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FINAL DRAFT
LAWRENCE LIVERMORE NATIONAL LABORATORY
LOW-LEVEL WASTE
SYSTEMS PERFORMANCE ASSESSMENT

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**LAWRENCE LIVERMORE NATIONAL LABORATORY
LOW-LEVEL WASTE SYSTEMS
PERFORMANCE ASSESSMENT**

EXECUTIVE SUMMARY

This Low-Level Radioactive Waste (LLW) Systems Performance Assessment (PA) presents a systematic analysis of the potential risks posed by the Lawrence Livermore National Laboratory (LLNL) waste management system. Potential risks to the public and environment are compared to established performance objectives as required by DOE Order 5820.2A.

The report determines the associated maximum individual committed effective dose equivalent (CEDE) to a member of the public from LLW and mixed waste. A maximum annual CEDE of 0.01 mrem could result from routine radioactive liquid effluents. A maximum annual CEDE of 0.003 mrem could result from routine radioactive gaseous effluents. No other pathways for radiation exposure of the public indicated detectable levels of exposure. The dose rate, monitoring, and waste acceptance performance objectives were found to be adequately addressed by the LLNL Program.

A systems analysis of the LLW and mixed waste management operation, required by DOE Order 5820.2A, demonstrates that the LLNL LLW management program has implemented all requirements of the Order with two exceptions:

- 1) Specific programmatic plans to minimize LLW shipments have not been completed. Currently there is a Laboratory wide-effort to complete an engineering study on waste minimization to serve as the basis for identifying and prioritizing additional waste minimization activities and for use in the planning and design of the DWTF.
- 2) Since the vast majority (over 99%) of the LLW at LLNL is LSA waste and because of the variability and rarity of other than LSA waste, there are no specific operational procedures implemented for the preparation and shipment of LLW which is not LSA waste. These procedures are prepared on a case-by-case basis as needed.

The current LLW and mixed waste management system provides a complete basic LLW management system as defined by DOE/LLW-63T (DOE, 1989a). This system results in public and environmental risks and doses which are as low as reasonably achievable (ALARA).

An outline of the cost of this base LLW management system, with projections of future costs and a discussion of closure costs, is provided. The current total system disposal cost for LLW was determined to be approximately \$2.50 per pound which increases to \$9.70 per pound by 1993. Preferred LLW management system options are reviewed with a cost-benefit analysis approach. An ALARA analysis is performed. The long-term solution for the problem of LLW will be addressed by the construction of the DWTF and the implementation of new treatment technologies. The new technologies will be implemented in compliance with EPA requirements, DOE guidance, and LLNL management policy.

The PA demonstrates that LLNL has implemented a LLW management system adequate to the requirements of DOE Order 5820.2A and that the performance objectives are being met by a factor of approximately 2,500. DOE LLW is being managed on a systematic basis at LLNL using waste generation, reduction, and segregation practices. Treatment and disposal technology has been implemented to properly contain radioactivity and maximize cost-effectiveness. Currently, there is no solution to the problem of disposing of land-disposal-restricted (LDR) mixed waste. It is being maintained in storage, awaiting guidance from DOE.

The LLNL LLW management system protects the public health and safety as required by DOE Orders and ensures operations are well within the applicable dose limits. Intruders into the facility after closure will receive no dose as a result of LLNL operations. Ground water resources are being protected consistent with federal, state, and local requirements. Releases to the environment from LLW management processes are ALARA.

**Lawrence Livermore National Laboratory
Low-Level Waste Systems
Performance Assessment**

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

Lawrence Livermore National Laboratory (LLNL) is required to prepare and maintain an overall waste management systems Performance Assessment (PA) addressing waste management practices used in generation, reduction, segregation, treatment, packaging, storage, and disposal of low-level waste (LLW).

The guideline for preparing a PA, DOE/LLW-63T (DOE, 1989a), provides the following goals:

- To provide maximum assurance that performance objectives are met
- To preserve existing disposal capacity
- To reduce long-term costs
- To ensure that technologies and practices take maximum advantage of, and are complementary to, existing hydrogeological and environmental characteristics.

This PA provides an assessment of the overall waste management system supporting the combination of waste management practices used in generation, reduction, segregation, treatment, packaging, storage, and disposal of LLW at LLNL.

LLW is defined by DOE Order 5820.2A (DOE, 1988a) as:

Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, or spent nuclear fuel or 11e(2) byproduct material as defined by this Order. Test specimens of fissionable material irradiated for research and development only, and not for the production of power or plutonium, may be classified as low-level waste, provided the concentration of transuranic is less than 100 nCi/g.

DOE Order 5400.3 (DOE, 1989b) sets forth requirements for the control of mixed wastes. DOE Order 5820.2A (DOE, 1988a), Chapter III, requires that Department of

Energy (DOE) LLW that contains non-radioactive hazardous waste components, i.e. mixed wastes, conform to the requirements of the Order and those of the Resource Conservation and Recovery Act (RCRA) of 1976 (EPA, 1976). LLW does not include mixed waste. Chapter III does not specifically require that mixed waste containing low levels of radioactivity be included in the PA. A PA peer review panel member has stated that the Order did not originally intend that mixed waste be included (Wilhite, 1990).

The following wastes are analyzed in this PA:

- Byproduct material (uranium and thorium mill tailings)
- Accelerator-produced material
- Naturally occurring material
- Special nuclear material
- Waste containing transuranic (TRU) isotopes at concentrations < 100 nCi/g
- Mixed wastes containing low levels of radioactivity
- Gaseous and liquid radioactive effluents from HWM operations.

LLNL does not currently dispose of LLW on-site; instead, all LLW is shipped to the DOE Nevada Test Site (NTS). Prior to the issuance of DOE Order 5820.2A (DOE, 1988a), LLW was disposed in landfills at Site 300. Many years ago, LLW also was disposed in two landfills at the Main Site. LLW placed in Main Site landfills was removed and the landfills were remediated. These efforts are documented in UCID-20869 (Buerer, 1983) and UCID-20662 (McConachie, et al., 1986). Communication with Environmental Restoration Division (ERD) personnel (Isherwood, 1990) indicated that no other Main Site landfills are believed to contain any radioactive waste.

Nine pits at Site 300 have received some LLW and other wastes. Placement of wastes into these pits is reviewed and environmental impact is assessed in UCAR-10242 (Taffet and Lamarre, 1988), UCID-21685 (Taffet, et al., 1989), UCID-21031 (Buddemeier, et al., 1987), UCAR-10202 (Taffet and Lamarre, 1989), and the Closure and Post Closure Plan - Landfill Pits 1 and 7 (LLNL, 1990a). Communication with Site 300 personnel (Lamarre and Taffet, 1990) indicated that no radioactive waste had been placed into these pits since the issuance of DOE Order 5820.2A (DOE, 1988a).

DOE Order 5820.2A (DOE, 1988a) specifies that only the LLW that was not disposed prior to issuance of the Order must be managed to accomplish the performance objectives. Because on-site disposal of LLW ceased prior to the issuance of DOE Order 5820.2A and no further on-site disposal into landfills is currently allowed, this PA is not required to analyze the pits and landfills at the Main Site and Site 300.

Release of airborne and liquid radioactive effluents occur from the numerous research projects conducted at LLNL. These releases are constrained in accordance with the requirements of DOE Order 5400.5 (DOE, 1990) and Draft Order 5400.XY (DOE, 1988d). This PA does not analyze the impact of airborne and liquid effluents from LLNL research projects. This PA does, however, address these effluents from the HWM facilities.

HWM and other LLNL personnel are occupationally exposed to external radiation fields and potential intakes of radioactive material. These exposures are regulated by DOE Order 5480.11 (DOE, 1989c). This PA does not analyze these.

The various LLNL research projects generate radioactive wastes that are temporarily stored in waste accumulation areas (WAAs). These wastes are removed from the WAAs by the HWM organization, stored on-site, some are processed, and ultimately shipped off-site for disposal.

This PA does not address potential accidents which may result in radiation exposures of the public.

This PA evaluates LLNL LLW operations relative to specific performance objectives developed in Section 2. These performance objectives are, predominately, radiation dose limits for members of the public. The specific terms and units used in radiation protection, health physics, are defined by DOE Order 5400.5 (DOE, 1990) and are presented in Appendix E of this report.

1.2 FACILITIES AND OPERATIONS

LLW is produced, characterized, and packaged by the various LLNL generator personnel. It is then transferred to HWM for storage, processing, and shipment for disposal as detailed in UCAR-10264 (LLNL, 1989a).

The operations at HWM facilities include the pickup, treatment, packaging, and disposal of hazardous, transuranic, mixed, and low-level radioactive wastes. Numerous radionuclides are handled and the associated activity can be highly variable.

HWM operations involving LLW and mixed waste are performed in nine buildings and associated storage and operations areas; these are located primarily in the southeast quadrant of the LLNL Main Site, with the exception of Building 233, located in the southwest quadrant, and Building 883, located at Site 300. Building 223 was not in use at the time of the PA walk-throughs but is scheduled to store solid mixed waste. Building 419 had suspended most activities and Building 883 had no radioactive waste in storage. The tasks and functions of storing, treating, handling, shipping, and disposing LLW and mixed waste are divided among the following buildings:

- Building 233 Solid Mixed Waste Storage
- Building 419 Decontamination/Size Reduction
- Building 513 Storage, Shredder, and Solidification
- Building 514 and Waste Water Filtration/Treatment/Temporary Storage
Associated Areas
- Building 612 and Segregation/Storage, Drum/Container Crushing
Associated Areas
- Building 614 Eight Cell Storage
- Building 624 Storage
- Building 625 Polychlorinated Biphenyl (PCB)/Asbestos/TRU Storage
- Building 883 Storage.

2.0 PERFORMANCE OBJECTIVES

The PA methodology and the applicable regulatory requirements are detailed in Appendices G and H, respectively.

Primary performance objectives are provided in DOE Order 5820.2A, Chapter III (DOE, 1988a).

Guidance on the conduct of waste management systems performance assessments is provided in DOE/LLW-63T (DOE, 1989a). Performance objectives applicable to systems performance assessments are also provided therein. These were considered in the development of the LLNL performance objectives. The specific LLNL performance objectives are summarized in Table 2-1. Accident emergency protection guidelines of the EPA and State of California are not performance objects as the PA does not address accidents.

In addition to these objectives, a further performance objective was selected to assure that, for waste shipped to the NTS from LLNL, the NTS performance objectives will be met. Meeting this objective requires LLNL to comply with NVO-325 (DOE, 1988b) for defense waste acceptance criteria, certification, and transfer.

LLNL LLW management performance is analyzed with respect to these performance objectives in Section 3 of this PA.

Table 2-1. LLNL Systems Performance Assessment Objectives

Regulations	Exposure Group	Performance Objectives Limit (Annual)	Type of DOE LLW Facility	Compliance Point	Compliance Period
DOE Orders					
5820.2A Ch. III	Public	25 mrem EDE ^{a,c}	LLW treatment, storage & disposal	Point of restricted access (fence, guards, signs, etc.)	Indefinite future
	Intruder	100 mrem EDE ^a (Continuous exposure)	LLW treatment, storage & disposal	Source term	Indefinite future beginning 100 years after loss of institutional control
	Intruder	500 mrem EDE ^a (Acute exposure)	LLW treatment, storage and disposal	Source term	Indefinite future beginning 100 years after loss of institutional control
5400.5	Public	100 mrem EDE ^a (for all facilities on a site)	All	Point of restricted access	During Operations
	Public	25 mrem DE ^{b,c} (Whole body)	All	Point of restricted access	During Operations
	Public	75 mrem DE ^b (Critical organ)	All	Point of restricted access	Indefinite future
	Public	4 mrem EDE ^a (Drinking water)	All	Closest public well	Indefinite future

^a Effective dose equivalent (ICRP, 1977/1979; DOE, 1988a)

^b Dose equivalent (ICRP, 1977/1979)

^c 25 mrem is considered the "action level" during the operational period.

Table 2-1. System Performance Assessment Objectives (continued)

Regulations	Exposure Group	Performance Objectives Limit (Annual)	Type of DOE LLW Facility	Compliance Point	Compliance Period
EPA					
40 CFR 61 Subpart H	Public	10 mrem EDE ^a (air emissions-whole body)	All not regulated by Parts 190, 191	Point of maximum annual air concentration in an unrestricted area where the public resides or abides	Indefinite future
40 CFR 141	Public	4 mrem DE ^b (water systems-whole body and organs)	All	Any public water system	Indefinite future
DOT					
49 CFR 173	Public	200 mrem/hr DE ^b , et al.	Transportation	Any point on external surface of package	During shipment
STATE OF CALIFORNIA					
Title 17 CCR	Public	Specific nuclide concentration limits for air and water	N/A (CA is developing agreement with EPA & DOE)	At point of release from facility	Operational
Division 20 Subsection 25600	Public	Monitor & control radioactivity in the environment	All	Outside laboratory boundaries	Operational

^a Effective dose equivalent (ICRP, 1977/1979; DOE, 1988a)

^b Dose equivalent (ICRP, 1977/1979)

^c 25 mrem is considered the "action level" during the operational period.

3.0 MAXIMUM LOW-LEVEL RADIOACTIVE WASTE SOURCE TERM

3.1 BACKGROUND

This PA is based on site-specific characterization data obtained by review of various LLNL documents, interviews of personnel, and tours of the LLW facilities. This data is used as the basis for the maximum LLW source term developed in the following Subsections. The maximum source term is of the maximum LLW radionuclide loading of the HWM program. It is based on the quantities of waste produced and shipped for disposal during CY 1989.

The maximum LLW source term, as defined in DOE/LLW-63T (DOE, 1989a), is a hypothetical limit set for each disposal site. Even though no LLW or mixed waste is disposed at LLNL, HWM operations may impact the public through the handling, storage, treatment, and shipment of LLW. Therefore, the performance of LLNL is assessed with regard to these processes.

Worst-case and reasonable case source terms are determined as the amounts of radioactivity that can be handled by HWM and still assure that the performance objectives are met.

3.2 ANALYSIS

DOE/LLW-63T (DOE, 1989a) defines the source term as the radionuclide loading that could impact the public by direct exposure and nuclide migration through the soil, water, and air. This PA considers that the dose pathways to members of the public are 1) exposure to direct radiation from LLW, from the point of its receipt at the WAAs until its transferral to its ultimate disposal facility, and 2) exposure to radionuclides released to the air, water, and soil during the normal processing of mixed and LLW. The radionuclide loading that results in impacts on the public from these two sources is defined as the source term for this PA. When possible, the masses and volumes of mixed and LLW are identified, as these are

important both to the associated cost of disposal and to the maintenance of existing disposal capacity.

Table 3-1 provides an historical summary of the yearly quantities of LLW and mixed waste generated between 1985 and 1989. These amounts represent the quantities prior to processing.

The amounts of radioactivity in solid LLW at the time of generation were determined from Solid Waste Information Management System (SWIMS) data, presented in Table 3-2. The isotopes of concern were selected based on their quantities and include tritium, naturally occurring actinides, U-233, and Pu-239.

The mixed waste inventory at HWM is provided in Table 3-3. Mixed waste has not been shipped off-site for burial since 1985. Liquid mixed wastes are partially treated by a filtration process to remove the radioactive and hazardous components from the liquid fraction sufficiently to allow discharge of the treated effluent to the sanitary sewer system. Liquid mixed waste treatment for 1988 is detailed in Table 3-4. Other decontamination processes are also available, as discussed in Section 4. Due to the lack of acceptable treatment technologies, LDR mixed waste is a significant problem, especially if it contains organics.

The amounts of radioactivity in mixed waste are low and vary by source. These are illustrated in Table 3-5 from information provided by the HWM Mixed Waste Database. This activity was non-uniformly distributed through the $8.6 \text{ E}+4 \text{ kg}$ of waste.

Table 3-6 provides a summary of LLW shipments to the NTS over the last 5 years. This data indicates a wide variance in the year-to-year mass, volume, and activity of LLW. The isotopic breakdown of radioactivity in LLW shipments from 1989 is provided in Table 3-7. The major constituents are H-3, Th-232, U-233, U-238 and Pu-239. This is comparable to the listing of isotopes identified at generation in Table 3-2.

Radioactivity in sewer discharges from HWM facilities are detailed in Table 3-8.

Radioactivity in airborne releases derived from HWM operations are identified in Table 3-9. Only one release of gaseous radioactive material was identified as occurring during 1989. This was one operation of the tritium bake-out oven on 22 February 1989 which released 0.5 Ci.

Table 3-1. Summary of LLW and Mixed Waste Generation by all LLNL Generators^a.

Calendar Year	LLW ^d (kg)	Mixed Waste (kg)
1985	1.91 E+5	1.41 E+5
1986	2.41 E+5	1.50 E+5
1987	3.69 E+5	4.25 E+5
1988	1.91 E+5	1.67 E+5
1989	4.16 E+5 ^b	1.83 E+5 ^c

^a From D. Hoyt, C. VanWarmerdam, D. Nakahara: File - RevGenRateWaste

^b In addition to the 4.16 E+5 kg of LLW generated in 1989, 4.54 E+4 kg of LLW was still in storage at HWM from previous years.

^c In addition to the 1.83 E+5 kg of mixed waste generated in 1989, 1.26 E+5 kg of mixed waste was still in storage at HWM from previous years.

^d LLW volume includes liquid and solid waste generation.

Table 3-2. Solid LLW Generation at LLNL for CY 1989^a.

Category	Isotope	Activity (Ci)	Mass (kg)	Volume (m ³)
2 (Uranium/Thorium)	Th-228	1.00 E-3		
	Th-232	1.46 E-3		
	U-233	1.40 E-1		
	U-234	4.00 E-8		
	U-235	1.24 E-4		
	U-238	7.78 E-2		
Total		2.20 E-1	4.821 E+4	1.673 E+2
3 (Fission Products)	MFP	7.29 E-2		
	Cs-137	1.76 E-4		
	Cu-64	1.10 E-5		
	Fe-55	9.11 E-6		
	Mn-54	8.00 E-8		
	Pu-239	4.05 E-1		
	Se-75	3.40 E-4		
	Sr-90	1.22 E-2		
Total		4.91 E-1	4.314 E+4	1.329 E+2
4 (Activation Products)	C-14	1.28 E-3		
	Cd-109	1.60 E-3		
	Co-56	3.40 E-5		
	Co-60	1.50 E-4		
	Na-22	1.15 E-5		
	Ni-59	3.00 E-6		
	Ni-63	5.20 E-7		
	S-35	6.29 E-3		
Total		9.37 E-3	1.506 E+4	4.778 E+1
5 (Tritium)	H-3	4.71 E+4	4.254 E+4	9.162 E+1

^a From: SWIMS Report for Calendar Year 1989 (LLNL, 1990d)

Table 3-2. Solid LLW Generation at LLNL for CY 1989^a (continued).

Category	Isotope	Activity (Ci)	Mass (kg)	Volume (m ³)
6 (β - γ -TRU)	Cf-252	1.18 E-5		
	Cm-244	1.00 E-3		
	Np-237	1.00 E-3		
	P-32	1.20 E-1		
	Pm-147	1.00 E-2		
Total		1.32 E-1	2.112 E+4	4.899 E+1
7 (Alpha)	Am-241	5.13 E-3		
	Am-243	5.00 E-13		
	Ac-227	1.40 E-1		
	Pu-238	5.06 E-6		
	Po-210	1.00 E-3		
	Pu-240	2.00 E-8		
	Pu-242	3.00 E-7		
	Ra-226	7.30 E-6		
	Th-230	9.00 E-8		
Total		1.46 E-1	1.595 E+4	4.601 E+1
8 (Other)	Ca-41	1.01 E-8	2.544 E+3	1.487 E+1

^a From: SWIMS Report for Calendar Year 1989 (LLNL, 1990d)

Table 3-3. Mixed Waste Inventory at the End of CY 1989^a.

Type	Mass (kg)
Mixed Waste in Storage, generated in 1989	4.69 E+3 kg
Mixed Waste in Storage, generated in 1984-88	1.26 E+5 kg
Mixed Waste Awaiting Treatment (liquids awaiting filtration and solidification; lab wastes; scintillation vials; contaminated equipment)	7.00 E+4 kg
Tank Farm Liquids	1.08 E+5 kg

^a From: D. Hoyt, C. VanWarmerdam, D. Nakahara; File: RevGenRateWaste

Table 3-4. Radioactivity in Liquid Mixed Waste Treated at the Building 514 Tank Farm in CY 1988^a.

	Type of Activity	Total Activity (μ Ci)	Concentration (μ Ci/mL)
Pre-Treatment in 1.54 E5 L	α	1.284 E+3	8.34 E-6
	β	3.61 E+2	2.34 E-6
	H-3	1.62 E+5	1.05 E-3
Post-Treatment ^b in 1.69 E5 L	α	2.37 E+1	1.40 E-7
	β	2.77 E+1	1.64 E-7
	H-3	6.17 E+4	3.65 E-4

^a From the HWM Mixed Waste Database

^b Post treatment volume increases because of addition of liquids during processing. Treated wastes meet all regulatory limits for sewer discharge.

Table 3-5. Radioactivity in Mixed Waste Received by HWM during CY 1989^a.

Isotope	Total Activity
U-238 (depleted Uranium)	5 E-1 Ci (1.5 E3 kg)
Th-232	2 E-5 Ci (1.8 E-1 kg)
U-235	1.6 E-2 Ci (7.4 kg)
H-3	15 Ci (1.5 E-6 kg)
A few entries indicated trace quantities MFPs, Cm-244, U-233, Mo-90, Zr-95, and other isotopes.	
Concentrations of radioactivity could not appropriately be averaged. The majority of entries contained only minor quantities of one isotope. Eight entries contained the vast majority of U-238. One entry contained 20% of the H-3. 170 entries of lab waste contained approximately uniform quantities (1 E-7 μ Ci) of U-238 and Th-232. A total of approximately 600 entries were recorded in the Mixed Waste Database.	

^a From the HWM Mixed Waste Database

Table 3-6. Summary of LLW Shipments^a.

Calendar Year	Gross Mass (kg)	Net Mass (kg)	Volume (m ³)	Activity (Ci)
1985	1.89 E+5	1.45 E+5	7.28 E+2	1.41 E+5
1986	2.40 E+5	1.88 E+5	6.88 E+2	2.72 E+5
1987	3.67 E+5	3.06 E+5	8.41 E+2	1.27 E+5
1988	1.82 E+5	1.39 E+5	6.51 E+2	5.88 E+2
1989	1.88 E+5	---	5.49 E+2	4.65 E+4

^a From HWM 90-556 (Hoyt, 1990a), for years 1985 through 1988, and from 1989 LLNL Radioactive Waste Shipping Documents.

Table 3-7. Isotopic Breakdown of CY 1989 LLW Shipments^a.

Isotope	Activity (Ci)
H-3	4.65 E+4
C-14	1.27 E-3
P-32	1.01 E-1
S-35	6.34 E-3
Ca-41	1.01 E-8
Mn-54	8.00 E-8
Fe-55	9.10 E-6
Ni-59	3.00 E-6
Ni-63	3.20 E-7
Co-60	1.40 E-4
Cu-64	1.10 E-5
Se-75	1.50 E-4
Sr-90	1.21 E-2
Cs-137	1.46 E-4
Po-210	1.00 E-3
Ra-226	7.35 E-6
Th-230	9.00 E-8
Ac-227	1.40 E-1
Th-230	9.00 E-6
Th-232	1.47 E-3 (1.3 E+1 kg)
U-233	1.40 E-1
U-234	2.00 E-8
U-235	1.20 E-4

^a From 1989 LLNL Radioactive Waste Shipping Documents. No mixed waste was shipped in CY 1989.

Table 3-7. Isotope Breakdown of CY 1989 LLW Shipments^a (continued).

Isotope	Activity (Ci)
U-238	7.74 E-2 (2.30 E+2 kg)
Np-237	1.00 E-3
Pu-238	5.06 E-6
Pu-239	3.93 E-1
Pu-240	2.00 E-8
Pu-242	3.00 E-7
Am-241	5.13 E-3
Am-243	5.00 E-13
Cm-244	1.00 E-3
Cf-252	1.11 E-5
Mixed Fission Products	7.31 E-2

- ^a From 1989 LLNL Radioactive Waste Shipping Documents. No mixed waste was shipped in CY 1989.

Table 3-8. Radioactivity in Sewer Discharges from HWM Facilities.

Calendar Year	α Activity (μ Ci)	β Activity (μ Ci)	H-3 (μ Ci)
1988 ^a	2.17 E+1	2.35 E+1	1.66 E+4
1989 ^b	1.83 E+1	3.53 E+1	4.92 E+3

^a Taken from HWM Treatment Records.

^b Taken from EPD Discharge Records.

Table 3-9. Identified Radioactive Airborne Effluents from HWM Facilities for CY 1989.

Date	Effluent	Source
22 February 1989	0.5 Ci H-3	Bldg. 419

For the purposes of this PA, the current or reasonable case LLW source term is defined as the radioactivity in LLW shipments as detailed in Table 3-7 and in the HWM liquid and airborne radioactive effluents as detailed in Tables 3-8 and 3-9.

The maximum or worst-case LLW source term is wholly dependant on the number and types of research and development activity conducted at the LLNL. For the purposes of this PA, the maximum allowable source term is projected from the current levels as approximately 2,500 times, based on the analysis in Subsection 3.2 and on the performance objectives. This is a conservative estimate based on the maximum estimated doses to members of the public for radioactive liquid and gaseous effluents. It is reasonable to expect that LLNL management policy will continue to prohibit any detectable direct radiation dose to the public from the storage of solid radioactive waste. Therefore, the theoretical maximum solid radioactive waste source term is not limited.

3.3 PERFORMANCE ASSESSMENT

The current source term (as defined in Tables 3-7, 3-8, and 3-9) could result in radiation doses to the public by 1) direct radiation exposures during handling, storage, and shipment and by 2) radioactive liquid and gaseous effluents to the environment from LLW processing activities. In this Subsection, the maximum dose associated with these pathways is estimated.

Direct radiation exposure is determined by review of radiation monitoring data at the LLNL Main Site and Site 300 boundary as presented in the 1988 Environmental Report, UCRL-50027-88 (LLNL, 1988c). Data for 1989 was not available at the time this PA was prepared. Appendix A (Tables A-21, A-22, and A-39) of UCRL-50027-88 states that the average penetrating radiation dose at the Main Site boundary was 62 mrem for 1988 compared to the 64 mrem background rate in the Livermore Valley. The average penetrating radiation dose at the Site 300 boundary for July through December 1988 was 39 mrem compared to the 38 mrem background rate in the surrounding off-site area. The boundary doses are not significantly different from the background doses within the accuracy of the

dosimetry system. The estimated direct radiation dose from all of LLNL, not just the LLW activities, is therefore indistinguishable from the background dose.

Direct radiation exposure from packages of LLW during shipment is limited by DOT requirements. The dose rate limits at the surface of packages and transport vehicles, are specified in 49 CFR 173.441. DOT regulations consider the doses associated with these dose rate limits as entailing minimal risk and as being ALARA. The impact of transportation of radioactive material on the environment was analyzed by the Nuclear Regulatory Commission (NRC) in NUREG-0170 (NRC, 1977a) and found to present an acceptably low level of risk. Assessment of LLW off-site transportation dose is not required by DOE/LLW-63T (DOE, 1989a).

The shipping documents for all the LLW waste shipments made during 1989 were reviewed. The documents provided dose rates on contact with the surface of each package and at 1 meter from the package. All were less than the DOT limits. The highest single package had a surface dose rate of 20 mr/hr. The vast majority had surface dose rates that were not different from the background exposure rate of the survey instrument, 0.2 mr/hr. The performance objective and its associated DOT requirements are met by a considerable margin.

The radiation dose to members of the public from radioactive liquid effluents through the sanitary sewer system is estimated using the RESRAD computer code. The details of this analysis are contained in Appendix A. The worst-case analysis calculates that a maximum 50-yr committed effective dose equivalent (CEDE) of 1 E-2 mrem would occur during the first year after release of the HWM sewer discharge activity listed in Table 3-8. 50-yr CEDEs decrease in subsequent years, reaching essentially zero in less than 10 years. The reasonable case analysis estimates that a maximum 50-yr CEDE of 3 E-5 mrem would occur during the first year, with doses decreasing thereafter. Both the worst-case and reasonable case doses are at a negligible level and require no estimation of a collective 50-yr CEDE. Background penetrating radiation in the vicinity of LLNL from all sources is approximately 63 mrem/yr. The NRC, EPA, and other regulatory agencies consider radiation exposures of less than 4 to 10 mrem/yr to be insignificant.

The 50-yr CEDE from airborne effluents from HWM facilities was estimated using the AIRDOS-PC computer code. The particulars of this analysis are contained in Appendix B. This worst-case analysis indicates that a 50-yr CEDE to the maximally exposed individual of 3 E-3 mrem would occur during the first year after release of the 1989 HWM airborne effluent activity listed in Table 3-9. This is a negligible dose and requires no estimation of a collective 50-yr CEDE.

The 50-yr CEDE from radioactive liquid effluents should not be added to the 50-yr CEDE from radioactive gaseous effluents. The 50-yr CEDE from liquid effluents occurs only to an individual at the point of sewage sludge dispersal. The 50-yr CEDE from airborne effluents occurs immediately outside the site boundary, to the nearest dose receptor.

Table 3-10 summarizes the estimates of the total 50-yr CEDE to the maximally exposed individual from HWM LLW operations. 50-yr CEDEs to individuals subsequent to site closure are estimated to be zero as detailed in Subsection 3.4. The State of California requirement to monitor and control radioactivity in the environment is addressed by the LLNL Environmental Monitoring Program, as detailed in Subsection 3.3. Compliance with the performance objective of adhering to NVO-325 is addressed in Subsection 4.3. LLNL requires adherence to NVO-325 and is instituting improvements to its program.

Table 3-11 compares the performance of LLNL LLW operations and associated doses, to the performance objectives developed in Section 2. Where a numerical limit is specified, a ratio of the estimated LLNL performance level to the limit is provided. From these ratios, the maximum LLW source term is determined and presented in Tables 3-7, 3-8, and 3-9.

The maximum LLW source term, Table 3-12, is not limited by the actual amount of radioactivity produced or in storage at LLNL. This is because the external dose rate from the vast majority of LLW at LLNL is very low. Even if the dose rates were not very low, the waste would be shielded so that the dose rate at the LLNL boundary would not be significantly different from the background level. Furthermore, the dose rate on packages of LLW during shipment does not limit the maximum LLW source term. This is because the dose rates are maintained less than the regulatory limit. The maximum LLW source term is limited only by the amounts of radioactivity in liquid and gaseous effluents.

Table 3-10. Dose Summary for Normal Operations.

Pathway	50-yr CEDE to the Maximally Exposed Individual
Direct Radiation from HWM Facilities	negligible
Direct Radiation During Shipment	N/A
Liquid Effluents	0.01 mrem
Gaseous Effluents	0.003 mrem

Table 3-11. HWM Compliance with LLW Performance Objectives.

Regulation	Limit	LLNL Result	Ratio of LLNL Dose to Performance Objective
5820.2A	25 mrem EDE ^a public	1 E-2 mrem	4E-4
5820.2A	100 mrem EDE ^a intruder-continuous	0	0
5820.2A	500 mrem EDE ^a intruder-acute	0	0
5400.5	100 mrem EDE ^a	3 E-3 mrem	3E-5
5400.5	25 mrem DE ^b whole body	3 E-3 mrem	1E-4
5400.5	75 mrem DE ^b critical organ	3 E-3 mrem	4E-5
5400.5	4 mrem EDE ^a drinking water	5E-9 mrem	1E-9
40 CFR 61 Subpart H	10 mrem EDE ^a whole body	3 E-3 mrem	3E-4
40 CFR 141	4 mrem	5 E-9 mrem	1E-9
49 CFR 173	200 mrem/hr	2 E+1 mr/hr	1E-1
State of CA Title 17	N/A	--	In Compliance
State of CA Division 20	Monitor and Control	See Sec. 3.3	In Compliance
NVO-325	Various	See Sec. 4.3	In Compliance

^a Effective Dose Equivalent

^b Dose Equivalent

HWM is in compliance with all numerical performance objectives.

Table 3-12. Maximum LLW Source Term.

Isotope	Activity (Ci)	Mode of Public Exposure	Ratio of LLNL Dose to Performance Objective from Table 3-11	Maximum Source Term (Ci)
U-223 ^a	1.4 E-1	Direct	0	Unlimited
Pu-239 ^a	3.9 E-1	Direct	0	Unlimited
H-3 ^a	4.65 E+4	Direct	0	Unlimited
Cs-137 ^b	3.53 E-5	Sewer	4 E-4	8.8 E-2 ^d
Pu-239 ^b	1.83 E-5	Sewer	4 E-4	4.5 E-2 ^d
H-3 ^b	4.92 E-3	Sewer	4 E-4	1.23 E+1 ^d
H-3 ^c	5.0 E-1	Air	3 E-4	1.66 E+3 ^e

- ^a Isotopes in solid LLW.
- ^b Isotopes in liquid effluents from LLW operations.
- ^c Isotope in gaseous effluent from LLW operations.
- ^d Maximum allowable annual release to sewer.
- ^e Maximum allowable annual release to air.

The performance objectives are met by a factor of more than 2,500.

3.4 ENVIRONMENTAL MONITORING

The LLNL Environmental Monitoring Program is conducted in accordance with Procedures Manual UCAR-10254 (LLNL, 1988b). It provides specific details on the methods, locations, and documentation of environmental samples. The results of the program are documented each year in an annual Environmental Report UCRL-50027-XX (LLNL, 19XX). Also published are semiannual reports entitled Wastewater Point-Source Monitoring at LLNL's Main Site (Grandfield, 19XX) and quarterly reports entitled LLNL Site 300 Groundwater Monitoring Program (LLNL, 19YY).

Measurements are made both in and around the LLNL Main Site and Site 300 to evaluate the effect of LLNL operations on the local environment. The annual reports are prepared to meet the requirements of DOE Orders 5484.1 (DOE, 1981) and 5400.1 (DOE, 1988c). They contain evaluations of LLNL's compliance with applicable guides, standards, and limits for radiological and non-radiological emissions to the environment.

Environmental measurements of radioactivity in air, soil, water, vegetation, and foodstuffs are made by sampling and radiochemical analysis. Direct radiation is measured by thermoluminescent dosimeters at the Main Site and Site 300 boundaries and in the surrounding area. Meteorological data are also accumulated.

The data from the various measurements and samplings are presented in the annual report. A review of hydrogeological information for the Main Site and Site 300 is also made. The radiological impact to the public is then assessed in accordance with DOE Orders. Four doses are calculated: LLNL perimeter, nearest resident, point of maximum exposure in the uncontrolled area, and the population dose within an 80 km radius of LLNL. The doses in the latest report (1988) are calculated as "effective dose equivalents" using models and methods consistent with NRC Regulatory Guide 1.109 (NRC, 1977b) and the dose conversion factors from ICRP 30 (ICRP, 1979). Doses from the air pathway are reported in terms of "dose equivalent" using the Clean Air Act Code models AIRDOS-EPA and RADRISK.

The doses projected from 1988 environmental monitoring data are presented in Tables 3-13 and 3-14. These are a minor percentage of the performance objectives and the applicable DOE Orders and EPA limits. Direct radiation measurements at the Main Site and Site 300 boundaries are equivalent to the measured background exposure and indicate no contribution from LLNL activities. The analytic methods used to evaluate the environmental samples are generally capable of detecting radioactivity at levels of 1/10,000 of the applicable limit. This sensitivity is adequate to detect changing trends in performance sufficiently in advance to allow application of any necessary corrective action before exceeding performance objectives.

To assure the validity of the environmental monitoring data, LLNL performs duplicate sampling and participates in both the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program and the 1988 DOE Environmental Measurements Laboratory Intercomparison Studies. The Environmental Monitoring Group is responsible for monitoring the various environmental media and has published and implemented a quality assurance plan, UCAR-10203 (LLNL, 1987).

A Predecisional Draft of a LLNL Environmental Protection Implementation Plan, UCAR-10307 (LLNL, 1989d), was published and states that an Environmental Monitoring Plan will be prepared to meet the requirements of DOE Orders 5400.1, 5400.3, and 5400.XY.

Overall, LLNL has had no adverse impact on the environment or the public as documented in the 1988 Environmental Report (LLNL, 1989c).

3.5 SITE CLOSURE AND POST-CLOSURE

Closure plans have been prepared for the HWM facilities and are contained in the RCRA Part B Permit Application (LLNL, 1989b). These plans address the radiological decontamination of HWM facilities to a level such that the various areas will be free of contamination and no post-closure maintenance will be necessary.

Although it is not required to address the decontamination and decommissioning of site project facilities in this PA, the need for such closure plans is identified in DOE Order

Table 3-13. Summary of Radiological Dose^d Assessment for CY 1988^e

Nuclide	Pathways			Total		Percent of DOE standard ^b
	Inhalation/ submersion ^a (mrem)	Ingestion- foodstuffs (mrem)	Ingestion -water (mrem)			
				(mrem)	(mSv)	
³ H, ¹⁴ C, ³² P, ³⁵ S, ¹²⁵ I	1 E-1	8 E-3	4 E-2	1.5 E-1	1.5 E-3	0.15%
¹³ N- ¹⁵ O	1 E-2	0	0	1 E-2	1 E-4	0.01%
LLNL Main Site Total ^o				1.6 E-1	1.6 E-3	0.16%

^a The inhalation/submersion 50-yr CEDE was derived using the Continuous-Point-Source code.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

^d Effective dose equivalent to the maximally exposed individual in the public.

^e From 1988 Environmental Report (LLNL, 1989c).

Table 3-14. Maximum Off-Site Dose^a from LLNL Sources for CY 1988^b.

LLNL Location/Source	Individual Dose (mrem)	Population Dose ^c (person-rem)
Main Site Atmospheric Emissions	1.6 E-1	7.3 E-1
Main Site Liquid Emissions	0	0
Site 300	2 E-3	7 E-5

^a These doses represent the maximum 50-yr CEDE from all LLNL emissions. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public.

^b From 1988 Environmental Report (LLNL, 1989c).

^c The population dose is the collective (combined) dose for all individuals residing within an 80-km radius of LLNL.

5820.2A, Chapter V. DOE Tiger Team findings RAD/CF-6 and WM/CF-2 identified that a site-wide program for decontamination and decommissioning of contaminated facilities had not yet been established. This matter is currently being addressed by LLNL but specific plans are not yet available.

3.6 CONCLUSIONS

Operation of the current LLW management system results in calculated doses to the public that are significantly lower than the identified regulatory limits. The performance objectives are met with a considerable margin. The additional performance objective, of assuring compliance with the NTS-WAC, is addressed as detailed in Subsection 4.3. The maximum source term, i.e. the maximum quantity of radionuclides that could be contained in LLW from LLNL, could be significantly higher and the performance objectives would still be met. This demonstrates that, from an ALARA and public health and safety standpoint, the current LLW management system is more than sufficient to protect public health and safety in accordance with the DOE standards, to ensure that external exposures are minimal, and to protect ground water resources.

4.0 ANALYSIS OF DISPOSAL SYSTEM COMPONENTS

The LLNL LLW waste management system is comprised of the components presented in the following Subsections. These components are systematically analyzed to identify those which meet the programmatic requirements of DOE Order 5820.2A (DOE, 1988a) and those for which further action is necessary. Program improvements that are currently in-process are described.

4.1 WASTE MINIMIZATION

DOE Order 5820.2A, Chapter III, paragraph 3.C, delineates specific waste minimization requirements.

The DOE Tiger Team Audit of 1990, Item WM/CF-6, found that all LLNL activities for waste minimization were not being implemented as required. LLNL is undertaking a program to correct this deficiency.

LLNL has instituted a formal Waste Minimization Program and issued revision 2 of its Waste Minimization Program Plan (LLNL, 1990b). The Laboratory Director issued a Statement on Waste Minimization on 27 February 1989 and made a strong commitment towards waste minimization. The Statement set a goal of reducing waste generation and increasing recycling. It requires each program to develop its own waste minimization mini-plan with specific goals and assigned responsibility for achieving those goals.

The Waste Minimization Program involves the formation of a Program team which meets with the management of each waste generating facility. The team visits each facility and interviews key operational personnel. Operational flow schematics are developed and specific waste minimization techniques are suggested. The team assists the programs and facilities in implementing these techniques.

Each directorate has developed a minimization mini-plan for its own waste generation activities. The larger programmatic waste generators are developing micro-plans for specific processes. Audits will be conducted to verify annual progress on meeting reduction goals and to identify areas for improvement.

A Waste Minimization Steering Committee consisting of representatives from each directorate has been formed. The Committee reviews and evaluates the proposed waste recharge system and the development of an auditable Waste Minimization Program Plan, including goals, for all appropriate waste streams. The Plan is being established as an auditable program with goals, incentives, procedures, and reports.

A formal Quality Assurance (QA) Plan calling for an annual program audit of the Waste Minimization Program is being developed. This QA Plan will follow the DOE/San Francisco Office (DOE/SAN) QA Plan, which is yet to be issued. In the interim, a draft LLNL QA Plan was issued for internal guidance on 4 August 1989 (LLNL, 1989g).

An employee incentive program is being considered for promoting waste minimization suggestions. Each waste generator is required in the Preparation Guide for Generators of Hazardous Chemicals and Radioactive Waste (Huss, 1987) to separate uncontaminated waste from LLW to facilitate cost-effective treatment and disposal. This Guide is currently being updated.

The DOE Headquarters (DOE/HQ) Waste Minimization Steering Committee conducts working group meetings several times a year. New technology and applications are discussed at these technical meetings.

Designs for new processes and facilities are formally reviewed and incorporate generation minimization principles. In particular, the Decontamination and Waste Treatment Facility (DWTF) is being designed to minimize waste generation through specific segregation, treatment, and reduction techniques. The DWTF is discussed further in Section 6.

Implementation of the Director's minimization policy is expected to produce a reduction of 25% to 50% in volume over a five-year period.

The waste minimization program, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.c.

4.2 WASTE CHARACTERIZATION

DOE Order 5820.2A, Chapter III, paragraph 3.d, delineates specific waste characterization requirements.

In 1988, the LLNL Environmental Protection Department (EPD) initiated a Hazardous Waste Management Requisition System which implements waste characterization requirements as part of an overall waste certification process. As part of the Requisition System, a Waste Disposal Tracking System introduced the use of a Waste Disposal Requisition (WDR) form.

The WDR is the primary record of a waste container's path from generator to final disposal. It supplies the data to a computerized tracking system that tracks waste from cradle to grave. Specific instructions are provided in Waste Disposal Requisition Guidelines (vanWarmerdam, 1990) for the implementation and use of the WDR system. Specific instructions to generators on the segregation, separation, packaging, and preparation for transportation are contained in a Preparation Guide for Generators of Hazardous Chemicals and Radioactive Waste at LLNL (Huss, 1987). The WDR system is a waste manifest system that records the specified waste characterization data required by DOE Order 5820.2A, Chapter III, paragraph 3.d. It provides an auditable record of the proper segregation, treatment, storage, and disposal of LLW. The identification of wastes classification is implemented by the WDR system, the Preparation Guide (Huss, 1987) and the LLW Certification Program Plan in Appendix E of the Hazardous Waste Management Plan (LLNL, 1989a).

Characterization of LLW in accordance with the additional requirements of DOE Order 5820.2A, Chapter III, paragraph 3.i., is addressed in Subsection 4.7.

The 1990 DOE Tiger Team audit noted that the LLNL characterization system for LLW did not provide sufficient assurance that the waste was being accurately and completely characterized. To address this concern and as part of ongoing improvements in LLNL's hazardous waste management, a LLW Compliance Program is being developed. The LLW Compliance Program specifies the requirements that waste generators must meet so that LLW can be accepted by HWM. These requirements address the NVO-325 (DOE, 1988b) certification and acceptance criteria. They also prescribe the requirements for identification of waste as mixed or radioactive, determination of concentrations and types of constituents, and determination of waste form.

A Low-Level Waste Compliance Plan (LLWCP) (SAIC, 1990c) has been issued in draft. The Plan specifies characterization requirements for waste generators with regard to

the chemical, radiological, and physical characteristics of wastes. The Plan contains and requires the use of a Generator Certification Form to document and certify that waste characterization is accurate and complete. The Plan also contains waste sampling and analysis requirements to assure that the methodologies used are appropriate, representative, and approved to the types of waste being sampled. Criteria for use of indirect characterization methodologies are included to assure compliance with NVO-325 (DOE, 1988b).

A draft document has identified ten high priority LLW waste streams and nine mixed waste streams at LLNL (SAIC, 1990e); an outline of these is contained in Appendix C.

The waste characterization program, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.d.

4.3 WASTE ACCEPTANCE CRITERIA

DOE Order 5820.2A, Chapter III, paragraph 3.e., delineates specific waste acceptance criteria.

LLNL disposes of its LLW at the NTS Radioactive Waste Management Sites. DOE Nevada Operations specifies waste acceptance criteria for the NTS disposal sites in Section 2 of NVO-325 (DOE, 1988b). These include both package and waste form criteria to assure compliance with EPA and DOT requirements and to satisfy operational concerns at NTS. Waste acceptance criteria have been established and submitted to the cognizant field organization, DOE Nevada Operations. The LLNL waste certification program is subject to audit by the NTS disposal site authorities.

The Hazardous Waste Management Plan (LLNL, 1989a) incorporates NVO-325 as Appendix A and requires compliance with the disposal site acceptance criteria. Appendix E to the Plan provides a LLW and mixed waste certification program plan. The Plan requires certification by a Certification Officer that all LLW shipped to NTS meet the NTS-Waste Acceptance Criteria.

Additionally, to assure that LLW meets HWM operational requirements as well as DOE/Nevada Operations requirements, the Plan specifies waste acceptance criteria for wastes that are to be transferred from LLNL generators to HWM.

The LLW Compliance Plan (SAIC, 1990c) delineates the specific NTS waste acceptance criteria and implements the use of a Waste Stream Characterization Data Sheet to document compliance with the NTS-Waste Acceptance Criteria. The LLW Compliance Plan also refines the HWM waste acceptance criteria and requires generators to demonstrate compliance before HWM acceptance of the waste.

The waste acceptance criteria, as currently implemented, meet the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.e.

4.4 WASTE TREATMENT

DOE Order 5820.2A, Chapter III, paragraph 3.f., delineates waste treatment requirements.

HWM LLW and mixed waste treatment methodologies are detailed in Facility Operating Procedure, listed in Appendix D. Radioactive and mixed liquid wastes are treated at the Building 514 Tank Farm. Table 3-4 provides a summary of liquid treatment results from 1988. Guidelines for release of treated liquid waste to the sanitary sewer are specified in UCAR-10235 (Grandfield, 1989). All treated waste listed in Table 3-4 was released to the sanitary sewer system after meeting approved discharge limits. A summary of all sewer discharges from HWM facilities, including the Building 514 Tank Farm, are contained in Table 3-8.

Building 419 has various specialized treatment processes available. However, this facility has been shut down throughout 1990 due to seismic qualification problems. HWM is providing on-call decontamination services to LLNL projects. The loss of use of this facility, as noted in the DOE 1990 Tiger Team Audit, has likely resulted in an increase in volume of LLW.

HWM facility operations are supported by documentation for operations, maintenance, personnel training, personnel qualification, monitoring, and emergency response. These aspects of HWM operations are analyzed in the Draft HWM Facilities Safety Analysis Document (SAIC, 1990b).

The maintenance of records for each package of LLW that enters and leaves the treatment facility is addressed by the HWM database systems and the WDR system described in Subsection 4.2.

LLW treatment has been sufficient to meet the performance objectives as demonstrated in Section 2 of this PA.

The waste treatment methodologies, as currently implemented, meet the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.f.

4.5 SHIPMENT MINIMIZATION

DOE Order 5820.2A, Chapter III, paragraph 3.g., delineates specific shipment minimization requirement.

At the time of this PA, LLNL had not shipped any LLW to the NTS since March 1990. Further shipments of radioactive waste are awaiting approval of the LLW application and implementation of the LLW Compliance Plan. The draft application to dispose of radioactive waste, dated May 1990, was submitted to the NTS and DOE Nevada Operations for review. The application contained a 3-year waste volume forecast of generally decreasing volumes for most waste streams.

HWM Facility Operating Procedures HWM 528 and 533 require the packaging, labeling, and shipment of LLW in accordance with NVO-325, DOT, and other requirements including DOE Order 1540.1 (DOE, 1982a).

LLW is prepared in accordance with guidance provided in Huss (1987) so that it can be transported safely about LLNL. The Hazardous Waste Management Plan (LLNL, 1989a) addresses the packaging and shipment of LLW both on- and off-site.

A LLW Certification Program Plan is presented as Appendix E to the Hazardous Waste Management Plan (LLNL, 1989a). This certification program can be audited and independently reviewed. The certification program is being further refined by implementation of the LLW Compliance Plan as discussed in Subsection 4.2, above.

No formal program addresses the minimization of LLW shipments. However, the effective result of the Hazardous Waste Management Plan is to minimize the number of shipments. The Waste Minimization Program also reduces the number of shipments of

radioactive waste by reducing the overall volume of waste produced. The LLW Compliance Program provides further controls on the handling of LLW and produce the incentive to minimize the number of shipments due to the rigor of its controls.

There is no specific programmatic requirement to minimize LLW shipments as required by DOE Order 5820.2A, Chapter III, paragraph 3.g. However, the specific requirements of paragraph 3.g. are addressed by the LLNL program.

4.6 STORAGE MINIMIZATION

DOE Order 5820.2A, Chapter III, paragraph 3.h., delineates specific storage minimization requirements.

LLW and mixed waste generation is summarized in Table 3-1. These quantities indicate that the amount of wastes in long-term storage has been minimized, although the amount of stored solid mixed waste has been accumulating since 1984. The accumulation of solid mixed waste is allowed as there is currently no approved pretreatment method.

The vast majority of liquid LLW and liquid mixed waste is processed through the Building 514 Tank Farm. At the time of this PA, there were 9,000 gallons in Tank 25 at Building 514.

Waste minimization efforts can reduce the amount of waste generated. Significant reductions are not expected for approximately 5 years. The current generation rate of solid LLW and mixed waste is approximately $1 \text{ E}+4 \text{ kg/month}$.

As demonstrated in Section 3, the calculated dose to the public from the storage of LLW is not detectable and is significantly less than the levels of the performance objectives. Most wastes are of such a low level that they produce no significant external radiation field. The small amount of wastes that do produce larger external fields are appropriately shielded.

Records of the wastes that enter and leave the HWM facilities are maintained by the WDR system described in Subsection 4.2 of this PA and in the various HWM computer-based systems.

For those facilities which are planned and which are being put into service after the issuance of DOE Order 5820.2A, appropriate construction design reports and justification-of-

need documents are being and have been produced. Draft Safety Analysis Documents for the HWM facilities have been completed (SAIC, 1990b).

Recent Draft and Final Environmental Impact Reports (UC, 1986; UC, 1987) have been issued for LLNL. An Environmental Impact Statement (DOE, 1982b) has also been issued for the LLNL and Sandia National Laboratories, Livermore sites. These documents contain analyses of the need for the storage facilities.

Operational procedures and plans are issued to specify the necessary actions and controls for safely handling LLW. A list of the current HWM Operational and Safety Procedures is provided in Appendix D.

Storage minimization at LLNL, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.h.

4.7 WASTE DISPOSAL

DOE Order 5820.2A, Chapter III, paragraph 3.i., delineates specific disposal requirements.

Adherence to the NTS-Waste Acceptance Criteria are required by the Hazardous Waste Management Plan (LLNL, 1989a). Specific disposal requirements for LSA waste regarding waste packaging, liquids in the disposal container, reactivity, toxic gas generation, gas packaging, and pyrophoricity are contained in Facility Operating Procedures HWM 528 and 533. These address all the additional disposal requirements detailed in DOE Order 5820.2A, Chapter III, paragraph 3.i.(5). Additional guidance is also contained in the Preparation Guide (Huss, 1987).

The draft LLW Compliance Plan (SAIC, 1990c) and HWM LLW Procedures Manual provide guidance on LLNL's LLW disposal methods.

No procedures were identified that addressed the disposal requirements for other than LSA shipments. During 1989 two radioactive waste shipments contained non-LSA waste (Radioactive Material N.O.S.). For these, no documented disposal procedure was identified. Since these are infrequent shipments, procedures are being developed on a case-by-case basis.

There are no specific shipment procedures for non-LSA wastes as required by DOE Order 5820.2A, Chapter III, paragraph 3.i. Waste disposal at LLNL, as currently implemented, meets the programmatic requirements of the Order for LSA radioactive waste. Waste disposal procedures for other than LSA shipments will be provided on a case-by-case basis by HWM.

4.8 CLOSURE PLAN

DOE Order 5820.2A, Chapter III, paragraph 3.j., specifies requirements for development of closure plans for new and existing LLW disposal sites. LLNL does not currently operate an on-site LLW disposal facility but ships all LLW to the NTS. As LLNL has not operated a LLW disposal site since the issuance of Order 5820.2A, no specific closure plan is required by Chapter III, paragraph 3.j.

4.9 ENVIRONMENTAL MONITORING PROGRAM

DOE Order 5820.2A, Chapter III, paragraph 3.k., delineates specific environmental monitoring program requirements.

The LLNL monitoring program and the doses projected from environmental monitoring data from 1988 are detailed in Subsection 3.2. These doses are a minor percentage of the performance objectives and the applicable DOE Order limits. Direct radiation measurements at the Main Site boundary are equivalent to the measured background exposure and indicate no detectable contribution from LLNL activities. The analytic methods used to evaluate the environmental samples are generally capable of detecting radioactivity at levels in the range of 1/10,000 times the respective limit. This sensitivity is adequate to detect changing trends in performance sufficiently in advance to allow application of any necessary corrective action before performance objectives are exceeded.

The environmental monitoring program at LLNL, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.k.

4.10 QUALITY ASSURANCE

DOE Order 5820.2A, Chapter III, paragraph 3.1., delineates specific quality assurance (QA) requirements.

The DOE 1990 Tiger Team Audit identified that HWM did not have a QA program to verify the accuracy of generator-supplied information on WDRs.

A HWM QA Plan has been published and is included as Appendix D to the Hazardous Waste Management Plan (LLNL, 1989a).

Other parts of the LLW program are addressed by individual QA plans. The Environmental Monitoring Group has published and implemented a QA plan, UCAR-10203 (LLNL, 1987), for the environmental monitoring program. Packaging and shipment are addressed in Supplement 1, M-078, of the LLNL QA Manual (LLNL, 1985).

Formal QA programs are being developed as part of the Waste Minimization Program and LLW Compliance Plan (SAIC, 1990c). The LLWCP QA program will address waste certification and verification of generator-supplied information. The EPD QA Management Plan (SAIC, 1990d) is issued in draft.

The QA program for LLW operational and disposal practices at LLNL, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.1.

4.11 DOCUMENTATION OF LLW MANAGEMENT

DOE Order 5820.2A, Chapter III, paragraph 3.m., delineates specific documentation requirements. DOE/LLW-63T (DOE, 1989a) also delineates specific requirements for LLW documentation.

The Hazardous Waste Management Requisition System implements waste documentation and characterization requirements as part of an overall waste certification process. As part of the Requisition System, the Waste Disposal Requisition (WDR) form provides the primary records of a waste container's path from generator to final disposal. The WDR contains the physical and chemical characteristics of the waste, the quantity of each major radionuclide, the weight, the volume, and other data necessary to demonstrate

compliance with waste manifest requirements. The WDR system and the Preparation Guide (Huss, 1987) provide the means to assure that waste is properly classified, treated, stored, shipped, and disposed.

The LLW Compliance Plan (SAIC, 1990a) specifies documentation requirements for waste generators with regard to the chemical, radiological, and physical characteristics of wastes. These address the NVO-325 (DOE, 1988b) certification and acceptance criteria and prescribe the requirements for identification of waste as mixed or radioactive, determination of concentrations and types of constituents, and determination of waste form. The Plan contains and requires the use of a Generator Certification Form to document and certify that waste characterization and classification are accurate and complete.

A computerized Waste Management Data System (WMDS) is being developed to support data management and LLW tracking. The WMDS will maintain a complete profile of each waste stream that has been characterized and approved, a list of approved generators, and detailed classification and characterization data for each container.

The documentation of the LLW management system, as currently implemented, meets the programmatic requirements of DOE Order 5820.2A, Chapter III, paragraph 3.m.

5.0 DETERMINATION OF BASE SYSTEM COST PERFORMANCE LEVEL

5.1 HISTORICAL WASTE MANAGEMENT EXPENDITURES

Total system costs for handling LLW include the costs for waste reduction, minimization, segregation, storage, treatment, transportation, and off-site disposal. The bulk of these costs are budgeted through HWM. However, the expenditures for handling wastes from the point of generation to the point of transfer to HWM are assumed by the individual waste generator. This study presents an initial survey and provides best estimates of generator manpower costs as quoted by HWM personnel.

Waste disposal costs have received growing financial emphasis at LLNL over the last 5 years. The HWM budget has increased from \$3.5M in fiscal year 1987 to \$6.4M in fiscal year 1989. One third of the 1989 budget, approximately \$2M, was dedicated to off-site disposal cost including packaging, shipment, and disposal. The remainder, approximately \$4M, was budgeted for on-site operations which include waste treatment, storage, packaging, segregation, characterization, and waste minimization. Major capital equipment and facilities costs total \$460K. In addition to HWM, the Environmental Restoration Division (ERD) and the Regulatory Compliance and Monitoring Division (RCMD) shared in the waste management process by performing site remediation, effluent monitoring, and regulatory compliance. The RCMD has now been replaced by the Environmental Guidance Division (EGD) and the Regulatory Affairs Division (RAD). A 5-year budget summary for these three divisions is provided in Table 5-1. These expenditures encompass activities involving all waste types (TRU, hazardous, mixed, and low-level radioactive waste).

5.2 CURRENT SYSTEM COST AT LLNL

Fiscal year 1989 (FY89) is the base year for this systems cost performance analysis. This analysis is based on the HWM charge-back pilot study (LLNL, 1988c) which assessed costs for the different waste types. It details on-site and off-site disposal costs for each. These data are provided in Table 5-2. Costs have increased dramatically for FY90.

The unit cost for each waste type is computed based on the amounts of wastes generated in the year 1989. A total of $1.45 \text{ E}+5 \text{ kg}$ ($3.2 \text{ E}+5 \text{ lbs.}$) of solid LLW and $2.73 \text{ E}+5 \text{ kg}$ ($7.2 \text{ E}+4 \text{ gallons}$) of liquid LLW were generated in 1989. Solid mixed waste was about $4.69 \text{ E}+5 \text{ kg}$. Liquid mixed waste was about $1.08 \text{ E}+5 \text{ kg}$.

A cost analysis for all LLW and mixed waste at LLNL is complex because equipment, manpower allocation, and maintenance are not dedicated only to processing LLW or mixed wastes. They are also applied to the hazardous and TRU wastes. In many of the cost accounts, specific activities and costs are not identified for LLW or mixed waste. Where separate cost elements for the various waste categories could not be identified, the actual costs associated with disposing of LLW and mixed waste was estimated based on the fraction of these wastes generated. It is assumed that the cost fraction for the LLW and mixed waste is approximately one-third of the total cost.

5.2.1. Waste Minimization Cost

The FY89 waste minimization budget for HWM is \$306K and is directed toward waste reduction program plans for radioactive and non-radioactive wastes. LLNL waste generators are conducting individual waste generation and minimization activities. There are approximately fourteen major waste generators at LLNL. It is estimated that each waste generator dedicates an average of a man-year effort (at \$50/hour) to this project. Activities include training, planning, evaluations, and implementation. Based on this manpower estimate, expected total cost for all the waste reduction activities by all the waste generators is \$1.5M. With \$306K cost for waste minimization by HWM, the total cost for all the waste minimization activities at LLNL was approximately \$1.8M for FY89. On the assumption that 30% of the waste generated in 1989 was LLW, approximately \$600K is attributed to the minimization effort for LLW. The waste minimization efforts for FY90 have increased substantially.

Table 5-1. Estimated 5-Year Budgets for EPD Divisions in \$K.

EPD Divisions	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989
RCMD	2583	3488	3870	4760	5102
HWM	3982	3657	3530	4795	5928
ERD	4324	4037	4200	10295	11470
Total EPD	10889	11182	11600	19850	22500

Table 5-2. Disposal Costs for Identified LLNL Waste Types.

Waste Type	Cost ^a		
	\$/gal	\$/Lb	\$/Cu ft
Aqueous M	\$15.76	\$1.89	\$117.90
Size Reduce	\$18.77	\$2.25	\$140.36
Solid (V)	\$18.77	\$2.25	\$140.36
Bio/Ber	\$20.85	\$2.50	\$155.96
Rad/LLW	\$17.60	\$2.11	\$131.63
Rad/GCD	\$22.77	\$2.73	\$170.36
Rad/Mixed	\$20.77	\$2.49	\$155.36
Land Ban	\$21.18	\$2.54	\$158.43
Empty	\$4.17	\$0.50	\$31.19
Complex	\$23.19	\$2.78	\$173.43

Legend

M = Medium (PH:3-11)
 GCD = Greater Confinement Disposal
 V = Variable Cost
 Bio/Ber = Biological Environmental Research

^a Computed unit costs are based on volume of wastes generated in 1989 base year.

5.2.2. Waste Segregation

Segregation is generally accomplished at the point of generation or at WAAs prior to transfer to HWM. The cost for this process to the various programs is primarily for man-hours provided by the individual programs and by HWM. These costs are not tracked in separate accounts. Segregation activities are also performed by HWM. For the various programs, it is estimated that 1 to 2 man-years are required for handling the wastes (or about \$2.1M for fourteen waste generators). Handling includes segregation, characterization, and shipping wastes; one-third of this effort is attributed to segregation. Therefore, approximately \$70K is expended by all the programs on waste segregation. For efforts provided by HWM, it is estimated that 20% of the support staff manpower budget (\$41K) and 50% of the field budget (\$36K) are attributable to the segregation effort.

Waste segregation is also accomplished as part of the Lab Packing activity at the HWM facilities. The cost for this operation was about \$750K. The total costs for segregation at LLNL are approximately \$900K. The portion of this total for LLW and mixed waste is approximately \$330K.

5.2.3 Waste Characterization

Waste characterization is accomplished either by the HWM Laboratory, Environmental Analytical Sciences laboratory, or an outside laboratory with control and guidance by the Environmental Analytical Sciences Laboratory. The cost incurred by HWM in FY89 was \$306K. The waste generators also perform waste characterization to ensure that wastes are characterized appropriately before transfer to HWM. It is estimated that characterization costs of the different programs amount to a total generator cost of approximately \$2 M. The total cost for characterizing all the wastes at LLNL is about \$2,306K and the cost incurred for LLW is about \$770K.

5.2.4 Storage

The cost for waste storage was not directly budgeted or tracked in FY89. The cost items that are attributed to storage are the costs for the storage facilities, equipment, and manpower.

For FY89, the cost of operating Complex 612 is \$680K, with half attributed to manpower. The cost for operating Building 514 is \$553K and the cost for operating Building 883 at Site 300 is estimated to be \$450K. Building 612 operations include processing of solid radioactive waste but the primary activity is storage of solid wastes. It is estimated that 90% of the costs (~\$612K) for Complex 612 are associated with storage operations. The principal activity in Building 514 is treatment of liquid waste and only 10% of the cost (~\$55K) is associated with activities involving temporary storage of the liquid waste. Site 300 facilities generate a mixed waste stream consisting of LLW and heavy-metal-contaminated gravels from on-site explosive testing. Building 883 is solely a storage facility. Storage activities at the WAA by the waste generators amount to about \$70K. Based on the above cost figures, it is estimated that the total cost for storing all waste is \$1.2M. The cost for storing LLW and mixed waste is approximately \$400K.

5.2.5 Treatment

The total FY89 budget for waste treatment, building maintenance, and storage for Buildings 514, 419, and the 612 Complex is about \$1M. Of this approximately one third, \$330K, is attributed to the treatment of LLW and mixed waste.

Other waste treatment costs include costs for compaction and waste recycling. These costs are for manpower and maintenance of equipment and facilities. These costs are not tracked by HWM.

5.2.6 Off-Site Disposal

The FY89 cost for disposing of LLW was \$160K and the cost for transportation was \$20K, for a total cost of \$180K.

5.2.7 Facility Costs

There are costs associated with maintaining the waste management facilities. Additionally, DOE Order 5481.1B requires that facilities handling hazardous and radioactive materials have a safety analysis performed. Currently, the HWM Safety Analysis Document is being updated. For FY89 the cost for this activity is \$80K. For FY89, general maintenance expenditures are \$227K, bringing the total facility cost for FY89 to \$307K.

5.2.8 Summary of Current System Costs

The above are direct costs associated with each of the major components of the waste disposal system. Costs were also incurred in FY89 for capital equipment upgrades that are not included in any of the above categories. In addition, there are many indirect costs associated with operating and managing any facility. These costs, occasionally referred to as the overhead expenses, include such items as administrative expenses for HWM, training, support staff, field operations, and other miscellaneous projects, such as seismic studies. Overhead expenses for FY89 were

FY89 Overhead Costs

	<u>\$K</u>
1. Administrative Costs (\$525K)	
• Operations Administration	266
• HWM Administration	259
2. Training (\$116K)	
• Operations Administration	85
• HWM Administration	31
3. Support Staff (\$856K)	

●	Procurement	243
●	Manpower	162
●	Other labor	354
●	Misc.	97
4.	Projects (\$102K)	
●	Seismic studies	10
●	Incinerator model	57
●	Other projects	35
5.	Field Support (\$36K)	36
		=====
	Total Overhead	1,635

These expenditures were analyzed and assigned to the individual components of the waste disposal system. A summary of the costs for the components of the waste disposal systems for all the operations and facilities is provided in Table 5-3. This study estimates the total system costs for managing and disposing of all the LLW and mixed waste at LLNL for FY89 at \$3,300K for a total of 6×10^5 kg of LLW and mixed waste. On the basis of this estimate, the total system disposal cost for LLW is about \$5.50 per kilogram or \$2.50 per pound.

5.3 FUTURE COSTS

The FY90 update of the Waste Management Plan (LLNL, 1989h) delineates future plans through FY94, including details for costs, milestones, and schedules for managing hazardous, radioactive, and mixed waste. To ensure compliance with all applicable DOE Orders and regulatory requirements, LLNL has identified a number of waste management operational areas and waste management systems that require improvement.

Future costs for LLW and mixed waste management are based on the estimates provided in the Waste Management Plan and by HWM Personnel. An approximately constant cost of \$1.5 M for generator minimization activities is included. These cost figures are summarized in Table 5-4.

Table 5-3. FY89 Total System Cost for Waste Disposal in \$K.

	All Wastes	Estimated Costs For LLW/Mixed Waste
HWM Waste Minimization	306	100
Generator Minimization Activities	1500	500
Segregation Activities	900	300
Characterization	2306	770
Storage	1200	400
Treatments	1000	330
Off-site Disposal	1420	180
Overhead Activities	1635	544
Capital Equipment	460	153
TOTAL	10,727	3277

5.4 CLOSURE COSTS

Detailed closure plans have been prepared for the HWM facilities and are provided in the RCRA Part B Permit Application (LLNL, 1989d). These plans, however, only address the radiological decontamination of HWM facilities without addressing the closure cost elements. No closure cost information was available for this analysis.

5.5 SUMMARY COSTS OF BASE SYSTEM

The total system cost for disposing of LLW and mixed waste for FY89 is about \$2.3M. The total cost for disposing of LLW and mixed waste will continue until FY93. In FY94 the total cost may begin to stabilize.

Assuming constant production of LLW and mixed waste in future years, the system cost per unit weight will increase by at least 30% per year for the next 5 years. The current cost of \$5.50 per kilogram for FY89 will increase to about \$21.30 per kilogram by FY94. These represent the costs for the base system at LLNL.

Other program improvements and equipment options are being considered for implementation by HWM. These are the preferred system options and the costs of these are additive to the costs of the base system for disposing of LLW and mixed waste. The preferred system options and their costs are discussed in Section 6.

Table 5-4. Estimated Future System Costs for Total Waste Management in \$K*.

	FY90	FY91	FY92	FY93	FY94
Waste Minimization Plan	462	840	2,990	7,190	9,190
Generator Minimization Activities	1,500	1,500	1,500	1,500	1,500
Waste Treatment	1,072	1,960	2,900	3,500	3,500
Waste Storage	7,189	1,408	8,500	9,000	9,000
Waste Disposal	1,263	5,874	5,680	6,100	6,100
Operations	5,984	4,176	10,800	10,800	10,800
Capital Equipment	538	775	2,010	2,160	2,060
General Plant Project	0	615	600	500	500
Total Waste	13,508	17,148	34,980	40,750	42,650
Total LLW and Mixed Waste (30% of System Cost)	4052	5144	10,494	12,225	12,795

* Supplied by L. Roszell, HWM, 20 November 1990.

6.0 DETERMINATION OF PREFERRED LLW SYSTEM

6.1 PREFERRED SYSTEM OPTIONS

Three major areas for improvement to the base system are under consideration at LLNL. The first major area is the construction of the Decontamination and Waste Treatment Facility (DWTF) Project (Project No. 86-D-103). This project will enhance waste management at LLNL with the construction of approximately 88,310 ft² of new facilities for decontamination and waste treatment. The DWTF will replace presently scattered and outmoded waste treatment and storage facilities with a new consolidated complex for the treatment of wastes. The expanded capacity will allow the processing and treatment of approximately 90% of the wastes generated at LLNL compared to the current 10%.

The estimated cost for the DWTF project is

<u>Cost Items</u>	<u>\$M</u>	
	<u>Total Cost</u>	<u>LLW and Mixed Waste Portion</u>
Engineering, Design, and Inspection	8.7	2.6
EIS, SAR, Environmental Permits	4.7	1.4
Construction Costs	33.5	11.5
Standard Equipment 2.6	1.7	
Decontamination and Relocation	3.2	1.0
Contingency (15%)	<u>6.7</u>	<u>2.0</u>
Total Project Cost	\$59.4M	\$20.2M

These costs are based on estimates provided in the Schedule 44, DOE FY92 Congressional Budget Request; and, for the construction and design activities which cannot be distinctly identified as costs pertaining to LLW or mixed waste, a factor of 30% of the total cost is assumed, as justified in Section 5.

The major buildings and processes for the DWTF project include

- Decontamination Building - Chemical/steam cleaning, grit blasting, vapor decontamination, electro-polishing, and ultrasonic cleaning

- Liquid Waste Processing - Blending, chemical adjustment, precipitation, evaporative concentration, crystallization, and solidification
- Waste Receiving, Classification, and Solid Waste Processing - Waste receiving, sorting, compacting, shredding, and packaging
- Reactive Materials - Chemical treatment and neutralization to reduce reactive chemicals and gases to an innocuous state
- Storage - Radioactive and mixed waste
- Operation Support Building - Offices and administration.

Construction of the DWTF buildings and facilities is expected to be completed by 1997 and operation will commence in 1998. At present, there are no viable alternatives for the on-site treatment of the range of mixed waste generated at LLNL. With $6 \text{ E}+5 \text{ kg/y}$ of LLW and mixed waste, the comparative cost for treating one kilogram of this waste is estimated to be \$1.12 for an assumed economic life of 30 years for the DWTF.

The second major area for improvements to the base system is the implementation of treatment units described in the recent RCRA Part A Permit Application (LLNL, 1990c). Insufficient information is currently available to estimate the total costs for these units. The cost data obtained are preliminary and based on discussions with HWM personnel. An implementation cost three times the capital equipment cost for each unit is assumed. In addition, a 10-year economic life for each unit is assumed. The treatment units are described in Subsection 6.1.1.

The third major area of improvement to the base system involves activities that resolve the major findings by the recent Tiger Team Audit and address the programmatic requirements of DOE Order 5820.2A (DOE, 1988a). These activities are described in Subsection 6.1.2.

6.1.1 Treatment Units

Vial Crusher. The vial crusher will be used for crushing plastic or glass liquid scintillation vials. This technology is necessary to separate mixed wastes into treatable streams. The vial

crusher can handle up to 7,000 plastic or 10,000 glass vials/hour. The unit treats only mixed waste and is expected to operate for about 20 days per year at 5 liters/day. The total volume of hazardous and mixed waste treated per year may be approximately ~ 100 liters (26 gal). The capital cost for purchasing the unit is about \$20K. The cost for implementation is estimated to be \$60K, bringing the total cost for the unit to \$80K. The comparative cost is \$80/kg.

Ram Flat Compactor. The ram flat compactor will be used for volume reduction of LLW within drums. This technology is necessary to minimize the waste volume sent to the NTS. The unit is expected to operate for about 100 days/year at a capacity of 1 ton/day. The ram flat compactor may compact 100 tons/year. The capital cost of the unit is about \$32K and the cost to implement is about \$96K. The total cost for implementing the system is \$128K. The total cost associated with LLW and mixed waste is \$38K, or 30% of the total cost. The comparative unit cost is \$0.13/kg.

Shredder. The shredder will handle a variety of debris-type contaminated wastes. This technology is necessary to minimize the waste volume sent to the NTS. The unit may process 65 tons of wastes per year. The capital cost for the shredder is estimated to be \$90K. The implementation cost is about \$270K. The total cost for implementing the system is about \$360K. The total cost associated with LLW and mixed waste is \$108K. The comparative cost is \$0.55/kg.

Drum Rinse Station. The drum rinse station will decontaminate drums and is necessary to minimize the waste volume sent to the NTS. The drums are the waste form for this analysis. The drum rinse station may process 50 metric tons/year. The capital cost of the station is estimated at \$45K, and the implementation cost is \$135K. The total cost for implementing the unit is \$180K. The total cost associated with LLW and mixed waste is \$41K. The comparative cost is \$0.27/kg.

HWM Evaporator. The evaporator will treat aqueous wastes with dissolved salts or particulate. The evaporator along with the centrifuge will replace the current Dorr-Oliver

filtration unit. This technology is necessary to minimize the waste volume sent to the NTS. The capital cost for the unit is about \$150K and the implementation cost is about \$450K. The total cost for implementing the unit is \$600K and the total cost associated with LLW and mixed waste is \$180K. This system may process $6.8 \text{ E}+5 \text{ L}$ ($1.8 \text{ E}+5 \text{ gal}$) of liquid wastes per year. The comparative cost is \$1.87/kg.

Centrifuge. This process will separate the various liquid and solid phases using centrifugal force. The centrifuge along with the evaporator will replace the current Dorr-Oliver filtration unit. This technology is necessary to separate mixed waste into treatable streams. It also treats multi-phase liquids. The capital cost for this process is about \$35K, and the implementation cost is estimated at \$105K. The total cost for implementing the system is about \$140K. The total cost associated with LLW and mixed waste is \$42K. This process may treat about $4.9 \text{ E}+5 \text{ L}$ ($1.3 \text{ E}+5 \text{ gal}$) per year. The comparative cost is \$0.03/kg.

Extractor/Washer. This unit will remove leachable constituents from solid waste streams. This technology is necessary to separate mixed waste into treatable streams. The extractor/washer also treats liquid wastes containing high concentrations of organic constituents. The capital cost for this unit is about \$100K, and the implementation cost is \$300K. The total cost for implementing the system is \$400K, and the total cost associated with LLW and mixed waste is \$120K. This system may treat about 250 liters (66 gal) of waste per year. The comparative cost is \$160/kg.

Stabilization. This process will reduce the ability of a waste to leach constituents by bonding the waste into a matrix. This process will replace current solidification operations. This technology must be implemented to comply with land disposal restrictions published in FR 22694, 40 CFR 148. This system treats aqueous waste solutions. The capital cost for this process is about \$10K and the implementation cost \$30K. The total cost for implementing the system is \$40K and the total cost associated with LLW and mixed waste is \$10K. This system may treat about 42 m^3 ($1.1 \text{ E}+4 \text{ gal}$) per year. The comparative cost is \$0.09/kg.

Amalgamation and Smelting. This process will purify metals by smelting. This technology must be implemented to comply with land disposal restrictions published in FR 22693, 40 CFR 148. Slag and other machining contaminants can be removed from uranium and thorium by smelting. The capital cost for this unit is about \$50K, and the cost for implementation is about \$150K. The total cost for implementing the system is estimated at \$200K. The total cost associated with LLW and mixed waste is \$60K. The total volume of metal wastes treated per year is estimated to be 2 m³ (2.5 yd³). The comparative cost is \$1/kg.

Drying. This process will remove the water from solid mixed waste with a high water content. This technology is necessary to dry filter media, soil, and debris from the extraction operation prior to treatment. The quantity of wastes treated per year is about 32 m³ (42 yd³). The capital cost for this operation is about \$10K, and the implementation cost is about \$30K. The total cost for implementing the system is \$40K. The system treats primarily LLW and mixed waste. The comparative cost is \$0.13/kg.

Controlled Water Reaction. This process will treat water reactives with the proper reactants to reduce their volatilities. This technology must be implemented to comply with land disposal restrictions published in FR 22694, 40 CFR 148. The capital cost for the unit is about \$10K, and the cost to implement it is about \$30K. The total cost for implementing the system is estimated at \$40K. The total cost associated with the LLW and mixed waste is about \$10K. The quantity of waste treated per year may be 45 kg (100 lbs.). The comparative cost is \$89/kg.

Macroencapsulator. Macroencapsulation will trap material inside an inert matrix to prevent release of radioactive constituents. This technology must be implemented to comply with land disposal restrictions published in FR 22694, 40 CFR 148. This system may treat about 2.5 yd³ (2 m³) per year. The capital cost of this unit is about \$15K, and the cost for implementing the unit is about \$45K. The total cost for implementing the system is \$60K. The system treats only LLW and mixed waste. The comparative cost is \$3/kg.

6.1.2 Program Improvements

Low Level Waste Compliance Program and Plan. This Program addresses the regulatory requirements for waste stream characterization, waste acceptance criteria, waste packaging, waste certification, and waste transfer established in NVO-325 (DOE, 1988b) and required by DOE Order 5820.2A, Chapter III, paragraphs 3.d and 3.e. The purpose of the LLW Compliance Program is to establish the requirements and responsibilities for the management of LLW. The total cost for drawing up the LLW Compliance Plan is about \$40K. This Plan must be implemented by the waste generator organizations. This is estimated to cost \$1M, for a total cost of \$1,040K.

Waste Sampling Program. This activity involves the design, development, and documentation of an enhanced waste sampling program at LLNL and is required for compliance with DOE Order 5820.2A, Chapter III, paragraph 3.d. The task assimilates existing sampling programs and procedures into a final overall program document. The cost incurred by HWM for this program plan is \$65K and is associated with establishing similar program plans for waste generators. The cost for implementing this program is estimated at \$1M. Total costs are estimated to be about \$1,065K.

Waste Certification. This effort involves establishing a QA Program, upgrading procedures, and generator training to add assurances that the wastes provided by the waste generators are properly characterized. Certification is required for compliance with DOE Order 5820.2A, Chapter III, paragraph 3.e. The total cost for establishing these procedures and programs is estimated at \$50K. The cost for implementing the program at LLNL is estimated to be about \$1M, for a total cost of \$1,050K.

Waste Acceptance Criteria. This task involves developing waste acceptance criteria procedures for HWM to comply with requirements of DOE Order 5820.2A, Chapter III, paragraph 3.e. The cost for this effort is estimated at \$75K. The implementation costs are estimated to be about \$1M, for a total cost of \$1,075K.

6.2 COST-BENEFIT AND ALARA ANALYSES

This Subsection presents the cost-benefit and ALARA analyses required by DOE/LLW-63T (DOE, 1989a).

6.2.1 Cost-Benefit Analysis

Cost factors associated with each option are estimated by dividing the total cost for implementing the system option by the quantity of LLW and mixed waste impacted by each of the options. This analysis does not include such recurring costs as annual maintenance, operating costs, or other costs for decommissioning the units. All equipment options are assumed to have an economic life of 10 years. The DWTF is assumed to have an economic life of 30 years. For the options involving the LLW program, the implementation costs are primarily estimated manpower efforts provided by other program generators. These procedures and documents can be subject to revisions on a yearly basis. The cycle for economic consideration of these options is one year.

Each system option discussed in Subsection 6.1 may be used for both radioactive and non-radioactive waste. The cost-benefit analysis considers only costs associated with LLW and mixed waste.

The LLW Compliance Plan deals with 10 LLW streams. The waste certification option deals with both LLW and mixed waste. The waste sampling and waste acceptance criteria address all the wastes, both radioactive and nonradioactive. The cost analysis of these two options is weighted by the quantity of radioactive waste. The results of the cost-benefit analysis are presented in Table 6-1 and Figure 6.1.

6.2.2 ALARA Analysis

DOE/LLW-63T (DOE, 1989a) regards the costs for the base system as those associated with the site meeting the minimum performance objectives.

The radiological cost-benefit (ALARA) analysis for the preferred LLW system options is performed in accordance with the guidance of International Commission on Radiological

Table 6-1. Cost-Benefit Factors for the Preferred System Options.

Preferred System Options	Economic Life	LLW and Mixed Waste Quantity Impacted (Base year 1989)	Total First Cost (in \$K)	Cost Ratio \$/kg	Collective Dose Ratio \$/Person-Rem (on-site)	Justification
Centrifugation	10	1.5 E+5 L	42	0.03	+1 E+5	This technology is necessary to separate mixed wastes into treatable streams.
Stabilization	10	1.3 E+1 m ³	12	0.09	+3 E+5	This technology must be implemented to comply with land disposal restrictions published in FR 22694, 40 CFR 148.
Drying	10	3.2 E+1 m ³	40	0.13	-8 E+5	This technology is necessary to dry filter media, soil and debris from extraction operation prior to treatment.
Ram-Flat Compactor	10	3 E+4 kg	38	0.13	-7 E+5	This technology is necessary to minimize waste volume sent to NTS.
Drum Rinse Station	10	1.5 E+4 kg	41	0.27	-2 E+6	This technology is a decontamination methodology which minimizes waste volume sent to NTS.
Shredder	10	2 E+4 kg	108	0.55	-3 E+6	This technology is necessary to minimize waste volume sent to NTS.
Waste Sampling	Annual	6 E+5 kg	320	0.53	-3 E+5	Required for compliance with DOE Order 5820.2A, Chapter III, paragraph 3.d.
WAC	Annual	6 E+5 kg	320	0.53	-3 E+5	Required for compliance with DOE Order 5820.2A, Chapter III, paragraph 3.e.
Amalgamation & Smelting	10	6 E-1 m ³	60	1.00	-6 E+6	This technology must be implemented to comply with land disposal restrictions published in FR 22693, 40 CFR 148.
DWTF	30 yr. life	6 E+5 kg	20,200	1.12	+1 E+7	Facilities needed to centralize HWM activities with improved safety and operational effectiveness.
Waste Certification	Annual	6 E+5 kg	1050	1.75	-1 E+7	Required for compliance with DOE Order 5820.2A, Chapter III, paragraph 3.e.
Evaporator	10	9.6 m ³	180	1.87	+6 E+6	This technology is necessary to minimize waste volume sent to NTS.
LLWCWP	Annual	4.16 E+5 kg	1040	2.50	-2 E+7	Required for compliance with DOE Order 5820.2A, Chapter III, paragraphs 3.d and e.

Table 6-1. Cost-Benefit Factors for the Preferred System Options (continued).

Preferred System Options	Economic Life	LLW and Mixed Waste Quantity Impacted (Base year 1989)	Total First Cost (in \$K)	Cost Ratio \$/kg	Collective Dose Ratio \$/Person-Rem (on-site)	Justification
Macroencapsulation	10	2 m ³	60	3.00	-2 E+7	This technology must be implemented to comply with land disposal restrictions published in FR 22693, 40 CFR 148.
Vial Crusher	10	1 E+2 L	80	80.00	-5 E+8	This technology is necessary to separate mixed wastes into treatable streams.
Controlled Water Rx.	10	1.4 E+1 kg	12	89.00	-5 E+8	This technology must be implemented to comply with land disposal restrictions published in FR 22694, 40 CFR 148.
Extraction & Washing	10	7.5 E+1 L	120	160.00	-1 E+9	This technology is necessary to separate mixed wastes into treatable streams.

Figure 6-1. Cost-Ratio and Waste Quantity for the Preferred System Options.

Protection (ICRP) Publications 26 and 37 (ICRP, 1977; ICRP, 1983). The dose to the maximally exposed member of the public from LLW activities is estimated in Table 3-10. The maximum dose from liquid effluents is estimated to be 1 E-2 mrem , with a most probable value of approximately 3 E-5 mrem . The dose from gaseous effluents is estimated as 3 E-3 mrem . The LLNL Environmental Report for 1988 (LLNL, 1988b) estimates a total collective dose of 0.73 person-rem to members of the public from gaseous effluents (see Table 3-14). The dose from liquid effluents and direct radiation was taken to be, essentially, zero in the Environmental Report. The 0.73 person-rem was due to the release of approximately 4 E+3 Ci of H-3 from the various LLNL facilities over the course of 1988. A simple ratio of the H-3 release of 5 E-1 Ci , from 1989 LLW activities as noted in Table 3-9, results in an estimated total collective dose of 9 E-5 person-rem to members of the public.

The single H-3 release noted in Table 3-9 is not related to the vast amount of LLW processed by HWM in 1989. However, it is used to estimate the collective dose from releases of gaseous radioactivity. Environmental monitoring data supports the conclusion that this is the primary mode of exposure to members of the public from LLNL activities. Low levels of gaseous effluents are possible from the various preferred system options and are not expected to be in excess of 5 E-1 Ci .

For the purpose of this analysis, it is assumed that the direct radiation exposure component to members of the public from LLW handling and disposal will be maintained at a less-than-detectable level. Also, it is further assumed that the liquid effluent exposure component will be maintained at an insignificant level in comparison to the gaseous effluent exposure component.

The collective dose impact of the current LLW system is, therefore, less than $1 \text{ E-1 person-mrem}$. ICRP Publication 37 specifies $\$100\text{-}200/\text{person-rem}$ as a typical valuation for radiation exposure in cost-benefit analysis and 10 CFR 50, Appendix I, specifies $\$1,000/\text{person-rem}$. At these levels, a collective dose of less than 1 person-mrem is ALARA and, therefore, the base LLNL LLW and mixed waste management system is an ALARA system.

Although this PA is concerned only with exposures to members of the public, the application of the ICRP Publications 26 and 37 methodology necessitates the consideration of collective dose as including the exposures of LLNL personnel. All the preferred system

options are technological systems that would result in the occupational exposure of HWM personnel during their implementation. The current level of collective occupational dose to HWM personnel is approximately $1 \text{ E-1 person-rem/year}$ (Hoyt, 1990b).

These collective doses, $9 \text{ E-5 person-rem/year}$ to the public and $1 \text{ E-1 person-rem/year}$ to HWM personnel, are assured to correspond to the 6 E+5 kg of LLW and mixed waste processed in 1989. Taking a simple ratio, it is assumed that the handling of a unitary mass of LLW and mixed waste will result in a dose of $1.7 \text{ E-7 person-rem/kg}$ throughout the course of a year; a collective dose ratio is calculated in Table 6-1 based on the annual quantity of waste that is projected to be handled by each of the preferred system options and the associated cost of the option. All of the options, with the exception of the DWTF, the evaporator, the centrifuge and stabilization are expected to be collective dose intensive, i.e., to result in more rather than less collective dose. HWM personnel will be required to be in proximity to the waste for processing and will accumulate additional dose when implementing these other options. The DWTF centrifuge, evaporator and stabilization options are being designed specifically to handle and process waste. They could result in lower collective doses to HWM personnel than the current processes. For the purpose of estimation, a 50% saving, in collective occupational dose is projected for each of these.

Table 6-1 details the cost factors for each of the options; estimated cost per person-rem saved and cost per additional person-rem expended. The later are represented by negative numbers (the closer the negative number is to zero, the less dose intensive it is). None of the collective dose intensive options are justified from solely a dose optimization standpoint. For the others the cost/person-rem is much in excess of the \$100-200/person-rem used in ICRP 37 and the \$1,000/person-rem specified in 10 CFR 50, Appendix I.

6.3 CONCLUSIONS

Collective dose effectiveness is not and should not be the sole criterion used to evaluate the preferred system options. Compliance with EPA requirements, DOE guidance, LLNL management policy, and amelioration of public concerns must also be considered. Nor can the options be evaluated simply on the basis of the cost factors. Other considerations such as technological effectiveness, engineering constraints, etc., have to be

weighed against the economic factors to provide a complete assessment of each option. The benefits of compliance with LLNL policy, DOE guidance, and EPA requirements, and amelioration of public concerns can justify the adoption of additional technologies.

7.0 REFERENCES

- Adams (1990), Superintendent, Livermore Water Reclamation Plant, personal communication to J. Russell, SAIC Internal document.
- ANSI/ASME (1989), *Quality Assurance Program Requirements for Nuclear Facilities*, NQA-1.
- Atomic Energy Act* (1954), Public Law 83-703.
- Buddemeier, R.W., Ruggieri, M.R., and Oberdorfer, J.A. (1987), *Tritium in Groundwater at Site 300*, LLNL, UCID-21031.
- Buerer, A. (1983), *Assessment and Cleanup of the Taxi Strip Waste Storage Area at LLNL*, LLNL, UCID-20869.
- Carpenter, D.W., Sweeney, J.J., Kasameyer, P.W., Burkhard, N.R., Knauss, K.G., and Schlemon, R.J. (1984), *Geology of the Lawrence Livermore National Laboratory Site and Adjacent Areas*, LLNL, Livermore, CA, UCRL-53316.
- Clean Air Act* (1977).
- Copland, J. (1990), personal communication with J. Copland, Geologist SAIC, regarding Holocene Age faulting, SAIC internal files.
- Department of Energy (1981), *Environmental Protection, Safety, and Health Protection Information Reporting Requirements*, U.S. Department of Energy, Washington, D.C., DOE Order 5484.1.
- Department of Energy (1982a), *Materials Transportation and Traffic Management*, U.S. Department of Energy, Washington, D.C., DOE Order 1540.1.
- Department of Energy (1982b), *Lawrence Livermore National Laboratory and Sandia National Laboratory Livermore Final Environmental Impact Statement Livermore Site, Livermore California*, U.S. Department of Energy, Washington, D.C., DOE/EIS-0028.
- Department of Energy (1983), *General Design Criteria*, U.S. Department of Energy, Washington, D.C., DOE Order 6430.1.
- Department of Energy (1984), *Environmental Protection of the Public and the Environment*, U.S. Department of Energy, Washington, D.C., DOE Order 5480.4.

- Department of Energy (1986), *Quality Assurance*, U.S. Department of Energy, Washington, D.C., DOE Order 5700.6B.
- Department of Energy (1988a), *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C., DOE Order 5820.2A.
- Department of Energy Nevada Operation (1988b), *Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements*, U.S. Department of Energy, Nevada Operations Office, NVO-325, UC-70B.
- Department of Energy (1988c), *General Environmental Protection Program*, U.S. Department of Energy, Washington, D.C., DOE Order 5400.1.
- Department of Energy (1988d), *Draft Radiological Effluent Monitoring and Environmental Surveillance*, U.S. Department of Energy, Washington, D.C., Draft DOE Order 5400.XY.
- Department of Energy (1989a), *Guidance for Conduct of Waste Management Systems Performance Assessment*, U.S. Department of Energy, Washington, D.C., Revision 1, DOE/LLW-63T.
- Department of Energy (1989b), *Hazardous and Radioactive Mixed Waste Program*, U.S. Department of Energy, Washington, D.C., DOE Order 5400.3.
- Department of Energy (1989c), *Radiation Protection for Occupational Workers*, U.S. Department of Energy, Washington, D.C., Change 1, DOE Order 5480.11.
- Department of Energy (1990), *Radiation Protection of the Public and the Environment*, U.S. Department of Energy, Washington, D.C., DOE Order 5400.5.
- Eisenbud, M. (1987), *Environmental Radioactivity from Natural, Industrial, and Military Sources*, Academic Press, Inc.
- Environmental Protection Agency (1976), *Resource Conservation and Recovery Act*, Environmental Protection Agency, Washington, D.C.
- Environmental Protection Agency (1989), *User's Guide for AIRDOS-PC Version 3.0*, Office of Radiation Protection Programs, Las Vegas, NV, EPA 520/6-89-035.
- Federal Water Pollution Control Act* (1972).
- Geomatrix Consultants, Inc. (1985), *Seismic Exposure Comparison Report and Spectra Report*, San Francisco, CA, prepared for LLNL, Livermore, CA, UCRL-15858.

- Gilbert, T.L., Yu, C., Yuan, Y.C., Zielen, A.J., Jusko, M.J., and Wallo, A. (1989), *A Manual for Implementing Residual Radioactive Material Guidelines*, Argonne National Laboratory, Energy and Environmental Systems Division, ANL/ES-160, DOE/CH/8901.
- Goveia, F., and Chapman, K.R. (1989), *Climatology of Lawrence Livermore National Laboratory*, LLNL, Livermore, CA, UCID-21686.
- Grandfield, C.H. (1989), *Guidelines for Discharges to the Sanitary-Sewer System*, LLNL, EPD, Guidance and Monitoring Division, UCAR-10235.
- Grandfield, C.H. (19XX), *Wastewater Point-Source Monitoring at Lawrence Livermore National Laboratory's Livermore Site*, Lawrence Livermore National Laboratory, Livermore, CA, UCAR-10204-XX-Y. (This is a semiannual series of reports where XX represents the year and Y represents the first or second semiannual period.)
- Hallisey, M.L. (1988), *RCRA Facility Assessment Additional Data Needs in Preparation for the Visual Site Inspection (VSI) Livermore Site*, LLNL, Livermore, CA.
- Hirabayashi, J.M. (1989), *Guidelines for Waste Accumulation Areas*, LLNL, EPD, Revision 1, UCAR-10192.
- Hoyt, D. (1990a), *Types and Quantities of Low Level Radioactive Waste (LLW) Containers Shipped from LLNL for Calendar Years 1980 to 1988*, Lawrence Livermore National Laboratory, HWM, HWM 90-556.
- Hoyt, D. (1990b), Lawrence Livermore National Laboratory, EPD, personal communication with J. Russell, SAIC internal document.
- Huss, J. (1987), *Preparation Guide for Generators of Hazardous Chemicals and Radioactive Waste at LLNL*, LLNL, EPD.
- International Commission on Radiological Protection (1977), *Recommendations of the International Commission on Radiological Protection*, Pergamon Press, New York, NY, Publication 26.
- International Commission on Radiological Protection and Measurement (1979), *Limits for Intakes of Radionuclides by Workers*, Publication 30, Pergamon Press, New York, N.Y.
- International Commission on Radiological Protection (1983), *Cost-Benefit Analysis in the Optimization of Radiation Protection*, Pergamon Press, New York, NY, Publication 37.

Isherwood, W. (1990), LLNL, ERD, personal communication with J.E. Russell, SAIC internal document.

Lamarre, A., and M. Taffet (1990), LLNL, Site 300, personal communication with J.E. Russell, SAIC internal document.

Limerinos, J.T., Lee, K.W., and Lupo, P.E. (1973), *Flood Prone Areas in the San Francisco Bay Region, California Water Resources Investigation (37-73) Open File Report*, San Francisco Bay Region Environment and Resources Planning Study, U.S. Department of Housing and Urban Development, Interpretive Report 4.

Lawrence Livermore National Laboratory (1985), *Quality Assurance Manual*, M-078.

Lawrence Livermore National Laboratory (1987), *Environmental Quality Verification Group Quality Assurance Plan*, EPD, Guidance and Monitoring Division, UCAR-10203.

Lawrence Livermore National Laboratory (1988b), *Environmental Quality Verification Group Procedures Manual*, EPD, Guidance and Monitoring Division, UCAR-10254.

Lawrence Livermore National Laboratory (1989a), *Hazardous Waste Management Plan*, EPD, HWM, UCAR-10264.

Lawrence Livermore National Laboratory (1989b), *Hazardous Waste Treatment and Storage Facilities Lawrence Livermore National Laboratory Livermore Site*, Resource Conservation and Recovery Act, Part B Permit Application, EPD, EGM, EPA ID Number CA 2890012584, UCAR-10275.

Lawrence Livermore National Laboratory (1989c), *Lawrence Livermore National Laboratory Environmental Report for 1988*, EPD, Guidance and Monitoring Division, UCRL-50027-88.

Lawrence Livermore National Laboratory (1989d) *Predecisional Draft Environmental Protection Implementation Plan*, Environmental Guidance Division, EPD, UCAR-10307.

Lawrence Livermore National Laboratory (1989e), *FY 1990 Update Lawrence Livermore National Laboratory Waste Management Plan Per DOE Order #5820.2A*, EPD, HWM.

Lawrence Livermore National Laboratory (1989f), *Seismic Review Report for Hazardous Waste Facility 419*, LLNL, Livermore, CA.

- Lawrence Livermore National Laboratory (1989g), *LLNL QA Plan (Draft)*, LLNL, Livermore, CA.
- Lawrence Livermore National Laboratory (1989h), *Waste Management Plan*, LLNL, HWM.
- Lawrence Livermore National Laboratory (1990a), *Closure and Post-Closure Plan - Landfill Pits 1 and 7*, Volumes I and II, revision 1.
- Lawrence Livermore National Laboratory (1990b), *LLNL Waste Minimization Program Plan*, EPD, HWM.
- Lawrence Livermore National Laboratory (1990c), *Part A Application Information on Treatment Units*, LLNL, HWM, memorandum HWM 90-919.
- Lawrence Livermore National Laboratory (1990d), "SWIMS Report for Calendar Year 1989," letter from R. Ragaini, LLNL, to T. Watanabe, EG&G Idaho, HWM 90-273.
- Lawrence Livermore National Laboratory (19XX), *Lawrence Livermore National Laboratory Environmental Report for 19XX*, UCRL-50027-XX. (This is an annual report where XX represents the year reported.)
- Lawrence Livermore National Laboratory (19YY), *LLNL Site 300 Groundwater Monitoring Program*, UCAR-10191-YY-X. (This is a quarterly series of reports where YY represents the year and X represents the calendar quarter.)
- Low-Level Radioactive Waste Policy Amendments Act* (1985), Public Law 99-240.
- Magee, M. (1990), personal communication with Mike Magee, LLNL Fire Department, SAIC internal files.
- McConachie, W.A., Como, J.P., Carpenter, D.W., and Ragaini, R.C. (1986), *East Traffic Circle Landfill Closure Report*, LLNL, EPD, UCID-20662.
- National Environmental Policy Act* (1969), Public Law 91-190.
- National Oceanic and Atmospheric Administration (1988), *Local Climatological Data Annual Summary with Comparative Data*, Washington, D.C., ISSN 0198-1013.
- Nelson, C. (1990), personal communication with Charles Nelson, National Weather Service, Sacramento, CA, SAIC internal files.
- Nuclear Regulatory Commission (1977a), *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes*, Washington, D.C., NUREG-0170.

- Nuclear Regulatory Commission (1977b), *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I*, Washington, D.C., Regulatory Guide 1.109.
- Nuclear Waste Policy Act* (1982), Public Law 97-425.
- Raber, E., and Carpenter, D.W., editors (1983), *An Evaluation of the Hydrogeology and Groundwater Chemistry Associated with Landfills at LLNL's Site 300*, LLNL, Livermore, CA, UCRL-53416.
- Resource Conservation and Recovery Act* (1976), Public Law 94-580, 1976.
- Science Applications International Corporation (1990a), *Draft Preliminary Safety Analysis Document for the Sewer Diversion System*, Science Applications International Corporation, Pleasanton, CA.
- Science Applications International Corporation (1990b), *Draft Hazardous Waste Management Safety Analysis Document*, Science Applications International Corporation, Pleasanton, CA.
- Science Applications International Corporation (1990c), *Draft Hazardous Waste Management Low-Level Waste Compliance Plan*, Science Applications International Corporation, Pleasanton, CA.
- Science Applications International Corporation (1990d), *Draft EPD Quality Assurance Management Plan*, Science Applications International Corporation, Pleasanton, CA.
- Science Applications International Corporation (1990e), *Letter Report for Definition of High Priority Waste Streams*, Science Applications International Corporation, Pleasanton, CA, letter from R. Graham, SAIC to D. Hoyt, LLNL.
- Science Applications International Corporation (1990f), *Draft Environmental Assessment for the Site 300 Revitalization Program*, Science Applications International Corporation, Pleasanton, CA.
- Scheimer, J.F. (1985), *Lawrence Livermore National Laboratory Site Seismic Safety Program - Summary of Findings*, LLNL, Livermore, CA, UCRL-53674.
- State of California (1988), *Fault Map of California with Locations of Volcanoes, Thermal Springs, and Thermal Wells*, Department of Conservation, Sacramento, CA.
- Scheimer, J.F., and Mills, J.M. (1984), *Seismicity Rates for Eastbay Faults*, LLNL, Livermore, CA, UCRL-53542.

- Taffet, M.J., Oberdorfer, J.A., and McIlvride, W.A. (1989), *Remedial Investigation and Feasibility Study for LLNL Site 300 Pit 7 Complex*, LLNL, UCID-21685.
- Taffet, M.J., and Lamarre, A.L. (1988), *Solid Waste Assessment Test (SWAT), Inactive Landfill Pit 6, LLNL Site 300, San Joachim County, California*, LLNL, July 1988, UCAR-10242.
- Taffet, M.J., and Lamarre, A.L. (1989), *Firing Table Gravel Removal at Site 300*, LLNL, UCAR-10202.
- University of California (1986), *Draft Environmental Impact Report for the University of California Contract with the Department of Energy for Operation and Management of Lawrence Livermore National Laboratory*, SCH-85112611.
- University of California (1987), *Final Environmental Impact Report for the University of California Contract with the Department of Energy for Operation and Management of Lawrence Livermore National Laboratory*, SCH-85112611.
- Uranium Mill Tailings Radiation Control Act (1978), Public Law 95-604.
- vanWarmerdan, C., Olund, T.S., and Huss, E.B. (1990), *Waste Disposal Requisition Guidelines*, LLNL, HWM.
- Woodward-Clyde Consultants (1985), *Lawrence Livermore National Laboratory Seismic Exposure Analysis*, Walnut Creek, CA, prepared for LLNL, Livermore, CA, UCRL-15853.
- Wilhite, E. (1990), personal communication with J.E. Russell, SAIC internal document.

8.0 ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ACRONYMS AND ABBREVIATIONS

ALARA	As low as reasonably achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CCR	California Code of Regulations
CDE	Committed dose equivalent
CEDE	Committed effective dose equivalent
CFR	Code of Federal Regulations
CY	Calendar Year
DCG	Derived concentration guideline
DE	Dose equivalent
DOE	United States Department of Energy
DOE/HQ	DOE Headquarters
DOE/NV	DOE/Nevada Operations Office
DOE/SAN	DOE/San Francisco Operations Office
DHS	(California) Department of Health Services
DOT	United States Department of Transportation
DWTF	Decontamination and Waste Treatment Facility
EDE	Effective dose equivalent
EIR	Environmental Impact Report
EPA	Environmental Protection Administration
EPD	Environmental Protection Department
ERD	Environmental Restoration Division
FSP	Facility Safety Procedure
FY	Fiscal Year
HEPA	High efficiency particulate air
HWM	Hazardous Waste Management Division
ICRP	International Commission on Radiological Protection

LDR	Land Disposal Restricted (Waste)
LLNL	Lawrence Livermore National Laboratory
LLW	Low-level radioactive waste
LLWCP	Low-Level Waste Compliance Plan
LSA	Low specific activity
MFP	Mixed Fission Products
NEPA	National Environmental Protection Act
N.O.S.	Not otherwise specified
NQA	Nuclear Quality Assurance
NRC	United States Nuclear Regulatory Commission
NTS	Nevada Test Site
NTS-WAC	Nevada Test Site Waste Acceptance Criteria
OSHA	Occupational Safety and Health Administration
OSP	Operational Safety Procedure
PA	Performance Assessment
PCB	Polychlorinated biphenyl
QA	Quality Assurance
RCMD	Regulatory Compliance and Monitoring Division
RAD	Regulatory Affairs Division
RCRA	Resource Conservation and Recovery Act
SAIC	Science Applications International Corporation
SWIMS	Solid Waste Information Management System
TRU	Transuranic
UC	University of California
WAA	Waste Accumulation Areas
WDR	Waste Disposal Requisition (form)
WMDS	Waste Management Data System

SYMBOLS

μ	micro (10^{-6})
mL	milliliter (10^{-3} liter)
L	liter
kg	kilogram
k	kilo (10^3)
Ci	Curie
gal	gallon
m	meter
mi	mile
K	thousands of dollars
M	millions of dollars
\$	dollars
α	alpha
β	beta
γ	gamma
mrem	millirem

APPENDICES

Appendix A:

Calculation of Liquid Effluent Dose

Appendix A Calculation of Liquid Effluent Dose

The RESRAD computer code, detailed in DOE/CH/8901 (Gilbert, et al., 1989) and implemented by DOE Order 5400.5 (DOE, 1990), is used to calculate the maximum dose to members of the public from releases of radioactivity to the sanitary sewer from LLW processing operations for both a worst-case and a reasonable-case scenario. The total 1989 radioactive liquid effluent identified in Table 3-8 in the text was used. The amount of alpha activity is conservatively taken to be all Pu-239 and the beta activity is conservatively taken to be all Cs-137. The entire year's radioactive effluent is assumed to be released in one day in the worst-case scenario. The release then flows through the sewer system to the Livermore Water Reclamation Plant. The release is then concentrated into one day's volume of sewage sludge, 23 m³ (Adams, 1990), and immediately spread as fertilizer on a local farmer's field. These are extremely conservative assumptions.

Releases of processed liquid to the sanitary sewer occur periodically throughout the year and the releases are, thereby, diluted by significant volumes of liquid. Also some activity may partition to the liquid phase during the sewage treatment process and be significantly less concentrated. The fractionation of radioactive material between the liquid and sludge phases will result in lower committed effective dose equivalents (CEDEs) to members of the public.

The sludge is assumed to be spread in a 1-cm thick layer over 2300 m² of a farmer's field. The density of the sludge is taken to be 1 g/cm³. Default parameters were used where appropriate site-specific parameters could not be postulated. Site specific parameters were specified for precipitation, soil, soil hydrology, irrigation, and occupancy factors to be representative of a farm in the Livermore Valley. The computer code assumes that the maximally exposed individual consumes fruit, vegetables, and grains from only the contaminated field from the time of contamination onward. Also, it assumes that livestock are fed only from the contaminated field and that this livestock represents the only source of meat and poultry for the maximally exposed individual. It is also assumed that the milk consumed by the individual comes only from the cattle grazing on the contaminated land. Further, it is assumed that the only source of water is from an on-site well, subject to

eventual leachate contamination. The mass loading for foliar deposition is taken as zero as the sludge is assumed to be applied directly to the ground. The fraction of ground water used for irrigation was taken as zero as most farms in the area are supplied by aqueduct or river rather than wells. These are extremely conservative assumptions.

The reasonable-case scenario assumes that the 1989 radioactive liquid effluent is released over the period of one year and concentrated into the sewage sludge product of that year, $8.4 \text{ E}+3 \text{ m}^3$. The sludge is then spread in a 1-cm thick layer over $8.4 \text{ E}+6 \text{ m}^2$ of a farmer's field. The same parameters used in the worst-case analysis are then applied.

The maximum CEDE calculated by RESRAD for the worst-case scenario is $1 \text{ E}-2$ mrem, which occurs in the first year subsequent to field contamination. The dose in the next year decreases to $9 \text{ E}-3$ mrem and is essentially zero within 10 years. RESRAD also estimates a subsequent dose of $5 \text{ E}-9$ mrem after 1,000 years, when the plutonium reaches the farm's well. The maximum CEDE calculated by RESRAD for the reasonable-case scenario is $3 \text{ E}-5$ mrem in the first year and decreasing doses in subsequent years. The output from RESRAD is contained in Tables A-1 and A-2. These are negligible doses.

Table A-1
Worst-Case Radioactive Liquid Effluent Dose Calculation

Residual Radioactivity Program, Version 3.121
Summary : RESRAD Sample Data

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File: SEWERHWM.DAT

Site-Specific Parameter Summary

Menu	Parameter	Used	Default
RO11	Area of contaminated zone (m**2)	2.300E+03	1.000E+04
RO11	Thickness of contaminated zone (m)	1.000E-02	1.000E+00
RO11	Length parallel to aquifer flow (m)	5.000E+01	1.000E+02
RO11	Basic radiation dose limit (mrem/yr)	1.000E+02	1.000E+02
RO11	Times for calculations (yr)	1.000E+00	1.000E+00
RO11	Times for calculations (yr)	1.000E+01	1.000E+01
RO11	Times for calculations (yr)	1.000E+02	1.000E+02
RO11	Times for calculations (yr)	1.000E+03	1.000E+03
RO11	Times for calculations (yr)	1.000E+04	1.000E+04
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO12	Initial principal radionuclide (pCi/g): Cs-137	1.500E+00	0.000E+00
RO12	Initial principal radionuclide (pCi/g): H-3	2.200E+02	0.000E+00
RO12	Initial principal radionuclide (pCi/g): Pu-239	8.000E-01	0.000E+00
RO13	Cover depth (m)	0.000E+00	0.000E+00
RO13	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00
RO13	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03
RO13	Contaminated zone total porosity	4.000E-01	4.000E-01
RO13	Contaminated zone effective porosity	2.000E-01	2.000E-01
RO13	Contaminated zone hydraulic conductivity (m/yr)	2.000E+02	1.000E+01
RO13	Contaminated zone b parameter	7.120E+00	5.300E+00
RO13	Evapotranspiration coefficient	6.000E-01	6.000E-01
RO13	Precipitation (m/yr)	4.000E-01	1.000E+00
RO13	Irrigation (m/yr)	1.000E+00	2.000E-01
RO13	Irrigation mode	overhead	overhead
RO13	Runoff coefficient	2.000E-01	2.000E-01
RO13	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06
RO14	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00
RO14	Saturated zone total porosity	4.000E-01	4.000E-01
RO14	Saturated zone effective porosity	2.000E-01	2.000E-01
RO14	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02
RO14	Saturated zone hydraulic gradient	2.000E-02	2.000E-02
RO14	Distance from surface to water table (m)	4.010E+00	5.000E+00
RO14	Water table drop rate (m/yr)	0.000E+00	1.000E-03
RO14	Well pump intake depth (m below water table)	1.000E+01	1.000E+01
RO14	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND
RO15	Number of unsaturated zone strata	1	1
RO15	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00
RO15	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00
RO15	Unsat. zone 1, total porosity	4.000E-01	4.000E-01
RO15	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01
RO15	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00
RO15	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02

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Site-Specific Parameter Summary (continued)

Menu	Parameter	Used	Default

R016	Distribution coefficients for Cs-137		
R016	Contaminated zone (cm**3/g)	1.000E+03	1.000E+03
R016	Unsaturated zone 1 (cm**3/g)	1.000E+03	1.000E+03
R016	Saturated zone (cm**3/g)	1.000E+03	1.000E+03
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for H-3		
R016	Contaminated zone (cm**3/g)	0.000E+00	0.000E+00
R016	Unsaturated zone 1 (cm**3/g)	0.000E+00	0.000E+00
R016	Saturated zone (cm**3/g)	0.000E+00	0.000E+00
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for Pu-239		
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03
R016	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter Ac-227		
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter Pa-231		
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter U-235		
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04
R017	Occupancy and shielding factor, external gamma	1.000E-02	6.000E-01
R017	Occupancy factor, inhalation	1.000E-02	4.500E-01
R017	Shape factor, external gamma	1.000E+00	1.000E+00
R017	Mixing height for airborne dust, inhalation (m)	3.000E+00	3.000E+00
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02
R018	Fraction of drinking water from site	1.000E+00	1.000E+00
R018	Fraction of aquatic food from site	5.000E-01	5.000E-01

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Summary : RESRAD Sample Data

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Site-Specific Parameter Summary (continued)

Menu	Parameter	Used	Default
RO19	Livestock fodder intake for meat (kg/day)	6.800E+01	5.800E+01
RO19	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01
RO19	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01
RO19	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02
RO19	Mass loading for foliar deposition (g/m**3)	0.000E+00	1.000E-04
RO19	Depth of soil mixing layer (m)	1.500E-01	1.500E-01
RO19	Depth of roots (m)	9.000E-01	9.000E-01
RO19	Drinking water fraction from ground water	1.000E+00	1.000E+00
RO19	Livestock water fraction from ground water	1.000E+00	1.000E+00
RO19	Irrigation fraction from ground water	0.000E+00	1.000E+00

Contaminated Zone Dimensions	Initial Soil Concentrations, pCi/g
Area: 2300.00 square meters	Cs-137 1.500E+00
Thickness: 0.01 meters	H-3 2.200E+02
Cover Depth: 0.00 meters	Pu-239 8.000E-01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) - Fraction of Basic Dose Limit Received at Time (t)

t (years):	0	1	10	100	1000	10000
TDOSE(t):	1.102E-02	9.477E-03	0.000E+00	0.000E+00	4.675E-09	0.000E+00
M(t):	1.102E-04	9.477E-05	0.000E+00	0.000E+00	4.675E-11	0.000E+00

Maximum TDOSE(t): 1.102E-02 mrem/yr at t = 0 years

Table A-2
Reasonable-Case Radioactive Liquid Effluent Dose Calculation

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Summary : RESRAD Sample Data

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Site-Specific Parameter Summary

Menu	Parameter	Used	Default
RO11	Area of contaminated zone (m**2)	8.400E+05	1.000E+04
RO11	Thickness of contaminated zone (m)	1.000E-02	1.000E+00
RO11	Length parallel to aquifer flow (m)	5.000E+01	1.000E+02
RO11	Basic radiation dose limit (mrem/yr)	1.000E+02	1.000E+02
RO11	Times for calculations (yr)	1.000E+00	1.000E+00
RO11	Times for calculations (yr)	1.000E+01	1.000E+01
RO11	Times for calculations (yr)	1.000E+02	1.000E+02
RO11	Times for calculations (yr)	1.000E+03	1.000E+03
RO11	Times for calculations (yr)	1.000E+04	1.000E+04
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO11	Times for calculations (yr)	0.000E+00	0.000E+00
RO12	Initial principal radionuclide (pCi/g): Cs-137	4.000E-03	0.000E+00
RO12	Initial principal radionuclide (pCi/g): H-3	6.000E-01	0.000E+00
RO12	Initial principal radionuclide (pCi/g): Pu-239	2.000E-03	0.000E+00
RO13	Cover depth (m)	0.000E+00	0.000E+00
RO13	Density of contaminated zone (g/cm**3)	1.600E+00	1.600E+00
RO13	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03
RO13	Contaminated zone total porosity	4.000E-01	4.000E-01
RO13	Contaminated zone effective porosity	2.000E-01	2.000E-01
RO13	Contaminated zone hydraulic conductivity (m/yr)	2.000E+02	1.000E+01
RO13	Contaminated zone b parameter	7.120E+00	5.300E+00
RO13	Evapotranspiration coefficient	6.000E-01	6.000E-01
RO13	Precipitation (m/yr)	4.000E-01	1.000E+00
RO13	Irrigation (m/yr)	1.000E+00	2.000E-01
RO13	Irrigation mode	overhead	overhead
RO13	Runoff coefficient	2.000E-01	2.000E-01
RO13	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06
RO14	Density of saturated zone (g/cm**3)	1.600E+00	1.600E+00
RO14	Saturated zone total porosity	4.000E-01	4.000E-01
RO14	Saturated zone effective porosity	2.000E-01	2.000E-01
RO14	Saturated zone hydraulic conductivity (m/yr)	1.000E+02	1.000E+02
RO14	Saturated zone hydraulic gradient	2.000E-02	2.000E-02
RO14	Distance from surface to water table (m)	4.010E+00	5.000E+00
RO14	Water table drop rate (m/yr)	0.000E+00	1.000E-03
RO14	Well pump intake depth (m below water table)	1.000E+01	1.000E+01
RO14	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND
RO15	Number of unsaturated zone strata	1	1
RO15	Unsat. zone 1, thickness (m)	4.000E+00	4.000E+00
RO15	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.600E+00
RO15	Unsat. zone 1, total porosity	4.000E-01	4.000E-01
RO15	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01
RO15	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00
RO15	Unsat. zone 1, hydraulic conductivity (m/yr)	1.000E+02	1.000E+02

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Summary : RESRAD Sample Data

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Site-Specific Parameter Summary (continued)

Menu	Parameter	Used	Default

R016	Distribution coefficients for Cs-137		
R016	Contaminated zone (cm**3/g)	1.000E+03	1.000E+03
R016	Unsaturated zone 1 (cm**3/g)	1.000E+03	1.000E+03
R016	Saturated zone (cm**3/g)	1.000E+03	1.000E+03
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for H-3		
R016	Contaminated zone (cm**3/g)	0.000E+00	0.000E+00
R016	Unsaturated zone 1 (cm**3/g)	0.000E+00	0.000E+00
R016	Saturated zone (cm**3/g)	0.000E+00	0.000E+00
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for Pu-239		
R016	Contaminated zone (cm**3/g)	2.000E+03	2.000E+03
R016	Unsaturated zone 1 (cm**3/g)	2.000E+03	2.000E+03
R016	Saturated zone (cm**3/g)	2.000E+03	2.000E+03
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter Ac-227		
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter Pa-231		
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R016	Distribution coefficients for daughter U-235		
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01
R016	Leach rate (/yr)	0.000E+00	0.000E+00
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03
R017	Mass loading for inhalation (g/m**3)	2.000E-04	2.000E-04
R017	Occupancy and shielding factor, external gamma	1.000E-02	6.000E-01
R017	Occupancy factor, inhalation	1.000E-02	4.500E-01
R017	Shape factor, external gamma	1.000E+00	1.000E+00
R017	Mixing height for airborne dust, inhalation (m)	3.000E+00	3.000E+00
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01
R018	Milk consumption (L/yr)	9.200E+01	9.200E+01
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01
R018	Drinking water intake (L/yr)	4.100E+02	4.100E+02
R018	Fraction of drinking water from site	1.000E+00	1.000E+00
R018	Fraction of aquatic food from site	5.000E-01	5.000E-01

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Site-Specific Parameter Summary (continued)

Menu	Parameter	Used	Default
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02
R019	Mass loading for foliar deposition (g/m**3)	0.000E+00	1.000E-04
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01
R019	Depth of roots (m)	9.000E-01	9.000E-01
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00
R019	Irrigation fraction from ground water	0.000E+00	1.000E+00

Residual Radioactivity Program, Version 3.121
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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	840000.00 square meters	Cs-137	4.000E-03
Thickness:	0.01 meters	H-3	6.000E-01
Cover Depth:	0.00 meters	Pu-239	2.000E-03

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) - Fraction of Basic Dose Limit Received at Time (t)

t (years):	0	1	10	100	1000	10000
TDOSE(t):	3.030E-05	2.605E-05	0.000E+00	0.000E+00	2.431E-11	0.000E+00
M(t):	3.030E-07	2.605E-07	0.000E+00	0.000E+00	2.431E-13	0.000E+00

Maximum TDOSE(t): 3.030E-05 mrem/yr at t = 0 years

Appendix B:

Calculation of Airborne Effluent Dose

Appendix B Calculation of Airborne Effluent Dose

The AIRDOS-PC computer code, detailed in EPA/520/6-89-035 (EPA, 1989) and implemented by DOE Order 5400.5 (DOE, 1990), is used to calculate the maximum dose to members of the public from releases of radioactivity to the air from LLW processing operations. The 0.5 Ci of H-3 identified in Table 3-9 of the text was used to approximate the annual gaseous radioactive effluent from all LLW and mixed waste processes. The default parameters of the computer code were used along with the site-specific wind data base for LLNL which was supplied with the code. The computer code assumes that the maximum exposed individual is at 300 m from the point of release and that the release is made from a 10 m stack. These are conservative assumptions.

The maximum committed effective dose equivalent calculated by AIRDOS-PC is 0.003 mrem. The output from AIRDOS-PC is contained in Table B-1.

Table B-1
HWM Tritium Release Dose Estimate

CLEAN AIR ACT COMPLIANCE REPORT

9/17/90 9:00 AM

Facility: LLNL HWM

Address:

City: Livermore

State: CA

Comments: HWM Tritium Release Dose Estimate

Year: 1989

Dose Equivalent Rates to Nearby
Individuals (mrem/year)

Effective Dose Equivalent	0.0026
Highest Organ Dose is to REMAINDER	0.0030

-----EMISSION INFORMATION-----

Radio- nuclide	Class	Amed	Stack #419 (Ci/y)	Stack #2 (Ci/y)	Stack #3 (Ci/y)	Stack #4 (Ci/y)	Stack #5 (Ci/y)	Stack #6 (Ci/y)
H-3	*	0.0	5.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01
Stack Height (m)			10.00	10.00	10.00	10.00	10.00	10.00
Stack Diameter (m)			0.00	0.00	0.00	0.00	0.00	0.00
Buoyant (cal/s)			0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01	0.0E-01

-----SITE INFORMATION-----

Wind Data	SUU0316.WND	Temperature (C)	20
Food Source	LOCAL	Rainfall (cm/y)	40
Distance to Individuals (m)	300	Lid Height (m)	1000

*NOTE: The results of this computer model are dose estimates.
They are only to be used for the purpose of determining
compliance and reporting per 40 CFR 61.93 and 40 CFR 61.94.

Appendix C:

High Priority Waste Streams at LLNL

Appendix C

High Priority Waste Streams at LLNL

Ten high priority LLW waste streams and nine mixed waste streams have been identified at LLNL (SAIC, 1990e). These are summarized in Subsections C.1 and C.2.

C.1 LOW-LEVEL RADIOACTIVE WASTE STREAMS

Waste Stream Number: BCLA-000000002

(Construction Debris)

This waste stream consists of wood, sheet rock, concrete, refuse metal, ceiling tiles, lights, flooring, asphalt, and other construction-related debris. The material is contaminated with low levels of plutonium, uranium, tritium, and other radionuclides. Waste material generated in the Plutonium Facility, Bldg. 332, is contaminated primarily with Pu-239; waste material generated in the Tritium Facility, Bldg. 331, is contaminated primarily with tritium; waste material from other programs such as Lasers, Biomedical and Environmental Research (BER), and Chemistry is contaminated with U-238 and other radionuclides. Construction wastes are generated at LLNL from the demolition or modification of existing facilities. There is no treatment associated with the waste stream and the final form is solid.

Waste Stream Number: BCLA-000000003

(Contaminated Equipment)

Contaminated equipment consists of bookcases, lockers, vacuum pumps, mills, lathes, and glove boxes. This waste stream includes bookcases and lockers from Bldg. 321 Machine Shop. These items are cut down to efficiently use the container volume. Vacuum pumps from Bldg. 332 which have been drained, disassembled, and decontaminated per approved procedures may also be included in this waste stream. The mills, lathes, and glove boxes from machine shops and miscellaneous laboratories are disassembled and decontaminated as required. The Facility Safety Procedure, "Decontamination and Size Reduction for Facility Bldg. 419," revised 12/88, has been implemented and contains the criticality safety requirements and the facility nuclide limits for transuranic (TRU) and fissile materials. The material is contaminated with low levels of plutonium, uranium, tritium, and other radionuclides. Waste material generated in the Plutonium Facility, Bldg. 332, is contaminated primarily with Pu-239; waste material generated in the Tritium Facility, Bldg. 331, is contaminated primarily with tritium; waste material from other programs such as Lasers, BER, and Chemistry is contaminated with U-238 and other radionuclides. Contaminated equipment is generated at LLNL through the daily use of the equipment until

its useful life is over or the equipment is damaged. Size reduction operations are performed on contaminated equipment to provide for the efficient use of the container volume.

Waste Stream Number: BCLA-000000004

(Contaminated Compactible Wastes)

Contaminated compactible wastes are generated at LLNL in conjunction with normal production and laboratory-related activities and include: paper (Kimwipes, Kaydrys), trash (plastic, cardboard, etc.), booties, rags, aluminum foil, tape, and bags.

Waste Stream Number: BCLA-000000005

(Contaminated Labware)

This waste stream consists of contaminated labware consisting of beakers, pipettes, hot plates, poly and glass sample containers, miscellaneous glassware, and laboratory equipment. Contaminated labware wastes are generated at LLNL in conjunction with normal laboratory processes.

Waste Stream Number: BCLA-000000006

(Marshall Islands Sample Debris)

This waste stream consists of debris from environmental samples from the Marshall Islands. This includes vegetation, fish, animal and soil residues, and wipes used for cleaning the counters and empty stainless steel cans used in the sample preparation process for analysis. The waste material is contaminated with low levels of Cs-137, Sr-90, Pu-239, Am-241, and Am-243.

Waste Stream Number: BCLA-000000007

(D-38 Contaminated Metals)

This waste stream consists of classified D-38 contaminated metal shapes generated from machining operations. This waste is generated in the Machine Shop, Bldg. 321; Lasers Building 169, 175, 490, 491, 492; and Materials Management Bldg. 233. There is no treatment associated with this waste and the final form is solid.

Waste Stream Number: BCLA-000000009 and BCLA-000000010

(Shot Table Debris)

These waste streams are firing table debris resulting from the detonation of test assemblies located at LLNL's Site 300 in Bldgs. 801, 850, and 851. The debris consists of gravel, wood, plastic, glass, concrete, and metal pieces that may be contaminated with low levels of

depleted uranium (U-238). Depleted uranium is used in experiments performed on the firing tables. It is used in only a small portion of the experiments actually performed each year at Site 300. Occasionally, detonation tests involve the use of stainless steel, vanadium, copper, and barium. These metals are integral parts of the devices being tested and their concentrations can vary from experiment to experiment. Upon detonation, material is scattered over the firing table and consists of: plastic and wood from the shot tent; wiring attached to the device and diagnostic equipment; glass from mirrors used to reflect the image to cameras; and shielding materials such as concrete. The gravel and construction debris is removed from the table prior to additional experiments.

Waste Stream Number: BCLA-000000011

(Tritium-Contaminated Soil)

This waste stream consists of soil contaminated with tritium which was generated during excavation activities at Bldg. 514. There is no treatment associated with the waste stream and the final form is solid.

Waste Stream Number: BCLA-000000012

(Contaminated Soil)

This waste stream consists of contaminated soil generated through site excavations for the purpose of construction and modification to building facilities. The soil is generated throughout the LLNL complex. There is no treatment associated with this waste stream and the final form is solid.

C.2 MIXED WASTE STREAMS

Nine mixed waste streams were generated by 11 buildings, according to the 1989 Hazardous Waste (TSDR) Report, and the 1989 Waste Data database compiled by HWM. The mixed waste streams that are already onsite include solids from Dorr-Oliver treatment and solids for which no treatment exists, as well as liquids containing solvents and oils. No solidification technology currently exists for the liquids, which are awaiting results of investigations of more stable cementation agents. The waste streams are listed below:

- Mixed coolants and rinse waters from material fabrication operations (treated on-site by the Dorr-Oliver)
- Mixed waste-filter cakes

- Mixed lab chemical solutions
- Mixed biomedical
- Mixed lab trash
- Mixed scintillation vials
- Mixed contaminated equipment
- Mixed metal scraps/chips
- Mixed dirt.

Appendix D:

Current HWM Operational and Safety Procedures

Appendix D

**CURRENT HWM
OPERATIONAL & SAFETY PROCEDURES
November 16, 1990.**

Procedure Number	Procedure Title	Status
FSP 419	Building 419 Facility Safety Procedure	Final
FSP 514	Building 514 Facility Safety Procedure	Final
FSP 612	Building 612 Facility Safety Procedure	Final
HWM 301	LLW Container Procurement, Receipt, and Inspection	Draft
HWM 302	LLW Container Request, Issuance, and Control	Draft
HWM 303	LLW Generator Identification and Characterization	Draft
HWM 304	LLW Generator Packaging, Verification, and WAA Transfer	Draft
HWM 305	LLW Nonconformance Reports and Corrections	Draft
HWM 306	LLW Transfer to and Receipt at HWM	Draft
HWM 307	(Reserved for HWM 555)	N/A
HWM 308	(Reserved for HWM 533-LSA Waste Shipment Preparation)	N/A
HWM 309	(Reserved for HWM 528-LSA Waste Shipments to NTS)	N/A
HWM 401	Sampling Containerized Liquids	Trial-Use
HWM 402	Analytical Sample Custody	Final
HWM 414	Acid Digestion of Oils, Greases or Waxes	Draft
HWM 415	Dissolution of Oils, Greases or Waxes	Final
HWM 416	Acid Digestion of Sediments, Sludges and Soils	Final
HWM 417	Alkaline Digestion	Draft
HWM 418	Total and Amenable Cyanide	Draft
HWM 420	pH Electrometric Measurement	Draft
HWM 422	Total Dissolved Solids-Residue, Filter	Draft

Procedure Number	Procedure Title	Status
HWM 423	Total Suspended Solids-Residue, Non Filter	Draft
HWM 424	Total Solids-Residue, Total	Draft
HWM 425	Volatile Solids-Residue, Volatile	Draft
HWM 426	Settleable Matter, (Imhoff Cone)	Draft
HWM 428	Total Organic Halides (TOX)	Final
HWM 429	Total Halides in Oils (TX)	Final
HWM 430	Purgeable Organic Halides	Final
HWM 431	Oil and Grease in Water (Partition-Gravimetric)	Final
HWM 432	Oil and Grease in Water (Partition-Infrared)	Draft
HWM 433	Oil and Grease Extraction Method/Sludge Sample	Draft
HWM 434	Paint Filter Liquids Test	Final
HWM 435	Liquid or Solid Determination	Final
HWM 438	Sample Log In	Final
HWM 447	Sample Disposal	Draft
HWM 449	Sampling Solid Rad/Mixed Waste	Draft
HWM 450	Sampling Containerized Rad/Mixed Liquids	Draft
HWM 502	Rotary Drum Filtration Unit	Final
HWM 503	LSA Solidification (Small Quantity)	Final
HWM 504	Retention Tank Pumpouts	Final
HWM 504A	Retention Tank Pumpout: Without a Built-in Pumping Mechanism	Draft
HWM 504B	Retention Tank Pumpout: Without a Built-in Pumping System	Draft
HWM 504C	Retention Tank Pumpout: With Built-in Pump Mechanism	Draft
HWM 505	Tank Farm (Liquid Transfers)	Final
HWM 511	Storage of Packaged Dry Rad Waste	Draft
HWM 512	LSA Solidification (Lightnin Mixer)	Draft

Procedure Number	Procedure Title	Status
HWM 513	Shredder	Final
HWM 516	Neutralization and pH Adjustment of Wastewater	Final
HWM 517	Encapsulation of Solid Waste (Drum Roller)	Draft
HWM 518	Hydrogen Peroxide Oxidation and Precipitation	Final
HWM 519	Treatment of Wastewater by Sulfide Precipitation	Final
HWM 520	Reduction and Hydroxide Precipitation of Hexavalent Chromium Solutions	Final
HWM 521	Wastewater Treatment by Metal Chelating	Final
HWM 522	Treatment of Trimsol Coolant Water	Final
HWM 525	Sewer Access Control	Final
HWM 528	Radioactive LSA Shipments to NTS	Final
HWM 530	Thursday Waste Run	Draft
HWM 531	Packing of Lab-packs	Draft
HWM 533	LSA Shipment Preparation	Final
HWM 539	Operation of the Ram Flat Compactor	Final
HWM 543	Receival and Storage at the Incinerator	Final
HWM 544	Packaging Non-Compactible Radioactive Waste	Draft
HWM 545	Bulking at Bldg. 624	Draft
HWM 549	Use of Material Handling Equipment	Draft
HWM 555	Compaction of dry, low level Radioactive Waste	Draft
HWM 556	Compactor/Baler Prefilter Replacement	Draft
HWM 557	Routine Inspection of the Compactor/Baler	Draft
HWM 558	HWM On-the-Job Training Administration	Trial-Use
OSP 514.7	Shredder Operation	Final
OSP 612.14	Bulking of Flammable Wastes	Final
CSP 612.16	Bulking of Aqueous Waste	Final
OSP 612.17	Bulking of Identical or Nearly Identical Materials	Final

Appendix E

DOE Order 5400.5 Definitions of Health Physics Terminology

Appendix E

DOE Order 5400.5 Definitions of Health Physics Terminology

The health physics methodology used in this PA is based on the International Commission on Radiological Protection (ICRP) Publication 30 (ICRP, 1979). It is consistent with the method specified in Department of Energy (DOE) Order 5400.5 (DOE, 1990) and the terms used in the text are used in accordance with the definitions in the Order.

As Low As Reasonably Achievable (ALARA):

ALARA is a phrase (acronym) used to describe an approach to radiation protection to control or manage exposures (both individual and collective to the work force and the general public) and releases of radioactive material to the environment as low as social, technical, economic, practical, and public policy considerations permit. As used in this report, ALARA is not a dose limit, but rather it is a process that has as its objective the attainment of dose levels as far below the applicable limits of the Order as practicable.

Committed Dose Equivalent (CDE):

The CDE (H_{50}) is the predicted total dose equivalent to a tissue or organ over a 50-year period after a known intake of a radionuclide into the body. It does not include contributions from external dose. CDE is expressed in units of rem (or sievert).

$$H_{50} = \int_{t_0}^{t_0+50y} H(t)dt, \text{ where}$$

H is the appropriate dose-equivalent rate and t_0 is the time of the intake.

This definition assumes that the intake occurs essentially instantaneously. Evaluation of the CDE from continuous or intermittent chronic intakes requires the appropriate integration and/or summation of the above equation, over time and for all intakes. Because the CDE is defined for occupational purposes, a 50-year working lifetime is assumed.

Effective Dose Equivalent (EDE):

The EDE is the summation of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This sum is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The EDE includes the CEDE from internal deposition of radionuclides and the EDE due to penetrating radiation from sources external to the body. EDE is expressed in units of rem (or sievert).

Committed Effective Dose Equivalent (CEDE):

The CEDE is the sum of the CDEs to various tissues in the body, each multiplied by the appropriate weighting factor. CEDE is expressed in units of rem (or sievert).

Derived Concentration Guideline (DCG):

The DCG is the concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an EDE of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye.

Dose Equivalent (DE):

DE is the product of absorbed dose in rad (or gray) in tissue and a quality factor. DE is expressed in units of rem (or sievert).

Dose:

The term dose is used generically to represent CDE, EDE, DE, and CEDE, as appropriate, when discussing the radiation exposure of members of the public from to radiation and radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off-site. It does not include dose received from occupational exposures, doses received from naturally occurring "background" radiation, doses received as a patient from medical practices, or doses received from consumer products.

Appendix F:

Site Characterization and Operational Practices

Appendix F Site Characterization and Operational Practices

F.1 SITE CHARACTERIZATION

Site characterization activities have been conducted for the LLNL Main Site and Site 300 and are presented in detail in the Draft Hazardous Waste Management Safety Analysis Document (Science Applications International Corporation (SAIC), 1990b). A summary of this information is presented below. This summary, as much as possible, reflects current information, updated from the 1989 base year, so that a general determination can be made of the extent to which the LLNL waste management system meets the performance objectives.

LLNL is located at two sites: the Main Site is in Alameda County, east of the city of Livermore, CA; Site 300 is on the Alameda and San Joaquin County borders, approximately 17 miles east of the Main Site.

F.1.1 Main Site Characteristics

This section provides a brief review of natural phenomena at the Main Site (winds, seismic events, and floods) that could affect low-level waste (LLW) activities. The LLNL Environmental Impact Report (EIR) (UC, 1986) for the University of California (UC) contract with the Department of Energy (DOE) provides additional information on the physical setting around LLNL.

Seismicity

The Main Site is located in a region that has experienced earthquakes within historical times. Active faults, considered capable of causing strong ground motion at Livermore, include the San Andreas, Hayward, Calaveras, Concord-Green Valley, Greenville, Las Positas, and Verona Faults (Scheimer, 1985). These faults are shown in Figure F-1. The

LEGEND

<u>Quaternary</u>	
	Alluvium and Marine Sediments
<u>Tertiary</u>	
	Sediments and Volcanics Including Pli-Pleistocene
<u>Jurassic-Cretaceous</u>	
	Great Valley Sequence
	Franciscan Assemblage
	Mesozoic Granite
	Fault
	Inferred Fault
	Concealed Fault

Figure F-1. Geology of the Livermore Region -- Includes Active Faults Potentially Capable of Affecting Livermore Site (Carpenter et al, 1984; Raber and Carpenter, 1983).

seismicity rates associated with these faults have been determined (Scheimer and Mills, 1984).

The nearby Greenville, Las Positas, Verona, and to a lesser extent, the Calaveras Faults are considered capable of producing strong ground motion at the Main Site (Scheimer, 1985). Earthquakes occurring on more distant faults were considered to have a very low probability of causing strong ground motion at the site (Woodward-Clyde, 1985; Geomatrix, 1985).

The probability of ground surface rupture at the Main Site as the result of earthquakes is considered extremely remote. No active faults are known to underlie the site; there is no historical record of surface rupture or faulting at the site; and extensive geologic investigations of potential faults and lineaments visible on aerial photographs found that recent sediments have not been displaced by fault movement (Carpenter et al., 1984).

During a siting investigation for the proposed Decontamination and Waste Treatment Facility (DWTF) in 1985, a surface crack was discovered in the LLNL salvage yard pavement. A seismic investigation of this area was conducted by LLNL and consulting geologists together with the State of California. The investigation concluded that it would be difficult, if not impossible, and costly to prove that the crack was not fault-induced or conclusively demonstrate compliance with the state and federal seismic location standards for siting new waste facilities (Geomatrix, 1985). These standards, however, are not applicable to existing hazardous waste management facilities.

The northern branch of the Las Positas Fault is mapped 61 m (200 ft) south of the southeast corner of the site, and is the nearest known strand of the fault. Within LLNL, no critical facilities or structures are situated in the Alquist-Priolo Act Special Studies Zone (UC, 1986). Earthquake-induced liquefaction or landslides causing soil failure are judged to be a negligible hazard at the Main Site (Scheimer, 1985).

Meteorology and Climate

The Livermore Valley is characterized by a Mediterranean climate. Summers in this area are typically warm and dry; extreme temperatures as high as 46°C (115°F) have been reported. The winters tend to be mild and wet, with regular formation of early morning surface fog. Most of the annual rainfall, which averages 36 cm (14 in), occurs between October and April and is associated with migratory low pressure systems from the Gulf of Alaska. However, rainstorms tend to be short, and abundant sunshine occurs throughout the year. The annual average temperature is 17°C (62°F).

The predominant winds during the summer dry season are from the west and southwest. During the wet season, northeast and north-northeast winds associated with post-frontal anti-cyclonic flow, are also common.

The wind rose shown in Figure F-2 displays the annual distribution of wind speed and frequency at the Main Site. This figure is based on data gathered in 1989 at LLNL from a 40-m (131-ft) tower in the northwest section of the Main Site. Windspeeds at this site are most often in the range of 5 to 7 meters per second (11 to 16 mi/hr). However, lower wind speeds, as well as winds of 11 to 16 m/s (25 to 36 mi/hr), are common during the wet season.

The atmosphere in the region of the Main Site is most often slightly stable or neutral. Based on wind records, the Pasquill-Gifford stability categories D and E occur about 70% of the time. In the summer, stability conditions D and E occur with near equal frequency, whereas E stability is somewhat more common during the winter (Gouveia and Chapman, 1989).

Surface Water

The major drainage paths in the Livermore Valley are Arroyo Valle, Arroyo Las Positas, Arroyo Mocho, Arroyo Seco, Cottonwood Creek, and Tassajara Creek. These streams are all intermittent, and flow generally to the west, with the exception of Tassajara

Average annual percent frequency of wind direction vs wind speed m/s
(Winds are based on 15 minute averages.)

Direction	0-2	2-3	3-5	5-7	7-9	9-11	11-16	16-20	>20	Total	Average speed m/s
N	1.3	0.5	0.9	0.6	0.5	0.1	0.0	0.0	0.0	3.8	3.9
NNE	1.1	1.0	1.5	0.5	0.1	0.0	0.0	0.0	0.0	4.3	3.3
NE	1.3	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	3.9	2.6
ENE	1.6	0.5	0.5	0.1	0.0	0.0	0.0	0.0	0.0	2.8	2.0
E	3.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.4
ESE	4.9	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.4	1.2
SE	2.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.1	1.2
SSE	1.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.3
S	2.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.6
SSW	2.2	0.9	0.7	0.2	0.1	0.0	0.0	0.0	0.0	4.1	2.4
SW	3.5	3.3	5.2	1.9	0.5	0.0	0.0	0.0	0.0	14.5	3.4
WSW	4.6	4.6	6.5	1.5	0.2	0.0	0.0	0.0	0.0	17.4	3.1
W	2.9	3.3	6.4	1.4	0.1	0.0	0.0	0.0	0.0	14.0	3.3
WNW	1.6	0.6	1.1	0.4	0.0	0.0	0.0	0.0	0.0	3.6	2.8
NW	1.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6
NNW	1.4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	2.1	2.2
Calm	---	---	---	---	---	---	---	---	---	11.0	---
Total	37.3	17.8	25.2	6.8	1.7	0.2	0.0	0.0	0.0	100.0	2.5

Figure F-2. Wind Rose for Main Site (LLNL, 1989c).

and Cottonwood Creeks, which flow south. Only Arroyo Las Positas and Arroyo Seco cross the Main Site.

Arroyo Seco crosses the southwest corner of the Main Site and receives a minor amount of site runoff. Arroyo Las Positas, which is normally dry most of the year, enters the Main Site from the east and flows across the northeast corner. Its course has been redirected to facilitate drainage from the site and to control erosion. This creek now flows to the northern perimeter and then west to an outlet at the northwest corner of the facility, where it joins the other main drainage facilities on the site. This outlet empties into a channel that flows north to the Western Pacific Railroad tracks, and then west again to its intersection with Arroyo Seco.

Other major surface water features near the site are the South Bay Aqueduct, which passes within about 161 m (0.1 mi) from the southeast corner of the Main Site, and the Del Valle Reservoir, which is 11 km (6.6 mi) southwest of the site.

Hetch Hetchy water supplies the South Bay Aqueduct which flows in an open channel as it passes near the Main Site. Users of the aqueduct include the Alameda Flood Control and Water Conservation District, Alameda County, and Santa Clara County. The water is used for domestic water supplies, irrigation, and groundwater recharge. Maximum flow in the aqueduct is 8.5 m³/sec (300 ft³/sec) with an average flow of 7.1 m³/sec (250 ft³/sec).

The Del Valle Reservoir is formed by an earthfill embankment on Arroyo Valle. The dam rises 68 m (225 ft) above the stream bed. The reservoir is used for flood control, conservation, water storage, and recreation.

The Livermore Valley rarely experiences severe weather. For example, the most rainfall recorded for a 24-hour period at the Livermore U.S. Weather Bureau Station is about 90 mm (3.5 in.). Furthermore, the U.S. Department of Urban Development Study has concluded that the Main Site would be unaffected by a postulated 100-year flood (Limerinos, et al., 1973).

Flooding in the Livermore Valley caused by seismic events would not reach the Main Site. If a postulated seismic failure of the Del Valle Dam occurred at the same time a landslide closed the Arroyo de la Laguna Canyon at the western end of the Livermore Valley, flood waters would flow to and collect at the western end of the Valley. The total

surface area of the Valley below the 120-m (394-ft) contour line is approximately 65 km² (16,060 acres) and the elevation at the western, or lower, end is about 100 m (328 ft) above mean sea level. Because the maximum capacity of the reservoir is 9.4×10^7 m³ (77,100 acre-ft) and the lowest Main Site elevation is approximately 150 m (492 ft) above mean sea level, the site would not be in the flood plane of water released from the postulated failure of the dam.

The South Bay Aqueduct transports water from the Bethany Reservoir near Byron, California, to Santa Clara County. During transport, water from the Aqueduct is impounded in the Patterson Reservoir, which is located 1.2 km (0.75 mi) east of the Site and has only a 1.8×10^4 m³ (14.6 acre-ft) capacity. Maximum flow in the aqueduct is 8.5 m³/sec with an average flow of 7.1 m³/sec (UC, 1986). If a seismic event caused a loss of water from the Patterson Reservoir or a break in the Aqueduct near the site, flood waters would flow into Arroyos Las Positas and Seco. Flooding of the Main Site would not occur.

F.1.2 Site 300 Characteristics

LLNL's Site 300 is located in the Altamont Hills of the Diablo Range. Site 300 activities include High Explosives (HE) testing and scientific experimentation. Solid waste disposal was also conducted in the past. The site is approximately 17 mi southeast of LLNL's Main Site, and 8 mi west of Tracy (Figure F-3). It occupies an area of 10.2 mi² and is a secure DOE facility. The majority of the site is within San Joaquin County while approximately 1.4 mi² (4.2 km²) lie in Alameda County (Figure F-4). Most of the surrounding area is used for ranch land or to support scientific experiments conducted by other organizations. Carnegie State Vehicle Recreation Area is located across Corral Hollow Road.

Site 300 is composed of ridges and canyons, varying in elevation from approximately 500 ft (152 m) at the Corral Hollow Creek entrance to over 1,700 ft (518 m) in the northwest quadrant. A more complete summary of geologic findings is contained in Raber and Carpenter (1983).

Figure F-3. Relative Location Map Showing Site 300 and Surrounding Communities (Raber, 1983).

Figure F-4. Site 300 Map with Location of Pits.

Seismicity

Site 300 is located on the eastern perimeter of an historically active seismic area. It is bound on the south and west by various active fault zones and is situated above several assumed inactive faults (Figure F-5). The known regionally active faults are the San Andreas (including its two associated branches--the Hayward and Calaveras Fault Zones), Greenville, Ortigalita, Concord, Las Positas, and Tesla. Activity along the Verona and Midway Faults is questionable, although considered active (Raber and Carpenter, 1983). Reports of ground-shaking earthquakes at Site 300 are the result of these regionally active faults. The most notable of these were the 24 January 1980 (Greenville Fault) and the 17 October 1989 (San Andreas Fault) earthquakes. While non-structural cracks were reported, no Site 300 structural damage was associated with these earthquakes. Due to the possibility of future seismic activity, Site 300 uses the same seismic design parameters as the Main Site (UC, 1986).

Four major faults, the Carnegie, Corral Hollow, Elk Ravine, and an unnamed fault have been mapped within or near the Site 300 boundaries (Raber and Carpenter, 1983). The Carnegie Fault traverses the Site along the southern border. The fault is obscured by alluvial deposits at Pit 6 and has produced, at depths below approximately 20 ft, near-vertical bedrock units; fault activity has not occurred within the last 70,000 years. However, recent pit mapping conducted for the Pit 6 remedial report does not completely rule out Holocene (less than 10,000 years) faulting (Copland, 1990). The Corral Hollow Fault roughly parallels the Greenville Fault, following a segment of Corral Hollow Road. No seismic activity has been attributed to this fault in or near Site 300, and it remains concealed by alluvial deposits. The Elk Ravine Fault bisects Site 300 from the northwestern to the southeastern corners. According to State of California guidelines, this fault is regarded as inactive. During previous studies, the unnamed fault, located in the center of the site, was mapped and determined to be inactive (Raber and Carpenter, 1983). Since all four faults are currently considered inactive, Site 300 is not listed as an Alquist-Priolo Act Special Studies Zone.

Figure F-5. Fault Zones and Geology of the Site Vicinity (State of California Department of Conservation, 1988b and Raber and Carpenter, 1983).

The supposed inactivity of Site 300's underlying faults reduces the possibility of future seismic-related surface rupture. The locally active faults can produce ground movement which potentially, but not historically, can lead to structural damage. This ground movement can also produce ground failures. In accordance with State of California regulations, liquefaction potential assessments were conducted in 1983 (Raber and Carpenter, 1983). Soil liquefaction and hydrocompaction potentials were determined unlikely or negligible, but landslides were deemed possible, especially on the steep slopes north of Pit 6, west of Pit 7 and around Pit 8.

Meteorology and Climate

Site 300 is considered a semi-arid, Mediterranean climatic area. As such, it experiences mild, wet winters and warm, dry summers. Strong winds are common at the site, but snow or thunderstorms occur infrequently. Heavy fog is also prevalent in the area. Visibility less than 1/4 mile has been reported for 44 days annually (Nelson, 1990; National Oceanic and Atmospheric Administration, 1988).

Winter temperatures average a maximum temperature of 57°F (14°C) and minimum of 39°F (4°C). Recorded temperatures are infrequently below freezing. Winter storms account for the majority of the 10-in (25-cm) average annual rainfall. Winter afternoon's relative humidity averages 60-70% increasing to 85-90% at night.

Precipitation decreases continually after April until autumn which is considered the driest season, averaging 30-50% relative humidity. July is the hottest month reaching an average temperature of 97°F (36°C). From spring until fall, marine air flows produce afternoon and evening westerly winds. The wind rose shown in Figure F-6 displays the annual distribution of wind speed and frequency at Site 300. Strong wind gusts, up to 160 ft/s (49 m/s), have been recorded at the Site (DOE, 1982b; UC, 1986).

Average annual percent frequency of wind direction vs wind speed m/s
(Winds are based on 15 minute averages.)

Direction	0-2	2-3	3-5	5-7	7-9	9-11	11-16	16-20	>20	Total	Average speed m/s
N	0.6	0.4	1.3	1.3	0.4	0.1	0.0	0.0	0.0	4.1	4.6
NNE	0.4	0.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	1.4	2.9
NE	0.7	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.6
ENE	0.8	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.1
E	0.7	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1.4	2.4
ESE	0.9	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.0	1.6	2.9
SE	0.7	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0	1.5	3.0
SSE	1.0	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0	1.8	2.4
S	1.6	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	2.8	2.4
SSW	1.0	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	2.1	2.6
SW	1.6	0.8	1.3	0.8	1.0	0.6	0.0	0.0	0.0	6.1	4.6
WSW	4.2	1.9	3.6	6.1	9.1	4.1	0.0	0.0	0.0	29.1	6.0
W	0.9	0.7	2.2	3.0	1.7	0.3	0.0	0.0	0.0	8.9	5.3
WNW	1.2	0.7	1.3	1.0	0.4	0.1	0.0	0.0	0.0	4.7	3.9
NW	2.5	2.1	2.5	1.9	1.4	0.3	0.0	0.0	0.0	10.8	4.1
NNW	1.7	1.2	3.3	3.1	1.8	0.5	0.0	0.0	0.0	11.6	4.9
Calm	---	---	---	---	---	---	---	---	---	8.6	---
Total	20.3	11.9	16.6	18.2	16.3	6.1	0.0	0.0	0.0	100.0	4.3

Figure F-6. Wind Rose for Site 300 (LLNL, 1989c).

Hydrology

Hydrology at Site 300 is greatly influenced by its climate and geologic environment. For example, surface water is highly seasonal and dependent upon the area's 10-in annual rainfall. Groundwater flow is dependent upon local geologic structures and the limited rainfall recharge. Groundwater depths vary across the site from several tens to several hundreds of feet.

Surface Water. Site 300's arid climate and varied topography limit the accumulation of surface water. Most of Site 300's run-off flows from a network of intermittent streams through Elk Ravine and Corral Hollow Creek and is eventually incorporated into the Delta Mendota Canal. Although Corral Hollow Creek has been categorized as a navigable waterway by the Central Valley Water Quality Control Board, the creek is limited to ephemeral flow and is almost always dry. Surface run-off is usually allowed to follow natural routes, but culverts have been installed where roads cross natural drainage courses.

Groundwater. Groundwater monitoring data presented by Raber and Carpenter (1983) and followed by numerous remedial investigations, have contributed to the understanding of Site 300's groundwater environment. Significant groundwater flow is largely contained in gently dipping Cierbo and Neroly Sandstone beds. Orogenic activity has fractured and locally displaced these beds, occasionally creating near vertical beds. At present, Site 300 uses two water supply wells that are screened in deep bedrock.

It is believed that two regional water-bearing zones underlie the site. Contained within fractures of the Neroly Sandstones and conglomerates is an unconfined water-table aquifer. Below this, in the deeper Neroly and Cierbo Sandstone beds, occur confined aquifers that can give rise to artisan wells. The occasional intermittent and seeping springs are associated with perched aquifers. Study of the bedrock aquifer system can be divided into four general areas, two located on either side of the Patterson Anticline, the third northeast of the Elk Ravine Fault and the fourth south of the Carnegie Fault.

Groundwater flow in the area south of the anticlinal axis is generally southward. North of the anticlinal axis, both aquifers follow the dips of Neroly and Cierbo beds flowing northeasterly. Across the Elk Ravine Fault, multiple confined aquifers were also identified.

They flow northeasterly but the fault produces an assumed groundwater barrier (Raber and Carpenter, 1983). South of the anticline and the Carnegie Fault, a claystone vertical bed acts as a groundwater dam. On the south side of this fault groundwater is found in the alluvium and the bedrock. Migration of groundwater from south to north is limited to flow along fractures in the claystone strata. The operation of the Carnegie State Vehicle Recreation Area Ranger's well (located off-site but north of Corral Hollow Road) also suggests a deeper aquifer within the Cierbo formation (Taffet and Lamarre, 1988).

F.2 OPERATIONAL PRACTICES

Operational practices such as inventory estimation, packaging, and treatment activities directly impact the Performance Assessment (PA) and are considered below. LLW is produced, characterized, and packaged by the various laboratory projects. An outline of these waste handling activities is contained in UCAR-10192 (Hirabayashi, 1989). LLW is then transferred to the Hazardous Waste Management (HWM) facilities for storage, processing, and shipment for disposal as detailed in UCAR-10264 (LLNL, 1989a).

In 1988 the LLNL Environmental Protection Department initiated a Hazardous Waste Management Requisition System which provides the basis for the LLW inventory system. As part of the Requisition System, the use of a WDR form was introduced.

WDRs are the primary records of a waste container's path from generation to final disposal. They form the basis for a computerized tracking system that tracks waste from cradle to grave. Specific instructions for the implementation and use of the WDR system are provided in Waste Disposal Requisition Guidelines (vanWarmerdam, 1990). Specific instructions to generators on segregation, separation, packaging, and preparation for transportation are contained in a Preparation Guide for Generators of Hazardous Chemicals and Radioactive Waste at LLNL (Huss, 1987). The WDR system is a waste manifest system which records the specified waste characterization data required by Doe Order 5820.2A, Chapter III, paragraph 3.d, as well as permits proper segregation, treatment, storage, and disposal of LLW. The identification of higher classification wastes is also implemented by

the WDR system, the Preparation Guide (Huss, 1987), and the LLW Certification Program Plan in Appendix E of the Hazardous Waste Management Plan (LLNL, 1989a).

As part of on-going improvements in HWM, a Low-Level Waste Compliance Plan (LLWCP) is being prepared which addresses waste inventory requirements, in addition to other requirements.

The buildings, areas, and operations that comprise HWM are described in the remainder of this section. The discussion focuses on the individual HWM buildings and complexes; their physical characteristics and uses. The operations at HWM facilities include the pickup, treatment, packaging, and disposal of hazardous, transuranic, mixed, and low-level radioactive wastes.

The HWM facilities in the southeast quadrant of the Main Site are shown in Figure F-7). The only exceptions are Building 233, located in the southwest quadrant, and Building 883, at Site 300. The majority of the HWM facilities were originally designed and built for other purposes (at various times from 1943 to present) and each has been retrofitted to meet changing LLNL needs. The tasks and functions of storing, treating, handling, shipping, and disposing of radioactive and mixed waste generated at LLNL are divided among the buildings as discussed in the remainder of this section.

F.2.1 Building 419

During the review period for this PA, most activities at Building 419 had been suspended by LLNL Management Directive. This PA assumes that the building is returned to service in its former capacity. Because it is an older facility, it does not meet current Uniform Building Code seismic guidelines as identified by the LLNL Structural Group (LLNL, 1989f).

Building 419 is a 7,860-ft² structure and adjacent storage areas (Figure F-8). The building receives items for decontamination and size reduction. In addition, a small quantity of radioactive waste is acid neutralized or solidified. The facility does generate waste sludge and spent cleaning fluids during cleaning and size reduction operations. Approximately 95 percent of the wastes generated at the facility are mixed wastes. Generated wastes are

- Building 233 Solid Mixed Waste Storage
- Building 419 Decontamination/Size Reduction
- Building 513 Storage, Shredder and Solidification
- Building 514 and Associated Areas Waste Water Filtration/Treatment/Temporary Storage
- Building 612 and Associated Areas Segregation/Storage, Drum/Container Crushing
- Building 614 Eight Cell Storage
- Building 624 Storage
- Building 625 Polychlorinated Biphenyl (PCB)/Asbestos/TRU Storage

Figure F-7. Site Map Showing LLNL Hazardous Waste Management Facilities

Figure F-8. Building 419 Floor Plan and Operational Areas.

transferred to the receiving area in Area 612 for subsequent processing, treatment, storage, and shipping for disposal, as appropriate and stipulated in UCAR-10192 (Hirabayashi, 1989). Building 419 receives some radioactive LLW and TRU wastes for solidification.

This building is used primarily to decontaminate or size reduce radioactive or mercury contaminated materials. Areas are under negative pressure with respect to the corridors and office areas. In addition, exhausts are filtered with high efficiency particulate air (HEPA) filters.

Decontamination operations are labor intensive, often incorporating several different processes. No radioactive materials are permitted in the office areas, and personnel and equipment are monitored for radioactive contamination before leaving operational areas. Signs in various work areas state the type of protective clothing required. Smoking, eating, and/or drinking are not allowed in operational areas.

Contaminated large equipment is brought into Room 124 on a forklift. First, loose contaminants are HEPA-vacuumed from the equipment. Most contaminated material is removed during this process. As some residual contaminants may remain in small crevices and inaccessible areas, the equipment then may be cut up to facilitate additional radioactive material removal and eventual disposal. Size reduction is usually done in a walk-in hood with a plasma arc torch, a cutoff saw, or screwdrivers, wrenches, etc. Contaminants exposed during this process are removed by vacuuming. Slightly contaminated items are steam-cleaned or sprayed with an all-purpose cleaner. Absorbent materials are then used to remove the contamination.

Treatment and equipment applications are determined by applicable Facility Safety Procedures (FSPs), Operational Safety Procedures (OSPs), and the area supervisor. Size-reduced parts and recovered material are radio-assayed, packaged, and sent to Area 612 for appropriate packaging, labeling, and documentation prior to shipment for disposal.

Items contaminated with tritium are heat-treated in the bake-out oven in Room 155 for 24 hrs. This oven is also used for drying and can be operated up to 430°C. A blower exhausts the vapors through an unfiltered stack.

Other more highly contaminated items are cleaned using any combination of the following operations:

- Electro Strip Tank Operations - An electrolyte fluid in this tank is used to remove the surface layer of contaminated metals
- Ultrasonic Tank Operations - High-frequency sound waves are used to decontaminate items such as wrenches and screwdrivers
- Vapor Degreaser Operations - The vapor degreaser contains approximately 350 gal of solvent when in use
- Hydro Finish (Vapor Blaster) Operations - A slurry composed of water and fine sand is sprayed on contaminated items at a high velocity. Glove ports are used to move items and to control the nozzle position
- Solvent Cleaning Operations - Highly contaminated items, such as glove boxes, are placed in one of the two walk-in hoods (Rooms 167 and 124) prior to decontamination. The operator, dressed in the appropriate protective clothing, uses an acid wash or appropriate solvent to loosen contamination and collects the solution in a carboy. The floor drain of the Room 124 hood connects to Building 419's retention tanks. The exhausts are two-stage HEPA filtered
- Chemical Cleaning Operations - Chemicals are used in HEPA hoods to decontaminate items as required. Also, items contaminated up to FSP specified levels may be sealed in plastic bags and temporarily stored in these hoods
- Neutralization Operations - Small amounts of liquid transuranic (TRU) acids are neutralized in the chemical hood.

F.2.2 Building 513

Building 513 is part of Complex 514 (Figure F-9) and houses the equipment for the shredding and/or solidification of radioactive and mixed wastes. Radioactive waste solidification occupies an area approximately 20 ft x 30 ft within Building 513. The solidification unit consists of a hopper through which an absorbent is added to the 55-gal drums. A stirring mechanism ensures waste material is well dispersed throughout the drum. Building 513 also houses equipment for shredding items contaminated with radioactive materials into a form suitable for subsequent treatment or shipment. A drum roller and mixer unit is also used for solidification of liquids. A drum tumbler is used for solidification/mixing of heterogeneous materials, e.g. solids and liquids.

Building 513

is a 3,500-ft² structure consisting of two main areas. The west portion of the building houses the two solidification units. The central portion of the building is used for storage of mixed and radioactive waste. The east portion of the building houses a shredder unit. All areas are constructed with concrete floors sealed with epoxy paint. The building's exterior walls and roof are covered with ribbed metal panels. Interior walls are dry wall construction.

F.2.3 Building 514

The 514 Complex is a treatment facility for large-volume, low-level radioactive, and nonradioactive liquid waste. The 30,000 ft² fence-enclosed area around the building is surfaced with asphalt and cement and includes Buildings 513 and 514 (Figure F-9).

Building 514 is a concrete and wooden structure with an approximately 2,880 ft² floor area. The surface of the floors in Rooms 108 and 112 have been painted with a polyamide-cured epoxy to protect against potential contamination and to facilitate cleaning.

The 514 Waste Water Treatment Tank Farm encompasses six treatment tanks, each of 1,500-gal capacity. A 25,000-gal emergency storage tank with an operational capacity of 14,500 gal and three retention tanks are also present (Hallisey, 1988). Tanks DO-1 and DO-2 each have 1,500-gal capacities; tank DO-3 has a 1,000-gal capacity.

The treatment tanks are interconnected by a series of pipes and remotely operated valves so that the liquids can be readily pumped from one tank to another during the treatment process. Other tanks containing chemicals can also be pumped to the waste water treatment tanks. The remote controls and indicators to operate the various pumps, stirrers, and valves for the waste treatment process are located inside Building 514, as is the diatomaceous-earth, Dorr-Oliver, rotary drum filter.

Wastes are collected and brought in portable tanks from stationary waste water retention tanks throughout the LLNL facility. HWM personnel pump out those retention tanks and have the wastes transported to Area 514 or 612. Smaller amounts of wastes contained in carboys and 55-gal drums are also received for treatment in the Tank Farm.

All treatment of mixed and radioactive wastes is documented and retained in a records system which provides an auditable history of each specific waste stream from the point of

Figure F-9. Complex 514 Waste Management Units [from UCAR-10275 (LLNL, 1989b)].

Figure F-10. Complex 612 Waste Management Units [UCAR-10275 (LLNL, 1989b)].

generation to the final disposition of the waste (LLNL, 1989b). At the Tank Farm, nonradioactive wastes are treated by changing the pH, only.

Also located within the 514 Complex are three underground sump tanks with lift pumps. The contents of these tanks can be pumped to D0-1 or D0-2 for sampling prior to disposal to the sanitary sewer. These pumps have automatic shut-off valves with audible alarms, triggered by each tank's high-level sensor.

Waste is temporarily stored in Storage Structures which are also used to store mixed waste to be processed in Building 514 via the Dorr-Oliver rotary drum filter or the silver recovery process.

F.2.4 The 612 Complex

The 612 Complex (Figure F-10) includes the following:

- Two Office Trailers, T-6179 and T-6178
- Drum/Container Storage Area
- Building 612 Mixed Waste Container Storage
- Receiving and Segregation Area
- Area 612 Portable Tank Storage
- Covered Storage Areas
- Area 612 Tank Trailer Storage
- Area 614 East and 614 West-Cell Storage
- Building 624.

Activities conducted in Building 612 and in the associated storage areas involve lab-packing, packaging, storage, labeling, size reduction, baling, drum crushing, portable tank storage, and preparation of radioactive waste for shipment off-site. Building 612 has 7,920-ft² of floor space and is divided into high bay; mechanical equipment room; and laboratory, office, and washroom areas. The walls are either steel-reinforced concrete block or ribbed metal panels on steel beams. There are roll-up doors in the south and east walls. The load-

bearing walls are set on spread footings. The floor is reinforced concrete. The floor areas in Rooms 100, 104, and 105 are covered with epoxy paint to prevent spills from soaking into the concrete and to aid in cleaning and decontamination. The tank, located at the north exterior of Building 612, is sampled for radioactivity (alpha, beta, tritium), pH, normality, copper, chromium, nickel, zinc, beryllium, silver, lead, cadmium, mercury, cyanide, and oil (ppm).

The wood-framed roof is supported by structural steel and concrete block walls. It is sheathed with 3/8-in-thick plywood. The roof is composed of a multi-layer asphalt waterproofing, surfaced with aggregate composites. Personnel doors are hollow metal with glass or louver panels.

In November/December 1989, the Receiving and Segregation Structure was upgraded with a continuous-pour reinforced concrete epoxy-coated floor and metal corrugated roof. The 42 ft x 100 ft structure is subdivided by berms into 5 bays to provide for segregation of hazard classes and secondary containment in accordance with Environmental Protection Agency (EPA) and Department of Health Services (DHS) requirements. Protection from weather for longer term storage of containers such as 5-gal carboys and 55-gal drums is also provided. Bays A and E are designed to hold 144 (55-gal) drums (7,920-gal per bay). Waste containers are stored on wooden or fiberglass secondary containment pallets to prevent contact between containers and potential spills. Pallet storage also facilitates spill detection and clean up during visual inspections. Other Storage Areas have a sealed asphalt floor and are entirely bermed.

LLNL Main Site and Site 300 radioactive wastes and mixed wastes are processed, stored, packaged, and prepared at Building 612 or in the 612 Complex for storage, treatment, shipment, and disposal or recycling. Operations at Building 612 include the following functions:

- Requisition Processing and Preapproval - comparison of waste to waste acceptance criteria and waste requisition system documentation for purposes of tracking treatment and disposal costs
- Tracking and documentation of mixed and radioactive waste handling from waste accumulation areas to final disposal, both on- and off-site

- Packaging, size-reduction, and baling
- Assuring that containers for shipment of wastes meet Department of Transportation (DOT) and other regulatory specifications
- Preparing manifests, notifications, placards and other materials for off-site shipments. TRU, LSA, and mixed radioactive waste are stored in multiple locations within Area 612. All waste must eventually be packaged in DOT-approved containers including wood boxes, metal boxes, or metal drums. Packaging of the waste is done in the 612 high bay, in the waste accumulation areas, or at the point of generation.

The southern portion of the Building 612 high bay is used for lab-packing operations. Laboratory-grade, individually packaged chemicals are brought into this area, segregated, and placed in appropriate drums based on DOT hazard class, compatibility, and disposal site requirements. When a drum is full, it is moved to the drum storage area.

The Drum/Container Storage Area stores only 55-gal drums, tuff tanks, and other tanks of waste. Drums are stored on plastic secondary containment pallets. Containers are stored in an asphalt or concrete-floored, bermed area within Complex 612 until they are shipped out to an approved off-site facility. The drum storage area is inspected on a daily basis.

LLW is compacted to reduce the volume. Objects that cannot be compacted are packaged in specially constructed containers. The packaged solid radioactive waste material is weighed, labeled, stored, and shipped to an off-site facility.

Building 612 also contains a HEPA-filtered drum crusher. Empty radioactive and mixed waste containers may be crushed by this unit. The crusher is checked for contamination after containers have been crushed. Crushed items go into a roll-off bin to be shipped off-site.

F.2.5 Building 625

Building 625 is used to handle and store polychlorinated biphenyl (PCB) waste materials and to store non-PCB materials such as asbestos and TRU wastes. Handling of

PCB materials, such as draining and packaging of capacitors and transformers and storage of asbestos wastes, is done on the west side of Building 625. TRU wastes are stored on the east side of the building.

F.2.6 Building 233

Building 233 was not in use at the time of the PA walk-through. The building is designated for solid mixed waste storage.

F.2.7 Building 883

Building 883 contained no radioactive material at the time of the PA review. the responsible Environmental Technician noted that, to his knowledge, no radioactive material has been stored in Building 883. The only LLW identified at Site 300 was shot table debris and gravel contaminated with extremely low levels of depleted uranium. This material was stored in large transportainers and approximately 60 SS-90 metal boxes and was located in a project waste accumulation area adjacent to Building 804. The technician noted that shipment of this material have been made to the Nevada Test Site disposal areas and to the laboratory proper directly from the waste accumulation area, without use of Building 883.

Appendix G:

Assessment Methodology

Appendix G Assessment Methodology

This Systems PA is composed of a number of steps, defined in DOE/LLW-63T (DOE, 1989a), that apply to all DOE facilities. These steps are

1. Determine the regulatory requirements and their associated radiation dose, contamination, and emission limits. These define the performance objectives of the LLW management program. This is performed in Appendix H.
2. Determine the maximum LLW source term, i.e., the maximum amount of LLW that LLNL can produce each year and still meet the performance objectives. This includes development of a current or reasonable case inventory and a worst-case or maximum inventory. This is performed in Section 3.
3. Determine the components of the disposal system. These components are defined in DOE Order 5820.2A (DOE, 1988a) and DOE/LLW-63T (DOE, 1989a) and are systematically analyzed in Section 4.
4. Determine the base system cost-performance level. The cost of this base system is determined using current LLNL budget information presented in Section 5.
5. Determine the preferred LLW system using ALARA and cost-benefit analysis. Further improvements toward meeting LLNL policy, DOE requirements, and other regulations are compared on a cost basis to identify the most cost-effective options. The effect of these options on dose minimization, ALARA, is also evaluated. This is performed in Section 6.

Appendix H:

Regulatory Requirements

Appendix H Regulatory Requirements

DOE Orders and Federal and state regulatory requirements were reviewed for applicability to LLW management at LLNL. A partial listing of these documents includes the following:

DOE Order 5820.2A, *Radioactive Waste Management*, September 26, 1988.

DOE Order 5400.1, *General Environmental Protection Program*, November 9, 1988.

Draft DOE Order 5400.XY, *Draft Radiological Effluent Monitoring and Environmental Surveillance*, September 14, 1988.

DOE Order 5400.3, *Hazardous and Radioactive Mixed Waste Program*, February 22, 1989.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, February 8, 1990.

DOE Order 5480.4, *Environmental Protection, Safety, and Health Protection Standards*, May 15, 1984.

DOE Order 6430.1, *General Design Criteria*, December 12, 1983.

DOE Order 5480.11, *Radiation Protection for Occupational Workers*, change 1, July 20, 1989.

DOE Order 5484.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements*, February 24, 1981.

DOE Order 1540.1, *Materials Transportation and Traffic Management*, May 3, 1982.

DOE Order 5700.6B, *Quality Assurance*, September 23, 1986.

DOE/LLW-75T, *Methodology for Compliance with DOE Order 5820.2A*, February 1989.

ANSI/ASME NQA-1, 1989; *Quality Assurance Program Requirements for Nuclear Facilities*.

Resource Conservation and Recovery Act, Public Law 94-580, 1976.

Nuclear Waste Policy Act, Public Law 97-425, 1982.

Uranium Mill Tailings Radiation Control Act, Public Law 95-604, 1978.

Low-Level Radioactive Waste Policy Amendments Act, Public Law 99-240, 1985.

National Environmental Policy Act, Public Law 91-190, 1969.

Atomic Energy Act, Public Law 83-703, 1954.

Clean Air Act, 1977.

Federal Water Pollution Control Act, 1972.

DOE/NVS NVO-325, UC-70B, *Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements*, October 1988.

US Environmental Regulations, Title 40 CFR.

US Energy Regulations, Title 10 CFR.

US Transportation Regulations, Title 49 CFR.

State of California, CCR, Title 17, *Health*.

State of California, Health and Safety Code, Division 20.

State of California, Title 22, Chapter 30.

From these documents, specific performance objectives for LLNL LLW and mixed waste management were developed from the following:

- DOE Order 5820.2A
- DOE Order 5400.5
- 40 CFR 61, Subpart H
- 40 CFR 141
- 49 CFR 173
- NVO-325
- State of California, Division 20, Subsection 25600.

DOE Order 5820.2A is the primary document governing LLW at DOE facilities and it specifies dose limits to members of the public both during operation and after closure. DOE Order 5400.5 also provides dose limits to members of the public during operation and after closure and radioactive effluent concentration limits. Environmental Protection Agency (EPA) regulations specify limits on emissions of hazardous air pollutants and contamination of water systems. Department of Transportation (DOT) regulations specify limits on the dose rates from packages and vehicles containing radioactive material during transport. State of California regulations regarding the control and monitoring of radioactivity in the environment are also applicable but specify no limits.

END

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