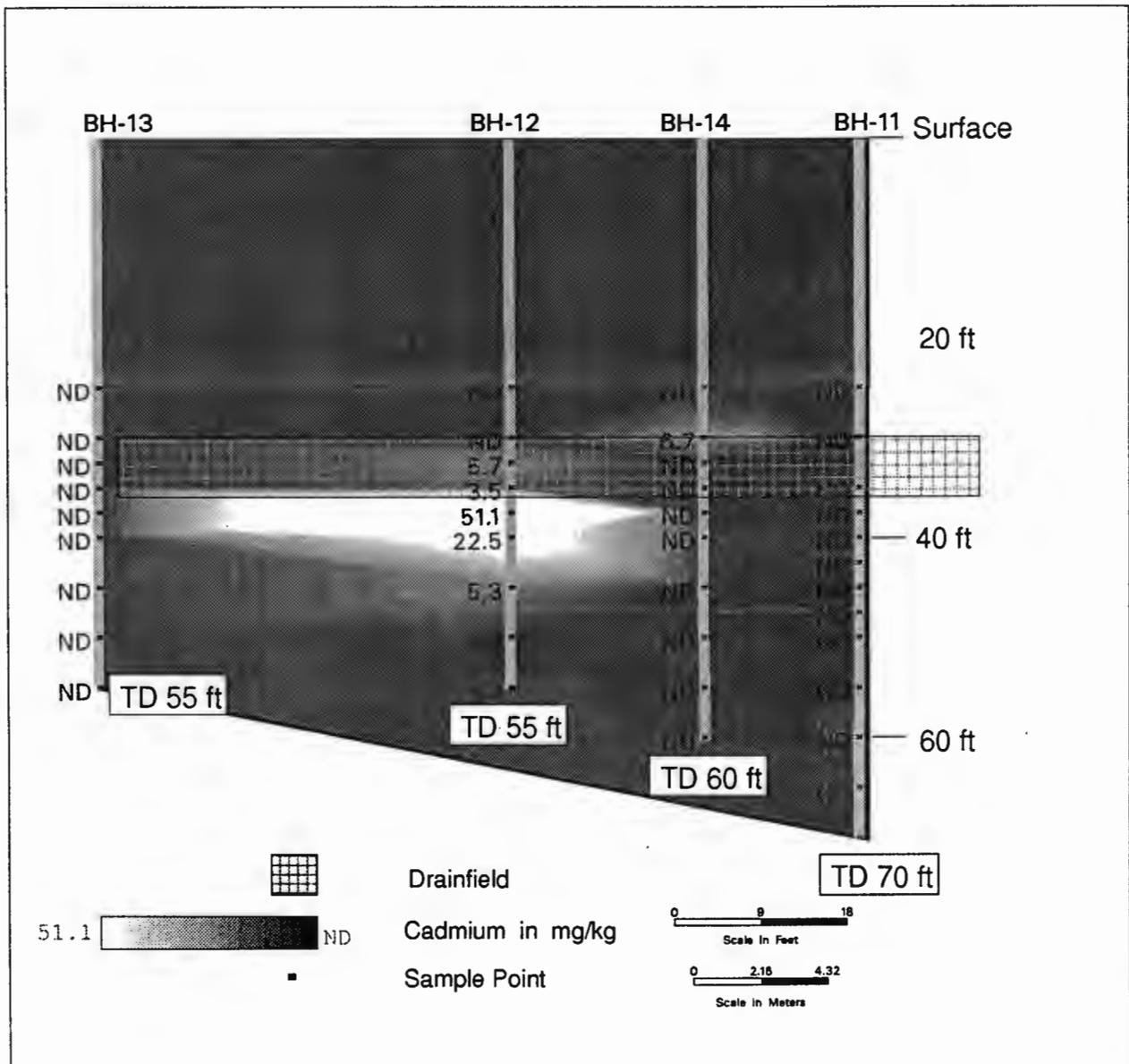


Figure 4-7. Cross Section of Cadmium at the LWDS Drainfield

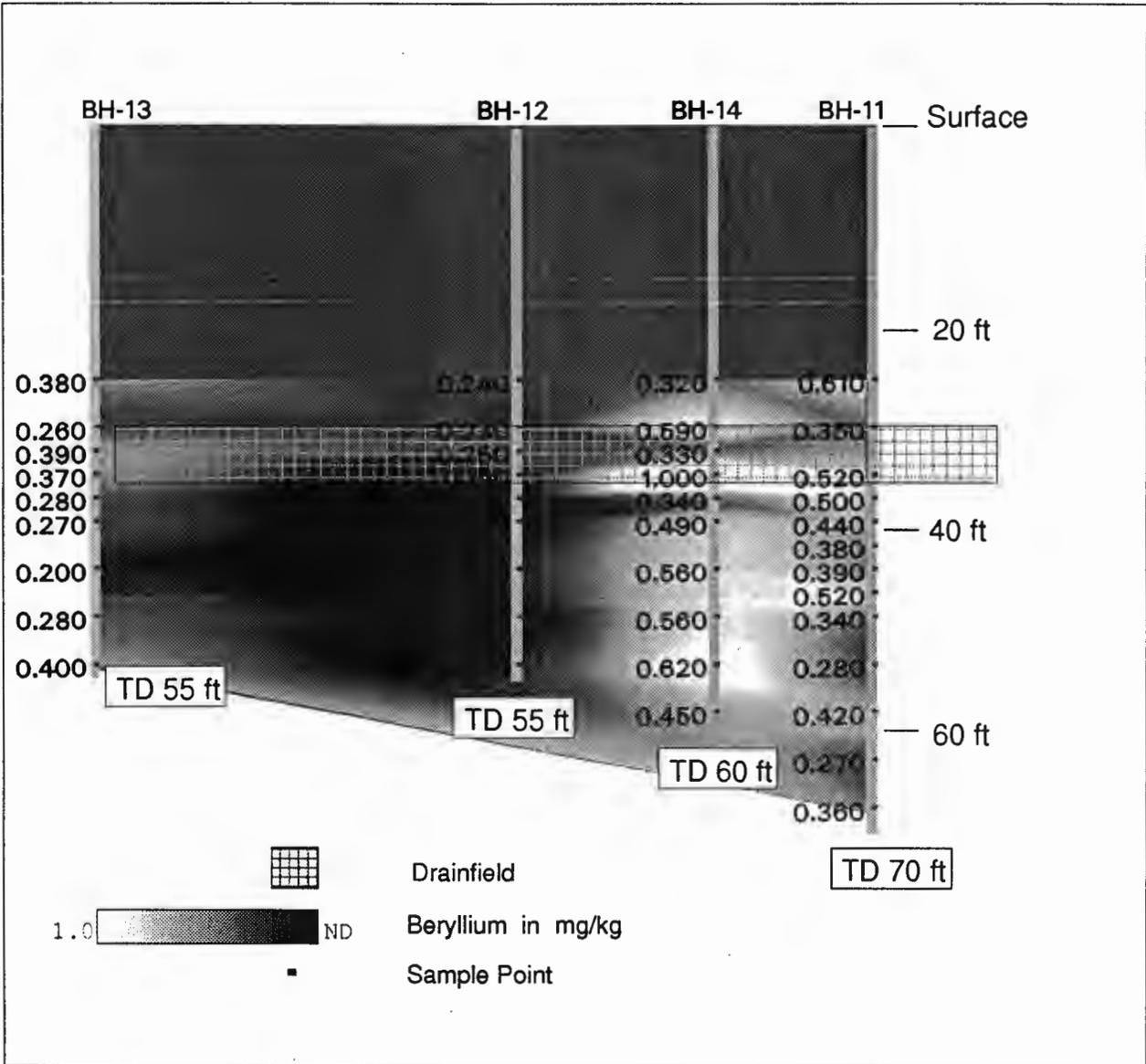


Figure 4-8. Cross Section of Beryllium at the LWDS Drainfield

Copper is definitely a contaminant at this site; however, it is not RCRA-regulated and has no toxicity.

Radionuclides

Table 4-4 lists all radiological contaminants at the drainfield. The total amount of contamination was fairly low; cobalt-60 and cesium-137 were the only detected anthropogenic radionuclides. Figures 4-10 and 4-11 show the contaminant contours for cobalt-60 and cesium-137. As with metals, radioactive contamination is limited to the

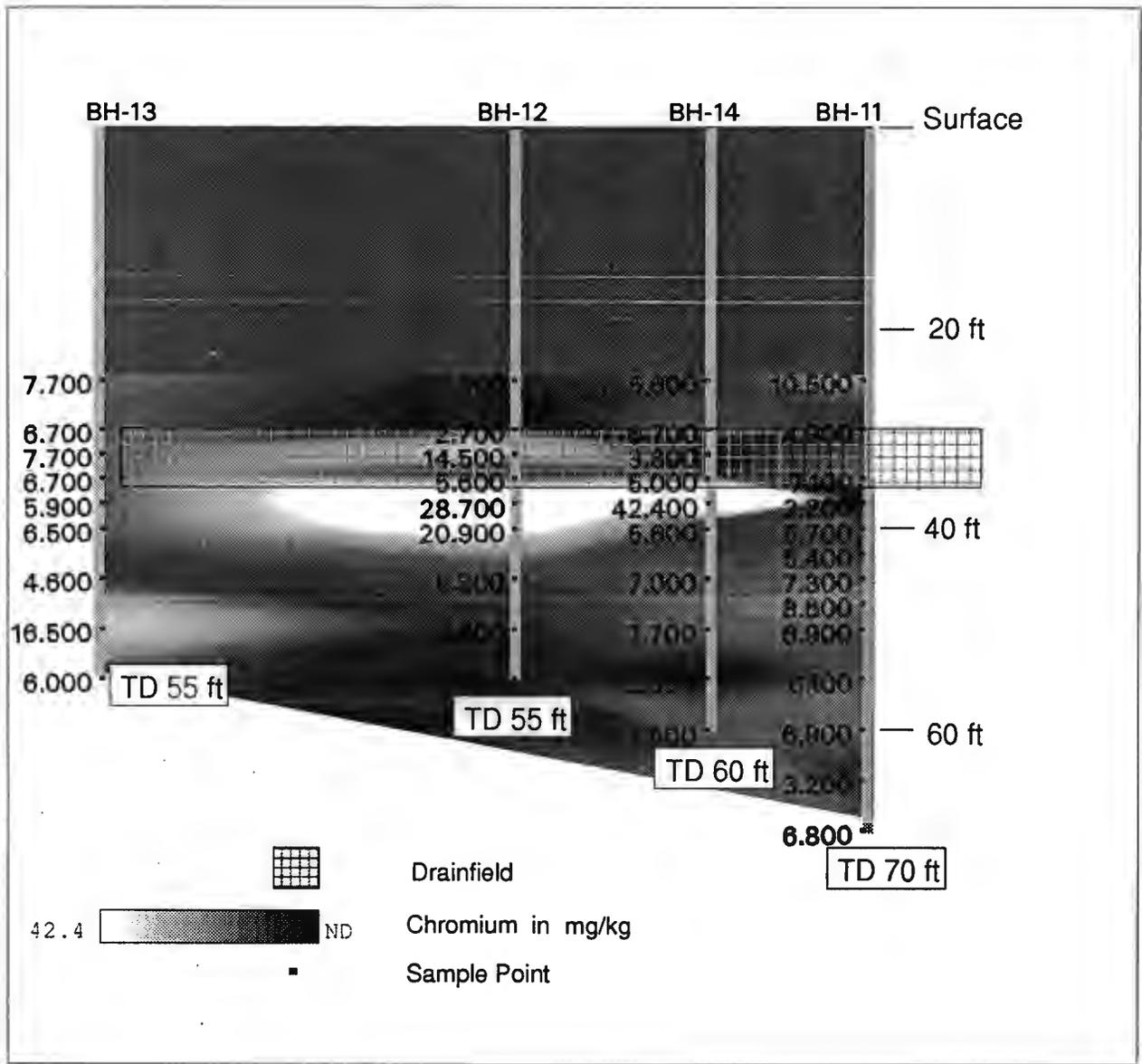


Figure 4-9. Cross Section of Chromium at the LWDS Drainfield

drainfield and adjacent soil. No contamination was detected at depths greater than 45 ft.

Ground Water

Ground-water contamination is evident in LWDS drainfield monitor well LWDS-MW1 by the consistent presence of VOCs and off-normal water chemistry. TCE has been

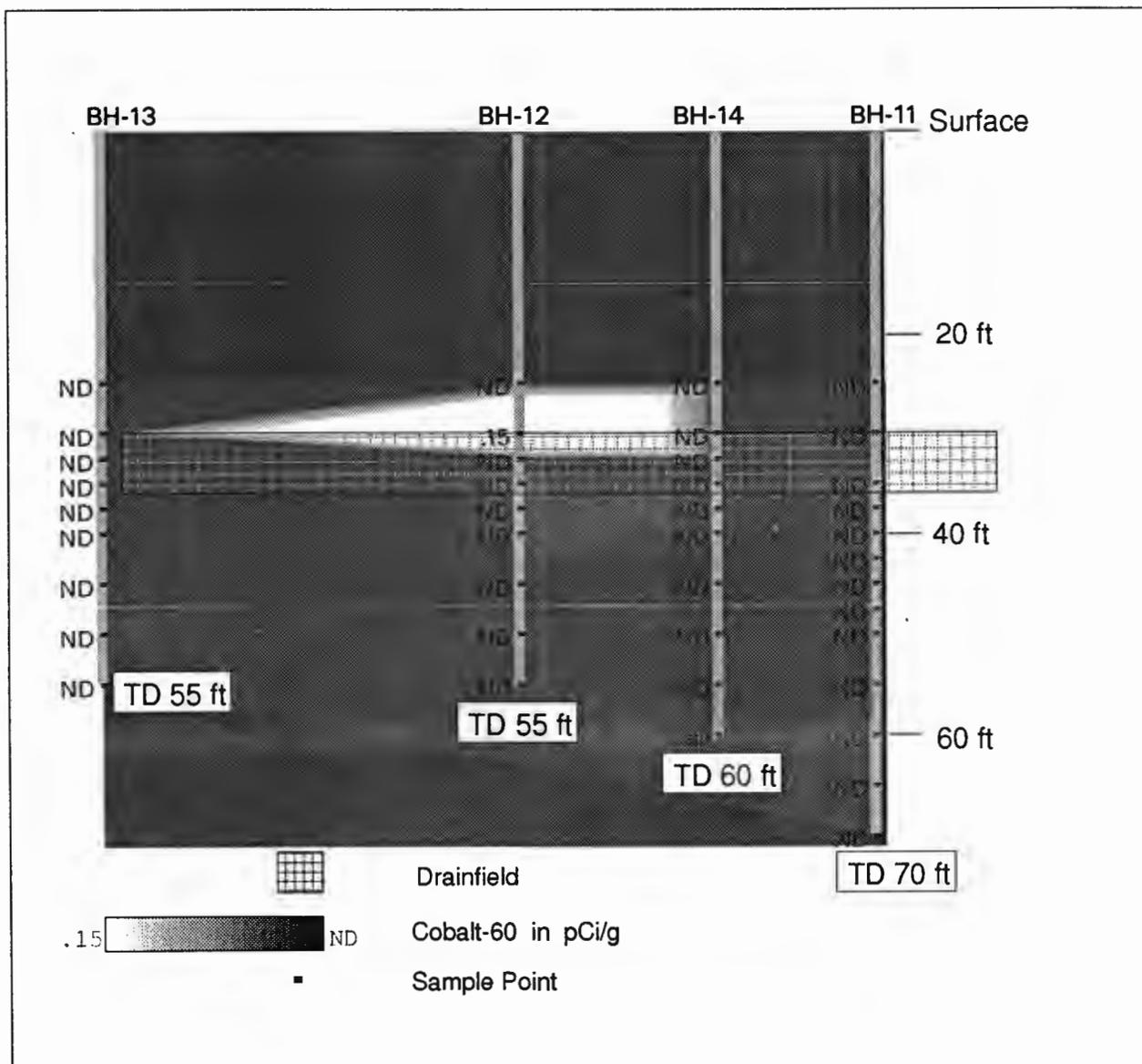


Figure 4-10. Cross Section of Cobalt-60 at the LWDS Drainfield

detected in all samples since September 1993 at concentrations from 12 to 16 ppb, and other organic contaminants are sometimes detected. This difference in water chemistry is the subject of a detailed evaluation by IT Corporation (IT, 1994d). Data indicate that inorganic constituents (arsenic, bromide, chloride, nitrate + nitrite [NPN], selenium, and sodium) and specific conductivity (SC) are generally higher for LWDS-MW1 relative to LWDS-MW2 and regional background wells. Results of three stable isotope analyses

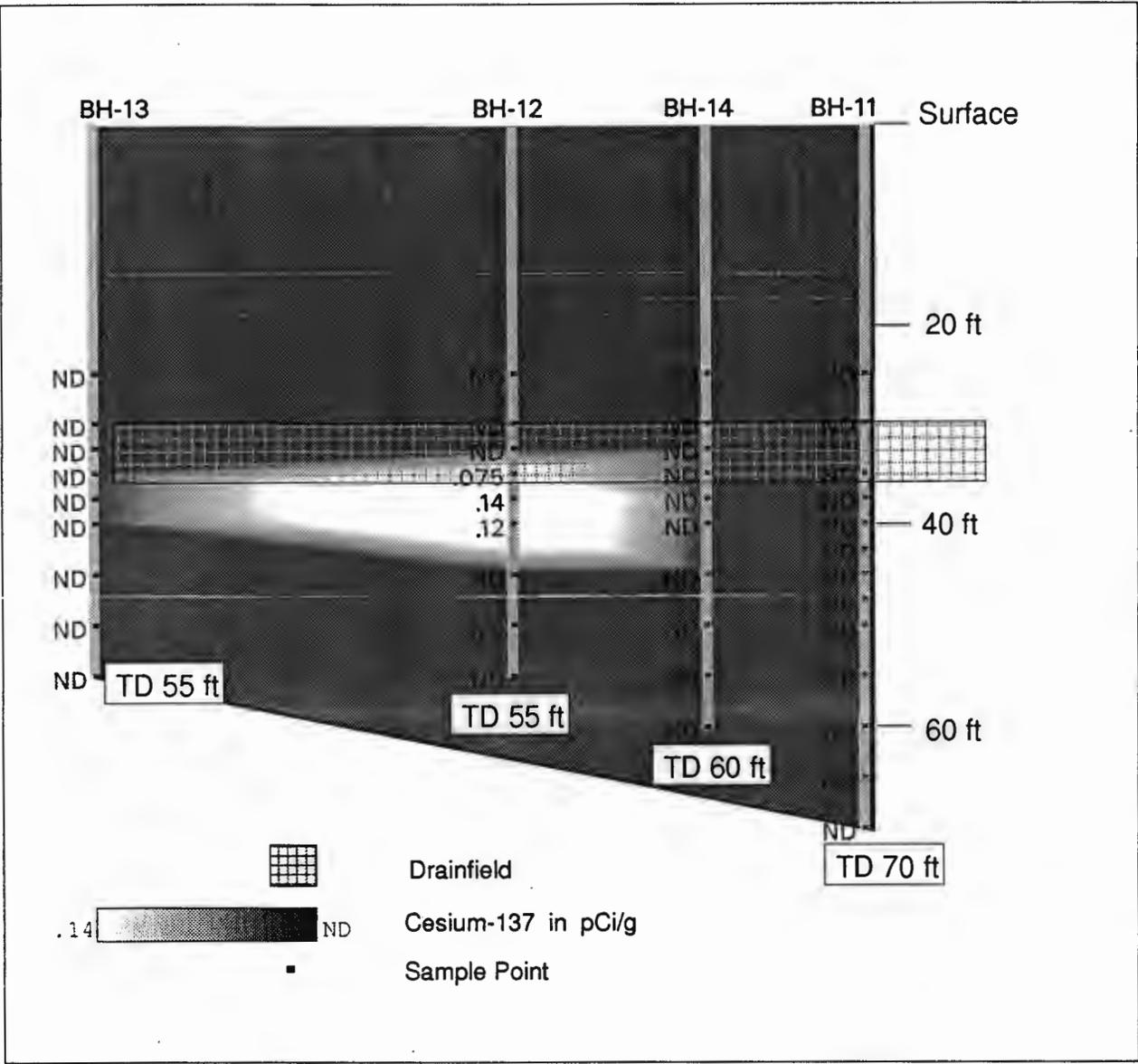


Figure 4-11. Cross Section of Cesium-137 at the LWDS Drainfield

(¹⁸O, ¹⁵N, and deuterium [D]) performed during the fourth quarter differ distinctly between the two LWDS wells. These chemical and isotopic differences appear consistent with the interpretation that TA-V discharge water has reached LWDS-MW1.

The concentration of TCE is approximately three times the drinking water standard. The LWDS drainfield contains no organic contamination in soil; another potential source area has been identified in the nearby TA-V seepage pits. The TA-V seepage pits have been added to the list of SNL/NM SWMUs as ER Site 275. The investigation of the seepage pits and the ground-water contamination problem has been transferred to the TA-III/V RFI.

4.2.4 Risk Assessment

The SNL/NM *Précis* computer model was used to estimate potential radiation doses, incremental lifetime cancer risks (ICRs), and the systemic toxic hazard index (HI) associated with contaminated soil at the drainfield (Knowlton, 1994). All estimates were made according to an industrial land-use scenario. The entire risk assessment has been provided in Annex I.

The risk assessment indicates that there would be no radiation dose to workers at the site from cesium-137 or cobalt-60. According to the analysis, industrial use of the site would meet the 25 millirem per year (mrem/yr) radiation dose limit specified in DOE Order 5820.2A, *Radioactive Waste Management*, for 1,000 years into the future (DOE, 1988).

The assessment also indicates that industrial use of the site would meet both the 1×10^{-6} ICR limit and the 1.0 HI judged acceptable by the EPA (EPA, 1989).

4.2.5 Summary and Conclusions

The requirements for determination of No Further Action are contained in the HSWA Module of the RCRA Part B permit:

. . . This permit modification application must contain information demonstrating that there are no releases of hazardous waste including hazardous constituents from a particular SWMU at the facility that pose threats to human health and/or the environment, . . .

This risk-based proposal contains information needed to make the No Further Action determination. The nature and extent of contamination at the LWDS drainfield has been

adequately defined in all directions using data acquired from the four boreholes; additional characterization is not required. Contamination is limited to the drainfield and the nearby region, and levels pose no threat to humans or the surrounding environment. The LWDS drainfield is recommended for No Further Action.

4.3 ER Site 4 LWDS Surface Impoundments

Site 4 consists of the two surface impoundments (Impoundments 1 and 2), constructed in June 1967 and June 1970, after the collapse of the LWDS drainfield. These impoundments are referred to in the RFA as SWMUs 18 and 19 (EPA, 1987). The two impoundments are located approximately 1000 ft northwest of the LWDS holding tanks and 400 ft north of the TA-III gate (Figure 4-12).

Impoundment 1, the eastern impoundment, covers 8100 ft² and measures 65 ft by 125 ft by 12 ft deep. Impoundment 2 covers approximately 9400 ft² and measures 102 ft by 92 ft by 20 ft deep. Neither impoundment is lined. Impoundments 1 and 2 were used for the disposal of primary coolant water from the SERF, and the potentially contaminated waste water from experiments and operations in the SERF buildings. In addition, waste oil and resin beads were disposed of in the surface impoundments on at least one occasion. The volume and radionuclide content of the discharges to Impoundments 1 and 2 between 1967 and 1971 were monitored and recorded. During those 5 years, approximately 12 million gal of waste water containing approximately 14 Ci of measured radioactivity were discharged. It is assumed that the majority of these radionuclides were deposited in Impoundment 1, because Impoundment 2 was installed later, near the end of the time in which radioactive discharges occurred. The short half-life activation products have decayed and potential residual contamination consists of fission products, other radionuclides, and laboratory solvents.

The last discharge of radioactive waste water from reactor operations occurred in April 1970. SERF waste-water discharges to the impoundments were tracked and recorded until July 1971, when the Atomic Energy Commission (AEC) relaxed this reporting requirement because the reactor was no longer in operation. Since that time, however,

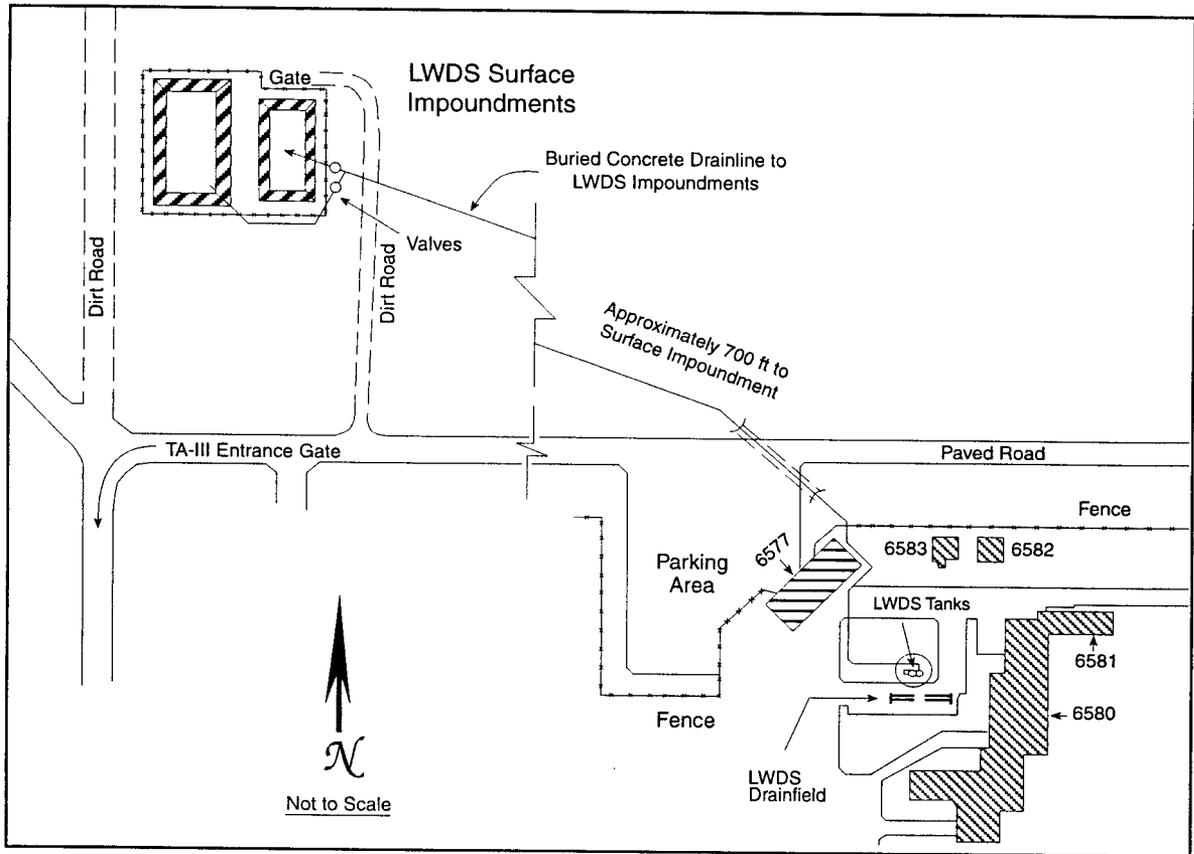


Figure 4-12. Liquid Waste Disposal System Site Map

the impoundments have continued to receive intermittent waste-water discharges consisting of unmonitored, reportedly uncontaminated process-chilled water and waste fluids discharged to the LWDS through sinks and floor drains in the HCF. These discharges were ordered to be stopped by the DOE in September 1992 and the impoundments are now inactive.

Previous Investigations

Water, soil, and sludge samples were collected at both impoundments from 1971 through 1984. This sampling was sporadic and poorly documented but, based on common practices at that time, it is believed that all of the samples were collected from the lagoon surfaces. At that time, cobalt-60, cesium-137, manganese-54, and some alpha and beta activity were identified at low levels.

In September 1983, one or both of the impoundments was used as a "decontamination catch bin" by the U.S. Air Force (USAF) for unknown purposes (SNL, 1983). Soil and

sludge samples collected 1 year later, in September 1984, from Impoundment 1 contained 24.6 parts per million (ppm) PCBs (SNL, 1984). A direct connection between this use of the impoundments and the level of PCBs found in the soil in the 1984 sampling cannot be verified due to the absence of USAF disposal information. Analyses were not conducted at that time for compounds other than PCBs. The sample was probably taken from the surface soil; PCBs are generally strongly sorbing chemicals.

4.3.1 Contamination Sources

The principal use of the LWDS surface impoundments as part of the LWDS network was well defined. Liquid waste from TA-V was conveyed to the impoundments where evaporation and infiltration occurred. Accordingly, the source of impoundment contamination is well understood as being the liquid waste from TA-V. The USAF activities at the impoundments are undocumented. Accordingly, additional surface sampling that accounts for surface discharges to the impoundments was also performed.

4.3.2 Field Investigation

Field investigations performed at the LWDS surface impoundments were designed to evaluate the horizontal and vertical extent of contamination. Investigation activities included: a surface inspection/walk-over, radiation and organic vapor surveys, surface sampling, a geophysical survey, nine boreholes, and installing one ground-water monitor well. These field investigations are described in the remainder of this subsection.

Preliminary Radiation Survey and Site Screening

A walk-over radiation survey and site screening was performed prior to any intrusive activities at the LWDS surface impoundments. The impoundments and surrounding region were carefully studied for any indications of potential contamination, such as soil discoloration or distressed vegetation. No soil discoloration or distressed vegetation was found; however, resin beads were dispersed in the soil directly beneath the surface of the Impoundment 1 drainline outfall. These resin beads probably resulted from backflushing of the ion-exchange resin beds, the major discharge activity of the SERF.

Surveys were conducted for detectable organic vapors and radioactive hotspots concurrent with the walk-over inspection. A slow scan of the entire fenced region inside and surrounding the impoundments was conducted using a micro-R-meter at a distance

of approximately 1 m above the ground and a 2-in. sodium iodide (NaI) gamma scintillation detector at ground level. An organic vapor analyzer (OVA) flame ionization detector (FID) was used to measure organic vapors.

No organic vapors were detected, and gross gamma-radiation levels were well within the normal background except for the area immediately beneath the Impoundment 1 drainline outfall (the same region that contains resin beads). The readings in this area were highest at the outfall and decreased with distance from the outfall. The readings were indistinguishable from background levels at approximately 5 to 7 yd from the outfall. The highest readings detected with the micro-R-meter were approximately 1.5 times the background levels and, with the NaI gamma scintillation detector, were approximately 3 times the background levels.

Surface Soil Sampling

The initial investigation at the LWDS surface impoundments involved collecting surface soil samples at grid locations within and around the impoundments. Licensed surveyors superimposed (and recorded) a 10-yd by 10-yd sampling grid over the 60-yd by 80-yd area. Samples were collected from the center of each 10-yd by 10-yd square. Judgmental samples were collected at the drainage outfalls on the surface and at a depth of 1.5 ft. A total of 80 soil samples was collected during this investigation. Figure 4-13 shows the locations of the surface soil samples and the overlying sample grid. A vegetation sample was collected and analyzed for possible uptake of tritium.

All soil samples were collected with a stainless-steel trowel that was decontaminated after collecting each sample. Prior to sampling at a given location, approximately 2 in. of sediment was scraped away to ensure that a representative sample was obtained. Appendix B describes the methods used for sample analyses.

Controlled Source Audiofrequency Magnetotelluric Investigation

In September 1992, GeoPacific Research and Exploration conducted a geophysical survey at the LWDS surface impoundments using Controlled Source Audiofrequency Magnetotellurics (CSAMT). This section summarizes the results of the survey; more information is available from the survey report (GeoPacific Research and Exploration, 1992). CSAMT is a non-invasive, remote-sensing technique deployed at ground-surface to provide subsurface, structural information through measurement of variations in the electrical resistivity. The survey was designed to assess the nature of subsurface

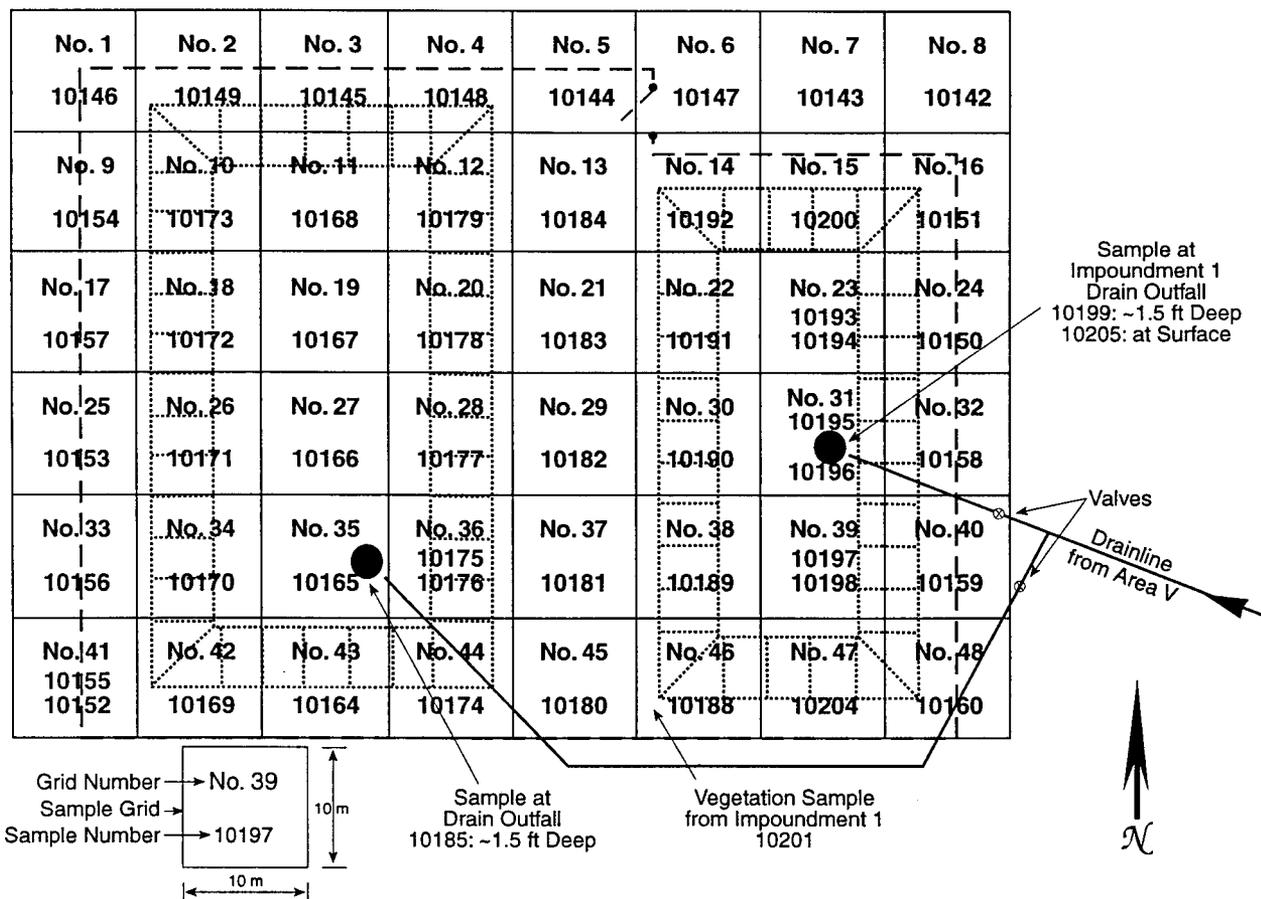


Figure 4-13. LWDS Surface Impoundments Surface Sample Location Map

features which may have resulted from infiltration of waste water into the surrounding subsurface environment. This was accomplished by determining the overall background electrical resistivity structure of the area and locating electrical resistivity anomalies expected to be associated with a water-containment sump.

The survey included instrument deployment and vector data acquisition at 100 surface sites. Sensor locations were chosen to help determine the lateral and vertical extent of migration of fluids from the LWDS surface impoundments. The CSAMT survey delineated a 100-yd by 200-yd area north and west of the LWDS surface impoundments

with significantly elevated electrical conductivity within approximately the upper 180 ft bgl. Figure 4-14 shows the location of the survey instruments and the area of elevated conductivity. Such an anomaly could be produced by locally increased dissolved contaminants, increased fluid saturation, increased local permeability, or a combination of these factors.

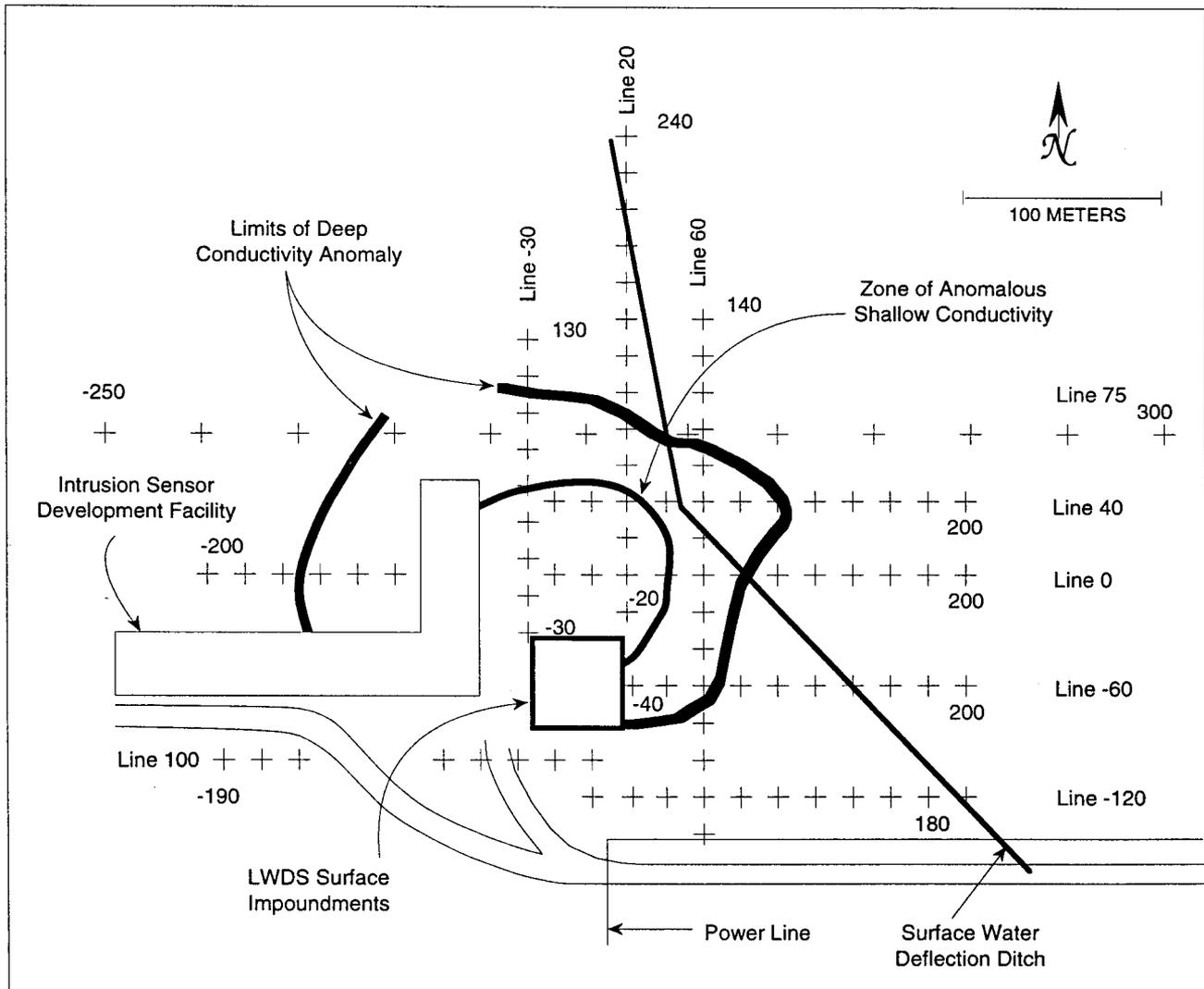


Figure 4-14. CSMAT Site Locations and Limits of the Conductivity Anomaly

CSAMT data collected along the southern edge of the sump show only limited resistivity variations and suggest that water from the sump has not migrated substantially to the south; however, it should be noted that buildings and roads limit the area available for data collection to the south, and there is a high level of cultural noise (i.e., interference from electrical sources in the area) on this side of the impoundments. Thus, conclusions about the resistivity structure to the south are more tentative than those regarding the resistivity structure to the north.

The background electrical resistivity structure away from the conducting anomaly north of the sump consists basically of two discrete layers. The shallow, high-resistivity layer has a vertical thickness of approximately 180 ft and is thought to be above the depth of fluid saturation. Below 180 ft, there is a substantial change in the electrical resistivity, which may indicate a lower soil moisture level. Physical conditions found in the impoundment subsurface investigations do not support the interpretations of the CSAMT survey, as discussed later in this section.

Boreholes

Nine boreholes have been drilled at the LWDS surface impoundments. Figure 4-15 shows the locations of these boreholes. Table 4-5 lists the numbers and depths of the boreholes drilled as part of the surface impoundment investigation.

Boreholes 1 through 5 were completed in August 1992. These perimeter boreholes were installed first and the boreholes planned for inside the impoundments were delayed by mixed waste problems (described in Section 4.1.2). As previously stated, continuous core was collected at each location. Soil samples were then collected from the core at 5-ft intervals and submitted to the analytical laboratory for analysis (as described in Appendix B). Section 4.3.3 summarizes the analysis results.

DOE approval to generate mixed waste was obtained in March 1994 and Boreholes 9 and 10 were completed in the impoundments. The field screening and analytical programs matched those used for previous boreholes (Appendices A and B). Section 4.3.3 also summarizes the analysis results.

Following an EPA directive, a second borehole was installed in each impoundment. Based on the results of the first set of boreholes, mixed waste generation was

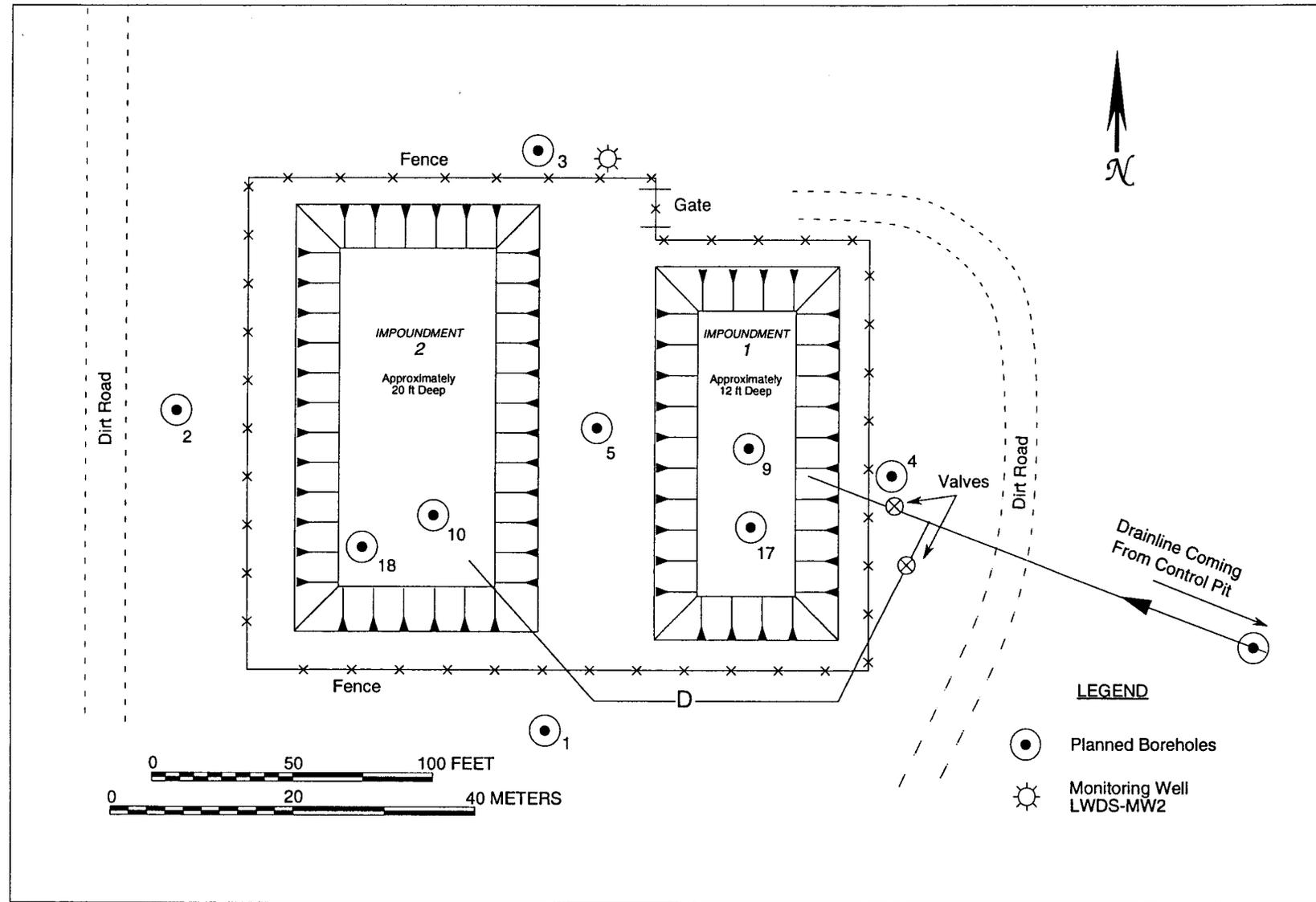


Figure 4-15. LWDS Surface Impoundments Borehole Locations

Table 4-5
Total Depths of Boreholes Drilled at the LWDS Surface Impoundments

Borehole Number	Total Depth (ft bgl)
BH-1	85
BH-2	100
BH-3	85
BH-4	100
BH-5	100
BH-9	60
BH-10	30
BH-17	60
BH-18	30
Note: ft bgl = feet below ground level.	

considered unlikely and a Failing F-10 hollow-stem auger drill rig was used. During this investigation, soil samples were collected with a split-spoon sampler at 5-ft intervals.

Monitor Well Installation

In September 1992, monitor well LWDS-MW2 was drilled north of the LWDS surface impoundments. The borehole was drilled with a combination of rotasonic, air rotary, and cable tool methods to a total depth of 531 ft bgl; it was completed in October 1992. The monitor well is constructed of 4.5-in.-diameter Schedule 40 stainless-steel screen and PVC riser. The screened interval extends from 506 to 526 ft bgl. Well development was performed in May 1993.

Ground-Water Sampling

Quarterly ground-water samples were collected from LWDS-MW2 following sampling procedures as summarized in the *LWDS Ground-Water Monitoring Project Site Sampling Plan* (IT, 1994c).

4.3.3 Nature and Extent of Contamination

A review of the analytical results with respect to background levels identified several metals and radiological contaminants. Most of the contamination in the impoundments was concentrated under the drainline outfalls and contamination was higher in Impoundment 1 than in Impoundment 2. PCBs also were identified in the southwest corner of Impoundment 2. The remainder of this subsection presents further contaminant details.

Metals

The metal-analytical results were evaluated as described in Section 3.2. Table 4-6 summarizes this evaluation. A total of seven metals were identified as surface impoundment contaminants. In general, metal contamination is limited to surface and near-surface samples, and is concentrated beneath the drainline outfalls. No contamination was detected at depths greater than 5 ft. Figures 4-16 through 4-22 show the surface contaminant contours developed for these metals.

Chromium-VI contaminant contours are not shown. Three chromium-VI results were slightly above the detection limit. The spatial analysis did not correspond with the other contaminants or known discharge points but based on a zero background level, the results indicated contamination and were included in the risk assessment. A brief review of Table 4-6 will show the validity of the spatial analysis. In many cases, the maximum measured concentration was less than background UTL. However, a spatial analysis showing a consistent constituent grouping would indicate anthropogenic contribution.

The opposite case was also true. A maximum concentration exceeding the background UTL did not necessarily indicate contamination. Rather, the spatial and statistical analysis was used to identify an anomalous high value.

Beryllium was problematic in that an especially high value (4.9 mg/kg) was measured in grid 48 (Figure 4-13). The anomalous value caused several statistical tests to fail for beryllium yet no pervasive problem was apparent. Six additional samples were taken (five soil and one duplicate) in the immediate vicinity of the high analysis result on May 23, 1995. These samples were analyzed off-site. The sample results ranged from

Table 4-6
Statistical Comparison of Site 4 to Background

Parameter	Distribution	T- Test		Wilcoxon	Quantile	Upper Tolerance Limit (UTL)	Maximum Concentration	Spatial	Site 4 Contaminant
		= Variance	≠ Variance						
Barium	Lognormal	Fail	Fail	Pass	Pass	398.1 (mg/kg)	849 (mg/kg)	Fail	Yes
Beryllium	Lognormal	Fail	Fail	Fail	Pass	.79 (mg/kg)	4.9 (mg/kg)	Pass	No
Cadmium	Lognormal	Pass	Pass	Pass	Pass	3.5 (mg/kg)	154 (mg/kg)	Fail	Yes
Chromium	Lognormal	Fail	Fail	Fail	Pass	22.9 (mg/kg)	97.7 (mg/kg)	Fail	Yes
Copper	Lognormal	Fail	Fail	Fail	Fail	16.7 (mg/kg)	239 (mg/kg)	Fail	Yes
Lead	Nonparametric	N/A	N/A	Fail	Pass	15 (mg/kg)	72.5 (mg/kg)	Fail	Yes
Nickel	Lognormal	Fail	Fail	Fail	Fail	15.4 (mg/kg)	173 (mg/kg)	Fail	Yes
Silver	Nonparametric	N/A	N/A	Pass	Pass	4.0 (mg/kg)	90.5 (mg/kg)	Pass	No
Zinc	Lognormal	Pass	Pass	Fail	Fail	46.7 (mg/kg)	198 (mg/kg)	Fail	Yes
Chromium-VI	N/A	N/A	N/A	N/A	N/A	N/A	11.2 (mg/kg)	Fail	Yes
Bismuth-212	Nonparametric	Pass	Pass	Pass	Pass	2.7 (pCi/g)	2.7 (pCi/g)	Pass	No
Bismuth-214	Nonparametric	N/A	N/A	Pass	Pass	0.8 (pCi/g)	1.4 (pCi/g)	Pass	No
Cesium-137	Nonparametric	N/A	N/A	Pass	Fail	0.9 (pCi/g)	10.1 (pCi/g)	Fail	Yes
Cobalt-60 ^a	N/A	N/A	N/A	N/A	N/A	N/A	11 (pCi/g)	Fail	Yes
Lead-212	Lognormal	Pass	Pass	Pass	Pass	1.1 (pCi/g)	1.4 (pCi/g)	Pass	No
Lead-214	Lognormal	Pass	Pass	Fail	Pass	.9 (pCi/g)	1.3 (pCi/g)	Pass	No
Potassium-40	Normal	Pass	Pass	Pass	Pass	25.3 (pCi/g)	35 (pCi/g)	Pass	No
Radium-226	Lognormal	N/A	N/A	Fail	Pass	2.1 (pCi/g)	3.68 (pCi/g)	Pass	No
Radium-228	Nonparametric	N/A	N/A	Fail	Fail	1.1 (pCi/g)	7.37 (pCi/g)	Pass	No
Thorium-232	Lognormal	Pass	Pass	Pass	Pass	1.26 (pCi/g)	1.18 (pCi/g)	Pass	No
Tritium	N/A	N/A	N/A	N/A	N/A	N/A	320 pCi/l	Fail	Yes
Uranium-235	Nonparametric	N/A	N/A	Fail	Fail	0.17 (pCi/g)	3 (pCi/g)	Fail	Yes
PCBs ^a	N/A	N/A	N/A	N/A	N/A	N/A	71 (ppb)	Fail	Yes

^aNot naturally occurring.

Note: mg/kg = milligrams per kilogram; N/A = not applicable; pCi/g = picocuries per gram; ppb = parts per billion.

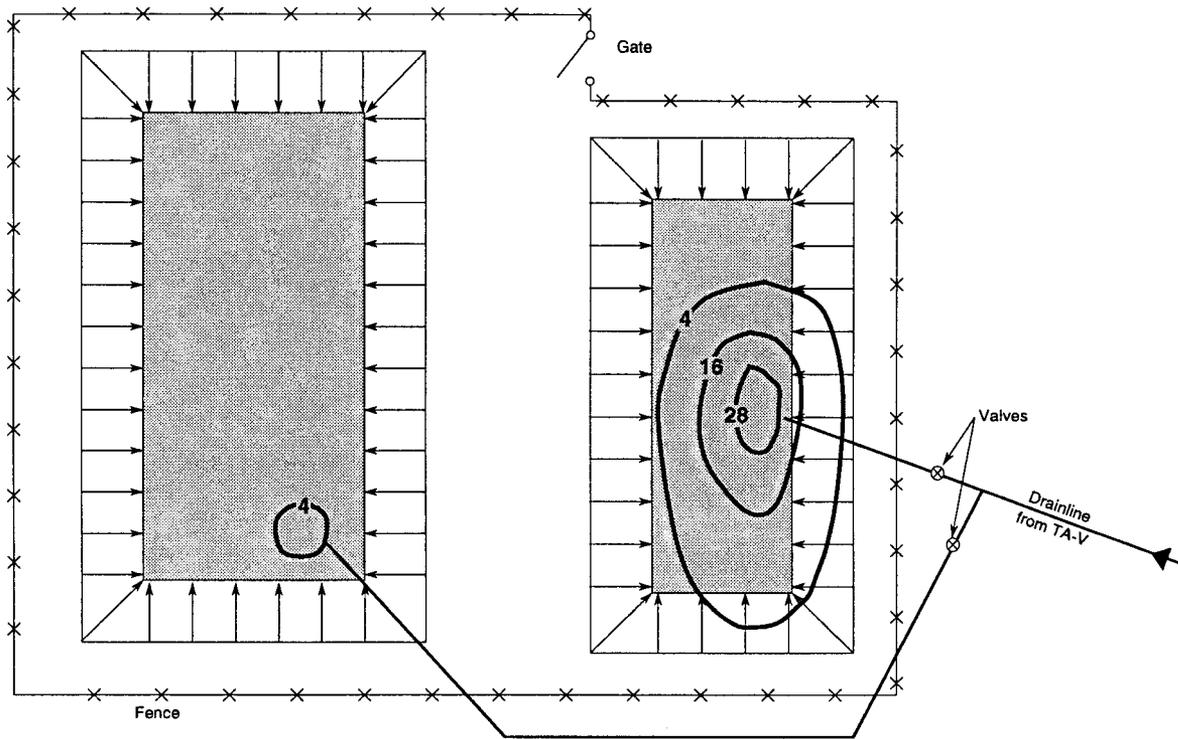


Figure 4-16. Surface Contaminant Contour Plots of Cadmium
(in milligrams per kilogram [mg/kg])

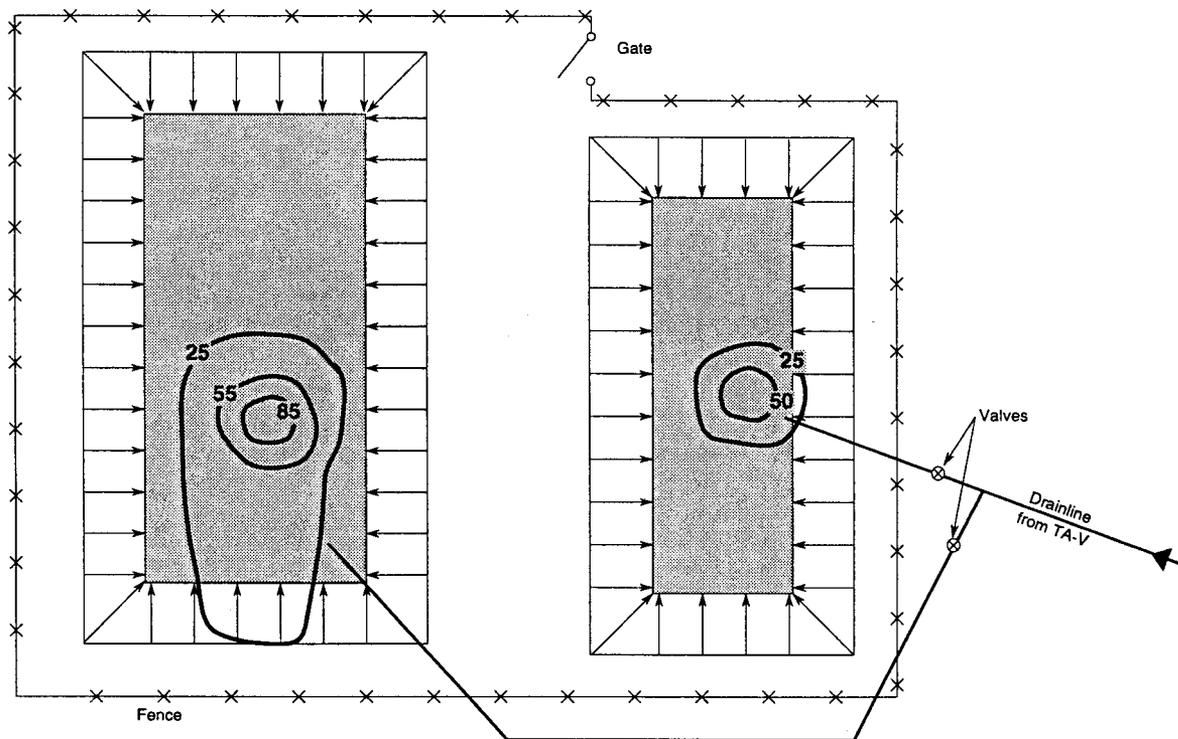


Figure 4-17. Surface Contaminant Contour Plots of Chromium
(in milligrams per kilograms [mg/kg])

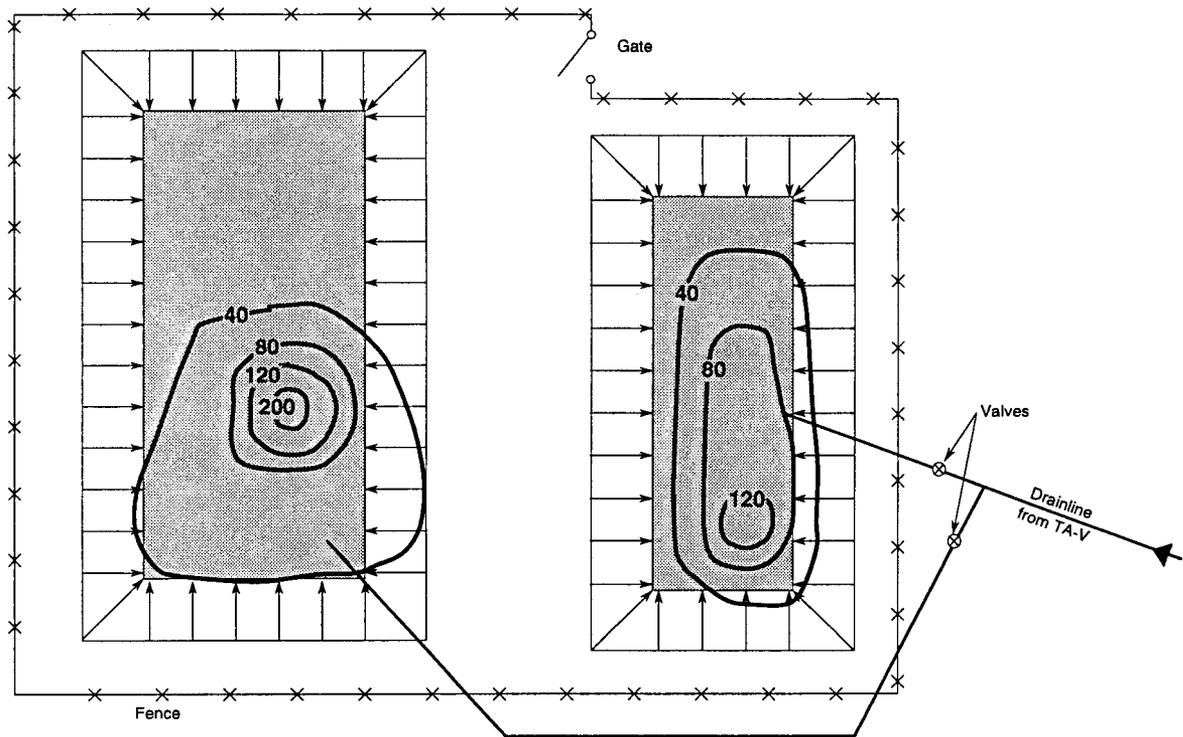


Figure 4-18. Surface Contaminant Contour Plots of Copper (in milligrams per kilogram [mg/kg])

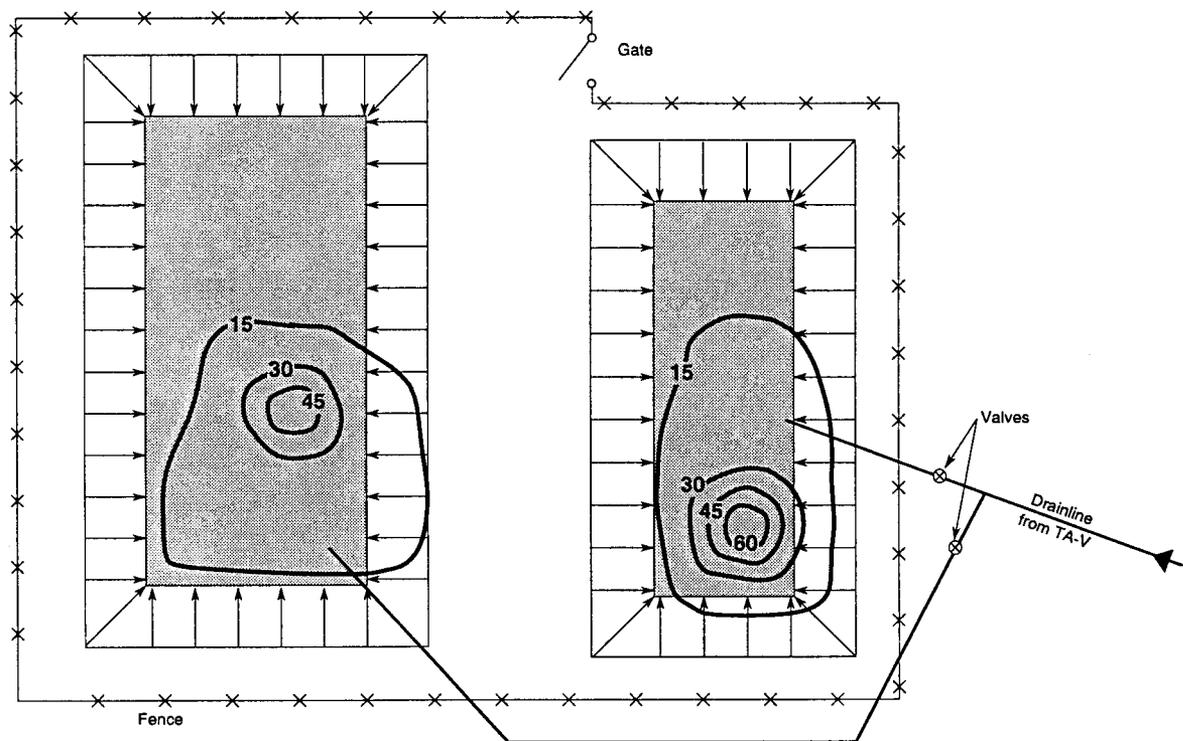


Figure 4-19. Surface Contaminant Contour Plots of Lead (in milligrams per kilogram [mg/kg])

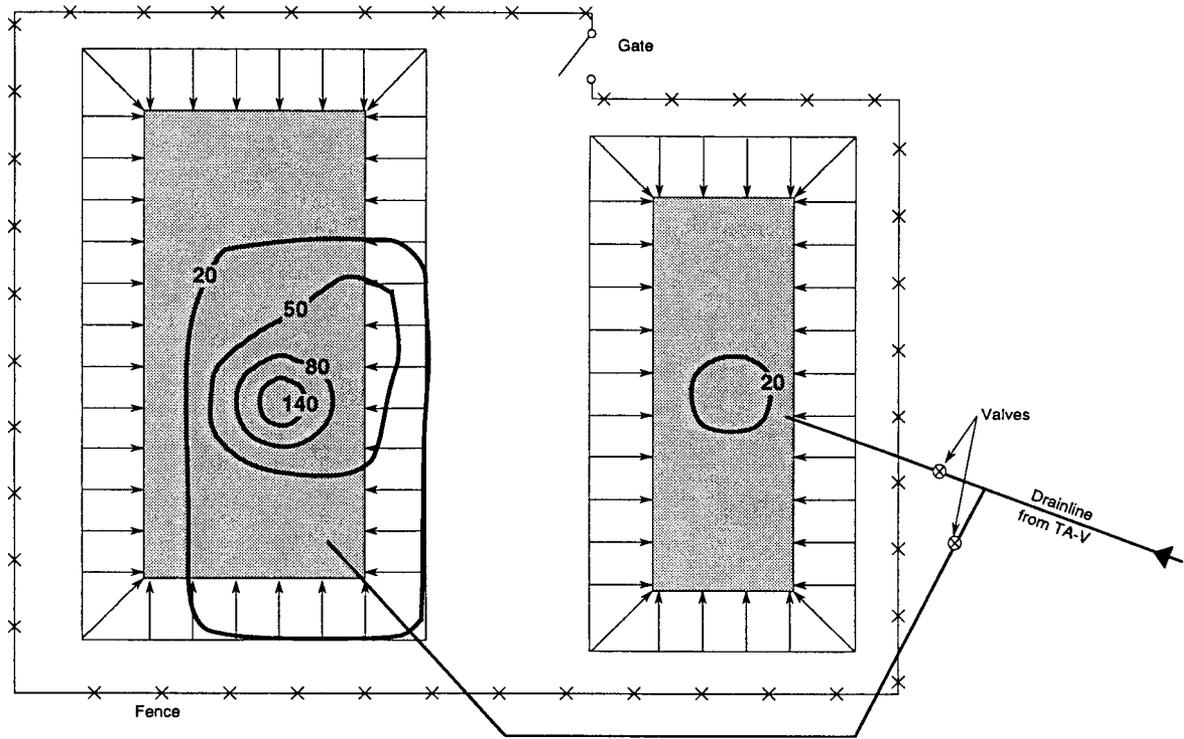


Figure 4-20. Surface Contaminant Contour Plots of Nickel
(in milligrams per kilogram [mg/kg])

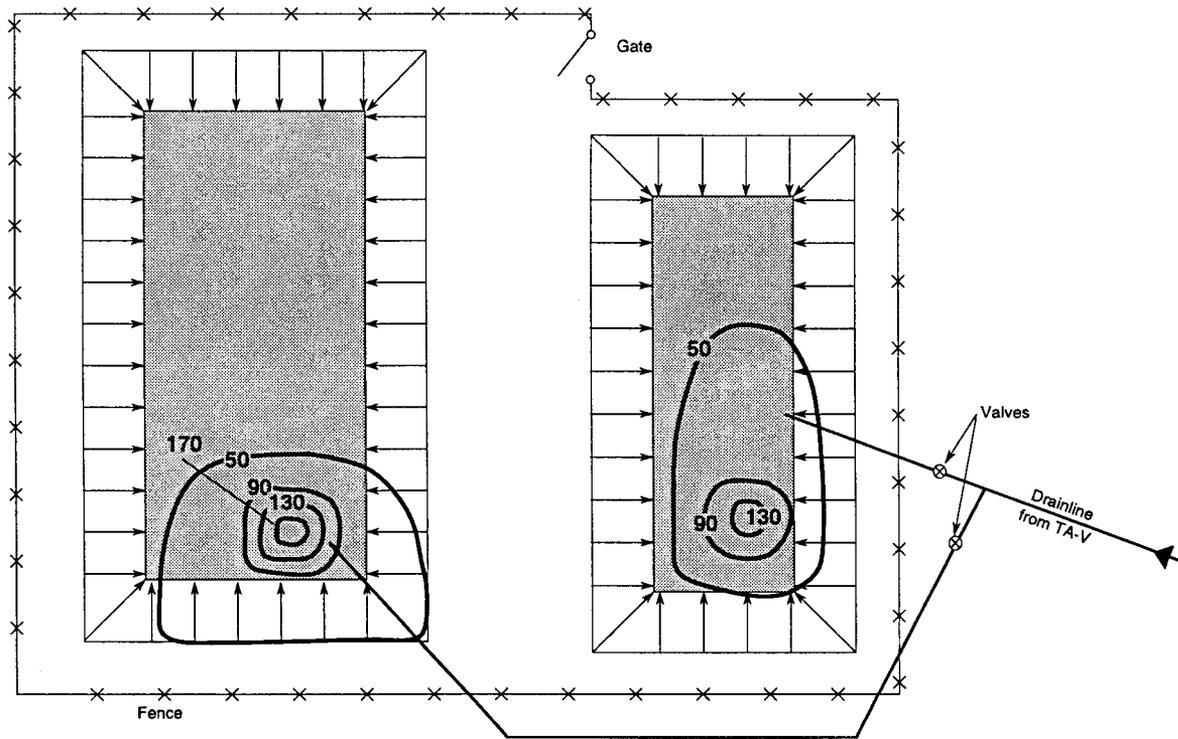


Figure 4-21. Surface Contaminant Contour Plots of Zinc
(in milligrams per kilogram [mg/kg])

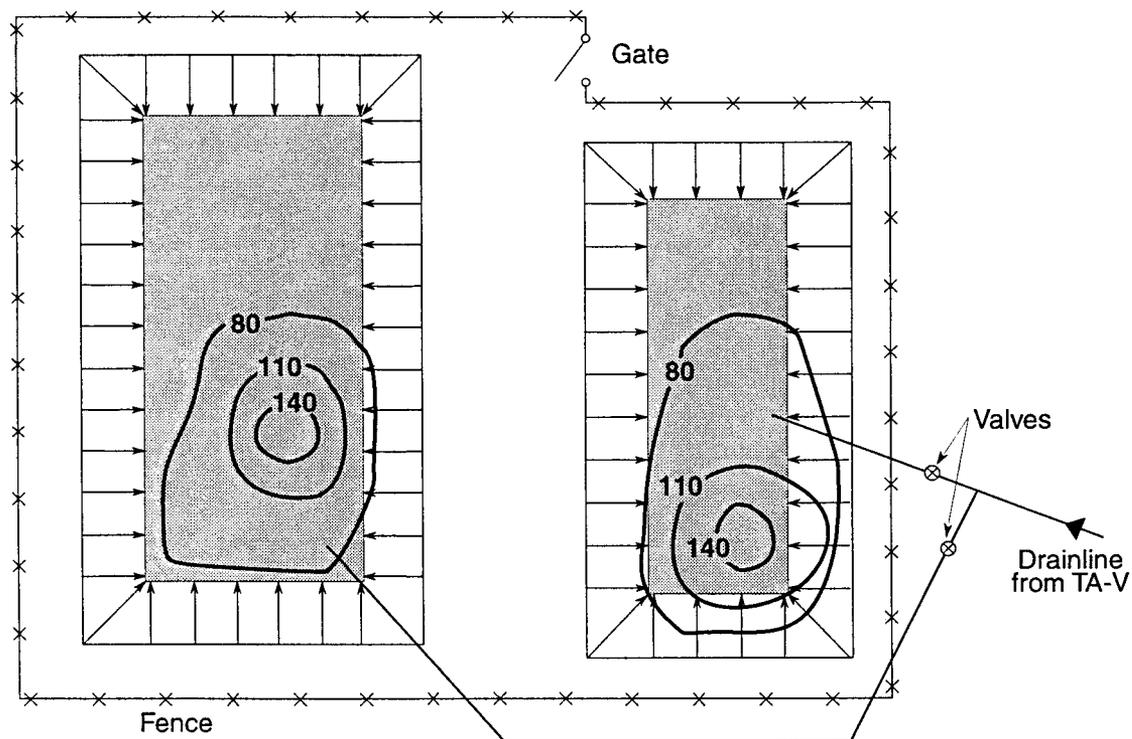


Figure 4-22. Surface Contaminant Contour Plots of Barium (in milligrams per kilogram [mg/kg])

0.35 to 1.3 mg/kg, which are typical values for this region. The new samples were not used in the statistical analysis but they show the original value as anomalous.

Radionuclides

Table 4-6 also summarizes the radionuclide analysis evaluation. Radionuclides well above background were only identified in samples collected during the surface sampling investigation. The surface contamination measured in this sampling event followed expected patterns. The highest levels of contamination were directly under the Impoundment 1 drainline outfall, whereas contamination is barely detectable in Impoundment 2. This pattern was expected because Impoundment 2 was constructed toward the end of the time period in which known radioactive contaminants were discharged. The total amount of contamination was fairly low; cobalt-60, cesium-137, tritium, and uranium-235 were the only detected anthropogenic radionuclides. Figures 4-23 through 4-25 show the surface contaminant concentration contours developed for cobalt-60, cesium-137, and uranium-235. Surface contaminant contours are not provided for tritium which had only trace levels barely detectable at 5 ft bgl in Boreholes 9 and 10.

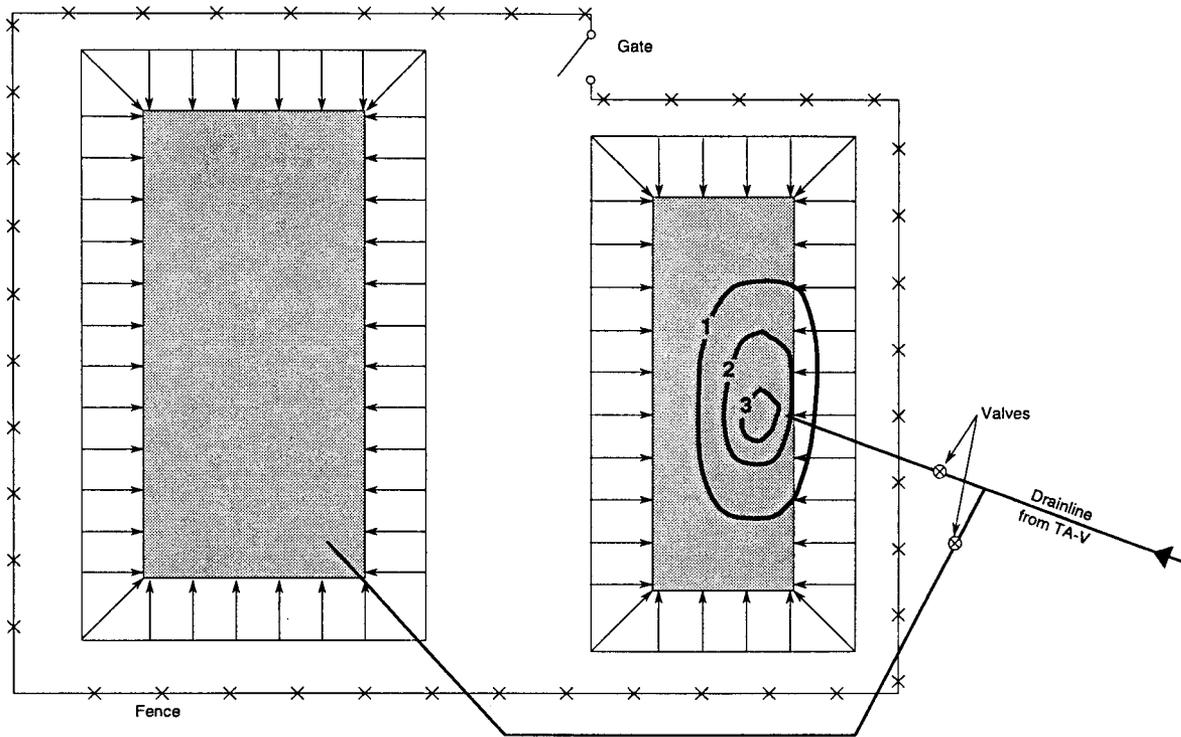


Figure 4-23. Surface Contaminant Contour Plots of Cobalt-60 at Impoundment 1
(in picocuries per gram [pCi/g])

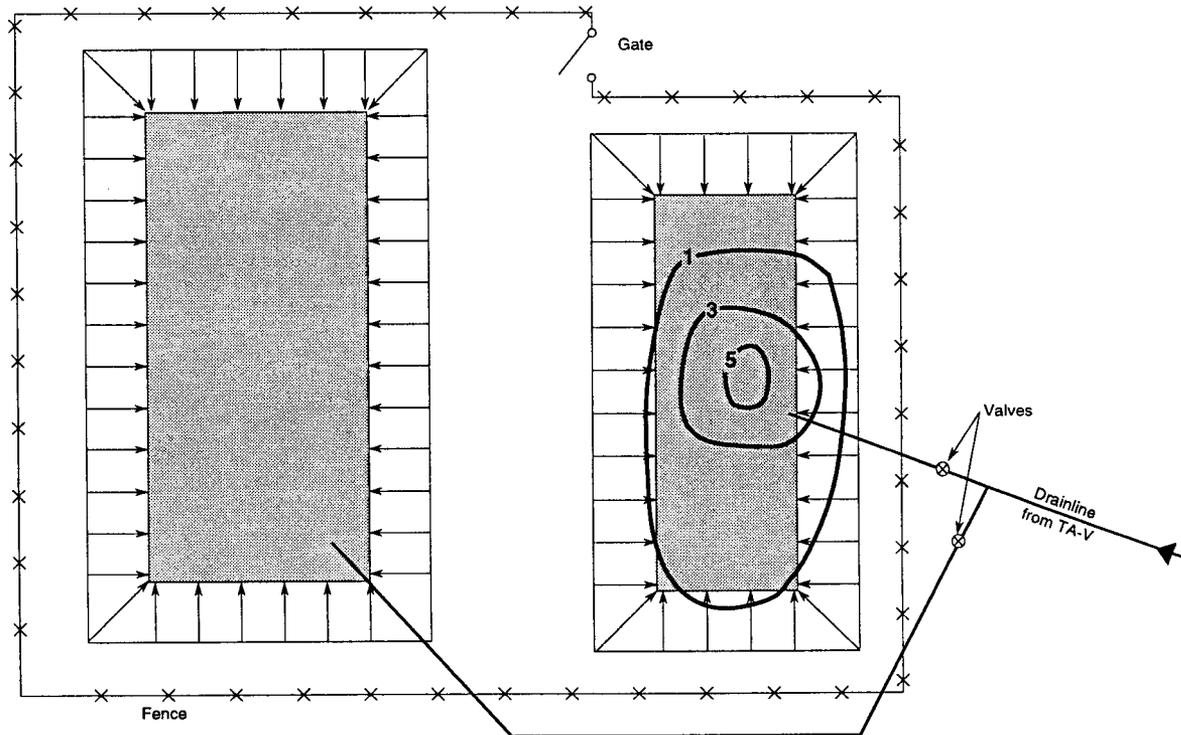


Figure 4-24. Surface Contaminant Contour Plots of Cesium-137 at Impoundment 1
(in picocuries per gram [pCi/g])

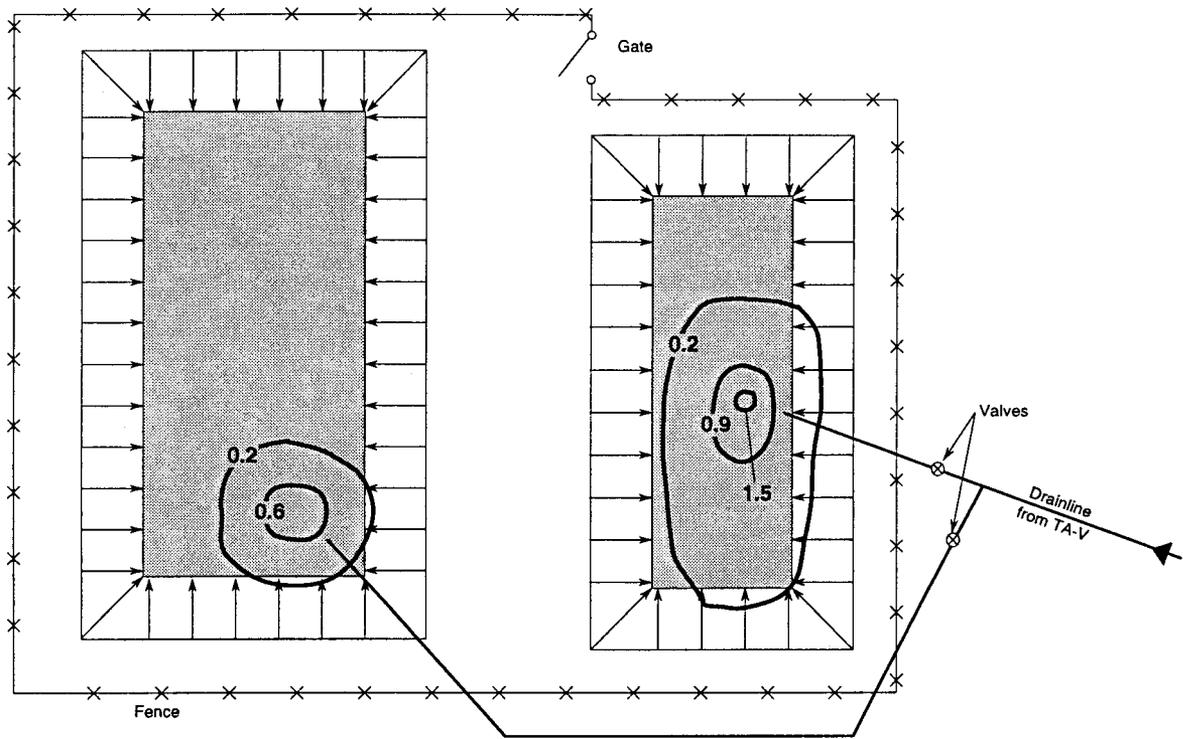


Figure 4-25. Surface Contaminant Contour Plots of Uranium-235 (in picocuries per gram [pCi/g])

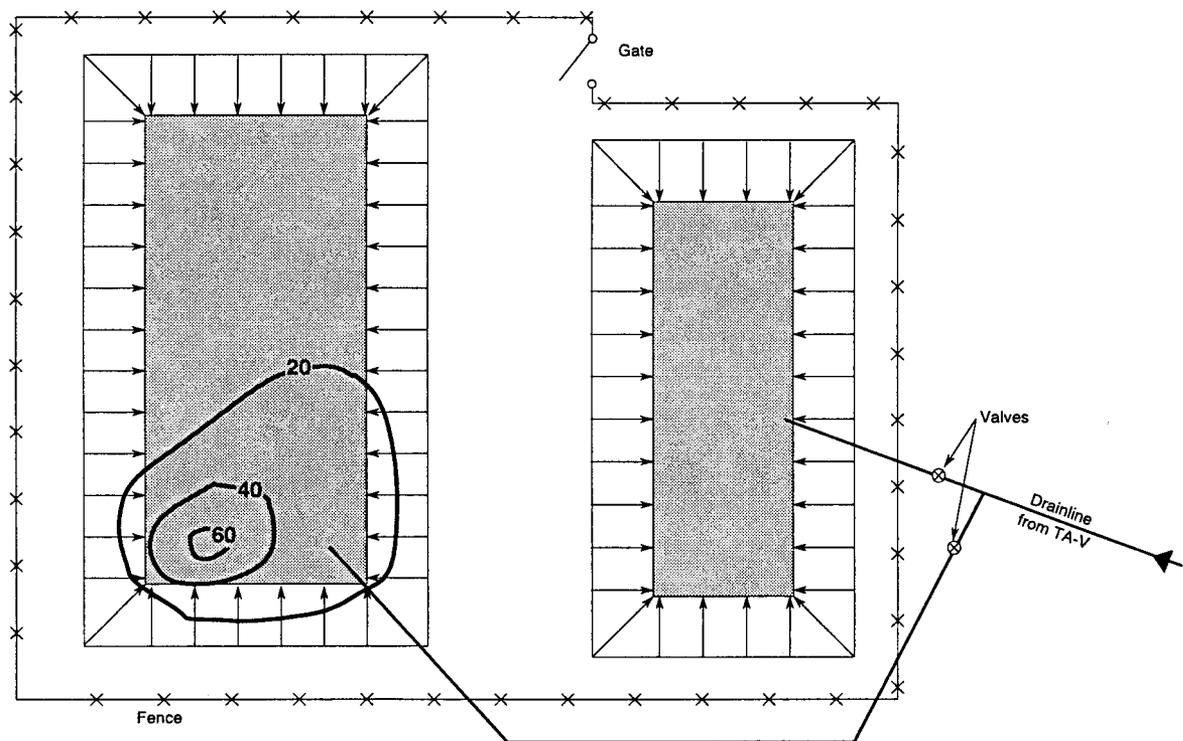


Figure 4-26. Surface Contaminant Contour Plots of Polychlorinated Biphenyls (PCBs) at Impoundment 2

Tritium was not detected in the vegetation sample.

Polychlorinated Biphenyls

The PCBs detected in surface soil do not follow the pattern described previously in that the highest concentrations of PCBs are not in the eastern impoundment beneath the drainline outfalls. PCB concentrations were not expected from TA-V activities and were not found near any drainlines; however, PCBs were detected in three soil samples collected from the southern end of the western impoundment (Impoundment 2). Figure 4-26 shows the surface contaminant concentration contours developed for PCBs in Impoundment 2. This concentration pattern could be explained by an isolated discharge in the southwest corner of Impoundment 2. No PCBs were detected in any soil samples collected from the subsurface. The highest result was 71 ppb, detected in the southwest corner of the western impoundment. This value compares favorably to the 40 CFR 264, proposed Subpart S, soil action level of 10,000 ppb for PCBs.

Ground Water

No contamination has been identified in monitor well LWDS-MW2 since its installation. Water quality analysis results appear to be representative of the regional background.

4.3.4 Risk Assessment

The SNL/NM *Précis* (Version 1.1.3) was used to estimate potential radiation doses, incremental lifetime cancer risks, and the systemic toxic hazard index associated with contaminated soil at the surface impoundments (Knowlton, 1994). All estimates were made according to an industrial land-use scenario. Annex II includes the entire risk assessment documentation.

This risk assessment indicates that external radiation exposure from cobalt-60 is a potential radiation dose to workers. Uranium-235 and tritium detected in some soil samples were not significant contributors to radiation dose. According to the analysis, a worker would have a 51 percent probability of exceeding the 25-mrem/yr radiation dose limit specified in DOE Order 5820.2A (DOE, 1988). The maximum radiation dose was estimated to occur in 1994, but the estimated dose is decreasing with time as a result of the radioactive decay of cobalt-60.

Estimates of incremental lifetime cancer risk from potential exposures to carcinogenic chemicals indicate that a worker in 1994 would have had a 52 percent probability of incurring greater than the 1×10^{-6} cancer risk limit judged acceptable by the EPA (EPA, 1989). This cancer risk was associated primarily with potential ingestion of soil containing cadmium and chromium-VI.

Estimates of systemic toxicity associated with potential exposures to chromium-VI, copper, mercury, nickel, and zinc indicate that the hazard index for a worker at ER Site 4 would be 0.04 or less with 95 percent probability. Thus, the estimated hazard index is far less than the value of 1.0 specified by the EPA (EPA, 1989).

Because sufficient information is not provided to address the potential health risk associated with lead in soil, no risk assessment for lead was made for this report. However, all lead concentrations reported for soil at ER Site 4 are far below the 400-ppm screening level specified by the EPA (EPA, 1994). The highest concentration of lead detected in soil at the LWDS surface impoundments was 72.5 ppm.

4.3.5 Summary and Conclusions

The risk assessment indicates that concentrations of cobalt-60, cadmium, and Chromium-VI may be high enough to require remediation at ER Site 4 (Section 4.3.4). However, the following recommendations are made to support a proposal of No Further Action:

1. Part of site closure activities will include filling the impoundments to grade with native soil. This leveling is required for safety considerations and is not considered a corrective measure. This fill will be a minimum of 6 ft and more than 12 ft thick in most places. This action, although not specifically required for risk reduction, will lower the total risk from carcinogenic chemicals and radionuclides under the industrial land-use scenario, such that estimated cancer risks and radiation doses are far below the applicable limits for the residential land-use scenario at 1×10^{-6} risk.

2. The risk assessment was based on the conservative EPA cancer risk limit of 1×10^{-6} specified in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual* (EPA, 1989). Recent EPA guidance provides cancer risk estimates up to 1×10^{-4} that might be acceptable (*Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, OSWER Directive 935,0-30, 1991). This latter guidance states, in part, "Records of Decision for remedial actions taken at sites posing risks within the 10^{-4} to 10^{-6} range must explain why remedial action is warranted." The risk assessment shows that cancer risk from cadmium and chromium-VI is well within the 1×10^{-4} risk limit and No Further Action would be appropriate.

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Annex I
Human Health Risk Assessment
ER Site 5, LWDS Drainfield

**LIQUID WASTE DISPOSAL SYSTEM DRAINFIELD
ENVIRONMENTAL RESTORATION SITE 5
HUMAN HEALTH RISK ASSESSMENT**

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1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL/NM), located in Albuquerque, New Mexico, is committed to the protection of human health and the environment. Because of this commitment, potential risks to human health were calculated for the constituents of concern (COC) detected in soil samples obtained from the Liquid Waste Disposal System (LWDS) drainfield, Environmental Restoration (ER) Site 5.

The following analysis involves calculating the potential radiation dose, cancer risk, or toxicity hazard to a worker at the site. This approach addresses uncertainties associated with various site-specific parameters (e.g., soil density and annual precipitation) and the variability of soil-contamination measurements. These calculations provide estimates of potential radiation dose, risk, and hazard and their uncertainties as compared with limits specified by regulations. Chapters 3.0 through 5.0 describe this approach.

Annual radiation doses resulting from the radionuclide COCs were estimated using the SNL/NM *Précis* computer program, Version 1.1.3a (SNL/NM 1994). The results of the radionuclide COCs human health risk assessment were compared with the 25 millirem per year (mrem/yr) dose rate, which is the U.S. Department of Energy (DOE) performance objective for limiting a radiation dose to any member of the public (DOE 1988).

Human health effects from potential exposure to nonradioactive COCs were also estimated using *Précis*. The Incremental Lifetime Cancer Risk (ICR) was estimated for potential exposures to carcinogenic chemicals. The hazard index (HI) was estimated for potential systemic toxic effects (e.g., kidney damage) resulting from exposure to noncarcinogenic chemicals. These calculated ICR and HI values were compared with values regarded as acceptable by the U.S. Environmental Protection Agency (EPA). The acceptable ICR is 1×10^{-6} ; the acceptable HI is 1.0 (EPA 1989).

2.0 SITE CHARACTERIZATION

2.1 Site Description

The ER Site 5 LWDS drainfield has been described in detail (SNL/NM 1993). Briefly, the drainfield was designed to receive liquid wastes discharged from the LWDS holding tanks. The below-grade drainfield was operational from 1963 to 1967, when it collapsed. According to health physics personnel working at that time, the collapse was observed as a sinking of the overlying pavement. The drainfield operation was well understood at the time and the action taken (to construct lagoons) suggests that its capacity to receive water was expected to be limited. No evidence of an overflow or spill, which would have occurred in the basement of Building 6580, has been found. The last recorded discharge was on May 11, 1967. The LWDS drainfield is buried approximately 36 ft deep and is located approximately 30 ft south of the LWDS holding tanks (Figure 2-1). The reported capacity of the drainfield is approximately 12,000 gallons.

2.2 Contamination Assessment

The only source of contamination at the drainfield was the liquid discharge stream from the holding tanks. This discharge entered the drainfield at the east end and infiltrated through it into the ground. Four soil borings were installed at the LWDS drainfield in March 1994 (Figure 2-2). Five borings were attempted. One borehole could not be installed through a large metal plate covering the midsection of the drainfield (Figure 2-2). Forty-five soil samples were collected from the cores at specified intervals. Fourteen samples were collected from Borehole LWDS-BH-11 at depths ranging from 25 to 70 ft below ground surface (bgs). Ten samples were collected from each of Boreholes LWDS-BH-12 and LWDS-BH-13 between 25 and 55 ft bgs, and eleven samples were collected from Borehole LWDS-BH-14 between 25 and 60 ft bgs.

The samples were analyzed at an off-site laboratory for tritium, gamma-emitting radionuclides, volatile and semivolatile organic compounds, and metals. Contaminants not detected in any of the 45 samples were not considered in this risk assessment. Contaminants that were detected above concentrations in samples collected to represent ER Site 5 background were considered to be COCs for the assessment of risks.

Two samples were taken between 0 and 30 ft bgs in each of the boreholes. All of these shallow samples contained no detectable contamination (see Sec. 4.2.2 of the main report). These data support the assumption that there is no contamination in soil at depths shallower than those at which the 45 samples considered in this risk assessment were taken.

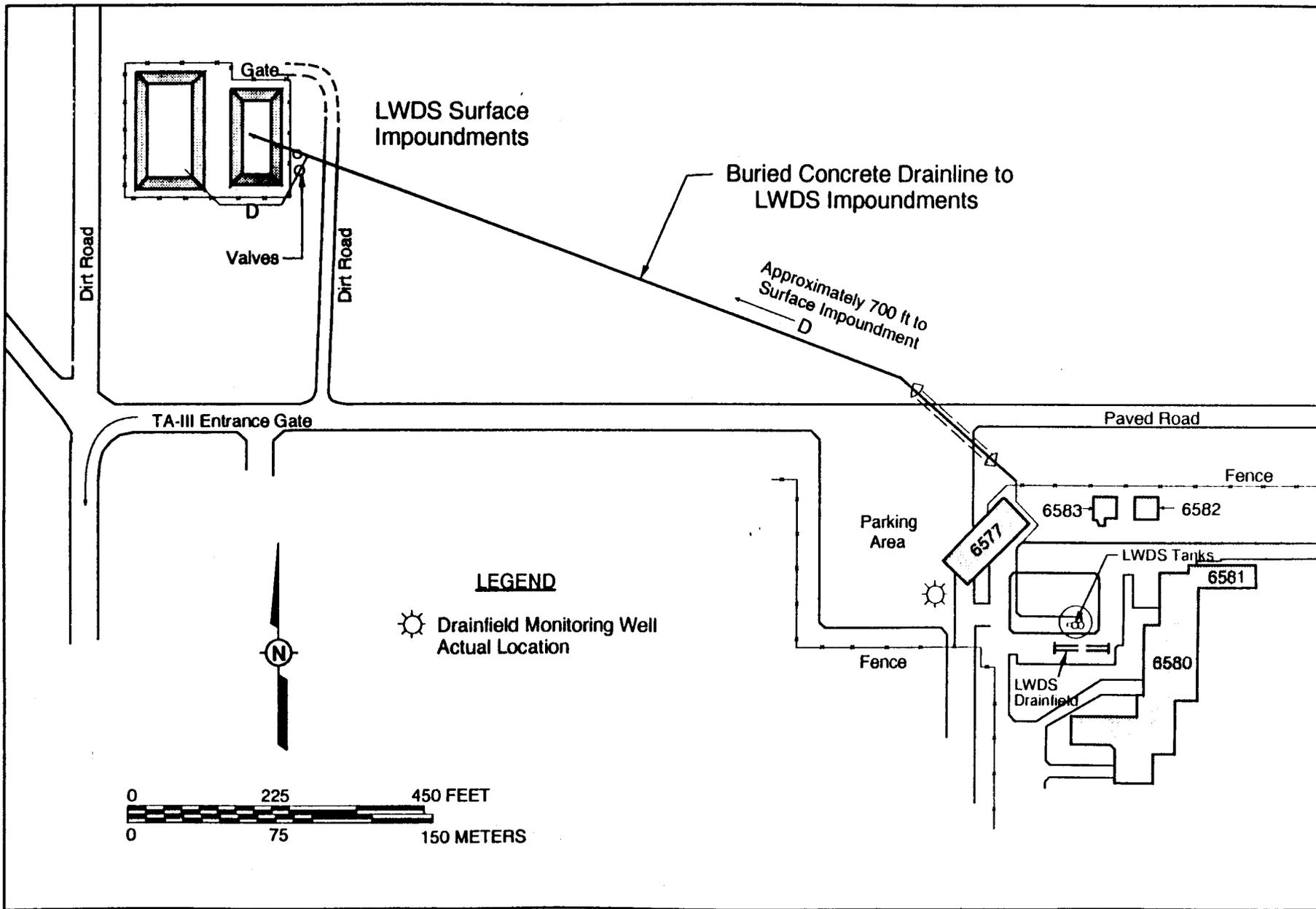
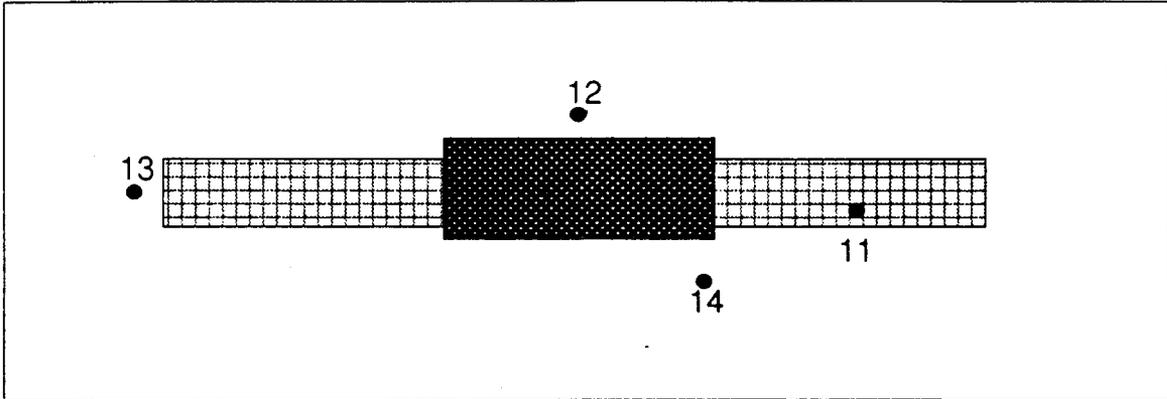


Figure 2-1
Liquid Waste Disposal System (LWDS) Site Map Showing Drainfield Location



Legend



LWDS Drainfield



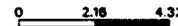
Metal Plate



LWDS borehole number



Scale in Feet



Scale in Meters

Adapted from Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System
Drawing MAPID - 950279

Figure 2-2. Liquid Waste Disposal System
Drainfield Borehole Locations

2.3 Constituents of Concern

The two radionuclides considered in the ER Site 5 risk assessment were cesium-137 and cobalt-60. One organic chemical (toluene) and four metals (beryllium, cadmium, chromium, and zinc) were identified as COCs. Appendix A summarizes the concentrations of these COCs in soil and their relative depths.

All of the data sets except for zinc contained undetected (U) concentrations and were evaluated by replacing U entries with one half the detection-limit. It is commonly found that large and complete data sets describing environmental soil contamination are lognormally distributed. Therefore, the distributions of ER Site 5 data sets were assumed to be lognormal (EPA 1992).

Table 2-1 shows the ER Site 5 COCs and the statistical distribution information used as input to *Précis*. Data sets for the two radionuclide COCs showed that only one of the 45 samples contained detectable cobalt-60 and three of the 45 samples contained detectable cesium-137. For the uncertainty calculations, these two data sets were represented by a lognormal-b distribution (SNL/NM 1994). In the lognormal-b distribution, the detection limit was assumed to represent the 0.1th percentile of a lognormal distribution, and the maximum concentration was assumed to be the 99.9th percentile (see Appendix A).

The zinc concentration distribution included a single measured concentration of 67.3 ppm zinc/gram soil, which is above the 99.9th percentile of the lognormal distribution (54.2 ppm zinc/gram soil). This circumstance is consistent with the distribution in which the probability of a concentration measured above 54.2 ppm is 0.1%. A somewhat more conservative risk analysis might be conducted if the 99.9th percentile of the zinc concentration were set to 67.3 ppm. However, the calculated Hazard Index of 0 (see Section 5.2) reflects zero calculated intake from any contaminant located 25 ft below the ground surface. The intake is not expected to increase above zero if the 99.9th percentile of the distribution is changed from 54.2 ppm to 67.3 ppm.

Table 2-1
Summary of 45 Core Sample Concentrations of Constituents of Concern in the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield

Contaminant (Unit of measure)	Concentration			
	Minimum Reported Value ^a	Maximum Reported Value	Lower Bound of Lognormal-b Distribution (0.1 percentile)	Upper Bound of Lognormal Distribution (99.9 percentile)
Cesium-137 (pCi/g)	0.021	0.140	0.02	0.14
Cobalt-60 (pCi/g)	0.036	0.150	0.04	0.15
Beryllium (ppm)	0.13	1.0	0.09	1.29
Cadmium (ppm)	0.31	51.1	0.02	154.44
Chromium (ppm)	2.2	42.4	1.14	39.0
Toluene (ppb)	1.2	51	0.16	67.06
Zinc (ppm)	10.90	67.30	8.17	54.22

^aThe minimum reported value in the data set is the lowest value recorded. If the data set includes samples with no detectable analyte, the detection limit was assumed to represent the minimum value.

3.0 EXPOSURE EVALUATION

The exposure assessment for contaminated soil at ER Site 5 was performed using *Précis* to estimate the potential annual radiation dose from radionuclides and the ICR and HI for nonradioactive COCs for a "reasonably maximally exposed" individual. This exposure assessment is conservative, meaning the exposure is overestimated.

Précis estimates an individual's annual radiation dose and hazardous chemical intake using a stochastic method. This technique provides an estimate of potential exposures by taking into account the uncertainties inherent in the program input parameters, such as COC concentration, soil density, depth to groundwater, etc. *Précis* evaluates this uncertainty in the exposure using a Latin hypercube sampling technique that randomly selects trial values for each of the input parameters according to their probability distributions and calculates an exposure concentration for each group of trial values. The resulting output provides a distribution of the individual's annual dose rate and intake of COCs. As such, the dose or intake frequency distribution represents the probability that the individual will receive a specified exposure, assuming that the exposure scenario does occur.

3.1 Radionuclide COC Exposure Evaluation

Evaluation of potential exposures to radionuclides includes assumed pathways for contact with contaminated media. These exposure pathways are based on land-use scenarios for the site.

The industrial land-use scenario was used to evaluate potential radionuclide exposures at ER Site 5. This scenario was evaluated using the *Précis* program under the following exposure assumptions:

- That the individual works exclusively at a randomly chosen location at ER Site 5 for an entire year. This highly conservative assumption was chosen to overestimate worker exposure.
- That the individual does not mitigate his or her potential exposures by avoiding contact with contamination or using personal protective equipment (i.e., the worker is unaware of the existence of contamination).
- That no food is grown at the site and that no drinking water well is available at the site.
- That the contaminated area is 194.7 m² (Figure 2-2).
- That the depth of contamination is represented by a bounded lognormal distribution ranging from 30 ft (9 m) below the surface to 70 ft (21 m), which represent the 0.1th percentile and the 99.9th percentile of the distribution, respectively.

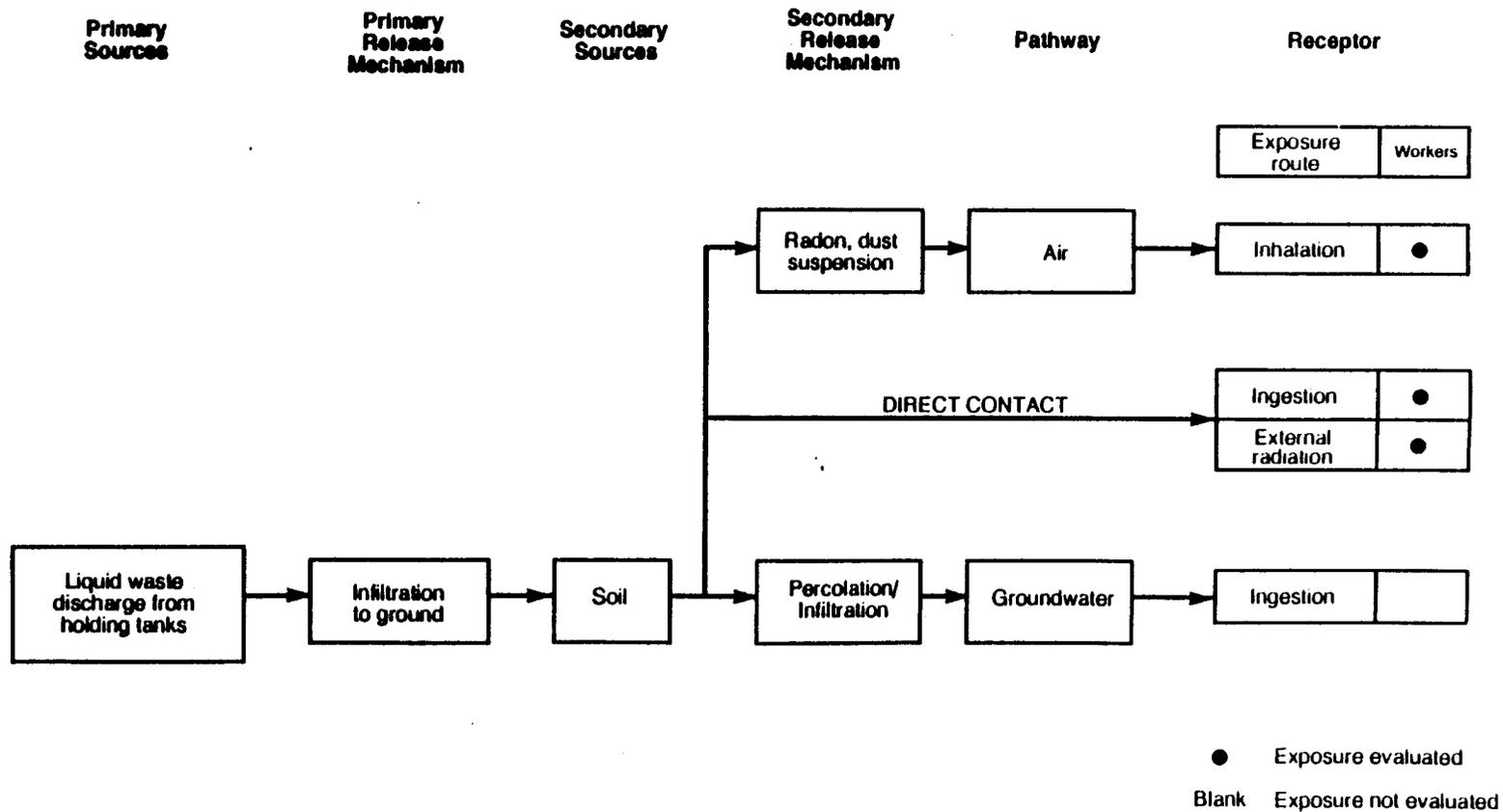


Figure 3-1
SNL/NM ER Site 5 Exposure Assessment Conceptual Model

- That the radionuclide COCs are distributed throughout the depth of contamination according to a bounded lognormal distribution, with the minimum reported detection limit representing the 0.1th percentile of each COC concentration and the maximum value representing the 99.9th percentile. Because this approach assumes that any of the COCs might be found at any depth in any of the four boreholes, it conservatively overestimates the extent of contamination. For example, cesium-137 is assumed to be distributed throughout the depth of contamination even though no cesium-137 was detected in Boreholes LWDS-BH-11, LWDS-BH-13, or LWDS-BH-14 (Appendix A).

Under these assumptions, the exposure pathways are:

- Inhalation of airborne dust
- Ingestion of contaminated soil
- Direct external gamma radiation

Figure 3-1 shows the fugitive dust inhalation, incidental soil ingestion, and external radiation exposure pathways that were evaluated. The assumptions include a probability (less than 0.1%) that the contamination measured at depth in the boreholes might also be present at the surface and might be available for inhalation and ingestion exposure. This is a conservative assumption that would overestimate the exposure.

3.2 Chemical COC Exposure Evaluation

The evaluation of potential worker exposures to nonradioactive contaminants was based on the same industrial land-use scenario assumptions used for radionuclides (Section 3.1). The airborne dust inhalation and ingestion pathways were evaluated, but the direct external gamma radiation pathway was not included (Figure 3-1).

The nonradioactive COCs were also assumed to be distributed throughout the depth of contamination according to a lognormal distribution bounded by the 0.1th and 99.9th percentiles. The bounding COC concentrations were calculated from a logarithmic fit of the measured COC concentrations (see Appendix A).

3.3 Sensitivity Analysis of *Précis* Input Parameters

Estimates of radiation dose and chemical risks (both carcinogens and noncarcinogens) were made from 100 stochastic *Précis* simulations. This number of simulations is greater than twice the number of uncertain parameters (Appendix B) and is considered sufficient to describe the uncertainty of the calculated result (SNL/NM 1994, Iman 1982).

The radiation dose for occupational exposure at ER Site 5 was estimated to be the same value (0 mrem/year) for all 100 simulations at all times through 1,000 years into the future. Likewise, ICR and HI calculated for exposure to chemicals were calculated to be the same

value (0) in all simulations. Because the uncertainties in input parameters did not result in any uncertainty in the calculated values, no sensitivity analysis was possible.

3.4 Summary of *Précis* Input Parameters

Appendix B summarizes both the stochastic and nonstochastic input parameters used by *Précis* to calculate the radiation dose, the ICR, and the HI for ER Site 5.

4.0 TOXICITY ASSESSMENT

Hazardous materials are classified by their carcinogenic or noncarcinogenic (often termed "systemic") effects on human health. Carcinogenicity risk is described as the probability that an individual will develop cancer sometime during his or her lifetime from a chronic intake of the carcinogen in question (EPA 1989).

Cancer risk from chronic exposure to a chemical carcinogen is described by a slope factor (SF) used to relate the daily carcinogen intake to an upper limit of the cancer risk. The SF values used in this assessment were obtained from the Integrated Risk Information System (IRIS) (EPA 1994) or from the Health Effects Assessment Summary Tables (HEAST) (EPA 1993). All radionuclides are classified by the EPA as Group A human carcinogens because of their ionizing radiation emissions. For the purposes of this risk assessment, the cancer risk from radiation is limited by the maximum-allowed radiation dose received of 25 mrem/yr (DOE 1988). This limit applies to the total radiation dose received from all exposure pathways.

Systemic toxicity is described by the reference dose (RfD) concept, which assumes that a threshold level exists for systemic toxicity (EPA 1989). The RfD is the estimate of daily contaminant intake for a human population, including sensitive subpopulations, that is expected to cause no adverse human health effects from chronic exposure. The RfD values used in this analysis were obtained from the IRIS (EPA 1994).

Chromium compounds can contain chromium in the Cr(III) or Cr(VI) oxidation state. Cr(VI) compounds are Class A human carcinogens; but there is no evidence for carcinogenicity from exposure to Cr(III) compounds (EPA 1994). Because information regarding the oxidation state of chromium detected at ER Site 5 is unavailable, all chromium was assumed to be in the Cr(VI) oxidation state. This conservative assumption was made to overestimate the cancer risk to a worker.

Toxicity information for each potential chemical of concern at ER Site 5 is summarized in Table 4-1 and described in detail in Appendix C.

**Table 4-1
Human Toxicity Factors Used for Calculations of
Incremental Lifetime Cancer Risk and
Hazard Index from Exposure to Constituents of Concern at the
SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield**

Nonradioactive Constituents of Concern	Reference Dose		Health Effect, Target Organ	Oral Slope Factor (kg-day/mg)	Inhalation Slope Factor (kg-day/mg)	Cancer Class (see Appendix C)	Tumor Site
	Oral (mg/kg-day)	Dust Inhalation (mg/m ³)					
Beryllium	5E-03 ^a	b	Inflammation, lung	4.3 ^a	8.4 ^a	B2	Lung
Cadmium	1E-03 ^a	b	Proteinuria, kidney	b	6.1 ^a	B1	Respiratory Tract
Chromium (VI)	5E-03 ^a	b	Proteinuria, kidney	b	41	A	Lung
Toluene	2E-01 ^a	1.14E-01 ^a	Confusion, central nervous system dysfunction, liver, kidney	b	c	D	c
Zinc	3E-01 ^a	b	Gastrointestinal disorders	b	c	D	c

^a Integrated Risk Information System (IRIS) (EPA 1994).

^b No data available to establish toxicity factor.

^c Not considered to be carcinogenic to humans (EPA 1994).

5.0 RISK CHARACTERIZATION OF COCs

The annual radiation dose from potential exposure to radionuclides, the ICR from exposure to carcinogenic chemical contaminants, and the HI for exposure to noncarcinogenic chemicals in soil at the LWDS drainfield were calculated using 100 *Précis* simulations based on industrial land-use scenario assumptions. This risk characterization employed a conservative approach that led to the overestimation of risk, as described in Section 3.0. Appendix D shows the results of *Précis* simulations.

5.1 Radiation Dose Characterization

The maximum radiation dose to potential workers from cesium-137 and cobalt-60 at ER Site 5 was calculated to be 0 mrem/year at all times through 1,000 years into the future. This calculated dose meets the 25 mrem/year regulatory limit specified for this risk assessment (DOE 1988). The low calculated radiation dose reflects complete shielding of gamma radiation by the 25 ft of overlying soil.

5.2 Risks and Hazards From Exposure to Hazardous Chemicals

The maximum ICR to potential workers from cadmium and chromium (VI) at ER Site 5 was calculated to be no incremental cancer risk at all times through 1,000 years into the future. This calculated ICR meets the 1×10^{-6} ICR regulatory limit specified for this risk assessment (EPA 1989). The maximum HI was also calculated to be zero at all times through 1,000 years into the future. This calculated value is well below the 1.0 HI regulatory limit (EPA 1989) and indicates no unacceptable hazard from potential exposures to the non-carcinogenic chemicals. Because beryllium, cadmium, and chromium (VI) are systemic toxicants as well as carcinogens, the contributions to both the ICR and the HI from potential beryllium, cadmium, and chromium (VI) exposure were calculated.

The calculation of ICR = 0 and HI = 0 follows from the calculation of no human intake of contaminants located at greater than 25 ft bgs according to the industrial land-use assumptions (see Section 3). According to EPA risk assessment methodology, zero intake represents zero risk or hazard (EPA 1989).

6.0 DISCUSSION

The radiation dose assessment for the industrial land-use scenario indicates that no appreciable dose (0 mrem/year) could be calculated through 1,000 years into the future and that 25 mrem/yr dose limit would be met at all times. This result indicates that gamma-emitting radionuclides located 25 ft below the surface are not available for inhalation as dust or for ingestion exposure of a worker at the surface. Further, the 25 ft of soil effectively shields the worker from gamma rays emitted by the radionuclides measured below the site.

Similarly, the cancer risk and the hazard index for COC were calculated to be far below acceptable limits. These results also indicate that hazardous chemicals located at 25 ft below the surface are not available for inhalation or ingestion exposure of a worker at the surface.

6.1 Uncertainty

The uncertainties of all input parameters (see Appendix B) did not result in any variability in radiation dose, ICR, or HI estimates.

6.2 Conclusions

Radiation dose, ICR, and HI values calculated using conservative worker exposure assumptions and conservative radiation dose and cancer risk limits indicate that there is no unacceptable radiation dose, cancer risk, or systemic toxicity hazard associated with cesium-137, cobalt-60, beryllium, cadmium, chromium, toluene, or zinc measured at ER Site 5. The location of radionuclide and hazardous chemical contaminants at greater than 25 ft below ground effectively removes exposure pathways to a worker at the surface.

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APPENDIX A
SITE CHARACTERIZATION DATA

Table A-1
Cadmium, Cesium-137, Cobalt-60, and Zinc Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION ppm	LN CONCENTRATION	DETECTION_LIMIT
LWDS-BH-11	47.50	CADMIUM	0.3100	-1.1712	NA
LWDS-BH-12	30.00	CADMIUM	0.3100	-1.1712	NA
LWDS-BH-12	55.00	CADMIUM	0.4000	-0.9163	NA
LWDS-BH-12	50.00	CADMIUM	0.4100	-0.8916	NA
LWDS-BH-11	25.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	30.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	35.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	37.50	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	40.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	42.50	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	45.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	50.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	55.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	60.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	65.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	70.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-11	70.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-12	25.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	25.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	30.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	32.50	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	35.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	37.50	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	40.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	45.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	50.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-13	50.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-14	32.50	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-14	45.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-14	50.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-14	60.00	CADMIUM	0.5000	-0.6931	NA
LWDS-BH-14	40.00	CADMIUM	0.5700	-0.5621	NA
LWDS-BH-14	55.00	CADMIUM	0.5800	-0.5447	NA
LWDS-BH-14	25.00	CADMIUM	0.8800	-0.1278	NA
LWDS-BH-14	60.00	CADMIUM	0.9600	-0.0408	NA
LWDS-BH-13	55.00	CADMIUM	1.0000	0.0000	NA
LWDS-BH-14	35.00	CADMIUM	2.5000	0.9163	NA
LWDS-BH-14	37.50	CADMIUM	2.5000	0.9163	NA
LWDS-BH-12	55.00	CADMIUM	3.0000	1.0986	NA
LWDS-BH-12	35.00	CADMIUM	3.5000	1.2528	NA
LWDS-BH-12	45.00	CADMIUM	5.3000	1.6677	NA
LWDS-BH-12	32.50	CADMIUM	5.7000	1.7405	NA
LWDS-BH-14	30.00	CADMIUM	6.7000	1.9021	NA
LWDS-BH-12	40.00	CADMIUM	22.5000	3.1135	NA
LWDS-BH-12	37.50	CADMIUM	51.1000	3.9338	NA
<i>Regression Statistics</i>					
Ln					
R Square		0.91			
Mean		0.51			
St. Deviation		1.51			
0.1 Value		0.02			
99.9 Value		154.44			

Table A-1
Cadmium, Cesium-137, Cobalt-60, and Zinc Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT
LWDS-BH-11	25.00	CESIUM-137	0.0590	-2.8302	NA
LWDS-BH-11	30.00	CESIUM-137	0.0510	-2.9759	NA
LWDS-BH-11	35.00	CESIUM-137	0.0600	-2.8134	NA
LWDS-BH-11	37.50	CESIUM-137	0.0380	-3.2702	NA
LWDS-BH-11	40.00	CESIUM-137	0.0380	-3.2702	NA
LWDS-BH-11	42.50	CESIUM-137	0.0450	-3.1011	NA
LWDS-BH-11	45.00	CESIUM-137	0.0430	-3.1466	NA
LWDS-BH-11	47.50	CESIUM-137	0.0440	-3.1236	NA
LWDS-BH-11	50.00	CESIUM-137	0.0490	-3.0159	NA
LWDS-BH-11	55.00	CESIUM-137	0.0420	-3.1701	NA
LWDS-BH-11	60.00	CESIUM-137	0.0420	-3.1701	NA
LWDS-BH-11	65.00	CESIUM-137	0.0210	-3.8632	NA
LWDS-BH-11	70.00	CESIUM-137	0.0470	-3.0576	NA
LWDS-BH-11	70.00	CESIUM-137	0.0460	-3.0791	NA
LWDS-BH-12	25.00	CESIUM-137	0.0560	-2.8824	NA
LWDS-BH-12	30.00	CESIUM-137	0.0960	-2.3434	NA
LWDS-BH-12	32.50	CESIUM-137	0.0550	-2.9004	NA
LWDS-BH-12	35.00	CESIUM-137	0.0750	-2.5903	NA
LWDS-BH-12	37.50	CESIUM-137	0.1400	-1.9661	NA
LWDS-BH-12	40.00	CESIUM-137	0.1200	-2.1203	NA
LWDS-BH-12	45.00	CESIUM-137	0.0540	-2.9188	NA
LWDS-BH-12	50.00	CESIUM-137	0.0370	-3.2968	NA
LWDS-BH-12	55.00	CESIUM-137	0.0430	-3.1466	NA
LWDS-BH-12	55.00	CESIUM-137	0.0380	-3.2702	NA
LWDS-BH-13	25.00	CESIUM-137	0.0470	-3.0576	NA
LWDS-BH-13	30.00	CESIUM-137	0.0380	-3.2702	NA
LWDS-BH-13	32.50	CESIUM-137	0.0420	-3.1701	NA
LWDS-BH-13	35.00	CESIUM-137	0.0440	-3.1236	NA
LWDS-BH-13	37.50	CESIUM-137	0.0360	-3.3242	NA
LWDS-BH-13	40.00	CESIUM-137	0.0400	-3.2189	NA
LWDS-BH-13	45.00	CESIUM-137	0.0410	-3.1942	NA
LWDS-BH-13	50.00	CESIUM-137	0.0370	-3.2968	NA
LWDS-BH-13	50.00	CESIUM-137	0.0360	-3.3242	NA
LWDS-BH-13	55.00	CESIUM-137	0.0460	-3.0791	NA
LWDS-BH-14	25.00	CESIUM-137	0.0340	-3.3814	NA
LWDS-BH-14	30.00	CESIUM-137	0.0390	-3.2442	NA
LWDS-BH-14	32.50	CESIUM-137	0.0380	-3.2702	NA
LWDS-BH-14	35.00	CESIUM-137	0.0540	-2.9188	NA
LWDS-BH-14	37.50	CESIUM-137	0.0370	-3.2968	NA
LWDS-BH-14	40.00	CESIUM-137	0.0310	-3.4738	NA
LWDS-BH-14	45.00	CESIUM-137	0.0460	-3.0791	NA
LWDS-BH-14	50.00	CESIUM-137	0.0490	-3.0159	NA
LWDS-BH-14	55.00	CESIUM-137	0.0400	-3.2189	NA
LWDS-BH-14	60.00	CESIUM-137	0.0450	-3.1011	NA
LWDS-BH-14	60.00	CESIUM-137	0.0330	-3.4112	NA

Table A-1
Cadmium, Cesium-137, Cobalt-60, and Zinc Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT
LWDS-BH-11	25.00	COBALT-60	0.0640	-2.7489	NA
LWDS-BH-11	30.00	COBALT-60	0.0580	-2.8473	NA
LWDS-BH-11	35.00	COBALT-60	0.0660	-2.7181	NA
LWDS-BH-11	37.50	COBALT-60	0.0510	-2.9759	NA
LWDS-BH-11	40.00	COBALT-60	0.0540	-2.9188	NA
LWDS-BH-11	42.50	COBALT-60	0.0460	-3.0791	NA
LWDS-BH-11	45.00	COBALT-60	0.0530	-2.9375	NA
LWDS-BH-11	47.50	COBALT-60	0.0450	-3.1011	NA
LWDS-BH-11	50.00	COBALT-60	0.0480	-3.0366	NA
LWDS-BH-11	55.00	COBALT-60	0.0650	-2.7334	NA
LWDS-BH-11	60.00	COBALT-60	0.0520	-2.9565	NA
LWDS-BH-11	65.00	COBALT-60	0.0360	-3.3242	NA
LWDS-BH-11	70.00	COBALT-60	0.0580	-2.8473	NA
LWDS-BH-11	70.00	COBALT-60	0.0490	-3.0159	NA
LWDS-BH-12	25.00	COBALT-60	0.0690	-2.6736	NA
LWDS-BH-12	30.00	COBALT-60	0.1500	-1.8971	NA
LWDS-BH-12	32.50	COBALT-60	0.0650	-2.7334	NA
LWDS-BH-12	35.00	COBALT-60	0.0750	-2.5903	NA
LWDS-BH-12	37.50	COBALT-60	0.0710	-2.6451	NA
LWDS-BH-12	40.00	COBALT-60	0.0730	-2.6173	NA
LWDS-BH-12	45.00	COBALT-60	0.0670	-2.7031	NA
LWDS-BH-12	50.00	COBALT-60	0.0530	-2.9375	NA
LWDS-BH-12	55.00	COBALT-60	0.0470	-3.0576	NA
LWDS-BH-12	55.00	COBALT-60	0.0440	-3.1236	NA
LWDS-BH-13	25.00	COBALT-60	0.0560	-2.8824	NA
LWDS-BH-13	30.00	COBALT-60	0.0450	-3.1011	NA
LWDS-BH-13	32.50	COBALT-60	0.0490	-3.0159	NA
LWDS-BH-13	35.00	COBALT-60	0.0420	-3.1701	NA
LWDS-BH-13	37.50	COBALT-60	0.0440	-3.1236	NA
LWDS-BH-13	40.00	COBALT-60	0.0540	-2.9188	NA
LWDS-BH-13	45.00	COBALT-60	0.0540	-2.9188	NA
LWDS-BH-13	50.00	COBALT-60	0.0430	-3.1466	NA
LWDS-BH-13	50.00	COBALT-60	0.0460	-3.0791	NA
LWDS-BH-13	55.00	COBALT-60	0.0540	-2.9188	NA
LWDS-BH-14	25.00	COBALT-60	0.0460	-3.0791	NA
LWDS-BH-14	30.00	COBALT-60	0.0810	-2.5133	NA
LWDS-BH-14	32.50	COBALT-60	0.0470	-3.0576	NA
LWDS-BH-14	35.00	COBALT-60	0.0430	-3.1466	NA
LWDS-BH-14	37.50	COBALT-60	0.0540	-2.9188	NA
LWDS-BH-14	40.00	COBALT-60	0.0410	-3.1942	NA
LWDS-BH-14	45.00	COBALT-60	0.0620	-2.7806	NA
LWDS-BH-14	50.00	COBALT-60	0.0510	-2.9759	NA
LWDS-BH-14	55.00	COBALT-60	0.0520	-2.9565	NA
LWDS-BH-14	60.00	COBALT-60	0.0570	-2.8647	NA
LWDS-BH-14	60.00	COBALT-60	0.0410	-3.1942	NA

Table A-1
Cadmium, Cesium-137, Cobalt-60, and Zinc Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (ppm)	LN CONCENTRATION	DETECTION_LIMIT
LWDS-BH-11	25.00	ZINC	31.8000	3.4595	NA
LWDS-BH-11	30.00	ZINC	18.4000	2.9124	NA
LWDS-BH-11	35.00	ZINC	23.9000	3.1739	NA
LWDS-BH-11	37.50	ZINC	22.6000	3.1179	NA
LWDS-BH-11	40.00	ZINC	24.0000	3.1781	NA
LWDS-BH-11	42.50	ZINC	18.9000	2.9392	NA
LWDS-BH-11	45.00	ZINC	24.1000	3.1822	NA
LWDS-BH-11	47.50	ZINC	21.6000	3.0727	NA
LWDS-BH-11	50.00	ZINC	21.9000	3.0865	NA
LWDS-BH-11	55.00	ZINC	14.2000	2.6532	NA
LWDS-BH-11	60.00	ZINC	20.8000	3.0350	NA
LWDS-BH-11	65.00	ZINC	14.0000	2.6391	NA
LWDS-BH-11	70.00	ZINC	24.9000	3.2149	NA
LWDS-BH-11	70.00	ZINC	24.2000	3.1864	NA
LWDS-BH-12	25.00	ZINC	20.8000	3.0350	NA
LWDS-BH-12	30.00	ZINC	16.2000	2.7850	NA
LWDS-BH-12	32.50	ZINC	25.1000	3.2229	NA
LWDS-BH-12	35.00	ZINC	18.3000	2.9069	NA
LWDS-BH-12	37.50	ZINC	67.3000	4.2092	NA
LWDS-BH-12	40.00	ZINC	36.3000	3.5918	NA
LWDS-BH-12	45.00	ZINC	17.5000	2.8622	NA
LWDS-BH-12	50.00	ZINC	18.4000	2.9124	NA
LWDS-BH-12	55.00	ZINC	11.6000	2.4510	NA
LWDS-BH-12	55.00	ZINC	22.7000	3.1224	NA
LWDS-BH-13	25.00	ZINC	28.6000	3.3534	NA
LWDS-BH-13	30.00	ZINC	20.0000	2.9957	NA
LWDS-BH-13	32.50	ZINC	27.4000	3.3105	NA
LWDS-BH-13	35.00	ZINC	30.2000	3.4078	NA
LWDS-BH-13	37.50	ZINC	21.1000	3.0493	NA
LWDS-BH-13	40.00	ZINC	17.5000	2.8622	NA
LWDS-BH-13	45.00	ZINC	30.1000	3.4045	NA
LWDS-BH-13	50.00	ZINC	22.4000	3.1091	NA
LWDS-BH-13	50.00	ZINC	22.4000	3.1091	NA
LWDS-BH-13	55.00	ZINC	10.9000	2.3888	NA
LWDS-BH-14	25.00	ZINC	20.5000	3.0204	NA
LWDS-BH-14	30.00	ZINC	19.5000	2.9704	NA
LWDS-BH-14	32.50	ZINC	16.4000	2.7973	NA
LWDS-BH-14	35.00	ZINC	23.8000	3.1697	NA
LWDS-BH-14	37.50	ZINC	18.8000	2.9339	NA
LWDS-BH-14	40.00	ZINC	22.3000	3.1046	NA
LWDS-BH-14	45.00	ZINC	19.4000	2.9653	NA
LWDS-BH-14	50.00	ZINC	16.9000	2.8273	NA
LWDS-BH-14	55.00	ZINC	11.0000	2.3979	NA
LWDS-BH-14	60.00	ZINC	16.2000	2.7850	NA
LWDS-BH-14	60.00	ZINC	24.6000	3.2027	NA
<i>Regression Statistics</i>					
Ln					
R Square		0.82			
Mean		3.05			
St Deviation		0.32			
0.1 Value		8.17			
99.9 Value		54.22			

Table A-2
Toluene Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (microgram/kg)	LN CONCENTRATION	DETECTION_LIMIT (microgram/kg)
LWDS-BH-11	37.5	TOLUENE	2	0.6931	NA
LWDS-BH-11	70	TOLUENE	5	1.6094	NA
LWDS-BH-11	60	TOLUENE	5.7	1.7405	NA
LWDS-BH-11	50	TOLUENE	5	1.6094	NA
LWDS-BH-11	45	TOLUENE	5	1.6094	NA
LWDS-BH-11	40	TOLUENE	5	1.6094	NA
LWDS-BH-11	32.5	TOLUENE	5	1.6094	NA
LWDS-BH-11	35	TOLUENE	5	1.6094	NA
LWDS-BH-11	25	TOLUENE	5	1.6094	NA
LWDS-BH-11	30	TOLUENE	3.4	1.2238	NA
LWDS-BH-11	42.5	TOLUENE	5	1.6094	NA
LWDS-BH-11	47.5	TOLUENE	1.8	0.5878	NA
LWDS-BH-11	65	TOLUENE	51	3.9318	NA
LWDS-BH-11	70	TOLUENE	5	1.6094	NA
LWDS-BH-11	55	TOLUENE	23	3.1355	NA
LWDS-BH-12	55	TOLUENE	1.9	0.6419	NA
LWDS-BH-12	55	TOLUENE	1.2	0.1823	NA
LWDS-BH-12	45	TOLUENE	3.2	1.1632	NA
LWDS-BH-12	37.5	TOLUENE	5	1.6094	NA
LWDS-BH-12	32.5	TOLUENE	5	1.6094	NA
LWDS-BH-12	25	TOLUENE	5	1.6094	NA
LWDS-BH-12	30	TOLUENE	5	1.6094	NA
LWDS-BH-12	35	TOLUENE	5	1.6094	NA
LWDS-BH-12	40	TOLUENE	5	1.6094	NA
LWDS-BH-12	50	TOLUENE	5	1.6094	NA
LWDS-BH-13	0	TOLUENE	5	1.6094	NA
LWDS-BH-13	25	TOLUENE	5	1.6094	NA
LWDS-BH-13	30	TOLUENE	5	1.6094	NA
LWDS-BH-13	32.5	TOLUENE	5	1.6094	NA
LWDS-BH-13	35	TOLUENE	1.2	0.1823	NA
LWDS-BH-13	37.5	TOLUENE	5	1.6094	NA
LWDS-BH-13	40	TOLUENE	5	1.6094	NA
LWDS-BH-13	45	TOLUENE	5	1.6094	NA
LWDS-BH-13	50	TOLUENE	5	1.6094	NA
LWDS-BH-13	50	TOLUENE	5	1.6094	NA
LWDS-BH-13	55	TOLUENE	5	1.6094	NA
LWDS-BH-14	40	TOLUENE	3.9	1.3610	NA
LWDS-BH-14	37.5	TOLUENE	5	1.6094	NA
LWDS-BH-14	35	TOLUENE	5	1.6094	NA
LWDS-BH-14	32.5	TOLUENE	5	1.6094	NA
LWDS-BH-14	30	TOLUENE	5	1.6094	NA
LWDS-BH-14	25	TOLUENE	5	1.6094	NA
LWDS-BH-14	60	TOLUENE	1.6	0.4700	NA
LWDS-BH-14	60	TOLUENE	1.8	0.5878	NA
LWDS-BH-14	55	TOLUENE	5.4	1.6864	NA
LWDS-BH-14	50	TOLUENE	2.7	0.9933	NA
LWDS-BH-14	45	TOLUENE	1.6	0.4700	NA
<i>Regression Statistics</i>					
Ln					
R Square	0.75				
Mean	1.17				
St. Deviation	1.01				
0.1 Value	0.16				
99.9 Value	67.06				

Table A-3
Beryllium and Chromium Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-05-BH11	25	CHROMIUM	10.5	2.3514	1
LWDS-05-BH11	30	CHROMIUM	4.9	1.5892	1
LWDS-05-BH11	35	CHROMIUM	7.1	1.9601	1
LWDS-05-BH11	37.5	CHROMIUM	2.2	0.7885	1
LWDS-05-BH11	40	CHROMIUM	5.7	1.7405	1
LWDS-05-BH11	42.5	CHROMIUM	5.4	1.6864	1
LWDS-05-BH11	45	CHROMIUM	7.3	1.9879	1
LWDS-05-BH11	47.5	CHROMIUM	8.6	2.1518	1
LWDS-05-BH11	50	CHROMIUM	6.9	1.9315	1
LWDS-05-BH11	55	CHROMIUM	6.1	1.8083	1
LWDS-05-BH11	60	CHROMIUM	6.9	1.9315	1
LWDS-05-BH11	65	CHROMIUM	3.2	1.1632	1
LWDS-05-BH11	70	CHROMIUM	6.8	1.9169	1
LWDS-05-BH11	70	CHROMIUM	7.5	2.0149	1
LWDS-05-BH12	25	CHROMIUM	3.8	1.3350	1
LWDS-05-BH12	30	CHROMIUM	2.7	0.9933	1
LWDS-05-BH12	32.5	CHROMIUM	14.5	2.6741	1
LWDS-05-BH12	35	CHROMIUM	5.6	1.7228	1
LWDS-05-BH12	37.5	CHROMIUM	28.7	3.3569	1
LWDS-05-BH12	40	CHROMIUM	20.9	3.0397	1
LWDS-05-BH12	45	CHROMIUM	5.8	1.7579	1
LWDS-05-BH12	50	CHROMIUM	3.6	1.2809	1
LWDS-05-BH12	55	CHROMIUM	7.4	2.0015	1
LWDS-05-BH12	55	CHROMIUM	2.6	0.9555	1
LWDS-05-BH13	25	CHROMIUM	7.7	2.0412	1
LWDS-05-BH13	30	CHROMIUM	6.7	1.9021	1
LWDS-05-BH13	32.5	CHROMIUM	7.7	2.0412	1
LWDS-05-BH13	35	CHROMIUM	6.7	1.9021	1
LWDS-05-BH13	37.5	CHROMIUM	5.9	1.7750	1
LWDS-05-BH13	40	CHROMIUM	6.5	1.8718	1
LWDS-05-BH13	45	CHROMIUM	4.6	1.5261	1
LWDS-05-BH13	50	CHROMIUM	10.5	2.3514	1
LWDS-05-BH13	50	CHROMIUM	16	2.7726	1
LWDS-05-BH13	55	CHROMIUM	6	1.7918	2
LWDS-05-BH14	25	CHROMIUM	5.6	1.7228	1
LWDS-05-BH14	30	CHROMIUM	6.7	1.9021	1
LWDS-05-BH14	32.5	CHROMIUM	3.8	1.3350	1
LWDS-05-BH14	35	CHROMIUM	5	1.6094	5
LWDS-05-BH14	37.5	CHROMIUM	42.4	3.7471	1
LWDS-05-BH14	40	CHROMIUM	5.6	1.7228	1
LWDS-05-BH14	45	CHROMIUM	7	1.9459	1
LWDS-05-BH14	50	CHROMIUM	7.7	2.0412	1
LWDS-05-BH14	55	CHROMIUM	2.3	0.8329	1
LWDS-05-BH14	60	CHROMIUM	11.3	2.4248	1
LWDS-05-BH14	60	CHROMIUM	7.5	2.0149	1
<i>Regression Statistics</i>					
In					
R Square	0.480279				
Mean	8.12				
St. Deviation	7.104563				
0.1 Value	-13.1937				
99.9 Value	29.43369				

Table A-3
Beryllium and Chromium Concentration in Core Samples Collected
at the SNL/NM ER Site 5 Liquid Waste Disposal System Drainfield Boreholes

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-05-BH11	25	BERYLLIUM	0.61	-0.4943	0.2
LWDS-05-BH11	30	BERYLLIUM	0.35	-1.0498	0.2
LWDS-05-BH11	35	BERYLLIUM	0.52	-0.6539	0.2
LWDS-05-BH11	37.5	BERYLLIUM	0.5	-0.6931	0.2
LWDS-05-BH11	40	BERYLLIUM	0.44	-0.8210	0.2
LWDS-05-BH11	42.5	BERYLLIUM	0.38	-0.9676	0.2
LWDS-05-BH11	45	BERYLLIUM	0.39	-0.9416	0.2
LWDS-05-BH11	47.5	BERYLLIUM	0.52	-0.6539	0.2
LWDS-05-BH11	50	BERYLLIUM	0.34	-1.0788	0.2
LWDS-05-BH11	55	BERYLLIUM	0.28	-1.2730	0.2
LWDS-05-BH11	60	BERYLLIUM	0.42	-0.8675	0.2
LWDS-05-BH11	65	BERYLLIUM	0.27	-1.3093	0.2
LWDS-05-BH11	70	BERYLLIUM	0.36	-1.0217	0.2
LWDS-05-BH11	70	BERYLLIUM	0.46	-0.7765	0.2
LWDS-05-BH12	25	BERYLLIUM	0.24	-1.4271	0.2
LWDS-05-BH12	30	BERYLLIUM	0.23	-1.4697	0.2
LWDS-05-BH12	32.5	BERYLLIUM	0.25	-1.3863	0.2
LWDS-05-BH12	35	BERYLLIUM	0.19	-1.6607	0.2
LWDS-05-BH12	37.5	BERYLLIUM	0.14	-1.9661	0.2
LWDS-05-BH12	40	BERYLLIUM	0.14	-1.9661	0.2
LWDS-05-BH12	45	BERYLLIUM	0.2	-1.6094	0.2
LWDS-05-BH12	50	BERYLLIUM	0.16	-1.8326	0.2
LWDS-05-BH12	55	BERYLLIUM	0.21	-1.5606	0.2
LWDS-05-BH12	55	BERYLLIUM	0.13	-2.0402	0.2
LWDS-05-BH13	25	BERYLLIUM	0.38	-0.9676	0.2
LWDS-05-BH13	30	BERYLLIUM	0.26	-1.3471	0.2
LWDS-05-BH13	32.5	BERYLLIUM	0.39	-0.9416	0.2
LWDS-05-BH13	35	BERYLLIUM	0.37	-0.9943	0.2
LWDS-05-BH13	37.5	BERYLLIUM	0.28	-1.2730	0.2
LWDS-05-BH13	40	BERYLLIUM	0.27	-1.3093	0.2
LWDS-05-BH13	45	BERYLLIUM	0.2	-1.6094	0.2
LWDS-05-BH13	50	BERYLLIUM	0.28	-1.2730	0.2
LWDS-05-BH13	50	BERYLLIUM	0.29	-1.2379	0.2
LWDS-05-BH13	55	BERYLLIUM	0.4	-0.9163	0.4
LWDS-05-BH14	25	BERYLLIUM	0.32	-1.1394	0.2
LWDS-05-BH14	30	BERYLLIUM	0.59	-0.5276	0.2
LWDS-05-BH14	32.5	BERYLLIUM	0.33	-1.1087	0.2
LWDS-05-BH14	35	BERYLLIUM	1	0.0000	1
LWDS-05-BH14	37.5	BERYLLIUM	0.34	-1.0788	0.2
LWDS-05-BH14	40	BERYLLIUM	0.49	-0.7133	0.2
LWDS-05-BH14	45	BERYLLIUM	0.56	-0.5798	0.2
LWDS-05-BH14	50	BERYLLIUM	0.56	-0.5798	0.2
LWDS-05-BH14	55	BERYLLIUM	0.62	-0.4780	0.2
LWDS-05-BH14	60	BERYLLIUM	0.44	-0.8210	0.2
LWDS-05-BH14	60	BERYLLIUM	0.55	-0.5978	0.2
<i>Regression Statistics</i>					
In					
R Square	0.864163				
Mean	0.355333				
St. Deviation	0.18109				
0.1 Value	-0.18794				
99.9 Value	0.898604				

APPENDIX B
***PRÉCIS* INPUT PARAMETERS**

Table B-1
Précis Input Parameters for
Radiation Dose Calculations

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**          Monte Carlo Simulation Summary Report          **  
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Date of simulation: Tue Apr 4 13:41:02 1995

Total number of runs: 100 LHS Seed: 256

```
*****  
**  
**          Précis Summary of Inputs          **  
**  
*****
```

Site Name: ER Site 5 Radionuclides

Land Use Scenario: Industrial

Pathway Selections:

- Gamma: active
- Dust: active
- Radon: active
- Plant: inactive
- Meat: inactive
- Milk: inactive
- Soil: active
- Water: inactive
- Fish: inactive

Model Assumptions

Water Transport: Nondispersion

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 194.7 square meters
 Justification: Calculated from Figure 2-2

Thickness of cover zone = 9.14 meters
 Justification: Calculated from Appendix A tables

Density of cover zone = 1.6 grams/cm**3
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Radon diffusion coefficient (cover) = 2e-06 meters/sec
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Radon diffusion coefficient (contaminated) = 2e-06 meters/sec
 LHS Settings: Normal-B 1.5e-06 3.5e-06
 Justification: Yu, 1992.

Depth of soil mixing area = 0.15 meters

Fraction of time spent indoors = 0.5
 Justification: Precis default, nonstochastic parameter
 consistent with exposure assumptions.

Radon-220 emanation factor = 0.1
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Occupancy and shielding factor, external gamma = 0.257587
 LHS Settings: Normal-B 0.23 0.33
 Justification: Justification: Calculated assuming 10 to 50% outdoor
 occupancy onsite, 25 to 50% indoor occupancy at 70% outside exposure
 Yu, 1992.

Occupancy factor, dust inhalation = 0.449762
 LHS Settings: Normal-B 0.3 0.6
 Justification: Justification: Calculated assuming 10 to 50% outdoor
 occupancy onsite, 25 to 50% indoor occupancy at 40% outside exposure
 Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter
 consistent with exposure assumptions.

Shape factor for external gamma = 1
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Radon vertical dimension of mixing = 2 meters
 LHS Settings: Uniform 1.5 2.5
 Justification: Yu, 1992.

Inhalation rate = 8851.23 meters**3/year
LHS Settings: Normal-B 3600 1.1e+04
Justification: EPA 1989

Length parallel to aquifer flow = 19.5 meters
Justification: Square root of the contaminated area.

Dilution length for inhalation = 3 meters
LHS Settings: Lognormal-B 0.03 250
Justification: Gilbert et al, 1989.

Mass loading for inhalation = 2.70567e-05 grams/meter**3
LHS Settings: Lognormal-B 9e-06 0.0004
Justification: Yu, 1992.

Fractional water content (cover) = 0.05
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil ingestion rate = 18.25 grams/year
Justification: EPA 1989

Thickness of contaminated zone = 0.364707 meters
LHS Settings: Lognormal-B 0.3 10.6
Justification: Thickness of contamination 1 to 35 ft, Appendix A tables.

Erosion rate of cover = 0.001 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Contamination is located below surface,
Appendix A tables

Average annual wind speed = 2 meters/sec
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Basic Radiation Dose Limit = 25 millirem/year
Justification: DOE, 1988

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 3 years
Time step - 3 = 5 years
Time step - 4 = 10 years
Time step - 5 = 30 years
Time step - 6 = 100 years
Time step - 7 = 300 years
Time step - 8 = 500 years
Time step - 9 = 1000 years

Soil b-parameter of contaminated zone = 1.74511
LHS Settings: Lognormal-B 0.4 10.3
Justification: SNL/NM, 1991. Monitoring Well MW-4, Chemical Waste Landfill.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of contaminated zone = 1.42797 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Yu, 1992.

Density of saturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.201965
LHS Settings: Normal-B 0.13 0.3
Justification: Yu, 1992.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 125 meters
Justification: Conservative (lower) value measure at the Chemical Waste
Landfill SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.451437
LHS Settings: Normal-B 0.24 0.57
Justification: Yu, 1992.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of cover material = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00568342 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is assigned to infiltration, Yu, 1992.

Shape Parameters (0.564 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (1.784 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (2.523 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (3.989 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (5.642 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (7.979 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (12.62 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (17.84 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (39.89 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (56.42 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (178.4 m) = 0
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (564.2 m) = 0
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Time since placement for guidelines = 0 years

**
** Nuclide Summary **
** (+D indicates daughters are included in dose calculation) **
**

Co-60 Initial Concentration (Soil) = 0.15
LHS Settings: Lognormal-B 0.04 0.15

Co-60 Initial Concent. (Water/Soil) = 0

Co-60 Kd in Contaminated Zone = 60
Justification: Sheppard, 1990.

Co-60 Kd in Unsaturated Zone = 60
Justification: Sheppard, 1990.

Co-60 Kd in Saturated Zone = 60
Justification: Sheppard, 1990.

Cs-137+D Initial Concentration (Soil) = 0.14
LHS Settings: Lognormal-B 0.02 0.14

Cs-137+D Initial Concent. (Water/Soil) = 0

Cs-137+D Kd in Contaminated Zone = 0.2
Justification: Sheppard, 1990.

Cs-137+D Kd in Unsaturated Zone = 0.2
Justification: Sheppard, 1990.

Cs-137+D Kd in Saturated Zone = 0.2
Justification: Sheppard, 1990.

```

*****
**                               Ground External Gamma Effective          **
**                               Dose Conversion Factors                 **
**                               (mrem/yr) / (pCi/cm**3)                 **
**                               **                                     **
*****

```

```

Co-60      soil density = 1.0 g/cm**3          2.2700E+01
Co-60      soil density = 1.8 g/cm**3          1.2500E+01
Cs-137+D   soil density = 1.0 g/cm**3          5.0300E+01
Cs-137+D   soil density = 1.8 g/cm**3          2.7700E+00

```

```

*****
**                               Depth Factors for External              **
**                               Gamma Radiation from Ground             **
**                               (dimensionless)                          **
*****

```

```

Co-60      soil density = 1.0 g/cm**3, thickness = .15m 6.8000E-01
Co-60      soil density = 1.0 g/cm**3, thickness = 0.5m 1.0000E+00
Co-60      soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Co-60      soil density = 1.8 g/cm**3, thickness = .15m 8.6000E-01
Co-60      soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Co-60      soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
Cs-137+D   soil density = 1.0 g/cm**3, thickness = .15m 7.2000E-01
Cs-137+D   soil density = 1.0 g/cm**3, thickness = 0.5m 9.8000E-01
Cs-137+D   soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Cs-137+D   soil density = 1.8 g/cm**3, thickness = .15m 9.1000E-01
Cs-137+D   soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Cs-137+D   soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00

```

```

*****
**                               Inhalation (dust) Effective             **
**                               Dose Conversion Factors                 **
**                               (mrem/yr) / (pCi/cm**3)                 **
*****

```

```

Co-60      1.5000E-04
Cs-137+D   3.2000E-05

```

```

*****
**                               Ingestion Effective Dose Conversion     **
**                               Factors                                   **
**                               (mrem/yr) / (pCi/cm**3)                 **
*****

```

```

Co-60      2.6000E-05
Cs-137+D   5.0000E-05

```

References

Sandia National Laboratories/New Mexico (SNL/NM), 1991. Compliance Agreement Final Report: Hydrogeological Characterization (Chemical Waste Landfill). Environmental Impact and Restoration Division. Sandia National Laboratories/New Mexico, Albuquerque, New Mexico.

Sheppard, M. I., Thibault, D. H., 1990, Default Soil Solid/Liquid Partition Coefficients, K_d S, for Four Major Soil Types: A Compendium, Health Physics, 59, 471-482.

U.S. Department of Energy (DOE), 1988. Department of Energy Order 5820.2A, Radioactive Waste Management, U.S. Department of Energy, Office of Defense Waste and Transportation Management, Washington, D.C.

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

Yu. C., Loureiro, C., Cheng, J.-J., Jones, L. G., Wang, Y. Y., Chia, Y. P., Faillace, E., 1992. Data Collection Handbook for Establishing Residual Radioactive Material Guidelines with RESRAD (Draft). U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Table B-2
***Precis* Input Parameters for**
Incremental Lifetime Cancer Risk (ICR) Calculations

```
*****  
**  
**           Monte Carlo Simulation Summary Report           **  
**  
*****
```

Date of simulation: Mon June 5 09:59:16 1995

Total number of runs: 100 LHS Seed: 256

```
*****  
**  
**           Precis Summary of Inputs           **  
**  
*****
```

Site Name: ER Site 5 Chemical Carcinogens

Land Use Scenario: Industrial

Pathway Selections:
 Gamma: inactive
 Dust: active
 Radon: inactive
 Plant: inactive
 Meat: inactive
 Milk: inactive
 Soil: active
 Water: inactive
 Fish: inactive

Model Assumptions
 Water Transport: Nondispersion

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 194.7 square meters
 Justification: Calculated from Figure 2-2

Thickness of cover zone = 9.14 meters
 Justification: Calculated from Appendix A tables

Density of cover zone = 1.52809 grams/cm**3
 LHS Settings: Normal-B 1.3 1.7
 Justification: Yu, 1992.

Depth of soil mixing area = 0.15 meters

Fraction of time spent indoors = 0.5
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Occupancy factor, dust inhalation = 0.497638
 LHS Settings: Normal-B 0.3 0.6
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite,
 25 to 50% indoor occupancy at 40% outside exposure Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02

Inhalation rate = 8229.78 meters**3/year
 LHS Settings: Normal-B 3600 1.1e+04
 Justification: EPA 1989

Length parallel to aquifer flow = 19.5 meters
 Justification: Square root of contaminated area

Dilution length for inhalation = 3.08633 meters
 LHS Settings: Lognormal-B 0.03 250
 Justification: Gilbert et al, 1989.

Mass loading for inhalation = 0.000140722 grams/meter**3
 LHS Settings: Uniform 9e-06 0.0004
 Justification: Yu, 1992.

Fractional water content (cover) = 0.05
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Soil ingestion rate = 18.5 grams/year
 Justification: EPA 1989

Thickness of contaminated zone = 6.70291 meters
LHS Settings: Normal-B 0.3 10.6
Justification: Thickness of contamination 1 to 35 ft, Appendix A tables.

Erosion rate of cover = 1e-09 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Contamination is located below surface,
Appendix A tables

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 5 years
Time step - 3 = 10 years
Time step - 4 = 20 years
Time step - 5 = 30 years
Time step - 6 = 100 years
Time step - 7 = 300 years
Time step - 8 = 500 years
Time step - 9 = 1000 years

Soil b-parameter of contaminated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of contaminated zone = 1.41979 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Yu, 1992.

Density of saturated zone = 1.4 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.4 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 136.898 meters
LHS Settings: Normal-B 124.7 150.9
Justification: Measurements made at the Chemical Waste Landfill
SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00417973 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is
assigned to infiltration, Yu, 1992.

Time since placement for guidelines = 0 years

Basic Cancer Risk Limit = 1e-06
Justification: EPA 1989

Basic Chemical Intake Limit = 100 mg/kg-day

```

*****
**
**                               Chemical Summary
**
**
*****
Beryllium   Initial Concentration (Soil) = 0.001
LHS Settings: Lognormal-B   8.8e-05   0.00129

Beryllium   Initial Concent. (Water/Soil) = 0

Beryllium   Kd in Contaminated Zone = 0
Justification: Conservative Kd indicating high mobility

Beryllium   Kd in Unsaturated Zone = 0
Justification: Conservative Kd indicating high mobility

Beryllium   Kd in Saturated Zone = 0
Justification: Conservative Kd indicating high mobility

Cadmium (diet)   Initial Concentration (Soil) = 0.00140522
LHS Settings: Lognormal-B   1.8e-05   0.154

Cadmium (diet)   Initial Concent. (Water/Soil) = 0

Cadmium (diet)   Kd in Contaminated Zone = 0
Justification: Conservative Kd indicating high mobility

Cadmium (diet)   Kd in Unsaturated Zone = 0
Justification: Conservative Kd indicating high mobility

Cadmium (diet)   Kd in Saturated Zone = 0
Justification: Conservative Kd indicating high mobility

Chromium(VI)   Initial Concentration (Soil) = 0.02
LHS Settings: Lognormal-B   0.0011   0.039

Chromium(VI)   Initial Concent. (Water/Soil) = 0

Chromium(VI)   Kd in Contaminated Zone = 0
Justification: Conservative Kd indicating high mobility

Chromium(VI)   Kd in Unsaturated Zone = 0
Justification: Conservative Kd indicating high mobility

Chromium(VI)   Kd in Saturated Zone = 0
Justification: Conservative Kd indicating high mobility

```

```

*****
**
**              Intake Conversion Factors
**              (yr/kg-day)
**
*****

```

```

BERYLLIUM      soil ingestion conversion factor,      1.4000E-05
BERYLLIUM      dust inhalation conversion factors, 1.4000E-05
BERYLLIUM      ingestion inhalation conversion factors, 1.4000E-05
CADMIUM (DIET) soil ingestion conversion factor, 1.4000E-05
CADMIUM (DIET) dust inhalation conversion factors, 1.4000E-05
CADMIUM (DIET) ingestion inhalation conversion factors, 1.4000E-05
CHROMIUM(VI)   soil ingestion conversion factor, 1.4000E-05
CHROMIUM(VI)   dust inhalation conversion factors, 1.4000E-05
CHROMIUM(VI)   ingestion inhalation conversion factors, 1.4000E-05

```

```

*****
**
**              Cancer Slope Factors
**              (yr/kg-day)
**
*****

```

```

BERYLLIUM cancer slope factors for - dust inhalation      8.4000E+00
BERYLLIUM cancer slope factors for - ingestion            4.3000E+00
CADMIUM (DIET) cancer slope factors - dust inhalation    6.1000E+00
CADMIUM (DIET) cancer slope factors - ingestion          0.0000E+00
CHROMIUM(VI) cancer slope factors for dust-inhalation    4.1000E+01
CHROMIUM(VI) cancer slope factors for-ingestion          0.0000E+00

```

References

Gilbert, T. L., Yu, C., Yuan, Y. C., Zielen, A. J., Jusko, M. J., Wallo III, A., 1989. A Manual for Implementing Residual Radioactive Material Guidelines. U.S. Department of Energy, Argonne National Laboratory ANL/ES-160, DOE/CH/8901, Argonne National Laboratory, Argonne, Illinois.

Sandia National Laboratories/New Mexico (SNL/NM), 1991. Compliance Agreement Final Report: Hydrogeological Characterization (Chemical Waste Landfill). Environmental Impact and Restoration Division. Sandia National Laboratories/New Mexico, Albuquerque, New Mexico.

Sheppard, M. I., Thibault, D. H., 1990, Default Soil Solid/Liquid Partition Coefficients, K_d S, for Four Major Soil Types: A Compendium, Health Physics, 59, 471-482.

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

Yu. C., Loureiro, C., Cheng, J.-J., Jones, L. G., Wang, Y. Y., Chia, Y. P., Faillace, E., 1992. Data Collection Handbook for Establishing Residual Radioactive Material Guidelines with RESRAD (Draft). U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Table B-3
Précis Input Parameters for
Hazard Index (HI) Calculations

```
*****
**
**           Monte Carlo Simulation Summary Report           **
**
*****
```

Date of simulation: Tue June 6 15:00:32 1995

Total number of runs: 100 LHS Seed: 256

```
*****
**
**           Précis Summary of Inputs                       **
**
*****
```

Site Name: ER Site 5 Chemical Hazard

Land Use Scenario: Industrial

Pathway Selections:

- Gamma: inactive
- Dust: active
- Radon: inactive
- Plant: inactive
- Meat: inactive
- Milk: inactive
- Soil: active
- Water: inactive
- Fish: inactive

Model Assumptions

Water Transport: Nondispersion

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 194.7 square meters
 Justification: Calculated from Figure 2-2

Thickness of cover zone = 9.14 meters
 Justification: Calculated from Appendix A tables

Density of cover zone = 1.5262 grams/cm**3
 LHS Settings: Normal-B 1.3 1.7
 Justification: Yu, 1992.

Depth of soil mixing area = 0.15 meters

Fraction of time spent indoors = 0.5
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Occupancy factor, dust inhalation = 0.538174
 LHS Settings: Normal-B 0.3 0.6
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite,
 25 to 50% indoor occupancy at 40% outside exposure Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter
 consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02

Inhalation rate = 6631.8 meters**3/year
 LHS Settings: Normal-B 3600 1.1e+04
 Justification: EPA 1989

Length parallel to aquifer flow = 19.5 meters
 Justification: Square root of contaminated area

Dilution length for inhalation = 1.49591 meters
 LHS Settings: Lognormal-B 0.03 250
 Justification: Gilbert et al, 1989.

Mass loading for inhalation = 2.32933e-05 grams/meter**3
 LHS Settings: Uniform 9e-06 0.0004
 Justification: Yu, 1992.

Soil ingestion rate = 18.5 grams/year
 Justification: EPA 1989

Thickness of contaminated zone = 6.36883 meters
LHS Settings: Normal-B 0.3 10.6
Justification: Thickness of contamination 1 to 35 ft, Appendix A tables.

Erosion rate of cover = 1e-09 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Contamination is located below surface,
Appendix A tables

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 5 years
Time step - 3 = 10 years
Time step - 4 = 20 years
Time step - 5 = 30 years
Time step - 6 = 100 years
Time step - 7 = 300 years
Time step - 8 = 500 years
Time step - 9 = 1000 years

Soil b-parameter of contaminated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of contaminated zone = 1.55049 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Yu, 1992.

Density of saturated zone = 1.4 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.4 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 138.386 meters
LHS Settings: Normal-B 124.7 150.9
Justification: Justification: Measurements made at the Chemical Waste
Landfill, SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00282936 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is
assigned to infiltration, Yu, 1992.

Time since placement for guidelines = 0 years

Basic Cancer Risk Limit = 1e-06
Justification: EPA 1989

Basic Chemical Intake Limit = 100 mg/kg-day

Basic Hazard Index Limit = 1
Justification: EPA 1989

Basic Chemical Intake Limit = 100 mg/kg-day

 **
 **
 **
 **
 **

Chemical Summary

Beryllium Initial Concentration (Soil) = 0.0001
 LHS Settings: Lognormal-B 8.8e-05 0.0013

Beryllium Initial Concent. (Water/Soil) = 0

Beryllium Kd in Contaminated Zone = 0
 Justification: Conservative Kd indicating high mobility

Beryllium Kd in Unsaturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Beryllium Kd in Saturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Cadmium (diet) Initial Concentration (Soil) = 0.00815239
 LHS Settings: Lognormal-B 1.8e-05 0.154

Cadmium (diet) Initial Concent. (Water/Soil) = 0

Cadmium (diet) Kd in Contaminated Zone = 0
 Justification: Conservative Kd indicating high mobility

Cadmium (diet) Kd in Unsaturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Cadmium (diet) Kd in Saturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Chromium(VI) Initial Concentration (Soil) = 0.002
 LHS Settings: Lognormal-B 0.00114 0.039

Chromium(VI) Initial Concent. (Water/Soil) = 0

Chromium(VI) Kd in Contaminated Zone = 0
 Justification: Conservative Kd indicating high mobility

Chromium(VI) Kd in Unsaturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Chromium(VI) Kd in Saturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Toluene Initial Concentration (Soil) = 5.10245e-07
 LHS Settings: Lognormal-B 1.6e-07 6.7e-05

Toluene Initial Concent. (Water/Soil) = 0

Toluene Kd in Contaminated Zone = 0
 Justification: Conservative Kd indicating high mobility

Toluene Kd in Unsaturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Toluene Kd in Saturated Zone = 0
 Justification: Conservative Kd indicating high mobility

Zinc (Metallic) Initial Concentration (Soil) = 0.0170831
LHS Settings: Lognormal-B 0.0082 0.0542

Zinc (Metallic) Initial Concent. (Water/Soil) = 0

Zinc (Metallic) Kd in Contaminated Zone = 0
Justification: Conservative Kd indicating high mobility

Zinc (Metallic) Kd in Unsaturated Zone = 0
Justification: Conservative Kd indicating high mobility

Zinc (Metallic) Kd in Saturated Zone = 0
Justification: Conservative Kd indicating high mobility

**
** Intake Conversion Factors **
** (yr/kg-day) **

BERYLLIUM	soil ingestion conversion factor	1.4700E-05
BERYLLIUM	dust inhalation conversion factors	1.6800E-05
BERYLLIUM	ingestion inhalation conversion factors	1.6800E-05
CADMIUM (DIET)	soil ingestion conversion factor	1.4700E-05
CADMIUM (DIET)	dust inhalation conversion factors	1.6800E-05
CADMIUM (DIET)	ingestion inhalation conversion factors	1.6800E-05
CHROMIUM(VI)	soil ingestion conversion factor	1.4700E-05
CHROMIUM(VI)	dust inhalation conversion factors	1.6800E-05
CHROMIUM(VI)	ingestion inhalation conversion factors	1.6800E-05
TOLUENE	soil ingestion conversion factor	1.4700E-05
TOLUENE	dust inhalation conversion factors	1.6800E-05
TOLUENE	ingestion inhalation conversion factors	1.6800E-05
ZINC (METAL)	soil ingestion conversion factor	1.4700E-05
ZINC (METAL)	dust inhalation conversion factors	1.6800E-05
ZINC (METAL)	ingestion inhalation conversion factors	1.6800E-05

**
** Reference Doses **
** (mg/kg-day) **

BERYLLIUM	reference doses for dust inhalation	0.0000E+00
BERYLLIUM	reference doses for ingestion	5.0000E-03
CADMIUM (DIET)	reference doses for dust inhalation	0.0000E+00
CADMIUM (DIET)	reference doses for ingestion	1.0000E-03
CHROMIUM(VI)	reference doses for dust inhalation	0.0000E+00
CHROMIUM(VI)	reference doses for ingestion	5.0000E-03
TOLUENE	reference doses for dust inhalation	1.1400E-01
TOLUENE	reference doses for ingestion	2.0000E-01
ZINC (METAL)	reference doses for dust inhalation	0.0000E+00
ZINC (METAL)	reference doses for ingestion	3.0000E-01

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APPENDIX C

TOXICITY PROFILES FOR CONSTITUENTS OF CONCERN

Classification of Human Carcinogens

A classification system for carcinogens describes uncertainties in available epidemiological and toxicological data. This "weight of evidence" classification is based on the thoroughness and appropriateness of available data. The classification system is as follows (EPA 1994):

Classification Group	Description
A	Human Carcinogen
B1 available	Probable human carcinogen; limited human data
B2	Probable human carcinogen; based on animal data only
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity to humans.

All radionuclides are considered to be carcinogens (Group A). The carcinogenicity of radionuclides is assumed to exceed their systemic toxicity (EPA 1994).

RADIONUCLIDE CONTAMINANTS

Cesium-137

Although this fission product is a pure beta emitter, its short lived daughter barium-137m, is a high energy, high intensity gamma emitter. This daughter makes cesium-137 an important external exposure hazard. Cesium-137 has a physical half-life of 30.2 years. Cesium that is inhaled or ingested is readily and almost completely absorbed into blood and distributed uniformly in the body. Approximately 10 percent of absorbed cesium is cleared from the body with a half-time of approximately 2 days and the remaining 90 percent is cleared with a half-time of approximately 110 days (ICRP 1979).

Cobalt-60

Cobalt-60 emits high energy gamma radiation. Therefore, the radionuclide is an important external exposure hazard. Cobalt-60 has a physical half-life of 5.27 years. Inhaled insoluble cobalt compounds are retained in the lung for long periods of time. Soluble cobalt compounds that are ingested are only poorly absorbed into the body. For the purposes of evaluating radiation dose, it is assumed that approximately 80 percent of the absorbed cobalt is located in the liver and the remaining 20 percent is uniformly distributed throughout the rest of the body. This cobalt located in tissues other than the lung is assumed to be removed from the body with half-times of 6 to 800 days (ICRP 1979).

CHEMICAL CONTAMINANTS

Beryllium, CASRN 7440-41-7

Beryllium is a metal for which the dietary uptake information is sketchy, leading to an uncertain daily uptake of about 0.01 mg/day. However, the daily uptake may vary up to two orders of magnitude (ICRP 1975). Gastric absorption of beryllium and its compounds is very low, and beryllium is not well-incorporated after inhalation. Soluble compounds, however, are better absorbed in the lung. Inhalation of large doses of beryllium lead to acute but mostly reversible inflammation of the lung tissue. Low-level exposures can lead to chronic beryllium disease, an irreversible fibrotic condition often resulting in premature death (Doull et al. 1991).

Beryllium and some of its compounds are suspected of carcinogenic action in the human lung. The epidemiological data are rated inadequate, primarily because of problems with the exposure assessment. In laboratory animals, however, there is a very strong dose-effect correlation yielding a B2 carcinogen classification.

Cadmium, CASRN 7440-43-9

Cadmium is a metal that has toxic effects similar to those of lead and its compounds. It is present in most foods and tissues, leading to an average daily intake of about 0.2 mg (ICRP 1975). Intake of cadmium and its compounds can occur by inhalation or ingestion. The kidney is the most sensitive organ and is damaged by excessive loss of both low and high molecular mass proteins (proteinuria). A number of effects in other organs, such as the lung, have also been reported. In the lung, tissue loss occurs at high exposures and chronic tissue inflammation occurs at lower levels, leading to emphysematous and fibrotic changes (Doull et al. 1991).

There is sufficient evidence of carcinogenicity in humans to classify cadmium as a Class B1 inhalation carcinogen. Although excess lung cancer risks were observed in epidemiological studies, confounding factors, such as smoking, were not sufficiently accounted for to support classification as a Class A carcinogen. There is no evidence for carcinogenicity associated with chronic cadmium ingestion.

Chromium (VI), CASRN 18540-29-9

Although chromium exists in several valence states, only the trivalent and hexavalent states are biologically significant. Chromium(III) compounds are less toxic than chromium(VI) forms. Chromium(VI) is a Class A carcinogen (EPA 1994). Epidemiologic studies indicate that inhalation exposure to chromate results in bronchogenic carcinoma. The relative risk to chromate plant workers in the development of respiratory cancer is greater than in the general population (Doull et al. 1991).

Toluene, CASRN 108-88-3

Toluene is used as an industrial solvent and as an additive to unleaded gasoline. Toluene is a colorless liquid with a vapor pressure of 36.7 mm Hg at 30° C (Browning 1965) and represents a potential inhalation hazard.

Toluene has been reported to produce reversible effects upon liver, renal, and nervous systems, with the nervous system being the most sensitive organ. High level toluene exposures produced incoordination, ataxia, unconsciousness and eventually, death. Lower level acute exposures in man produce dizziness, exhilaration and confusion. Very few studies of the nervous system have been performed at levels below 1000 ppm and most of the results were inconclusive (Benignus 1981a and 1981b). Findings of enlargement of liver have been reported in painters exposed to toluene at concentrations ranging from 100-1100 ppm. Macrocytosis, moderate decrease in erythrocyte count and absolute lymphocytosis were also reported; but no leukopenia was reported (ACGIH 1986).

Peripheral blood lymphocytes from 32 male rotogravure workers showed no significant difference from controls in frequency of chromosome aberrations and sister chromatic exchanges (Maki-Paakkanen 1980).

Toluene is not classifiable as to human carcinogenicity (Class D) (EPA 1994).

Zinc, CASRN 7440-66-6

Zinc is an essential trace nutrient in the human diet and occurs widely in foodstuffs, particularly in meats, seafood, dairy products, and vegetables. The daily intake of zinc through the diet is 6 to 40 mg (ICRP 1975). Some zinc compounds are of low toxicity; but acute exposures can cause dermatitis upon skin contact and intestinal disorders upon ingestion. "Metal fume fever" has been observed upon high-level inhalation exposures, however, no chronic effects of zinc inhalation have been reported. Although some zinc compounds are suspected to be carcinogenic, no slope factors are available. Elemental zinc in itself is not a human carcinogen (Class D) (EPA 1994).

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APPENDIX D

**ANNUAL RADIATION DOSES FROM RADIONUCLIDES AND
DAILY INTAKES OF HAZARDOUS CHEMICALS FOR
EXPOSURE PATHWAYS ASSUMED IN THE
INDUSTRIAL LAND-USE SCENARIO**

Table D-1
 Estimated Radiation Dose from Potential Exposure to Radionuclides
 for the Industrial Land-Use Scenario at ER Site 5
 (Example of one of the 100 *Précis* simulations described in Section 5.0)

Residual Radioactivity Program, Version 4.20 10-APR-9 09:48 Page 1
 Summary : ER Site 5 Radionuclides File: SAMPRAD.DAT

Contaminated Zone Dimensions	Initial Soil Concentrations, pCi/g
Area: 194.70 square meters	Co-60 6.608E-02
Thickness: 6.98 meters	Cs-137 4.471E-02
Cover Depth: 9.14 meters	

t = 0 Summary

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
 As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Radio- Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.												
Co-60	0.000E+00	0.000	0.000E+00	0.0000										
Cs-137	0.000E+00	0.000	0.000E+00	0.0000										
===== Total	0.000E+00	0.0000												

Total Dose TDOSE(t), mrem/yr
 Basic Radiation Dose Limit = 25 mrem/yr

Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	5.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	5.000E+02	1.000E+03
TDOSE(t):	0.000E+00									
M(t):	0.000E+00									
Maximum TDOSE(t): 0.000E+00 mrem/yr at t = 1.000E+03 years										

Table D-2
 Estimated Daily Intake of Hazardous and Carcinogenic Chemicals from Potential Exposure
 for the Industrial Land-Use Scenario at ER Site 5
 (Example of one of the 100 *Précis* simulations described in Section 5.0)

Contaminated Zone Dimensions	Initial Soil Concentrations, mg/g									
Area: 194.70 square meters	BERYLLIUM		7.076E-04							
Thickness: 6.26 meters	CADMIUM (DIET)		9.619E-05							
Cover Depth: 9.14 meters	CHROMIUM (VI)		3.057E-03							
	TOLUENE		1.255E-06							
	ZINC (METALLIC)		1.680E-02							
t = 0 Summary										
Total Intake Contributions INTAKE(i,p,t) for Individual Chemicals (i) and Pathways (p) As mg/kg-day and Fraction of Total Intake At t = 0.000E+00 years										
	Water Independent Pathways									
	Direct		Dust		Vapor		Plant		Meat	
Chemical	mg/kg-d	fract.	mg/kg-d	fract.	mg/kg-d	fract.	mg/kg-d	fract.	mg/kg-d	fract.
BERYLLIUM	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
CADMIUM (DIET)	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
CHROMIUM (VI)	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
TOLUENE	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
ZINC (METALLIC)	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total Intake TINTAKE(t), mg/kg-day Basic Chemical Intake Limit = 100 mg/kg-day Total Mixture Sum M(t) = Fraction of Basic Intake Limit Received at Time (t)										
t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	2.000E+01	3.000E+01	1.000E+02	3.000E+02	5.000E+02	1.000E+03
INTAKE(t):	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
M(t):	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Maximum INTAKE(t):	0.000E+00 mg/kg-day at t = 1.000E+03 years									

Annex II
Human Health Risk Assessment
ER Site 4, LWDS Surface Impoundments

**LIQUID WASTE DISPOSAL SYSTEM
ENVIRONMENTAL RESTORATION SITE 4
HUMAN HEALTH RISK ASSESSMENT**

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July 1995

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1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL/NM), located in Albuquerque, New Mexico, is committed to the protection of human health and the environment. Because of this commitment, potential risks to human health and the associated action levels were calculated for the constituents of concern (COC) detected in soil samples obtained from the Liquid Waste Disposal System (LWDS), Environmental Restoration (ER) Site 4.

The following analysis involves calculating the potential radiation dose, cancer risk, or toxicity hazard to a worker at the site. This approach addresses uncertainties associated with various site-specific parameters (e.g., soil density and annual precipitation) and the variability of soil-contamination measurements. These calculations provide estimates of potential radiation dose, risk, and hazards and their uncertainties as compared with limits specified by regulations. Sections 3.0 through 5.0 describe this approach.

Annual radiation doses resulting from the radionuclide COCs were estimated using the SNL/NM *Précis* computer program, Version 1.1.3a (SNL/NM 1994a). The results of the radionuclide COC human health risk assessment were compared with the 25 millirem per year (mrem/yr) dose rate, which is the U.S. Department of Energy (DOE) performance objective for limiting a radiation dose to any member of the public (DOE 1988).

Human health effects from potential exposure to nonradioactive COCs were also estimated using *Précis*. The incremental lifetime cancer risk (ICR) was estimated for potential exposures to carcinogenic chemicals. The hazard index (HI) was estimated for potential systemic toxic effects (e.g., kidney damage) resulting from exposure to noncarcinogenic chemicals. These calculated ICR and HI values were compared with values regarded as acceptable by the U.S. Environmental Protection Agency (EPA). The acceptable ICR is 1×10^{-6} ; the acceptable HI is 1.0 (EPA 1989).

2.0 SITE CHARACTERIZATION

2.1 Site Description

The ER Site 4 Liquid Waste Disposal System consists of two unlined surface impoundments used from 1967 to 1971. The impoundments are located outside of Technical Area (TA) 5 and north of the TA-3 fence (Figure 2-1a and 2-1b, SNL/NM 1993). The western impoundment is 100 feet (ft) long by 50 ft wide by 30 ft deep. The eastern impoundment has the same dimensions but is 20 ft deep. These impoundments collected radioactive waste water discharged from the TA-5 holding tanks that received waste from the TA-5 hot cell laboratory and reactor and from the floor drains and sinks in Building 6580.

2.2 Contamination Assessment

Soil samples were obtained from ER Site 4 in October 1994 (SNL/NM 1993). Surface and subsurface samples were analyzed for radioactive and chemical contaminants. Contaminants not detected in any sample were not considered further. Contaminants that were detected above ER Site 4 background concentrations were considered to be COC for the assessment of risks.

Although copper was detected in some of these soil samples, copper is not regulated under Resource Conservation and Recovery Act (RCRA) (Title 40 Code of Federal Regulations Part 261, Appendix VIII [40 CFR 261, Appendix VIII]) except as copper cyanide produced in copper mining operations (40 CFR 261.4). Therefore, copper was not included in this risk assessment.

Appendix A summarizes the COC concentrations in soil at ER Site 4. All of the COC data sets were fitted to determine if the data were normally or lognormally distributed. Several of the COC data sets are heavily censored, such that the distribution type could not be determined. It is commonly found that large and uncensored data sets describing environmental soil contamination are lognormally distributed. Therefore, all of the ER Site 4 data distributions were determined or assumed to be lognormally distributed (Appendix A).

The chromium concentration distribution included a single measured concentration of 97.7 ppm chromium/gram soil, which is above the 99.9th percentile of the lognormal distribution (90.9 ppm chromium/gram soil). This circumstance is consistent with the distribution in which the probability of a concentration measured above 90.9 ppm is 0.1%. An assignment of the 97.7 ppm value to the 99.9th percentile of the distribution is not expected to appreciably affect the small Hazard Index associated with potential exposure to noncarcinogenic chemicals (see Section 5.2).

The distribution of ER Site 4 data sets that could not be shown to be normal or lognormal were assumed to be lognormal (EPA 1992), with the detection limit set equal to 0.1th percentile and the maximum detected value set equal to the 99.9th percentile.

2.3 Constituents of Concern

Four radionuclides, seven metal species, and one polychlorinated biphenyl (PCB) compound were identified as COC in soil at ER Site 4. Except for the PCB aroclor-1260, no other organic chemicals were analyzed above laboratory quantitation limits, and none are considered to be contaminants at the site. Table 2-1 shows the COCs and the statistical distribution information used as input to *Précis*.

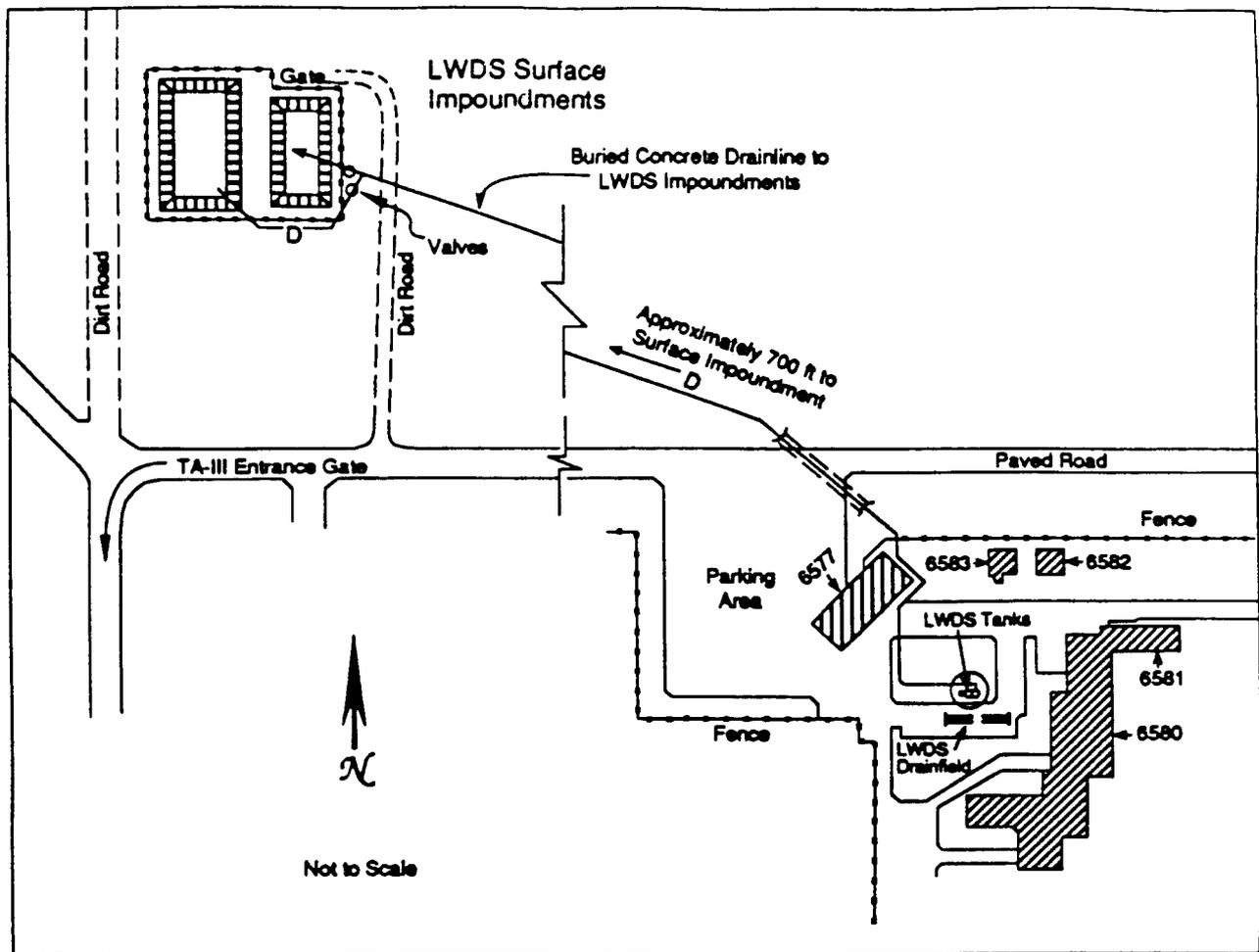


Figure 2-1a Liquid Waste Disposal System

No. 1 10146	No. 2 10149	No. 3 10145	No. 4 10148	No. 5 10144	No. 6 10147	No. 7 10143	No. 8 10142
No. 9 10154	No. 10 10173	No. 11 10168	No. 12 10179	No. 13 10184	No. 14 10192	No. 15 10200	No. 16 10151
No. 17 10157	No. 18 10172	No. 19 10167	No. 20 10178	No. 21 10183	No. 22 10191	No. 23 10193 10194	No. 24 10150
No. 25 10153	No. 26 10171	No. 27 10166	No. 28 10177	No. 29 10182	No. 30 10190	No. 31 10195 10196	No. 32 10158
No. 33 10156	No. 34 10170	No. 35 10165	No. 36 10175 10176	No. 37 10181	No. 38 10189	No. 39 10197 10198	No. 40 10159
No. 41 10155 10152	No. 42 10169	No. 43 10164	No. 44 10174	No. 45 10180	No. 46 10188	No. 47 10204	No. 48 10150



Sample at
Drain Outfall
10199: ~1.5 ft Deep
10205: at Surface

Sample at
Drain Outfall
10185: ~1.5 ft Deep

Vegetation Sample
from Impoundment 1
10201

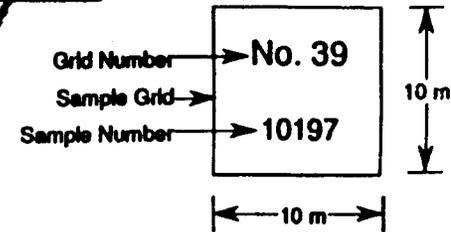
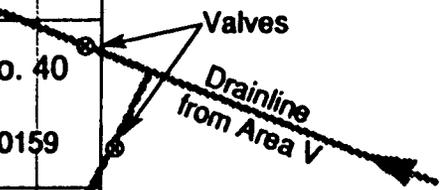


Figure 2-1b Surface Sample Location Map

Table 2-1
Summary of Soil Concentrations for Constituents of Concern at the
SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

Contaminant (Unit of measure)	Soil Concentration					
	Number of Samples	Minimum ^a	Maximum	Distribution (Appendix A)	0.01 Percentile	99.9 Percentile
Cesium-137 (pCi/g)	26	0.037	10.1	Lognormal	0.003	81.6
Cobalt-60 (pCi/g)	26	0.033	11	Lognormal	0.002	36.4
Tritium (pCi/g)	30	0.05	0.40	Lognormal	0.015	0.58
Uranium-235 (pCi/g)	26	0.049	3.0		0.015	3.85
Aroclor-1260 (ppb) ^b	24	33	71	Lognormal	33	71
Barium (ppm)	26	54.5	232	Lognormal	0.011	81.6
Cadmium (ppm)	26	0.5	154	Lognormal	0.003	480.2
Chromium(III) (ppm)	26	6.2	97.7	Lognormal	1.92	90.9
Chromium(VI) (ppm)	22	0.1	11.2	Lognormal	0.007	35.2
Lead (ppm) ^c	26	5.8	72.5	c	c	c
Nickel (ppm)	26	4.7	173	Lognormal	0.82	209.0
Zinc (ppm)	26	21	198	Lognormal	6.92	286.1

^aThe minimum reported value in the data set is the lowest value recorded. If the data set contains nondetects, the detection limit represents the minimum value.

^bThe analytical data for Aroclor-1260 could not be fitted. The analytical data set was heavily censored (i.e., there was a large number of samples with no detected analyte). Therefore, the detection limit and maximum detected values were assumed to represent the 0.1 and 99.9 percentiles, respectively.

^cThe soil-screening standard for lead is 400 ppm (EPA, 1994a). No calculations were made in this report for lead contamination.

3.0 EXPOSURE EVALUATION

The exposure assessment for COC-contaminated soil at ER Site 4 was performed using *Précis* to estimate the potential annual radiation dose from radionuclides and the ICR and HI for nonradioactive COC for a "reasonably maximally exposed" individual. This exposure assessment is conservative, meaning the exposure is overestimated.

Précis estimates an individual's annual radiation dose and hazardous chemical intake using a stochastic technique. This method provides an estimate of potential exposures by taking into account the uncertainties inherent in the program input parameters, such as COC concentration, soil density, depth to groundwater, etc. *Précis* evaluates this uncertainty in the exposure using a Latin-hypercube sampling technique that randomly selects trial values for each of the input parameters according to their probability distributions and calculates an exposure concentration for each group of trial values. The resulting output provides a distribution of the individual's annual dose rate and COC intake. As such, the dose, or intake, distribution represents the probability that the individual will receive a specified exposure, assuming that the exposure scenario does occur.

3.1 Radionuclide COC Exposure Evaluation

Evaluation of potential exposures to radionuclides includes assumed pathways for contact with contaminated media. These exposure pathways are based on land-use scenarios for the site.

The industrial land-use scenario was used to evaluate potential radionuclide exposures at ER Site 4. This scenario was evaluated using the *Précis* program under the following exposure assumptions:

- That the individual works exclusively at a randomly chosen location at ER Site 4 for an entire year. This highly conservative assumption was chosen to overestimate worker exposure.
- That the individual does not mitigate his or her potential exposures by avoiding contact with contamination or using personal protective equipment (i.e., the worker is unaware of the existence of contamination).
- That no food is grown at the site and no drinking water well is available at the site.
- That the area of contamination ranged from 1400 to 1900 square meters (m^2). The 1400 m^2 value represents the area contour of maximum COC concentration located near the Surface Impoundment Drainline Outfalls (Figure 2-1b). The 1900 m^2 value represents the area contour in which any COC concentration above background was detected (see Sec. 4.3.3 of this report titled "Results of

the LWDS Remedial Action Field Investigation report). These values were assumed to represent the 0.1 and 99.9th percentiles used in *Précis*.

- That concentration as a function of depth was represented by a lognormal distribution from 0.1 to 99.9th percentiles over the depth range from 0.025 to 1 (m).

Under these assumptions, the exposure pathways are:

- Inhalation of airborne dust
- Ingestion of contaminated soil
- Direct external gamma radiation

The fugitive dust inhalation, incidental soil ingestion, and external gamma radiation exposure pathways were evaluated as shown in Figure 3-1.

3.2 Chemical COC Exposure Evaluation

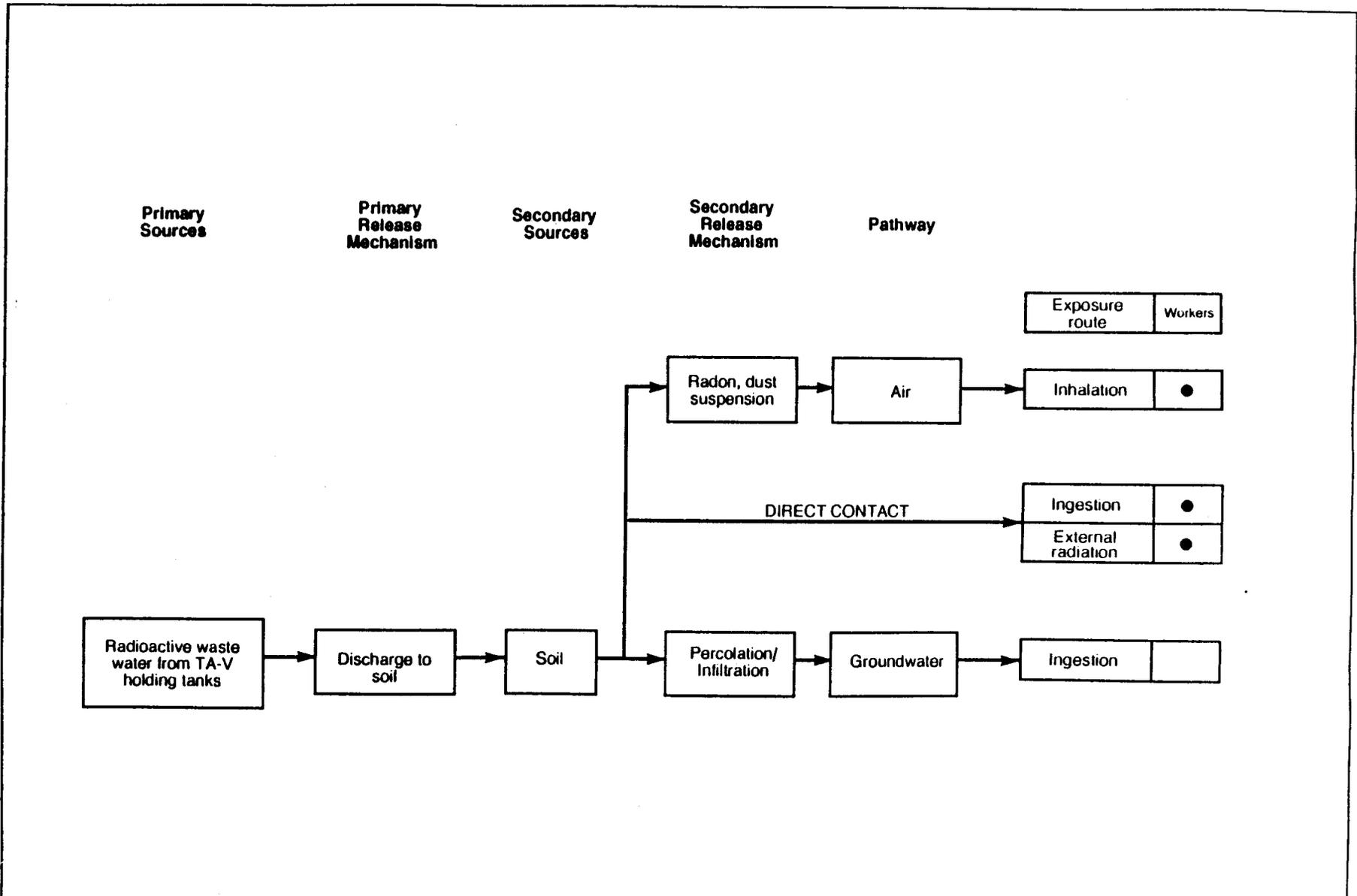
Evaluation of potential exposures to nonradioactive contaminants was also based on the industrial land-use scenario. The evaluation of exposures of potential workers to nonradioactive chemicals was based on the same assumptions used for exposures to radionuclides (Section 3.1). The airborne dust inhalation and ingestion pathways were evaluated, but the direct external gamma radiation pathway was not included (Figure 3-1).

3.3 Sensitivity Analysis of *Précis* Input Parameters

A sensitivity analysis of the uncertainties in *Précis* input parameters was performed to determine which of the input parameters had the greatest influence on the uncertainty of the calculated annual radiation dose or risk.

Probability distributions were developed for *Précis* input parameters specific to SNL/NM (e.g., geological and precipitation parameters) and for certain input parameters related to the worker (e.g., inhalation rate). Measured COC concentrations (Appendix A) were used to describe probability distributions for soil contamination. Preliminary estimates of radiation dose and chemical risks (both carcinogens and noncarcinogens) were made from 100 stochastic *Précis* simulations using the above distributions and the cumulative probability distribution of the estimates was plotted. The three simulations representing the 5, 50, and 95th percentiles of the cumulative probability distribution of the dose and risk estimates were selected as representative of the overall distribution. These three simulations were the basis for the sensitivity evaluation.

Précis performs the sensitivity analysis by systematically varying each input parameter by 1 percent of its value, keeping all other parameters constant, and evaluating the impact of this perturbation on the calculated results. The sensitivities of the calculated results to



Exposure evaluated
 Exposure not evaluated

Figure 3-1
SNL/NM ER Site 4 Exposure Assessment Conceptual Model

these small changes in each input parameter were ranked to determine which input parameters introduced the greatest perturbation in the calculated dose. Parameters that did not effect the calculated result by more then 0.05 percent were considered to be nonsensitive and were treated as nonstochastic parameters in subsequent uncertainty calculations.

The parameters contributing the greatest uncertainty in radiation dose estimates were:

- Thickness of the contaminated zone
- Density of the contaminated zone
- Precipitation rate

The parameters contributing the greatest uncertainty in chemical risk estimates were:

- Thickness of the contaminated zone
- Area of the contaminated zone
- Soil ingestion rate

These uncertain parameters, in addition to the COC concentrations in soil, were treated as stochastic variables in subsequent dose calculations.

3.4 Summary of *Précis* Input Parameters

Appendix B summarizes the both the stochastic and nonstochastic input parameters used by *Précis* to calculate the radiation dose, the ICR, and the HI for ER Site 4. Hydrogeologic parameters used were compiled from measurements made at many SNL/NM locations. As such, the values used were not necessarily made at ER Site 4 and reflect the wider range of SNL/NM measurements. This wider range of input parameters represents a conservative overestimation of uncertainty in radiation dose and risk estimates.

4.0 TOXICITY ASSESSMENT

Hazardous materials are classified by their carcinogenic or noncarcinogenic (often termed "systemic") effects on human health. Carcinogenicity risk is described as the probability that an individual will develop cancer at sometime during his or her lifetime from a chronic intake of the carcinogen in question (EPA 1989). Cancer risk for chronic exposure to a carcinogen is described by a slope factor (SF) used to relate the daily carcinogen intake to the cancer risk. The SF values used in this analysis were obtained from the Integrated Risk Information System (IRIS) (EPA 1994b) or from the Health Effects Assessment Summary Tables (HEAST) (EPA 1993).

All radionuclides are classified by the EPA as Group A human carcinogens because of their ionizing radiation emissions. For the purposes of this risk assessment, the cancer risk from radiation is limited by the maximum-allowed radiation dose from exposure from all pathways to 25 mrem/yr (DOE 1988).

Systemic toxicity is described by the reference dose (RfD) concept, which assumes that a threshold level exists for systemic toxicity (EPA 1989). The RfD is the estimate of daily contaminant intake for a human population, including sensitive subpopulations, that is expected to cause no adverse human health effects from chronic exposures. The RfD values used in this analysis were obtained from the IRIS (EPA 1994b).

Toxicity information for each potential chemical of concern at ER Site 4 is summarized in Table 4-1 and described in detail in Appendix C.

Table 4-1
Human Toxicity Factors Used for Calculations of Incremental Lifetime Cancer Risk or
Hazard Index from Exposure to Constituents of Concern at the SNL/NM ER Site 4 Liquid Waste
Disposal System Impoundments

Nonradioactive Constituents of Concern	Reference Dose (mg/kg-day)		Non-Cancer Health Effect, Target Organ	Slope Factor (kg-day/mg)		Cancer Class (see Appendix B)	Tumor Site
	Oral	Inhalation		Oral	Inhalation		
Aroclor-1260 (PCBs)	b	b	Chloracne, skin Dysfunction, liver	7.7	b	B2	Trabecular carcinoma
Barium	7E-02	b	Increased blood pressure	b	b	c	c
Cadmium	1E-03 ^a	b	Proteinuria, kidney	b	6.3 ^a	B1	Respiratory tract
Chromium (III)	1.0 ^a	b	Proteinuria, kidney	c	c	c	c
Chromium (VI)	5E-03 ^a	b	Proteinuria, kidney	b	42 ^a	A	Respiratory tract
Lead	b	b	Dysfunction, nervous system, kidney, blood	b	b	B2	Kidney
Nickel	2E-02 ^a	b	Gastrointestinal disorders	b	b	Nickel salts not classified	c
Zinc	3E-01 ^a	b	Gastrointestinal disorders	c	c	D	c

^aIntegrated Risk Information System (IRIS) (EPA 1994a).

^bNo data available to establish toxicity factor (EPA 1994a).

^cNot considered to be carcinogenic to humans (EPA 1994b).

^dHealth Effects Assessment Summary Tables (HEAST) (EPA 1993).

5.0 RISK CHARACTERIZATION OF COCs

The annual radiation dose from potential exposure to radionuclides, the ICR from exposure to carcinogenic chemical contaminants, and the HI for exposure to noncarcinogenic chemicals in soil at the LWDS were calculated using *Précis*. These quantities and their associated uncertainties were estimated from 100 simulations based on industrial land-use scenario assumptions. This risk characterization employs a conservative approach that leads to the overestimation of risk, as described in Section 3.0.

5.1 Radiation Dose Characterization

The maximum radiation dose was calculated to occur in 1994, the year the radionuclides were measured in soil samples (Table 5-1). The 95th percentile of the estimated dose is 23 mrem/year, which is less than the 25 mrem/year regulatory limit (DOE 1988). These radiation dose calculations reflect the highly conservative assumptions as described in Section 3.0. Accordingly, a person working continually at ER Site 4 during 1994 would have had a 95 percent probability of receiving less than the 25 mrem/yr radiation dose limit.

The major contributor to radiation dose was cobalt-60 at the time of maximum dose (1994). Cesium-137, uranium-235, and tritium were minor contributors to the total dose. Direct external radiation was the dominant exposure pathway contributing to dose. Exposure from inhaled airborne dust or ingested soil contributed negligible radiation dose. Appendix D provides the radiation doses from exposure pathways assumed in the land-use scenario. The calculated radiation dose decreases with the decay of radionuclides, resulting primarily from the decay of cobalt-60 with a half-life of 5.27 years (Table 5-1). Thus, a worker employed at ER Site 4 during 2004 would have a 95 percent probability of receiving an estimated radiation dose of approximately 9 mrem/yr or less.

5.2 Risks and Hazards From Exposure to Hazardous Chemicals

The maximum ICR was calculated to occur in 1994, the year the carcinogenic chemicals were measured in soil samples (Table 5-2). The 95th percentile of the estimated ICR is 2.4×10^{-6} , which is above the 1×10^{-6} regulatory limit (EPA 1989).

Dust inhalation and soil ingestion were the dominant exposure pathways contributing to ICR. Exposure from ingested soil contributed negligible cancer risk. Chromium(VI) was the major contributor to ICR, although cadmium and PCBs (aroclor-1260) also contributed appreciably. Appendix D provides the intakes from exposure pathways assumed in the land-use scenario.

The maximum HI was also calculated to occur in 1994 (Table 5-3). The 95th percentile of the estimated HI is 0.04, which is below the 1.0 regulatory limit (EPA 1989). Although the exposure assessment includes conservative assumptions (Section 3.0), a person working continually at ER Site 4 during 1994 would have had a 95 percent probability or greater of

**Table 5-1
Annual Radiation Dose Estimates Based on 100 Précis Simulations
of Worker Exposure to Radionuclides in Soil at the SNL/NM ER
Site 4 Liquid Waste Disposal System Impoundments**

Estimated Radiation Dose Rate (mrem/yr)	Time Since Sample Analyzed (year)						
	0 (1994) ^a	1 (1995)	3 (1997)	5 (1999)	10 (2004)	30 (2024)	100 (2094)
Minimum	1.7E-01	1.5E-01	1.1E-01	8.7E-02	4.4E-02	3.2E-03	4.0E-07
5 Percentile	5.7E-01	5.1E-01	3.9E-01	3.1E-01	1.6E-01	8.2E-03	9.7E-07
50 Percentile	3.1E+00	2.7E+00	2.0E+00	1.6E+00	9.3E-01	1.4E-01	7.1E-04
90 Percentile	1.5E+01	1.4E+01	1.1E+01	8.2E+00	4.4E+00	6.4E-01	2.6E-02
95 Percentile	2.3E+01	2.1E+01	1.7E+01	1.4E+01	9.3E+00	1.0E+00	4.1E-02
Maximum	8.8E+01	7.7E+01	5.9E+01	4.5E+01	2.4E+01	2.9E+00	8.6E-02

^aThe maximum radiation dose radiation occurs in 1994, the year the samples were taken and analyzed.

**Table 5-2
Cumulative Incremental Cancer Risk Estimates
Based on 100 Précis Simulations of Worker Exposure to Chemicals
in Soil at the ER Site 4 Liquid Waste Disposal System Impoundments**

Estimated Incremental Lifetime Cancer Risk	Time Since Sample Analyzed (year)						
	0 (1994) ^a	1 (1995)	3 (1997)	5 (1999)	10 (2004)	30 (2024)	100 (2094)
Minimum	1.5E-08	1.3E-08	9.9E-09	8.1E-09	5.9E-09	4.2E-09	1.7E-09
5 Percentile	3.7E-08	3.5E-08	3.1E-08	2.7E-08	2.3E-08	1.6E-08	8.1E-09
50 Percentile	2.8E-07	2.8E-07	2.6E-07	2.5E-07	2.4E-07	2.1E-07	1.4E-07
90 Percentile	1.5E-06	1.5E-06	1.5E-06	1.5E-06	1.5E-06	1.4E-06	1.1E-06
95 Percentile	2.4E-06	2.3E-06	2.3E-06	2.2E-06	2.1E-06	2.1E-06	1.3E-06
Maximum	7.4E-06	7.4E-06	7.3E-06	7.2E-06	7.1E-06	6.7E-06	6.6E-06

^aThe maximum incremental lifetime cancer risk was calculated to occur in 1994, the year the samples were taken and analyzed.

meeting the HI of 1.0 designated as acceptable.

Table 5-3
Cumulative Hazard Index Estimates,
Based on 100 *Précis* Simulations of Worker Exposure to Chemicals
in Soil at the ER Site 4 Liquid Waste Disposal System Impoundments

Estimated Hazard Index	Time Since Sample Analyzed (year)						
	0 (1994) ^a	1 (1995)	3 (1997)	5 (1999)	10 (2004)	30 (2024)	100 (2094)
Minimum	7.9E-04	5.9E-04	2.5E-04	1.6E-04	3.6E-05	7.6E-06	3.5E-06
5 Percentile	1.4E-03	1.1E-03	5.3E-04	2.7E-04	1.4E-04	6.2E-05	3.6E-05
50 Percentile	1.1E-02	9.2E-03	6.9E-03	5.4E-03	2.4E-03	5.6E-04	2.9E-04
90 Percentile	2.7E-02	2.1E-02	1.7E-02	1.4E-02	9.7E-03	4.9E-03	3.2E-03
95 Percentile	3.6E-02	3.1E-02	2.6E-02	2.1E-02	1.2E-02	6.4E-03	5.8E-03
Maximum	6.5E-02	5.7E-02	4.3E-02	3.3E-02	2.4E-02	1.6E-02	1.4E-02

^aThe maximum hazard index was calculated to occur in 1994, the year the samples were taken and analyzed.

Health effects of lead could not be evaluated because the necessary RfD of SF have either not been developed or have been withdrawn (EPA 1994b). A concentration of 400 microgram lead per lead/g soil (ppm) has been provided as a screening level for initiation of risk reduction activities under a residential land-use scenario (EPA 1994a), and higher soil concentrations might be allowed under certain site-specific conditions. All of the lead concentrations measured in soil samples collected at the ER Site 4 LWDS Impoundments are far below 400 ppm (Appendix A).

5.3 Exposure to Buried Radionuclides and Carcinogenic Chemicals

Occupational exposures to radionuclides and noncarcinogenic hazardous chemicals at ER Site 4 are estimated to meet regulatory limits with 95 percent confidence. The estimated ICR associated with exposure to carcinogenic chemicals is greater than the 1×10^{-6} cancer risk considered acceptable by the EPA (EPA 1989). Therefore, the ICRs for exposure to cadmium, chromium(VI), and aroclor-1260 were recalculated using the same *Précis* input parameters, except that a 2-m clean soil cover was assumed (Appendix E). The results of 100 *Précis* simulations showed no calculable cancer risk, indicating that there would be no intake of carcinogenic chemicals under the industrial land-use scenario. Therefore, *Précis* calculated no ICR, in accordance with EPA methodology (EPA 1989).

Although the 95th percentile of the maximum 1994 radiation dose estimate (23 mrem/yr) is less than the 25 mrem/yr regulatory limit, it might be considered that the doses are similar within the uncertainties of the calculations. Therefore, the radiation dose was calculated for radionuclide COC located beneath a 2-m clean soil cover. The maximum radiation dose was calculated to be less than 2×10^{-8} mrem/year at the ground surface (Appendix E).

The 2-m clean soil cover would effectively eliminate the exposure pathways for both radionuclide and chemical COCs under the industrial land-use scenario.

6.0 DISCUSSION

Radiation dose estimates for the industrial land-use scenario (Table 5-1) indicate that the 25 mrem/yr dose limit (assuming maximum dose) would have been met with 95 percent probability in 1994. Because uranium-235 and tritium do not emit appreciable penetrating radiation, these isotopes are insignificant contaminants relative to cobalt-60 and cesium-137. Cobalt-60 contributed the majority of the radiation dose, which is expected to decrease significantly as cobalt-60 decays with a 5.27 year half-life. Thus, the total maximum radiation dose is expected to decrease further below the 25 mrem/yr dose limit to approximately 10 mrem/yr within ten years.

The estimated HI for noncarcinogenic chemicals measured at ER Site 4 under the industrial land-use scenario (see Table 5-3) was less than the specified limit of 1.0 (EPA 1989). Therefore, these metals can be removed from further consideration in remediation decisions at ER Site 4. Because all measured lead concentrations are below the 400 ppm screening level for remediation (EPA, 1994a), lead can be removed from consideration also.

Cadmium, chromium(VI), and PCBs (aroclor-1260) contributed significantly to the ICR under the industrial land-use scenario (Appendix D). The 95th percentile of the estimated ICR is 2.4×10^{-6} (see Table 5-2), which is above the 1×10^{-6} regulatory limit (EPA 1989). If 2 meters of clean cover are applied to the site, the ICR would be far less than the 1×10^{-6} risk considered acceptable (EPA 1989). A 2-m clean soil cover would also reduce the radiation dose from radionuclides to far less than the 25 mrem/yr regulatory limit (DOE 1988).

6.1 Uncertainty

The parameters contributing the greatest uncertainty in radiation dose estimates were the thickness of the contaminated zone, the density of the contaminated soil, and the precipitation rate. The thickness and density of the contaminated zone are closely associated with the gamma radiation shielding provided by soil. Although the precipitation rate is not directly related to gamma shielding, infiltration of rain water through soil provides a mechanism for leaching gamma emitters from soil and removing dissolved radionuclides below the surface soil, thus providing for increased shielding.

The parameters contributing the greatest uncertainty in ICR estimates for chemical COCs were the thickness of the contaminated zone, the area of the contaminated zone, and the soil ingestion rate. These three parameters are closely associated with the accessibility of the exposed individual to contamination. This result indicates that the *Précis* model (when applied under the industrial land-use scenario) might be more sensitive to uncertainties in soil ingestion parameters than the combined uncertainties in parameters related to contaminant dispersion or dust inhalation (e.g., wind speed).

6.2 Conclusions

Radiation dose, ICR, and HI values were calculated using conservative worker exposure assumptions. The results indicate that cesium-137, cobalt-60, tritium, uranium-235, barium, chromium (III), lead, nickel, and zinc can be removed from further consideration at the ER Site 4 LWDS Impoundments. Based on these calculations and the measured concentrations of cadmium, and chromium (VI), and PCBs (aroclor-1260) in soil, remediation decisions might be required to reduce the estimated cancer risk at ER Site 4. Further evaluation showed that cadmium, chromium (VI), PCBs, and all other COC measured at ER Site 4 would meet regulatory limits and could be removed from further consideration if a 2-m clean soil cover was added to the site.

7.0 REFERENCES

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APPENDIX A
SITE CHARACTERIZATION DATA

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (ug/kg)	LN CONCENTRATION	DETECTION_LIMIT (ug/kg)
LWDS-04-BH17-0	0	AROCLOR-1260	33	3.4965	33
LWDS-04-BH18-0	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-11	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-12	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-19	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-22	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-23	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-23	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-27	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-31	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-31	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-34	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-35	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-36	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-36	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-36	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-39	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-39	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-42	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-43	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-44	0	AROCLOR-1260	33	3.4965	33
LWDS-SS-48	0	AROCLOR-1260	35	3.5553	33
LWDS-SS-HS	1	AROCLOR-1260	39	3.6636	33
LWDS-SS-HS	0	AROCLOR-1260	71	4.2627	33
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.186364951		R Square	0.167804387	
Mean	3.537843682		Mean	34.91666667	
St. Deviation	0.158440922		St. Deviation	7.790276362	
0.1 Value	21.38138998		0.1 Value	11.54583758	
99.9 Value	55.32176701		99.9 Value	58.28749575	
<i>Because these data are severely censored, they could not be fit to either a log-normal or a normal distribution. Therefore, the minimum (33 ug/kg) and maximum (71 ug/kg) concentrations were assumed to represent the 0.1 percentile and 99.0 percentile of the distribution and were used for input into PRECIS.</i>					

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-HS	0	BARIUM	54.5	3.9982	1
LWDS-04-BH17-0	0	BARIUM	56.5	4.0342	1
LWDS-SS-22	0	BARIUM	58.6	4.0707	1
LWDS-SS-35	0	BARIUM	59	4.0775	1
LWDS-04-BH09	5	BARIUM	61.8	4.1239	1
LWDS-SS-31	0	BARIUM	62.8	4.1400	1
LWDS-SS-42	0	BARIUM	63.8	4.1558	1
LWDS-SS-HS	1	BARIUM	64.1	4.1604	1
LWDS-SS-36	0	BARIUM	67.7	4.2151	1
LWDS-SS-31	0	BARIUM	68.3	4.2239	1
LWDS-SS-19	0	BARIUM	69.7	4.2442	1
LWDS-SS-36	0	BARIUM	70.2	4.2513	1
LWDS-SS-43	0	BARIUM	73.9	4.3027	1
LWDS-SS-12	0	BARIUM	75.6	4.3255	1
LWDS-04-BH10	5	BARIUM	83.2	4.4212	1
LWDS-SS-23	0	BARIUM	83.9	4.4296	1
LWDS-SS-36	0	BARIUM	90.2	4.5020	1
LWDS-SS-34	0	BARIUM	91	4.5109	1
LWDS-SS-44	0	BARIUM	95.7	4.5612	1
LWDS-SS-11	0	BARIUM	98.3	4.5880	1
LWDS-SS-23	0	BARIUM	114	4.7362	1
LWDS-04-BH18-0	0	BARIUM	124	4.8203	1
LWDS-SS-39	0	BARIUM	187	5.2311	1
LWDS-SS-27	0	BARIUM	189	5.2417	2
LWDS-SS-39	0	BARIUM	195	5.2730	1
LWDS-SS-48	0	BARIUM	232	5.4467	1
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.848574512		R Square	0.708515986	
Mean	4.464829229		Mean	95.76153846	
St. Deviation	0.420378042		St. Deviation	49.36171048	
0.1 Value	24.62334808		0.1 Value	-52.32359298	
99.9 Value	306.728612		99.9 Value	243.8466699	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-11	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-12	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-31	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-35	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-43	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-44	0	CADMIUM	0.5	-0.6931	0.5
LWDS-SS-19	0	CADMIUM	0.55	-0.5978	0.5
LWDS-SS-34	0	CADMIUM	0.64	-0.4463	0.5
LWDS-04-BH10	5	CADMIUM	0.66	-0.4155	0.5
LWDS-SS-22	0	CADMIUM	0.79	-0.2357	0.5
LWDS-SS-42	0	CADMIUM	0.85	-0.1625	0.5
LWDS-SS-36	0	CADMIUM	0.86	-0.1508	0.5
LWDS-SS-36	0	CADMIUM	0.88	-0.1278	0.5
LWDS-04-BH18-0	0	CADMIUM	0.9	-0.1054	0.5
LWDS-SS-31	0	CADMIUM	1	0.0000	0.5
LWDS-SS-36	0	CADMIUM	1.1	0.0953	0.5
LWDS-SS-48	0	CADMIUM	4.5	1.5041	0.5
LWDS-SS-39	0	CADMIUM	5.1	1.6292	0.5
LWDS-SS-39	0	CADMIUM	5.2	1.6487	0.5
LWDS-SS-27	0	CADMIUM	5.3	1.6677	1
LWDS-04-BH09	5	CADMIUM	22.8	3.1268	0.5
LWDS-SS-23	0	CADMIUM	25.7	3.2465	0.5
LWDS-SS-23	0	CADMIUM	32.7	3.4874	0.5
LWDS-04-BH17-0	0	CADMIUM	35.5	3.5695	0.5
LWDS-SS-HS	0	CADMIUM	35.9	3.5807	0.5
LWDS-SS-HS	1	CADMIUM	154	5.0370	0.5
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.834532027		R Square	0.339846428	
Mean	0.85354085		Mean	12.99730769	
St. Deviation	1.773579678		St. Deviation	31.13353055	
0.1 Value	0.011479434		0.1 Value	-80.40328396	
99.9 Value	480.237073		99.9 Value	106.3978993	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT (pCi/g)
LWDS-04-BH18-0	0	CESIUM-137	0.0366	-3.3077	N/A
LWDS-SS-11	0	CESIUM-137	0.078	-2.5510	0.078
LWDS-SS-12	0	CESIUM-137	0.093	-2.3752	0.093
LWDS-SS-22	0	CESIUM-137	0.093	-2.3752	0.093
LWDS-SS-44	0	CESIUM-137	0.11	-2.2073	0.11
LWDS-SS-42	0	CESIUM-137	0.13	-2.0402	N/A
LWDS-04-BH17-0	0	CESIUM-137	0.161	-1.8264	N/A
LWDS-SS-35	0	CESIUM-137	0.19	-1.6607	N/A
LWDS-SS-31	0	CESIUM-137	0.2	-1.6094	N/A
LWDS-SS-34	0	CESIUM-137	0.2	-1.6094	N/A
LWDS-SS-36	0	CESIUM-137	0.2	-1.6094	0.2
LWDS-SS-43	0	CESIUM-137	0.2	-1.6094	N/A
LWDS-SS-19	0	CESIUM-137	0.25	-1.3863	N/A
LWDS-SS-31	0	CESIUM-137	0.25	-1.3863	N/A
LWDS-SS-48	0	CESIUM-137	0.315	-1.1552	N/A
LWDS-SS-27	0	CESIUM-137	0.81	-0.2107	N/A
LWDS-SS-36	0	CESIUM-137	1	0.0000	N/A
LWDS-SS-36	0	CESIUM-137	1.1	0.0953	N/A
LWDS-04-BH10	5	CESIUM-137	1.9	0.6419	0.049
LWDS-SS-39	0	CESIUM-137	2.3	0.8329	N/A
LWDS-SS-HS	0	CESIUM-137	2.7	0.9933	N/A
LWDS-SS-39	0	CESIUM-137	3.5	1.2528	N/A
LWDS-04-BH09	5	CESIUM-137	7.5	2.0149	0.18
LWDS-SS-HS	1	CESIUM-137	7.7	2.0412	N/A
LWDS-SS-23	0	CESIUM-137	8.36	2.1235	N/A
LWDS-SS-23	0	CESIUM-137	10.1	2.3125	N/A
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.94106118		R Square	0.618470626	
Mean	-0.63891084		Mean	1.902946154	
St. Deviation	1.680285311		St. Deviation	3.000629013	
0.1 Value	0.003414355		0.1 Value	-7.093940886	
99.9 Value	81.60945248		99.9 Value	10.90483319	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-44	0	CHROMIUM	6.2	1.8245	1
LWDS-SS-36	0	CHROMIUM	6.4	1.8563	1
LWDS-SS-36	0	CHROMIUM	7.3	1.9879	1
LWDS-SS-31	0	CHROMIUM	8.1	2.0919	1
LWDS-04-BH17-0	0	CHROMIUM	8.2	2.1041	1
LWDS-SS-31	0	CHROMIUM	8.6	2.1518	1
LWDS-SS-43	0	CHROMIUM	9	2.1972	1
LWDS-04-BH09	5	CHROMIUM	9.1	2.2083	1
LWDS-SS-23	0	CHROMIUM	9.1	2.2083	1
LWDS-SS-36	0	CHROMIUM	9.3	2.2300	1
LWDS-SS-HS	0	CHROMIUM	9.7	2.2721	1
LWDS-SS-34	0	CHROMIUM	10.4	2.3418	1
LWDS-04-BH10	5	CHROMIUM	10.7	2.3702	1
LWDS-SS-12	0	CHROMIUM	11.2	2.4159	1
LWDS-04-BH18-0	0	CHROMIUM	11.4	2.4336	1
LWDS-SS-42	0	CHROMIUM	11.5	2.4423	1
LWDS-SS-23	0	CHROMIUM	13.3	2.5878	1
LWDS-SS-11	0	CHROMIUM	14.5	2.6741	1
LWDS-SS-39	0	CHROMIUM	15.3	2.7279	1
LWDS-SS-39	0	CHROMIUM	15.7	2.7537	1
LWDS-SS-HS	1	CHROMIUM	19.7	2.9806	1
LWDS-SS-48	0	CHROMIUM	21.8	3.0819	1
LWDS-SS-27	0	CHROMIUM	24.2	3.1864	2
LWDS-SS-35	0	CHROMIUM	30.6	3.4210	1
LWDS-SS-22	0	CHROMIUM	52.1	3.9532	1
LWDS-SS-19	0	CHROMIUM	97.7	4.5819	1
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.784914077		R Square	0.43020425	
Mean	2.580180517		Mean	17.35	
St. Deviation	0.643206095		St. Deviation	19.0401313	
0.1 Value	1.91661811		0.1 Value	-39.77039391	
99.9 Value	90.90352703		99.9 Value	74.47039391	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-11	0	CHROMIUM VI	0.1	-2.3026	0.1
LWDS-SS-12	0	CHROMIUM VI	0.1	-2.3026	0.1
LWDS-SS-22	0	CHROMIUM VI	0.1	-2.3026	0.1
LWDS-SS-43	0	CHROMIUM VI	0.1	-2.3026	0.1
LWDS-SS-44	0	CHROMIUM VI	0.1	-2.3026	0.1
LWDS-SS-35	0	CHROMIUM VI	0.11	-2.2073	0.1
LWDS-SS-HS	1	CHROMIUM VI	0.19	-1.6607	0.1
LWDS-SS-23	0	CHROMIUM VI	0.2	-1.6094	0.2
LWDS-SS-48	0	CHROMIUM VI	0.2	-1.6094	0.2
LWDS-SS-19	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-23	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-31	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-31	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-42	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-HS	0	CHROMIUM VI	0.5	-0.6931	0.5
LWDS-SS-36	0	CHROMIUM VI	1	0.0000	0.2
LWDS-SS-36	0	CHROMIUM VI	1	0.0000	1
LWDS-SS-36	0	CHROMIUM VI	1	0.0000	1
LWDS-SS-27	0	CHROMIUM VI	2.5	0.9163	2.5
LWDS-SS-34	0	CHROMIUM VI	2.5	0.9163	2.5
LWDS-SS-39	0	CHROMIUM VI	10	2.3026	10
LWDS-SS-39	0	CHROMIUM VI	11.2	2.4159	10
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.895943824		R Square	0.413833856	
Mean	-0.736709553		Mean	1.518181818	
St. Deviation	1.432285782		St. Deviation	3.023014321	
0.1 Value	0.006515529		0.1 Value	-7.550861145	
99.9 Value	35.16839441		99.9 Value	10.58722478	

Table A-1

Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT (pCi/g)
LWDS-04-BH18-0	0	COBALT-60	0.0332	-3.4052	0.0332
LWDS-04-BH10	5	COBALT-60	0.056	-2.8824	0.056
LWDS-SS-35	0	COBALT-60	0.0716	-2.6367	0.0716
LWDS-SS-43	0	COBALT-60	0.0742	-2.6010	0.0742
LWDS-SS-22	0	COBALT-60	0.076	-2.5770	0.076
LWDS-SS-12	0	COBALT-60	0.082	-2.5010	0.082
LWDS-SS-11	0	COBALT-60	0.09	-2.4079	0.09
LWDS-SS-31	0	COBALT-60	0.11	-2.2073	0.11
LWDS-SS-42	0	COBALT-60	0.11	-2.2073	0.11
LWDS-SS-31	0	COBALT-60	0.113	-2.1804	0.113
LWDS-SS-48	0	COBALT-60	0.113	-2.1804	0.113
LWDS-SS-44	0	COBALT-60	0.12	-2.1203	0.12
LWDS-SS-19	0	COBALT-60	0.15	-1.8971	0.15
LWDS-SS-34	0	COBALT-60	0.17	-1.7720	0.17
LWDS-SS-36	0	COBALT-60	0.23	-1.4697	N/A
LWDS-SS-36	0	COBALT-60	0.24	-1.4271	0.24
LWDS-04-BH17-0	0	COBALT-60	0.242	-1.4188	N/A
LWDS-SS-36	0	COBALT-60	0.4	-0.9163	N/A
LWDS-SS-27	0	COBALT-60	0.66	-0.4155	N/A
LWDS-SS-39	0	COBALT-60	0.7	-0.3567	N/A
LWDS-SS-39	0	COBALT-60	0.9	-0.1054	N/A
LWDS-SS-23	0	COBALT-60	1.71	0.5365	N/A
LWDS-SS-23	0	COBALT-60	3.07	1.1217	N/A
LWDS-SS-HS	0	COBALT-60	3.4	1.2238	N/A
LWDS-SS-HS	1	COBALT-60	10.2	2.3224	N/A
LWDS-04-BH09	5	COBALT-60	11	2.3979	0.21
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.871573125		R Square	0.397566946	
Mean	-1.233965814		Mean	1.312346154	
St. Deviation	1.609466016		St. Deviation	2.873228911	
0.1 Value	0.002328889		0.1 Value	-7.307340578	
99.9 Value	36.39503021		99.9 Value	9.932032886	

Table A-1

Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-04-BH10	5	LEAD	5.8	1.7579	0.3
LWDS-SS-44	0	LEAD	5.9	1.7750	0.5
LWDS-SS-11	0	LEAD	6	1.7918	0.5
LWDS-04-BH17-0	0	LEAD	6.3	1.8405	5
LWDS-SS-31	0	LEAD	6.9	1.9315	0.5
LWDS-SS-35	0	LEAD	6.9	1.9315	1
LWDS-SS-22	0	LEAD	7.1	1.9601	0.5
LWDS-SS-31	0	LEAD	7.4	2.0015	0.5
LWDS-SS-12	0	LEAD	7.5	2.0149	0.5
LWDS-SS-48	0	LEAD	8	2.0794	1
LWDS-SS-42	0	LEAD	9	2.1972	1
LWDS-SS-43	0	LEAD	9	2.1972	1
LWDS-SS-19	0	LEAD	10.3	2.3321	1
LWDS-SS-23	0	LEAD	12.9	2.5572	1
LWDS-SS-23	0	LEAD	13.8	2.6247	2.5
LWDS-SS-36	0	LEAD	15.7	2.7537	2.5
LWDS-SS-34	0	LEAD	16	2.7726	2.5
LWDS-04-BH09	5	LEAD	16.9	2.8273	2.5
LWDS-SS-36	0	LEAD	25.7	3.2465	2.5
LWDS-SS-HS	0	LEAD	26.7	3.2847	2.5
LWDS-SS-HS	1	LEAD	27.8	3.3250	2.5
LWDS-04-BH18-0	0	LEAD	29	3.3673	5
LWDS-SS-36	0	LEAD	30.9	3.4308	2.5
LWDS-SS-27	0	LEAD	58.1	4.0622	5
LWDS-SS-39	0	LEAD	70.8	4.2599	5
LWDS-SS-39	0	LEAD	72.5	4.2836	5
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.916587963		R Square	0.671231189	
Mean	2.638691822		Mean	19.72692308	
St. Deviation	0.794437626		St. Deviation	19.33536775	
0.1 Value	1.290950727		0.1 Value	-38.27918018	
99.9 Value	151.7151424		99.9 Value	77.73302634	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-HS	1	NICKEL	4.7	1.5476	4
LWDS-SS-HS	0	NICKEL	5.2	1.6487	4
LWDS-04-BH17-0	0	NICKEL	5.8	1.7579	4
LWDS-SS-36	0	NICKEL	6	1.7918	4
LWDS-SS-36	0	NICKEL	6.1	1.8083	4
LWDS-04-BH09	5	NICKEL	6.6	1.8871	4
LWDS-SS-44	0	NICKEL	6.7	1.9021	4
LWDS-SS-43	0	NICKEL	6.9	1.9315	4
LWDS-04-BH10	5	NICKEL	7	1.9459	4
LWDS-SS-34	0	NICKEL	7.1	1.9601	4
LWDS-SS-23	0	NICKEL	8.1	2.0919	4
LWDS-SS-31	0	NICKEL	8.3	2.1163	4
LWDS-04-BH18-0	0	NICKEL	8.8	2.1748	4
LWDS-SS-31	0	NICKEL	9.8	2.2824	4
LWDS-SS-36	0	NICKEL	10.3	2.3321	4
LWDS-SS-23	0	NICKEL	10.4	2.3418	4
LWDS-SS-39	0	NICKEL	15.4	2.7344	4
LWDS-SS-42	0	NICKEL	15.4	2.7344	4
LWDS-SS-39	0	NICKEL	16.1	2.7788	4
LWDS-SS-11	0	NICKEL	27.5	3.3142	4
LWDS-SS-22	0	NICKEL	29.5	3.3844	4
LWDS-SS-27	0	NICKEL	30.9	3.4308	8
LWDS-SS-35	0	NICKEL	45.3	3.8133	4
LWDS-SS-48	0	NICKEL	45.8	3.8243	4
LWDS-SS-12	0	NICKEL	70.2	4.2513	4
LWDS-SS-19	0	NICKEL	173	5.1533	4
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.843607616		R Square	0.419460562	
Mean	2.574582768		Mean	22.57307692	
St. Deviation	0.922556994		St. Deviation	34.63359707	
0.1 Value	0.824409245		0.1 Value	-81.32771429	
99.9 Value	208.9831761		99.9 Value	126.4738681	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT (pCi/g)
LWDS-04-BH18-0	0	TRITIUM	120 pCi/L	N/A	300
LWDS-SS-22	0	TRITIUM	-0.1	N/A	N/A
LWDS-SS-34	0	TRITIUM	-0.1	N/A	N/A
LWDS-SS-36	0	TRITIUM	-0.1	N/A	N/A
LWDS-SS-43	0	TRITIUM	-0.1	N/A	N/A
LWDS-SS-48	0	TRITIUM	-0.1	N/A	N/A
LWDS-SS-22	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-34	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-36	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-43	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-48	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-31	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-39	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-HS	0	TRITIUM	0.05	-2.9957	N/A
LWDS-SS-11	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-12	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-19	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-23	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-27	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-31	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-35	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-36	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-36	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-44	0	TRITIUM	0.1	-2.3026	N/A
LWDS-SS-42	0	TRITIUM	0.2	-1.6094	N/A
LWDS-SS-HS	1	TRITIUM	0.2	-1.6094	N/A
LWDS-SS-23	0	TRITIUM	0.3	-1.2040	N/A
LWDS-SS-39	0	TRITIUM	0.4	-0.9163	N/A
LWDS-04-BH10	5	TRITIUM	310 pCi/L	N/A	250
LWDS-04-BH09	5	TRITIUM	320 pCi/L	N/A	280
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.811606111		R Square	0.607861823	
Mean	-2.378674931		Mean	0.113636364	
St. Deviation	0.609680578		St. Deviation	0.088884379	
0.1 Value	0.014880306		0.1 Value	-0.153016775	
99.9 Value	0.577161477		99.9 Value	0.380289502	
<i>Negative concentrations and those concentrations that have units of pCi/L are excluded from this analysis.</i>					

Table A-1

Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (pCi/g)	LN CONCENTRATION	DETECTION_LIMIT (pCi/g)
LWDS-04-BH18-0	0	URANIUM-235	0.0488	-3.0200	0.0488
LWDS-04-BH17-0	0	URANIUM-235	0.0793	-2.5345	0.0793
LWDS-SS-35	0	URANIUM-235	0.11	-2.2073	0.11
LWDS-SS-43	0	URANIUM-235	0.127	-2.0636	0.127
LWDS-SS-11	0	URANIUM-235	0.14	-1.9661	0.14
LWDS-SS-22	0	URANIUM-235	0.14	-1.9661	0.14
LWDS-SS-48	0	URANIUM-235	0.146	-1.9241	0.146
LWDS-SS-42	0	URANIUM-235	0.15	-1.8971	0.15
LWDS-SS-44	0	URANIUM-235	0.15	-1.8971	0.15
LWDS-SS-12	0	URANIUM-235	0.16	-1.8326	0.16
LWDS-04-BH10	5	URANIUM-235	0.17	-1.7720	0.092
LWDS-SS-31	0	URANIUM-235	0.17	-1.7720	0.17
LWDS-SS-31	0	URANIUM-235	0.175	-1.7430	0.175
LWDS-SS-34	0	URANIUM-235	0.18	-1.7148	0.18
LWDS-SS-19	0	URANIUM-235	0.19	-1.6607	0.19
LWDS-SS-39	0	URANIUM-235	0.2	-1.6094	N/A
LWDS-SS-23	0	URANIUM-235	0.23	-1.4697	0.23
LWDS-SS-36	0	URANIUM-235	0.23	-1.4697	0.23
LWDS-SS-36	0	URANIUM-235	0.25	-1.3863	0.25
LWDS-SS-39	0	URANIUM-235	0.3	-1.2040	N/A
LWDS-SS-36	0	URANIUM-235	0.38	-0.9676	0.38
LWDS-SS-23	0	URANIUM-235	0.42	-0.8675	N/A
LWDS-SS-27	0	URANIUM-235	0.78	-0.2485	N/A
LWDS-04-BH09	5	URANIUM-235	1.4	0.3365	0.21
LWDS-SS-HS	0	URANIUM-235	1.5	0.4055	N/A
LWDS-SS-HS	1	URANIUM-235	3	1.0986	N/A
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
ln			Normal		
R Square	0.786105197		R Square	0.420578139	
Mean	-1.436655653		Mean	0.416388462	
St. Deviation	0.928096037		St. Deviation	0.640455363	
0.1 Value	0.014684779		0.1 Value	-1.504977629	
99.9 Value	3.848303713		99.9 Value	2.337754551	

Table A-1
Aroclor-1260, Barium, Cadmium, Cesium-137, Chromium, Chromium (VI), Cobalt-60, Lead, Nickel, Tritium, Uranium-235 and Zinc Concentrations in Core
Samples Collected at the SNL/NM ER Site 4 Liquid Waste Disposal System Impoundments

SSNUMBER	SAMPLE_DEPTH (ft)	COMMON_NAME	CONCENTRATION (mg/kg)	LN CONCENTRATION	DETECTION_LIMIT (mg/kg)
LWDS-SS-44	0	ZINC	21	3.0445	2
LWDS-04-BH10	5	ZINC	22.4	3.1091	2
LWDS-SS-11	0	ZINC	23.6	3.1612	2
LWDS-SS-22	0	ZINC	24.1	3.1822	2
LWDS-SS-31	0	ZINC	25.2	3.2268	2
LWDS-SS-35	0	ZINC	27.5	3.3142	2
LWDS-SS-43	0	ZINC	28.5	3.3499	2
LWDS-SS-31	0	ZINC	28.8	3.3604	2
LWDS-SS-42	0	ZINC	30	3.4012	2
LWDS-SS-12	0	ZINC	30.2	3.4078	2
LWDS-04-BH09	5	ZINC	30.8	3.4275	2
LWDS-SS-19	0	ZINC	31.5	3.4500	2
LWDS-SS-23	0	ZINC	35.2	3.5610	2
LWDS-04-BH17-0	0	ZINC	44.9	3.8044	2
LWDS-SS-HS	1	ZINC	47.4	3.8586	2
LWDS-SS-36	0	ZINC	49.1	3.8939	2
LWDS-SS-23	0	ZINC	49.9	3.9100	2
LWDS-SS-36	0	ZINC	50.3	3.9180	2
LWDS-SS-34	0	ZINC	53.8	3.9853	2
LWDS-SS-36	0	ZINC	56	4.0254	2
LWDS-SS-HS	0	ZINC	59.7	4.0893	2
LWDS-SS-48	0	ZINC	71.8	4.2739	2
LWDS-04-BH18-0	0	ZINC	106	4.6634	2
LWDS-SS-39	0	ZINC	144	4.9698	2
LWDS-SS-39	0	ZINC	148	4.9972	2
LWDS-SS-27	0	ZINC	198	5.2883	4
<i>Regression Statistics</i>			<i>Regression Statistics</i>		
In			Normal		
R Square	0.880972693		R Square	0.647089283	
Mean	3.795132982		Mean	55.29615385	
St. Deviation	0.620409214		St. Deviation	44.77930308	
0.1 Value	6.916468733		0.1 Value	-79.0417554	
99.9 Value	286.1055		99.9 Value	189.6340631	

APPENDIX B
***PRÉCIS* INPUT PARAMETERS**

Table B-1
***Précis* Input Parameters for**
Radiation Dose Calculations

```
*****
**
**           Monte Carlo Simulation Summary Report           **
**
*****
Date of simulation: Wed Jun 14 15:12:43 1995

Total number of runs: 100           LHS Seed: 256

*****
**
**           Précis Summary of Inputs                       **
**
*****
Name: ER Site 4 Radionuclides

Land Use Scenario: Industrial

Pathway Selections:
  Gamma: active
  Dust: active
  Radon: active
  Plant: inactive
  Meat: inactive
  Milk: inactive
  Soil: active
  Water: inactive
  Fish: inactive

Model Assumptions
  Water Transport: Nondispersion
```

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 1554 square meters
 LHS Settings: Lognormal-B 1400 1900
 Justification: 1400 m² is the area contour of maximum COC concentration located near the Drainline Outfall (Figure 2-1b). 1900 m² is the area contour in which any COC concentration was detected.

Thickness of cover zone = 0 meters

Density of cover zone = 1.6 grams/cm**3
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Radon diffusion coefficient (cover) = 2e-06 meters/sec
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Radon diffusion coefficient (contaminated) = 2e-06 meters/sec
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Depth of soil mixing area = 0.15 meters
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Radon emanation factor = 0.2
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Occupancy and shielding factor, external gamma = 0.496157
 LHS Settings: Normal-B 0.23 0.33
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite, 25 to 50% indoor occupancy at 70% outside exposure Yu, 1992.

Occupancy factor, dust inhalation = 0.489403
 LHS Settings: Normal-B 0.3 0.6
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite, 25 to 50% indoor occupancy at 40% outside exposure Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape factor for external gamma = 1
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Radon vertical dimension of mixing = 2 meters
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Inhalation rate = 9496.96 meters**3/year
 LHS Settings: Normal-B 3600 1.1e+04
 Justification: EPA, 1989

Length parallel to aquifer flow = 57.4 meters
Justification: Nonstochastic parameter correlated to the contamination area
Yu, 1992.

Dilution length for inhalation = 3 meters
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Mass loading for inhalation = 4.41948e-05 grams/meter**3
LHS Settings: Lognormal-B 9e-06 0.0004
Justification: Yu, 1992.

Fractional water content (cover) = 0.05
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil ingestion rate = 18.25 grams/year
Justification: EPA, 1989

Thickness of contaminated zone = 0.173995 meters
LHS Settings: Lognormal-B 0.025 1
Justification: Surface contamination from approx. 1 inch to approx. 3 ft.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Conservative assumption to overestimate retention of
contamination on the site.

Average annual wind speed = 2 meters/sec
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Basic Radiation Dose Limit = 25 millirem/year
Justification: DOE, 1988

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 3 years
Time step - 3 = 5 years
Time step - 4 = 10 years
Time step - 5 = 30 years
Time step - 6 = 100 years
Time step - 7 = 300 years
Time step - 8 = 500 years
Time step - 9 = 1000 years

Soil b-parameter of contaminated zone = 2.99888
LHS Settings: Lognormal-B 0.4 10.3
Justification: SNL/NM, 1991. Monitoring Well MW-4, Chemical Waste Landfill.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of contaminated zone = 1.48044 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Yu et al. 1992.

Density of saturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.207437
LHS Settings: Normal-B 0.13 0.3
Justification: Yu et al. 1992.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 125 meters
Justification: Conservative (lower) value measure at the Chemical Waste
Landfill SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.489796
LHS Settings: Normal-B 0.24 0.57
Justification: Yu et al., 1992.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of cover material = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00460367 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is assigned to infiltration.

Shape Parameters (0.564 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (1.784 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (2.523 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (3.989 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (5.642 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (7.979 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (12.62 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (17.84 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (39.89 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (56.42 m) = 1
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (178.4 m) = 0
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Shape Parameters (564.2 m) = 0
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Time since placement for guidelines = 0 years

```
*****  
**  
**                               Nuclide Summary                               **  
** (+D indicates daughters are included in dose calculation) **  
**  
*****
```

Ac-227+D Initial Concentration (Soil) = 0

Ac-227+D Initial Concent. (Water/Soil) = 0

Ac-227+D Kd in Contaminated Zone = 450
Justification:Sheppard, 1990

Ac-227+D Kd in Unsaturated Zone = 450
Justification:Sheppard, 1990

Ac-227+D Kd in Saturated Zone = 450
Justification:Sheppard, 1990

Co-60 Initial Concentration (Soil) = 0.24
LHS Settings: Lognormal-B 0.00233 36.4

Co-60 Initial Concent. (Water/Soil) = 0

Co-60 Kd in Contaminated Zone = 60
Justification:Sheppard, 1990

Co-60 Kd in Unsaturated Zone = 60
Justification:Sheppard, 1990

Co-60 Kd in Saturated Zone = 60
Justification:Sheppard, 1990

Cs-137+D Initial Concentration (Soil) = 0.78
LHS Settings: Lognormal-B 0.003414 81.61

Cs-137+D Initial Concent. (Water/Soil) = 0

Cs-137+D Kd in Contaminated Zone = 0.2
Justification:Sheppard, 1990

Cs-137+D Kd in Unsaturated Zone = 0.2
Justification:Sheppard, 1990

Cs-137+D Kd in Saturated Zone = 0.2
Justification:Sheppard, 1990

H-3 Initial Concentration (Soil) = 0.4
LHS Settings: Lognormal-B 0.01488 0.5772

H-3 Initial Concent. (Water/Soil) = 0

H-3 Kd in Contaminated Zone = 0

H-3 Kd in Unsaturated Zone = 0

H-3 Kd in Saturated Zone = 0

Pa-231 Initial Concentration (Soil) = 0

Pa-231 Initial Concent. (Water/Soil) = 0

Pa-231 Kd in Contaminated Zone = 0

Pa-231 Kd in Unsaturated Zone = 0

Pa-231 Kd in Saturated Zone = 0

U-235+D Initial Concentration (Soil) = 1.77
LHS Settings: Lognormal-B 0.01469 3.848

U-235+D Initial Concent. (Water/Soil) = 0

U-235+D Kd in Contaminated Zone = 0.3
Justification:Sheppard, 1990

U-235+D Kd in Unsaturated Zone = 0.3
Justification:Sheppard, 1990

U-235+D Kd in Saturated Zone = 0.3
Justification:Sheppard, 1990

```

*****
**
**           Ground External Gamma Effective           **
**           Dose Conversion Factors                 **
**           (mrem/yr) / (pCi/cm**3)                **
**
*****

```

Ac-227+D	soil density = 1.0 g/cm**3	2.7600E+00
Ac-227+D	soil density = 1.8 g/cm**3	1.5200E+00
Co-60	soil density = 1.0 g/cm**3	2.2700E+01
Co-60	soil density = 1.8 g/cm**3	1.2500E+01
Cs-137+D	soil density = 1.0 g/cm**3	5.0300E+00
Cs-137+D	soil density = 1.8 g/cm**3	2.7700E+00
H-3	soil density = 1.0 g/cm**3	0.0000E+00
H-3	soil density = 1.8 g/cm**3	0.0000E+00
Pa-231	soil density = 1.0 g/cm**3	2.2100E-01
Pa-231	soil density = 1.8 g/cm**3	1.2100E-01
U-235+D	soil density = 1.0 g/cm**3	8.9400E-01
U-235+D	soil density = 1.8 g/cm**3	4.9000E-01

```

*****
**
**                               Depth Factors for External          **
**                               Gamma Radiation from Ground         **
**                               (dimensionless)                      **
*****
Ac-227+D soil density = 1.0 g/cm**3, thickness = .15m 7.9000E-01
Ac-227+D soil density = 1.0 g/cm**3, thickness = 0.5m 9.7000E-01
Ac-227+D soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Ac-227+D soil density = 1.8 g/cm**3, thickness = .15m 9.1000E-01
Ac-227+D soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Ac-227+D soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
Co-60 soil density = 1.0 g/cm**3, thickness = .15m 6.8000E-01
Co-60 soil density = 1.0 g/cm**3, thickness = 0.5m 1.0000E+00
Co-60 soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Co-60 soil density = 1.8 g/cm**3, thickness = .15m 8.6000E-01
Co-60 soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Co-60 soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
Cs-137+D soil density = 1.0 g/cm**3, thickness = .15m 7.2000E-01
Cs-137+D soil density = 1.0 g/cm**3, thickness = 0.5m 9.8000E-01
Cs-137+D soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Cs-137+D soil density = 1.8 g/cm**3, thickness = .15m 9.1000E-01
Cs-137+D soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Cs-137+D soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
H-3 soil density = 1.0 g/cm**3, thickness = .15m 1.0000E+00
H-3 soil density = 1.0 g/cm**3, thickness = 0.5m 1.0000E+00
H-3 soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
H-3 soil density = 1.8 g/cm**3, thickness = .15m 1.0000E+00
H-3 soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
H-3 soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
Pa-231 soil density = 1.0 g/cm**3, thickness = .15m 7.9000E-01
Pa-231 soil density = 1.0 g/cm**3, thickness = 0.5m 1.0000E+00
Pa-231 soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
Pa-231 soil density = 1.8 g/cm**3, thickness = .15m 9.2000E-01
Pa-231 soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
Pa-231 soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00
U-235+D soil density = 1.0 g/cm**3, thickness = .15m 8.7000E-01
U-235+D soil density = 1.0 g/cm**3, thickness = 0.5m 1.0000E+00
U-235+D soil density = 1.0 g/cm**3, thickness = 1.5m 1.0000E+00
U-235+D soil density = 1.8 g/cm**3, thickness = .15m 1.0000E+00
U-235+D soil density = 1.8 g/cm**3, thickness = 0.5m 1.0000E+00
U-235+D soil density = 1.8 g/cm**3, thickness = 1.5m 1.0000E+00

```

```

*****
**
**           Inhalation (dust) Effective
**           Dose Conversion Factors
**           (mrem/yr) / (pCi/cm**3)
**
*****

```

Ac-227+D	6.7000E+00
Co-60	1.5000E-04
Cs-137+D	3.2000E-05
H-3	6.3000E-08
Pa-231	1.3000E+00
U-235+D	1.2000E-01

```

*****
**
**           Ingestion Effective Dose Conversion Factors
**           (mrem/yr) / (pCi/cm**3)
**
*****

```

Ac-227+D	1.5000E-02
Co-60	2.6000E-05
Cs-137+D	5.0000E-05
H-3	6.3000E-08
Pa-231	1.1000E-02
U-235+D	2.5000E-04

References

- Sandia National Laboratories/New Mexico (SNL/NM), 1991. Compliance Agreement Final Report: Hydrogeological Characterization (Chemical Waste Landfill). Environmental Impact and Restoration Division. Sandia National Laboratories/New Mexico, Albuquerque, New Mexico.
- Sheppard, M. I., Thibault, D. H., 1990, Default Soil Solid/Liquid Partition Coefficients, K_d S, for Four Major Soil Types: A Compendium, Health Physics, 59, 471-482.
- U.S. Department of Energy (DOE), 1988. Department of Energy Order 5820.2A, Radioactive Waste Management, U.S. Department of Energy, Office of Defense Waste and Transportation Management, Washington, D.C.
- U.S. Environmental Protection Agency (EPA), 1989. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, US , Office of Emergency and Remedial Response, Washington, D.C.
- Yu. C., Loureiro, C., Cheng, J.-J., Jones, L. G., Wang, Y. Y., Chia, Y. P., Faillace, E., 1992. Data Collection Handbook for Establishing Residual Radioactive Material Guidelines with RESRAD (Draft). U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Table B-2
Précis Input Parameters for
Incremental Lifetime Cancer Risk (ICR) Calculations

```
*****  
**                                                                 **  
**           Monte Carlo Simulation Summary Report           **  
**                                                                 **  
*****
```

Date of simulation: Thu Jun 15 16:33:20 1995

Total number of runs: 100 LHS Seed: 256

```
*****  
**                                                                 **  
**           Précis Summary of Inputs           **  
**                                                                 **  
*****
```

Site Name: ER 4 Metals Chemical Carcinogens

Land Use Scenario: Industrial

Pathway Selections:
 Gamma: inactive
 Dust: active
 Radon: inactive
 Plant: inactive
 Meat: inactive
 Milk: inactive
 Soil: active
 Water: inactive
 Fish: inactive

Model Assumptions
 Water Transport: Nondispersion

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 1550 square meters
 LHS Settings: Lognormal-B 1400 1900
 Justification: 1400 m² is the area contour of maximum COC concentration located near the Drainline Outfall (Figure 2-1b). 1900 m² is the area contour in which any COC concentration was detected.

Thickness of cover zone = 0 meters

Density of cover zone = 1.57875 grams/cm³
 LHS Settings: Normal-B 1.3 1.7
 Justification: Yu et al. 1992.

Depth of soil mixing area = 0.15 meters
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Fraction of time spent indoors = 0.5
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Occupancy factor, dust inhalation = 0.589704
 LHS Settings: Normal-B 0.3 0.6
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite, 25 to 50% indoor occupancy at 40% outside exposure Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Inhalation rate = 4343.05 meters³/year
 LHS Settings: Normal-B 3600 1.1e+04
 Justification: EPA, 1989, Yu et al, 1992.

Length parallel to aquifer flow = 55 meters
 LHS Settings: Lognormal-B 54.5 60.3
 Justification: Correlated to the contamination area.

Dilution length for inhalation = 1.84955 meters
 LHS Settings: Lognormal-B 0.03 250
 Justification: Gilbert et al, 1989.

Mass loading for inhalation = 0.000108647 grams/meter³
 LHS Settings: Uniform 9e-06 0.0004
 Justification: Yu et al, 1992.

Soil ingestion rate = 10 grams/year
 LHS Settings: Normal-B 0.0365 12.5
 Justification: EPA, 1989

Thickness of contaminated zone = 0.107951 meters
 LHS Settings: Lognormal-B 0.025 0.61
 Justification: Assumed surface contamination from approx. 1 inch to 2 ft.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Conservative assumption to overestimate retention of contamination on the site.

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 3 years
Time step - 3 = 5 years
Time step - 4 = 10 years
Time step - 5 = 20 years
Time step - 6 = 30 years
Time step - 7 = 100 years
Time step - 8 = 300 years
Time step - 9 = 500 years

Soil b-parameter of contaminated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Density of contaminated zone = 1.49595 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Density of saturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 137.604 meters
LHS Settings: Normal-B 124.7 150.9
Justification: Measurements made at the Chemical Waste Landfill SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00459136 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is
assigned to infiltration.

Time since placement for guidelines = 0 years

Basic Cancer Risk Limit = $1e-06$
Justification: EPA, 1989

Basic Hazard Index Limit = 1
Justification: EPA, 1989

Basic Chemical Intake Limit = 100 mg/kg-day

 **
 ** Chemical Summary **
 **

Cadmium (diet) Initial Concentration (Soil) = 0.013
 LHS Settings: Lognormal-B 1.148e-05 0.4802

Cadmium (diet) Initial Concent. (Water/Soil) = 0

Cadmium (diet) Kd in Contaminated Zone = 7
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Cadmium (diet) Kd in Unsaturated Zone = 7
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Cadmium (diet) Kd in Saturated Zone = 7
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Chromium(VI) Initial Concentration (Soil) = 0.0016
 LHS Settings: Lognormal-B 6.51e-06 0.03517

Chromium(VI) Initial Concent. (Water/Soil) = 0

Chromium(VI) Kd in Contaminated Zone = 1.7
 Justification: Sheppard, 1990.

Chromium(VI) Kd in Unsaturated Zone = 1.7
 Justification: Sheppard, 1990.

Chromium(VI) Kd in Saturated Zone = 1.7
 Justification: Sheppard, 1990.

Polychlorinated Biphenyls Initial Concentration (Soil) = 4.782e-05
 LHS Settings: Lognormal-B 2.138e-05 5.532e-05

Polychlorinated Biphenyls Initial Concent. (Water/Soil) = 0

Polychlorinated Biphenyls Kd in Contaminated Zone = 0

Polychlorinated Biphenyls Kd in Unsaturated Zone = 0

Polychlorinated Biphenyls Kd in Saturated Zone = 0

```

*****
**
**                               Intake Conversion Factors                               **
**                               (yr/kg-day)                                           **
*****

```

```

CADMIUM (DIET)           soil ingestion conversion factor,      1.4000E-05
CADMIUM (DIET)           dust inhalation conversion factors,    1.4000E-05
CADMIUM (DIET)           ingestion inhalation convers. factors, 1.4000E-05
CHROMIUM (VI)            soil ingestion conversion factor,      1.4000E-05
CHROMIUM (VI)            dust inhalation conversion factors,    1.4000E-05
CHROMIUM (VI)            ingestion inhalation convers. factors, 1.4000E-05
POLYCHLORINATED BIPHENYLS soil ingestion conversion factor,      1.4000E-05
POLYCHLORINATED BIPHENYLS dust inhalation conversion factors,    1.4000E-05
POLYCHLORINATED BIPHENYLS ingestion inhalation convers. factors, 1.4000E-05

```

```

*****
**
**                               Cancer Slope Factors                               **
**                               (yr/kg-day)                                           **
*****

```

```

CADMIUM (DIET)           cancer slope factors for dust inhalation 6.1000E+00
CADMIUM (DIET)           cancer slope factors for ingestion      0.0000E+00
CHROMIUM (VI)            cancer slope factors for dust inhalation 4.1000E+01
CHROMIUM (VI)            cancer slope factors for ingestion      0.0000E+00
POLYCHLORINATED BIPHENYLS cancer slope factors for dust inhalation 0.0000E+00
POLYCHLORINATED BIPHENYLS cancer slope factors for ingestion      7.7000E+00

```

References

Gilbert, T. L., Yu, C., Yuan, Y. C., Zielen, A. J., Jusko, M. J., Wallo III, A., 1989. A Manual for Implementing Residual Radioactive Material Guidelines. U.S. Department of Energy, Argonne National Laboratory ANL/ES-160, DOE/CH/8901, Argonne National Laboratory, Argonne, Illinois.

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Sheppard, M. I., Thibault, D. H., 1990, Default Soil Solid/Liquid Partition Coefficients, K_d S, for Four Major Soil Types: A Compendium, Health Physics, 59, 471-482.

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

Yu. C., Loureiro, C., Cheng, J.-J., Jones, L. G., Wang, Y. Y., Chia, Y. P., Faillace, E., 1992. Data Collection Handbook for Establishing Residual Radioactive Material Guidelines with RESRAD (Draft). U.S. Department of Energy, Argonne National Laboratory, Argonne, Illinois.

Table B-3
Précis Input Parameters for
Hazard Index (HI) Calculations

```
*****  
**  
**           Monte Carlo Simulation Summary Report           **  
**  
*****
```

Date of simulation: Fri Jun 16 10:02:10 1995
Total number of runs: 100 LHS Seed: 256

```
*****  
**  
**           Précis Summary of Inputs           **  
**  
*****
```

Site Name: ER 4 Metals Chemical Hazard

Land Use Scenario: Industrial

Pathway Selections:
 Gamma: inactive
 Dust: active
 Radon: inactive
 Plant: inactive
 Meat: inactive
 Milk: inactive
 Soil: active
 Water: inactive
 Fish: inactive

Model Assumptions
 Water Transport: Nondispersion

 **
 ** Parameter Summary **
 **

Area of contaminated zone = 1550 square meters
 LHS Settings: Lognormal-B 1400 1900
 Justification: 1400 m² is the area contour of maximum COC concentration located near the Drainline Outfall (Figure 2-1b). 1900 m² is the area contour in which any COC concentration was detected.

Thickness of cover zone = 0 meters

Density of cover zone = 1.61204 grams/cm**3
 LHS Settings: Normal-B 1.3 1.7
 Justification: Yu et al, 1992.

Depth of soil mixing area = 0.15 meters
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Fraction of time spent indoors = 0.5
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Occupancy factor, dust inhalation = 0.354503
 LHS Settings: Normal-B 0.3 0.6
 Justification: Calculated assuming 10 to 50% outdoor occupancy onsite, 25 to 50% indoor occupancy at 40% outside exposure Yu, 1992.

Fraction of time outdoors = 0.25
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Hydraulic gradient of saturated zone = 0.02
 Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Inhalation rate = 7003.86 meters**3/year
 LHS Settings: Normal-B 3600 1.1e+04
 Justification: EPA, 1989; Yu et al, 1992.

Length parallel to aquifer flow = 56.3345 meters
 Justification: Correlated to the contamination area.

Dilution length for inhalation = 4.22974 meters
 LHS Settings: Lognormal-B 0.03 250
 Justification: Gilbert et al, 1989.

Mass loading for inhalation = 0.000352143 grams/meter**3
 LHS Settings: Uniform 9e-06 0.0004
 Justification: Yu et al, 1992.

Soil ingestion rate = 10 grams/year
LHS Settings: Normal-B 0.0365 12.5
Justification: EPA, 1989

Thickness of contaminated zone = 0.10084 meters
LHS Settings: Lognormal-B 0.025 0.61
Justification: Assumed surface contamination from approx. 1 inch to 2 ft.

Erosion rate of contaminated zone = 1e-09 meters/year
Justification: Conservative assumption to overestimate retention of contamination on the site.

Time since placed = 0 years

Time step - 1 = 1 years
Time step - 2 = 5 years
Time step - 3 = 10 years
Time step - 4 = 20 years
Time step - 5 = 30 years
Time step - 6 = 100 years
Time step - 7 = 300 years
Time step - 8 = 500 years
Time step - 9 = 1000 years

Soil b-parameter of contaminated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Soil b-parameter of saturated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Soil b-parameter of unsaturated zone = 5.3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Density of contaminated zone = 1.40021 grams/cm**3
LHS Settings: Normal-B 1.3 1.7
Justification: Yu et al, 1992.

Density of saturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Density of unsaturated zone = 1.6 grams/cm**3
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of contaminated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of saturated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Effective porosity of unsaturated zone = 0.2
Justification: Precis default, nonstochastic parameter consistent with SNL/NM-specific value.

Thickness of unsaturated zone = 144.469 meters
LHS Settings: Normal-B 124.7 150.9
Justification: Measurements made at the Chemical Waste Landfill
SNL/NM, 1991.

Hydraulic conductivity of contaminated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of saturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Hydraulic conductivity of unsaturated zone = 100 meters/year
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of contaminated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of saturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Total porosity of unsaturated zone = 0.4
Justification: Precis default, nonstochastic parameter
consistent with SNL/NM-specific value.

Evapotranspiration Coefficient = 0
Justification: Conservative assumption in which no water is evaporated and
all precipitation is assigned to infiltration.

Precipitation = 0.00459136 meters/year
LHS Settings: Lognormal-B 0.0009 0.02
Justification: Conservative assumption in which all precipitation is
assigned to infiltration.

Time since placement for guidelines = 0 years

Basic Cancer Risk Limit = 1e-06
Justification: EPA, 1989

Basic Hazard Index Limit = 1
Justification: EPA, 1989

Basic Chemical Intake Limit = 100 mg/kg-day

 **
 ** Chemical Summary **
 **

Barium Initial Concentration (Soil) = 0.02580
 LHS Settings: Lognormal-B 0.02462 0.3067

Barium Initial Concent. (Water/Soil) = 0

Barium Kd in Contaminated Zone = 0

Barium Kd in Unsaturated Zone = 0

Barium Kd in Saturated Zone = 0

Cadmium (diet) Initial Concentration (Soil) = 0.0291612
 LHS Settings: Lognormal-B 1.148e-05 0.4802

Cadmium (diet) Initial Concent. (Water/Soil) = 0

Cadmium (diet) Kd in Contaminated Zone = 78.1485
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Cadmium (diet) Kd in Unsaturated Zone = 23.4616
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Cadmium (diet) Kd in Saturated Zone = 231.167
 LHS Settings: Lognormal-B 2.7 2450
 Justification: Sheppard, 1990.

Chromium(III) Initial Concentration (Soil) = 0.0165372
 LHS Settings: Lognormal-B 0.001917 0.0909

Chromium(III) Initial Concent. (Water/Soil) = 0

Chromium(III) Kd in Contaminated Zone = 89.6126
 LHS Settings: Lognormal-B 1.7 1723
 Justification: Sheppard, 1990.

Chromium(III) Kd in Unsaturated Zone = 32.4082
 LHS Settings: Lognormal-B 1.7 1723
 Justification: Sheppard, 1990.

Chromium(III) Kd in Saturated Zone = 10.3225
 LHS Settings: Lognormal-B 1.7 1723
 Justification: Sheppard, 1990.

Chromium(VI) Initial Concentration (Soil) = 0.000596163
 LHS Settings: Lognormal-B 6.52e-06 0.03517

Chromium(VI) Initial Concent. (Water/Soil) = 0

Chromium(VI) Kd in Contaminated Zone = 1.7
 Justification: Sheppard, 1990.

Chromium(VI) Kd in Unsaturated Zone = 1.7
 Justification: Sheppard, 1990.

Chromium(VI) Kd in Saturated Zone = 1.7
Justification: Sheppard, 1990.

Nickel (metallic) Initial Concentration (Soil) = 0.0806179
LHS Settings: Lognormal-B 0.0008244 0.209

Nickel (metallic) Initial Concent. (Water/Soil) = 0

Nickel (metallic) Kd in Contaminated Zone = 0

Nickel (metallic) Kd in Unsaturated Zone = 0

Nickel (metallic) Kd in Saturated Zone = 0

Zinc (Metallic) Initial Concentration (Soil) = 0.0446061
LHS Settings: Lognormal-B 0.006916 0.2861

Zinc (Metallic) Initial Concent. (Water/Soil) = 0

Zinc (Metallic) Kd in Contaminated Zone = 9.02842
LHS Settings: Lognormal-B 0.1 1e+05
Justification: Sheppard, 1990

Zinc (Metallic) Kd in Unsaturated Zone = 1986.42
LHS Settings: Lognormal-B 0.1 1e+05
Justification: Sheppard, 1990

Zinc (Metallic) Kd in Saturated Zone = 32.4644
LHS Settings: Lognormal-B 0.1 1e+05
Justification: Sheppard, 1990

 **
 ** Intake Conversion Factors **
 ** (yr/kg-day) **

BARIUM	soil ingestion conversion factor,	3.9200E-05
BARIUM	dust inhalation conversion factors,	3.9200E-05
BARIUM	ingestion inhalation convers. factors,	3.9200E-05
CADMIUM (DIET)	soil ingestion conversion factor,	3.9200E-05
CADMIUM (DIET)	dust inhalation conversion factors,	3.9200E-05
CADMIUM (DIET)	ingestion inhalation convers. factors,	3.9200E-05
CHROMIUM(III)	soil ingestion conversion factor,	3.9200E-05
CHROMIUM(III)	dust inhalation conversion factors,	3.9200E-05
CHROMIUM(III)	ingestion inhalation convers. factors,	3.9200E-05
CHROMIUM(VI)	soil ingestion conversion factor,	3.9200E-05
CHROMIUM(VI)	dust inhalation conversion factors,	3.9200E-05
CHROMIUM(VI)	ingestion inhalation convers. factors,	3.9200E-05
NICKEL (METAL)	soil ingestion conversion factor,	3.9200E-05
NICKEL (METAL)	dust inhalation conversion factors,	3.9200E-05
NICKEL (METAL)	ingestion inhalation convers. factors,	3.9200E-05
ZINC (METAL)	soil ingestion conversion factor,	3.9200E-05
ZINC (METAL)	dust inhalation conversion factors,	3.9200E-05
ZINC (METAL)	ingestion inhalation convers. factors,	3.9200E-05

```

*****
**
**          Reference Doses          **
**          (mg/kg-day)             **
*****

```

BARIUM	reference doses for dust inhalation	1.4300E-04
BARIUM	reference doses for ingestion	7.0000E-02
CADMIUM (DIET)	reference doses for dust inhalation	0.0000E+00
CADMIUM (DIET)	reference doses for ingestion	1.0000E-03
CHROMIUM(III)	reference doses for dust inhalation	0.0000E+00
CHROMIUM(III)	reference doses for ingestion	1.0000E+00
CHROMIUM(VI)	reference doses for dust inhalation	0.0000E+00
CHROMIUM(VI)	reference doses for ingestion	5.0000E-03
NICKEL (METAL)	reference doses for dust inhalation	0.0000E+00
NICKEL (METAL)	reference doses for ingestion	2.0000E-02
ZINC (METAL)	reference doses for dust inhalation	0.0000E+00
ZINC (METAL)	reference doses for ingestion	3.0000E-01

References

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APPENDIX C

TOXICITY PROFILES FOR CONSTITUENTS OF CONCERN

Classification of Human Carcinogens

A classification system for carcinogens describes uncertainties in available epidemiological and toxicological data. This "weight of evidence" classification is based on the thoroughness and appropriateness of available data. The classification system is as follows (EPA 1994):

Classification Group	Description
A	Human Carcinogen
B1 available	Probable human carcinogen; limited human data
B2	Probable human carcinogen; based on animal data only
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity to humans.

All radionuclides are considered to be carcinogens (Group A). The carcinogenicity of radionuclides is assumed to exceed their systemic toxicity (EPA 1994).

RADIONUCLIDE CONTAMINANTS

Cesium-137

Although this fission product is a pure beta emitter, its short lived daughter barium-137m, is a high energy, high intensity gamma emitter. This daughter makes cesium-137 an important external exposure hazard. Cesium-137 has a physical half-life of 30.2 years. Cesium that is inhaled or ingested is readily and almost completely absorbed into blood and distributed uniformly in the body. Approximately 10 percent of absorbed cesium is cleared form the body with a half-time of approximately 2 days and the remaining 90 percent is cleared with a half-time of approximately 110 days (ICRP 1979).

Cobalt-60

Cobalt-60 emits high energy gamma radiation. Therefore, the radionuclide is an important external exposure hazard. Cobalt-60 has a physical half-life of 5.27 years. Inhaled insoluble cobalt compounds are retained in lung for long periods of time. Soluble cobalt compounds that are ingested are only poorly absorbed into the body. For the purposes of evaluating radiation dose, it is assumed that approximately 80 percent of the absorbed cobalt is located in the liver and the remaining 20 percent is uniformly distributed throughout the rest of the body. This cobalt located in tissues other than lung is assumed to be removed from the body with half-times of 6 to 800 days (ICRP 1979).

Tritium

Tritium (H-3) is both a primordial and anthropogenic isotope. Tritium decays with a half-life of 12.3 years and emits only low-energy beta radiation. Tritium has no radioactive daughters. Tritium is readily oxidized in the environment and exchanged with water to form HTO (NCRP 1979). As a result, HTO is quickly and completely absorbed by inhalation, ingestion, and by direct contact with the skin. Absorbed HTO is distributed uniformly in the body and is eliminated with a half-times of approximately 10 days, primarily by urinary excretion (NCRP 1979).

Uranium-235

Uranium-235 is either a natural or anthropogenic isotope and is the parent of a long decay chain. Uranium-235 is primarily an alpha emitter with a half-life of 7.0×10^8 years. Retention of inhaled uranium compounds is determined by solubility. Inhaled insoluble compounds are retained in lung for long periods of time. Soluble compounds are readily absorbed into blood. Of the absorbed uranium, approximately 12 percent is translocated to kidney and 20 percent is translocated to bone. An additional 12 percent is distributed throughout the body and the remainder is excreted (ICRP 1979). Ingested soluble uranium compounds behave in the same manner; but are only poorly absorbed to blood from the gastrointestinal tract.

CHEMICAL CONTAMINANTS

Barium, CASRN 7440-39-3

Barium is relatively abundant in nature and occurs in plant and animal tissue. From soluble compounds, barium is absorbed in small quantities into the human body and retained there. The daily intake is about 0.75 mg, but the retention time is short, probably less than a day (ICRP 1975). The considerable oral toxicity of barium is usually masked by the low solubility of most barium compounds. In soluble form, however, it leads to gastroenteritis and effects on the heartbeat, up to and including ventricular fibrillations (Doull et al. 1991). By inhalation, barium ores lead to mild pneumoconiosis, which is usually reversible after termination of exposure.

Cadmium, CASRN 7440-43-9

Cadmium is a metal that has toxic effects similar to those of lead and its compounds. It is present in most foods and tissues, leading to an average daily intake of about 0.2 mg (ICRP 1975). Intake of cadmium and its compounds can occur by inhalation or ingestion. The kidney is the most sensitive organ and is damaged by excessive loss of both low and high molecular mass proteins (proteinuria). A number of effects in other organs, such as the lung, have also been reported. In the lung, tissue loss occurs at high exposures and chronic tissue inflammation occurs at lower levels, leading to emphysematous and fibrotic changes (Doull et al. 1991).

There is sufficient evidence of carcinogenicity in humans to classify cadmium as a Class B1 inhalation carcinogen. Although excess lung cancer risks were observed in epidemiological

studies, confounding factors, such as smoking, were not sufficiently accounted for to support classification as a Class A carcinogen. There is no evidence for carcinogenicity associated with chronic cadmium ingestion.

Chromium(III), CASRN 16065-83-1

Although chromium exists in several valence states, only the trivalent and hexavalent states are biologically significant. Chromium(III) compounds are less toxic than chromium(VI) forms. There is no evidence that chromium(III) is converted to chromium(VI) in biological systems. Chromium(III) is a systemic toxicant to the kidney. Acute exposure to either trivalent or hexavalent chromium compounds causes dermatitis, penetrating ulcers on the hands and forearms, perforation of the nasal septum, and inflammation of the larynx and liver (Doull et al. 1991).

Chromium(VI), CASRN 18540-29-9

Chromium(VI) is a Class A carcinogen (EPA 1994). Epidemiologic studies indicate that inhalation exposure to chromate results in bronchogenic carcinoma. The relative risk to chromate plant workers in the development of respiratory cancer is greater than in the general population (Doull et al. 1991).

Lead and Inorganic Lead Compounds, CASRN 7439-92-1

The toxicity of lead and its compounds has been investigated extensively. Lead is a contaminant in most foods, resulting in a daily intake of about 0.4 mg (ICRP 1975). Toxic effects of lead to the central nervous system, the peripheral nervous system, the kidneys, and the blood have been reported. Because its toxicity apparently does not exhibit a threshold, the EPA has published no oral RfDs for lead.

There is sufficient evidence of carcinogenicity in animal experiments with lead compounds to classify lead and its inorganic compounds as probable human carcinogens, Class B2. Kidney tumors were observed in these experiments at high doses. However, as a result of dosimetry uncertainties, no estimates for the slope factors are available at present.

Nickel and Soluble Salts, CASRN 117-81-7

Nickel occurs in the normal human diet, particularly vegetables and grains. Daily mean dietary intake is 0.2 to 0.6 mg (ICRP 1975). At high exposure levels, nickel is a skin irritant and ingestion leads to intestinal disorders. The systemic toxicity of nickel depends strongly on its chemical form. Nickel carbonyl is a highly toxic vapor, while other forms are only moderately toxic by ingestion (Doull et al. 1991).

Some nickel compounds, such as nickel carbonyl and nickel subsulfide, are designated as Class A carcinogens based on lung and nasal cancer observed in nickel refinery workers. These observations have been confirmed in laboratory animal experiments. No slope factor for nickel ingestion is available.

PCBs, CASRN 1336-36-3

The class of PCBs consists of a number of different mixtures of many isomers, with chlorine contents ranging from 10 to 70 percent. The acute health effects of PCB fall into two classes; skin effects and toxic action on the liver. A suspected delayed effect is cancer of the liver (Class B2). The effect on the skin is a painful condition called chloracne. The skin and hepatotoxic action of PCBs increases with the chlorine content of the mixture. For aroclor-1260 the chlorine content is about 60 percent (Doull et al. 1991).

Zinc, CASRN 7440-66-6

Zinc is an essential trace nutrient in the human diet and occurs widely in foodstuffs, particularly in meats, seafood, dairy products, and vegetables. The daily intake of zinc through the diet is 6 to 40 mg (ICRP 1975). Some zinc compounds are of low toxicity; but acute exposures can cause dermatitis upon skin contact and intestinal disorders upon ingestion. "Metal fume fever" has been observed upon high-level inhalation exposures, however, no chronic effects of zinc inhalation have been reported. Although some zinc compounds are suspected to be carcinogenic, no slope factors are available. Elemental zinc in itself is not a human carcinogen (Class D) (EPA 1994).

References

Doull, J., C. D. Klaassen, M. O. Amdur, 1991. Cassarett and Doull's Toxicology, Macmillan Publishing Co., New York, Chapter 19.

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U.S. Environmental Protection Agency (EPA), 1994. Integrated Risk Information System (IRIS) Data File, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

APPENDIX D

**ANNUAL RADIATION DOSES FROM RADIONUCLIDES AND
DAILY INTAKES OF HAZARDOUS CHEMICALS FOR
EXPOSURE PATHWAYS ASSUMED IN THE
INDUSTRIAL LAND-USE SCENARIO**

Exposure Pathways

The following example output is from one of the 100 *Précis* simulations described in Section 5.0. As such, the numerical values do not appear in the main text except as included in Tables 5-1 through 5-3.

The exposure pathways shown in the example output are related to the exposure pathways in the conceptual model (Figure 3-1) as follows:

- the *Ground* pathway in the example is the *External Radiation* exposure pathway in Figure 3-1,
- the *Dust* and *Radon* pathways in the example is the *Inhalation* exposure pathway in Figure 3-1, and
- the *Soil* pathway in the example is the *Ingestion* exposure pathway in Figure 3-1.

Because radon is a uranium daughter, the *Radon* inhalation pathway was included for uranium dose estimates but was excluded from cobalt-60, cesium-137, and tritium dose estimates. The *Plant*, *Meat*, *Milk*, *Water*, and *Fish* ingestion pathways below are excluded under the industrial land-use scenario assumptions (Section 3.0).

Table D-1
 Estimated Annual Radiation Dose from Potential Exposure to Radionuclides
 for the Industrial Land-Use Scenario at ER Site 4

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	1599.67 square meters	Co-60	3.704E-02
Thickness:	0.21 meters	Cs-137	1.050E-01
Cover Depth:	0.00 meters	H-3	5.969E-02
		U-235	1.468E-01

Total Dose TDOSE(t), mrem/yr
 Basic Radiation Dose Limit = 25 mrem/yr
 Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	5.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	5.000E+02	1.000E+03
TDOSE(t):	3.963E-01	3.637E-01	3.085E-01	2.642E-01	1.871E-01	7.336E-02	1.367E-02	8.393E-04	6.221E-05	9.326E-08
M(t):	1.585E-02	1.455E-02	1.234E-02	1.057E-02	7.483E-03	2.934E-03	5.468E-04	3.357E-05	2.489E-06	3.730E-09

Maximum TDOSE(t): 3.963E-01 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
 As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
 Water Independent Pathways

Radio- Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.												
Co-60	2.151E-01	0.5427	1.244E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.318E-05	0.0000
Cs-137	1.399E-01	0.3530	7.525E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.184E-05	0.0002
H-3	0.000E+00	0.0000	8.424E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.147E-08	0.0000
U-235	3.678E-02	0.0928	3.947E-03	0.0100	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.024E-04	0.0013
Total	3.918E-01	0.9886	3.949E-03	0.0100	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.875E-04	0.0015

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
 As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
 Water Dependent Pathways

Radio- Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.										
Co-60	0.000E+00	0.0000	2.151E-01	0.5427										
Cs-137	0.000E+00	0.0000	1.400E-01	0.3532										
H-3	0.000E+00	0.0000	5.232E-08	0.0000										
U-235	0.000E+00	0.0000	4.123E-02	0.1040										
Total	0.000E+00	0.0000	3.963E-01	1.0000										

*Sum of all water independent and dependent pathways.

APPENDIX E

**RADIATION DOSES AND DAILY INTAKES OF HAZARDOUS
CHEMICALS ACCORDING TO THE INDUSTRIAL LAND-
USE SCENARIO WITH A TWO METER CLEAN SOIL COVER**

Table E-1
 Estimated Daily Intake from Potential Exposure to Radionuclides for the
 Industrial Land-Use Scenario at ER Site 4 with Two Meters of Clean Cover

Contaminated Zone Dimensions				Initial Soil Concentrations, pCi/g									
Area:	1599.67	square meters		Co-60	3.704E-02								
Thickness:	0.21	meters		Cs-137	1.050E-01								
Cover Depth:	2.00	meters		H-3	5.969E-02								
				U-235	1.468E-01								
Total Dose TDOSE(t), mrem/yr Basic Radiation Dose Limit = 25 mrem/yr Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)													
t (years):	0.000E+00	1.000E+00	3.000E+00	5.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	5.000E+02	1.000E+03			
TDOSE(t):	3.689E-11	3.275E-11	2.581E-11	2.036E-11	1.128E-11	1.184E-12	2.921E-14	1.730E-16	6.993E-17	1.327E-16			
M(t):	1.476E-12	1.310E-12	1.033E-12	8.144E-13	4.513E-13	4.737E-14	1.168E-15	6.921E-18	2.797E-18	5.306E-18			
Maximum TDOSE(t):	3.689E-11 mrem/yr at t = 0.000E+00 years												

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
 As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Radio- Nuclide	Ground		Dust		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.												
Co-60	3.644E-11	0.9877	0.000E+00	0.0000										
Cs-137	4.535E-13	0.0123	0.000E+00	0.0000										
H-3	0.000E+00	0.0000												
U-235	5.298E-22	0.0000	0.000E+00	0.0000										
===== Total	3.689E-11	1.0000	0.000E+00	0.0000										

Appendix A
General Field Procedures

APPENDIX A GENERAL FIELD PROCEDURES

A.1 Radioactive Screening

All field operations conducted at the Liquid Waste Disposal System (LWDS) were supported full-time by qualified health-physics technicians from Department 7714, Radiation Protection. Field screening for radioactive contamination was continuous and included:

- Collecting swipe samples for loose surface contamination,
- Screening with hand-held radiacs for general radiation levels and total surface contamination, and
- Monitoring for airborne radioactive contamination with both general-area and personal air-sampling devices.

All radioactive screening was conducted in accordance with Department 7714-approved procedures.

A.2 Subsurface Soil Sampling

The first sixteen soil borings were drilled with a Barber 70E drill rig modified to use a rotasonic method. Sonic drilling consists of a truck-mounted drill rig with a sonic head that transmits a 10,000-cycle per minute vibration to the core bit through the quill, drill string, and core barrel. Vibrations are generated by two synchronized eccentrics that rotate in opposite directions. Forces cancel each other in the horizontal movements and reinforce each other in the vertical. A diamond button core-bit was attached to the bottom of the core barrel. The drill string was rotated while coring to expose the core-bit's buttons to the full annular area. Four-inch core was collected with a 10-ft steel sample barrel; material under the core-bit was pulverized by the vibrations and moved sideways in the borehole.

The benefit of the rotasonic method is that it does not generate soil cuttings. The drill cuttings are displaced outward in the borehole, not returned to the surface, thus reducing the potential for waste generation. After the potential to generate mixed

waste was better understood, the final two borings were completed using a Failing F-10 auger rig.

Continuous core samples were collected with a 4-in. hollow-stem auger or sonic core barrel. After retrieval, the core samples were immediately sampled for volatile organic contaminants (VOCs) coincident with screening for volatile organics using an organic vapor analyzer (OVA) flame ionization detector (FID), and screened for radioactivity using both the pancake Geiger Müller (GM) detector and a sodium-iodide (NaI) detector.

All cores were photographed and the lithology was described. The core was geologically logged by the U.S. Geological Survey (USGS). The visual characterization included composition of the framework, matrix, bedding, texture, soil moisture, and color, as outlined in Field Operating Procedure (FOP) 94-05 (SNL, 1994a).

Samples for radioactive and chemical analyses were collected from the core at discrete intervals using a stainless-steel trowel that was decontaminated between samples. The samples were placed directly into appropriate sample containers. The core barrels and sampling equipment were decontaminated between each retrieved sample core.

Drill cuttings were placed in appropriate containers dependent upon the expected waste characterization. The boreholes were backfilled to the surface with a mixture of bentonite cement and grout upon completion of the sampling. The grout mixture was added to the bottom of the boring with a tremie pipe as the augers were slowly retracted. To eliminate the potential for hole collapse and ensure the placement of a continuous grout plug, the tremie pipe was maintained below the grout surface.

A.3 Monitoring Well Installation

Monitoring well installation procedures are identical to those described for subsurface soil sampling, with the exception that a Dresser rig was used in place of the original Barber rig. The retrieved core samples were also screened for saturation and grain size to identify any perched zone and subsequent confining layer. If a possible perched zone was identified, drilling stopped and the auger and overshot casing were retracted approximately 2 ft. Operations were held for at least 60 min (usually overnight) to allow

ground water to recharge into the open borehole. Water levels were recorded during the waiting period. Although several possible perched zones were identified, no actual perch zones were encountered. All ground-water monitoring wells were completed at the water table.

Monitoring well LWDS-MW2 was screened with Type 304 stainless-steel as required in the LWDS RCRA Facility Investigation (RFI) work plan (SNL, 1994b). Monitoring well LWDS-MW1 was completed several months after LWDS-MW2. During this time, there was considerable controversy regarding the possible presence of chromium at the Chemical Waste Landfill (CWL). Steel-constructed screens were identified as a possible contributor to the chromium contamination. LWDS-MW1 was completed entirely with Schedule 80 polyvinyl chloride (PVC) pipe to avoid this issue. Each monitoring well was constructed with a 5-ft sump. The sand filter pack was designed based on a sieve grain-size analysis of the aquifer soil. Figures A-1 and A-2 show cross-sectional views of the monitoring wells' construction.

In each well, the remaining riser to the surface was constructed of PVC pipe. All joints were flush threaded and a rubber gasket was placed at each coupling to prevent grout seepage into the well. No adhesives, glues, grease, or their agents were used to secure the couplings. A 10-ft bentonite seal was installed over the filter pack. The bentonite seal was pumped through the tremie pipe using a mixture of a high-viscosity slurry and finely ground bentonite flakes. A select mixture of uniform volclay grout was pumped from the bentonite seal to the ground level to minimize the potential contamination problems during well development. The initial grout mixture was installed in a 20-ft lift using a tremie pipe and allowed to harden for at least 12 hr. The remaining grout was then pumped to the surface. The drill casing was retracted in conjunction with installation of the annular materials to eliminate the potential for borehole collapse.

A 3-ft by 3-ft, 4-in.-thick sloped concrete pad was constructed around each monitoring well. Three 2-in., concrete-filled steel posts are equally spaced around LWDS-MW2. LWDS-MW1, which is in the TA-V parking lot, is sloped to the surrounding pavement.

All development activities were performed in accordance with applicable Environmental Restoration (ER) Project procedures. To reduce the large quantities of water introduced by jetting, swabbing and bailing methods were used for development. Well purging was

GROUND-WATER MONITOR WELL DATA SHEET

WELL NUMBER: LWDS-MW2
 LOCATION: Sandia National Laboratories, Liquid Waste Disposal System
Surface Impoundments
 DATE INSTALLATION COMPLETED: 30OCT92
 DATE OF DEVELOPMENT: 30MAR93
 DRILL METHOD: Sonic air rotary and driven casing

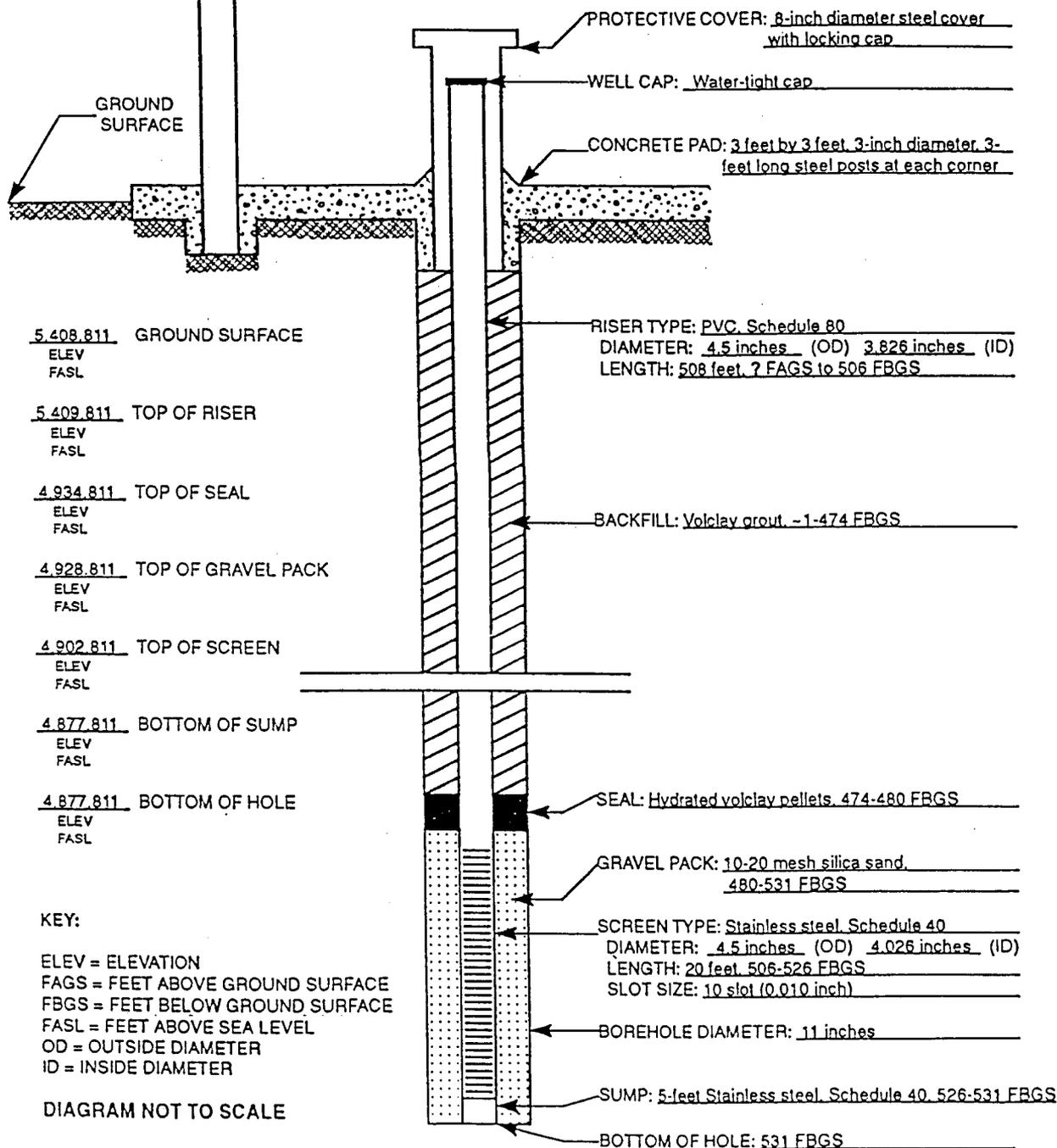


Figure A-1. Cross-Sectional View of Liquid Waste Disposal System Monitoring Well 2 (LWDS-MW2)

GROUND-WATER MONITOR WELL DATA SHEET

WELL NUMBER: LWDS-MW1
 LOCATION: Sandia National Laboratories, Liquid Waste Disposal System, Drain Fields
 DATE INSTALLATION COMPLETED: 03MAY93
 DATE OF DEVELOPMENT: 14JUL93
 DRILL METHOD: Sonic, air rotary, and driven casing

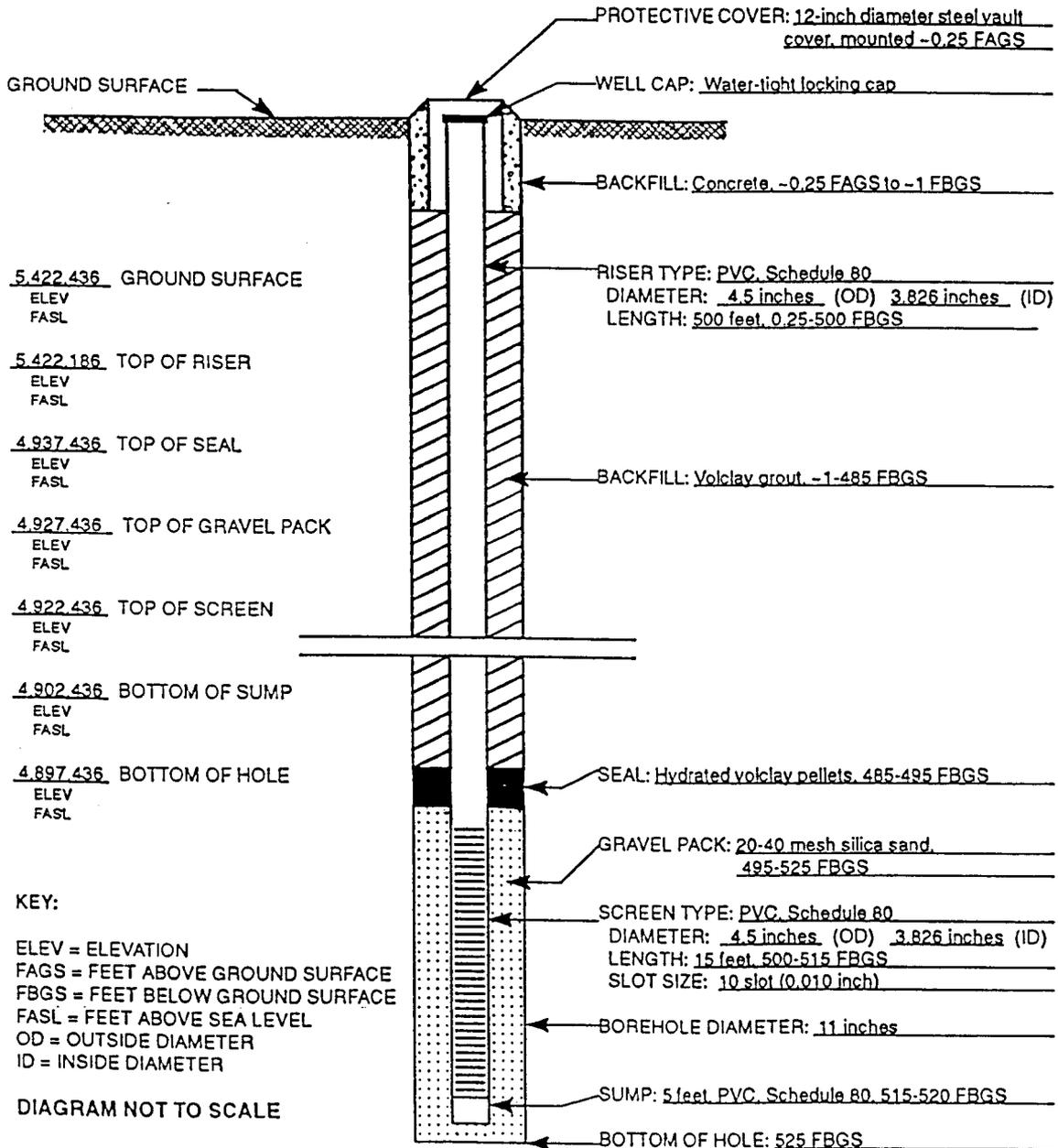


Figure A-2. Cross-Sectional View of Liquid Waste Disposal System Monitoring Well 1 (LWDS-MW1)

accomplished with a submersible pump. The criteria for the completion of well development were based on consistent measurements of pH, conductivity, temperature, and turbidity. Ground-water sampling was performed in accordance with procedures set forth in the *LWDS Ground-Water Sampling and Analysis Plan* (IT, 1994).

Each monitoring well was surveyed for piezometric surface, total depth, and surface elevation. Horizontal and vertical (longitudinal and latitudinal, and elevation) coordinates were surveyed by a certified contractor survey crew with a field team manager overseeing the work. The survey elevations are included in the well construction diagrams (Figures A-1 and A-2).

A.4 Equipment Decontamination

Equipment decontamination was conducted in accordance with FOP 94-26 (SNL, 1994c). All equipment was thoroughly decontaminated between drilling operations and sampling events, and monitored for radioactive contamination. Personnel decontaminated the drilling equipment prior to each use, after drilling each monitoring well, and after completing all drilling activities. The drilling equipment was cleaned with a high-pressure steam cleaner and rinsed with clean water. All reusable sampling utensils were cleaned with trisodium phosphate (TSP) detergent and water, followed by repeated rinsing with distilled water.

A.5 Geological Data Collection

Geologic data were described and recorded following guidelines described in FOP 94-05 (SNL, 1994a). The guidelines describe unconsolidated sediments retrieved as cores and cuttings and include:

- Name of unconsolidated sediment (sand, pebbles, cobbles, etc.).
- Texture as indicated by grain-size distribution (American Geological Institute, 1989, Data Sheet 19.1), particle shape (Compton, 1962), sorting (Compton, 1962), grading, packing (American Geological Institute, 1989, Data Sheets 23.1 and 23.2), and fabric.
- Composition (mineralogy) of larger-grained sediments.
- Color using the rock-color chart (Goddard and others, 1984, 1991).
- Sedimentary structures.

- Degree of consolidation and cementation, presence of caliche or calcium carbonate, reaction with 10 percent hydrochloric acid (HCl).
- Moisture content.
- Description of basal contact.

These lithologic descriptors were limited to those readily visible to the eye or with the use of a 10X hand lens.

In addition to lithologic descriptions, other field observations were made. These observations are reported as written communication, U.S. Geological Survey, Liquid Waste Disposal System Well Installation, Field Notes (1993), and may be accessed through SNL, Environmental Operations Records Center, Albuquerque, New Mexico.

A suite of geophysical logging techniques provided an approximate representation of the borehole lithology, the location of the water table, and other unsaturated zone characteristics. These techniques included gamma-gamma log, neutron log, and induction log.

The gamma-gamma instrument consisted of a 20-Ci americium-241 gamma source with a single detector. With this technique, measured readings in counts per second (cps) are converted by calibration to apparent density values in grams per cubic centimeter (gm/cc). Calibration was conducted before and after logging using blocks of acrylic (1.4 gm/cc) and aluminum (2.65 gm/cc). The gamma-gamma log provided information relative to formation densities within the vicinity of the borehole wall.

Data from the neutron log were used to identify relative porosity values of the formation. A decrease in American Petroleum Institute (API) units represents an increase in relative formation porosity. The neutron tool consists of a 3-Ci americium-241/beryllium (Am-241 Be) neutron source and an epithermal neutron detector. The noncompensating (single-detection) 1-11/16-in. tool used is an omnidirectional instrument that also records data in counts per second. The recorded cps units are converted to API units by normalizing to known and established values.

The induction log measurements were used to assist in identifying lithologic features and water content contrasts.

A.4 References

American Geological Institute, 1989, "Data Sheets for Geology in the Field, Laboratory, and Office: American Geological Institute.

Compton, R. R., 1962, *Manual of Field Geology*, New York, John Wiley and Sons, 378 p.

Goddard, E. N., P. D. Trask, R. K. DeFord, O. N. Rove, J. T. Singewald, R. M. Overbeck, 1984, *Rock-Color Chart*, Geological Society of America, 16 p.

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International Technology Corporation (IT), 1994, "LWDS Ground-Water Monitoring Project Site-Specific Sampling Plan," Project Number 301455.140, IT, Albuquerque, NM (March 1994).

Sandia National Laboratories (SNL), 1994a, "Borehole Lithologic Logging," Field Operating Procedure (FOP) 94-05, Sandia National Laboratories, Albuquerque, NM.

Sandia National Laboratories (SNL), 1994b, "Liquid Waste Disposal System RCRA Facility Investigation Work Plan," Sandia National Laboratories/New Mexico, Albuquerque, NM.

Sandia National Laboratories (SNL), 1994c, "General Equipment Decontamination," Field Operating Procedure (FOP) 94-26, Sandia National Laboratories, Albuquerque, NM.

U.S. Geological Survey (USGS), 1994, "Liquid Waste Disposal System Well Installation, Field Notes, SNL ER for Technical Areas and Miscellaneous Sites," USGS, Albuquerque, NM.

Appendix B

Analytical Program

APPENDIX B ANALYTICAL PROGRAM

The analytical program was devised to evaluate all constituents that were thought to be prevalent in the liquid waste from Technical Area V (TA-V) and some additional compounds possibly discharged when the U.S. Air Force (USAF) used the site. Table B-1 lists the common groupings of the Liquid Waste Disposal System (LWDS) constituents of concern (COCs) and associated analytical methods. Sections B.1 through B.3 further describe the test methods used for the analysis of soil and ground-water samples collected at the site.

Table B-1
Constituents of Concern at the LWDS

Constituent	Analytical Method
Radionuclides	Gamma spectroscopy (for gamma emitters) and EPA Test Method H-01 (for tritium)
Volatile Organic Contaminants (VOCs)	EPA Test Method 8240
Semi-Volatile Organic Contaminants (SVOCs)	EPA Test Method 8270
Metals	Target analyte list (TAL) metals (EPA Test Methods 6010, 7061, 7421, 7470, 7741 and 7841)
Polychlorinated Biphenyls (PCBs)	EPA Test Method 8080

B. 1 Organics

All soil and ground-water samples collected during the LWDS investigation were analyzed for volatile organic contaminants (VOCs) via U.S. Environmental Protection Agency (EPA) Test Method 8240 and for SVOCs via EPA Test Method 8270. As a result of the historical review of impoundment activities, selected samples were also analyzed for polychlorinated biphenyls (PCBs) via EPA Test Method 8080.

Ground-water samples from well LWDS-MW1 were initially analyzed for VOCs via EPA Test Method 8240, which includes both gas chromatography and mass spectrometry analyses. This test method typically has a quantitation limit of 5 micrograms per liter

($\mu\text{g/L}$) or parts per billion (ppb), and historically has been preferred because the presence of organic constituents is verified by a second analytical instrument. Following the identification of trichloroethene (TCE) in well LWDS-MW1 in early 1994, SNL/NM switched to EPA Test Method 8010 for VOCs, which utilizes gas chromatography alone. The detection limit for this analytical method is 0.5 ppb. Verification of sample constituents is achieved by performing a second analysis.

B.2 Metals

Soil and ground-water samples were analyzed for the target analyte list (TAL) metals identified in 40 CFR Part 264 and chromium-VI in some cases. Table B-2 presents a complete list of the metals analyzed and their detection limits.

B.3 Radionuclides

Soil samples were evaluated for the presence of gamma-emitting radionuclides through the use of a one-hour count gamma spectroscopy and for the presence of tritium by EPA Test Method H-01.

Table B-2
Metals Analyses at the LWDS

Metal	EPA Test Method	Detection Limit (mg/kg)
Aluminum	6010	0.20
Antimony	6010	0.60
Arsenic	7061	0.002
Barium	6010	0.02
Beryllium	6010	0.005
Cadmium	6010	0.005
Calcium	6010	0.2
Chromium	6010	0.02
Chromium-VI	7196	0.1
Cobalt	6010	0.02
Copper	6010	0.02
Iron	6010	0.02
Lead	7421	0.003
Magnesium	6010	0.20
Manganese	6010	0.005
Mercury	7470	0.0002
Nickel	6010	0.02
Potassium	6010	0.20
Selenium	7741	0.002
Silver	6010	0.01
Sodium	6010	0.20
Thallium	7841	0.10
Vanadium	6010	0.02
Zinc	6010	0.02
Note: mg/kg = milligrams per kilogram.		

B.4 References

U.S. Environmental Protection Agency (EPA), 1986, "Test Methods for Evaluating Solid Waste," Volume IA: "Laboratory Manual Physical/Chemical Methods," SW-846, Third Edition, EPA, Office of Solid Waste and Emergency Response, Washington, DC (November 1986).

Sandia National Laboratories (SNL), 1994, "Liquid Waste Disposal System RCRA Facility Investigation Work Plan," Sandia National Laboratories, Albuquerque, NM.

Resource Conservation and Recovery Act (RCRA), 40 CFR 264.

