PRELIMINARY DESIGN OF LLRW DISPOSAL FACILITY FOR THE STATE OF TEXAS

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ABSTRACT

The Texas LLW disposal facility is designed to satisfy all applicable performance and design requirements. Low-gamma Class A and mixed waste are to be disposed in modular concrete canisters, while high-gamma Class A, Class B, and Class C waste are to be disposed in below-grade steel-reinforced concrete vaults. In the structural design of disposal units, reasonable assurance of water tightness is provided by satisfying requirements of ACI 224R-80 and ACI 350-80, which are the controlling requirements for the structures. Requirements of ACI 318-83 are satisfied for canisters and those of ACI 349-80 for vaults. In all cases, the capabilities provided to the structure exceed the environments to which the structures will be subjected. Drainage features are designed to accommodate conditions projected to prevail during the hypothetical Probable Maximum Precipitation and Probable Maximum Flood events.

Migration of water from the surface to the water table is projected to take at least 100,000 years effectively eliminating groundwater doses. The largest projected effective whole-body equivalent dose rate is estimated to be about 12 mrem/yr to an adjacent farmer via external gamma radiation. Occupational radiation exposures to workers are estimated to total less than 19 person-rem/yr, of which about one-third is received by personnel who are conservatively assumed to visually inspect each low-gamma Class A waste container. These results are comparable to other estimates of occupational radiation dose rates on the basis of projected dose per curie disposed.

The life cycle costs of the facility are estimated to total $233 million. The uniform disposal charge is estimated to be less than $105 per cubic foot of waste disposed. After 100 years of institutional control, the Closure and Maintenance Fund is projected to have a value of $100 million.

FACILITY DESCRIPTION

General

The disposal facility for the State of Texas is intended to accommodate all low-level radioactive waste (LLW) and mixed waste (MW) expected to be generated in the Texas over its 30-year operating life. The annual LLW disposal rate was estimated to be about 100,000 ft^3/yr and the annual MW disposal rate to be about 1,000 ft^3/yr(1).

All low-gamma Class A waste and mixed waste will be disposed in modular concrete canisters that may be fabricated onsite. Such waste will be offloaded into the waste Receiving and Storage Building. Under normal conditions, this waste will be processed immediately but can under rare unusual circumstances be placed in storage for a limited period of time until normal conditions can be restored.

Processing of the waste amounts to transferring the waste containers from the shipping vehicle to the building, where each container is inspected. Acceptable containers are placed into a concrete canister until the latter will accommodate no further containers. Void spaces between containers inside the canister are filled with grout and the grouted canister is transported to a holding area where the grout is allowed to cure. When the grout has cured, the canisters are transported to the Class A or mixed waste disposal areas.

Unacceptable containers are placed in the remedial action bay to rectify any problems before disposal.

High-gamma Class A, Class B and Class C waste are not taken to the waste Receiving and Storage Building except under unusual conditions which require use of the remedial action bay. Normally, such waste containers are transported directly to the Class B/C disposal area, where they are offloaded into the active Class B/C disposal unit.

Class A Disposal Units

The Class A disposal area consists of 30 Class A disposal units, each sized to receive the waste expected to be delivered to the disposal facility over a one-year period. Each Class A disposal unit is an excavation in the earth, such that the top of the topmost canister is at least 1.0 ft below natural grade.

The base of each Class A disposal unit, from the bottom up, consists of:

- 18 inches of gravel to allow drainage of percolating water.
- 18 inches of roller compacted concrete to provide a stable surface and to direct percolating water to the French drain.
- 18 to 24 inches of gravel for drainage.

The roller compacted concrete is constructed so that any water which may arrive at its upper surface will be directed to a French drain and sump system to facilitate performance monitoring. The French drain and sump system is designed so that accumulating water which is not removed by pumping will overflow the sump to the gravel layer in the bottom of the excavation, where it will continue to percolate into natural soil below. Hence, the potential for contact between water and waste is minimized by design and construction.

The Class A disposal units are provided with cover systems that place at least 8 ft of cover material on top of the topmost canister. The cover system, from the bottom up, consists of:

- 12 inches of granular fill for drainage.
- 42 inches of compacted clay for moisture barrier.
- 12 inches of sand for drainage.
- 12 inches of gravel for drainage.
- 18 inches of riprap for surface stability in the arid climate.

Class B/C Disposal Units

The Class B/C disposal area consists of four Class B/C below-grade vaults, each vault consisting of eight independent disposal structures. Each disposal structure is a group of six disposal cells comprised by a common mat foundation, exterior walls, interior walls, and roof.

The base of each Class B/C disposal unit, from the bottom up, consists of:

- 12 inches of gravel to allow drainage of percolating water.
- 18 inches of roller compacted concrete to provide stable surface.
- At least 18 inches of gravel for drainage.

This subgrade system, including French drains and sumps, similar to that of the Class A disposal units, is designed so that accumulating water which is not removed by pumping will overflow the sump to the gravel layer in the bottom of the excavation, where it will continue to percolate into natural soil below. Hence, the potential for contact between water and waste is minimized by design and construction.

Each Class B/C disposal unit is constructed so the top of the waste in the disposal vaults is at least 8.9 ft below natural grade. The Class B/C disposal units are provided with cover systems that place at least 16.5 ft of cover material on top of the topmost waste container. The cover system, from the bottom up, consists of:

- 40 inches of granular fill inside the vault for shielding.
- 44 inches of concrete roof.
- A waterproof membrane.
- 6 inches of sand for drainage.
- 42 inches of compacted clay for moisture barrier.
- 12 inches of sand for drainage.
- 24 inches of compacted native soil for bulk.
- 12 inches of gravel for drainage.
- 18 inches of riprap for surface stability in the arid climate.

Thus, sufficient cover is provided over any Class C waste that may be disposed in the unit to satisfy requirements for protecting inadvertent intruders.

Mixed Waste Disposal Unit

The mixed waste disposal units are similar to the Class A disposal units except that they are provided with a double impermeable liner system, a leachate collection and removal system, a leakage detection and removal system, and an impermeable membrane liner in the disposal unit cover system. The double impermeable liner system is placed so that the liners are under all waste disposed in the disposal unit and so that they extend up to 12 inches below natural grade. In the highly unlikely event that water accumulates in the disposal unit without being removed by active means, the water will overflow from the disposal unit and percolate downward into natural soil, rather than being released to the surface.

The leachate collection and removal system and the leakage detection and removal system are constructed so that if accumulating water is not removed by pumping, the water will overflow from the associated sumps into a specially constructed drain field. This feature helps minimize the potential for contact between water and waste, as required.

The base of each mixed waste disposal unit, from the bottom up, consists of:

- 36 inches of compacted clay for moisture barrier.
- An impermeable membrane.
- 12 inches of granular drainage blanket.
- An impermeable membrane.
- 12 inches of granular drainage blanket.
- 24 inches of granular drainage blanket.
- The mixed waste disposal units are provided with cover systems that place at least 9 ft of cover

material on top of the topmost canister. The cover system, from the bottom up, consists of :

- 48 inches of compacted backfill.
- 12 inches of gravel for drainage.
- 18 inches of compacted clay for moisture barrier.
- An impermeable membrane.
- 12 inches of gravel for drainage.
- 18 inches of riprap for surface stability in the arid climate.

STRUCTURAL ASSESSMENT

The general approach to concrete member design followed in the project is summarized below:

- Analyze the structure under required loading conditions.
- Assume necessary element characteristics based on requirements of ACI 224R-80; ACI 350-80; and ACI 318-83 for modular concrete canisters or ACI 349-80 for below-grade vaults.
- Determine the total deterioration thickness resulting from sulfate attack over the design life of each element.
- Determine the necessary concrete cover and waterproofing coatings to delay onset of steel corrosion.
- Determine the final element characteristic necessary to achieve the design life.
- Verify that the assumed element characteristics are adequate for the required loading conditions.

The results of these analyses are presented in the following paragraphs.

Modular Concrete Canisters

The modular concrete canisters are made of steel reinforced Type V Portland cement concrete and are designed to perform as required for 200 years.

In order to determine the necessary structural characteristics of the modular concrete canister for low-gamma Class A and mixed waste disposal, ring tension, bending moments, and shear forces were calculated as recommended by ACI 318-83 (2). Concern for watertightness and long service life also required analyses following recommendations of ACI 224R-80 (3) and ACI 350R-83 (4) for cracking control and ACI 201.2R-77 (Reaffirmed 1982)(5) for material characteristics control.

In all cases, the strength of the structure provided substantially exceeds the calculated loading conditions (bending moment, shear, and tension). Requirements for cracking control are also satisfied by the canister design. These facts provide reasonable assurance that the canisters will perform as planned.

Below-Grade Vaults

The below-grade vaults are made of steel reinforced Type V Portland cement concrete and are designed to perform as required for 500 years.

Ring tension, bending moments, and shear forces were calculated as recommended by ACI 349-80 (6). Concern for watertightness and long service life also required analyses following recommendations of ACI 224R-80 and ACI 350R-83 for cracking control and ACI 201.2R-77 (Reaffirmed 1982) for material characteristics control.

The roof was designed assuming two separate support conditions: simple support on all four edges and fixed support on all four sides. Walls were analyzed under two support conditions: fixed on three edges and free on top (before roof construction) and fixed on three sides and simple support on top (after roof construction). The mat foundation was analyzed in the transverse and longitudinal directions assuming an elastic support condition, using the STRUDL code.

Allowances for sulfate attack of the concrete and chloride attack of reinforcing steel were made. Reinforcing steel was provided according to requirements of ACI 349-80.

In all cases, the strength of the structure provided substantially exceeds the calculated loading conditions (bending moment, shear, and tension). Requirements for cracking control are also satisfied by the vault design. These facts provide reasonable assurance that the vault will perform as intended.

DRAINAGE AND STABILITY ASSESSMENT

Diversion dikes were sized to accommodate runoff from the hypothetical Probable Maximum Flood (PMF). Drainage ditches and the main drainage ways were sized to accommodate runoff from the hypothetical Probable Maximum Precipitation event (PMP) using the Manning and rational equations. The runoff retention ponds were sized to retain runoff from the 100-year frequency, 24-hour duration storm, assuming no infiltration.

The disposal unit cover systems were designed to allow annual percolation of no more than 0.66 inches. The percolating waster drainage system was sized to accommodate this rate of percolation over the entire area of the disposal units, allowing for partial blockage of flow areas on all pipes.

The potentials for wind erosion, subsurface erosion, surface gully erosion, and surface sheet erosion were evaluated, given the assumed wind conditions and precipitation and runoff events. All drainage components and systems were designed to withstand these potentials so that stability was reasonably assured.

RADIOLOGICAL PERFORMANCE ASSESSMENT

Radiation exposures were projected for four exposure scenarios judged to be reasonable for the Texas disposal facility. These scenarios are described below.

Intruder-explorer

Following the assumed end of the institutional control period (100 years after site closure), an individual was assumed to frequent the disposal area for 1,000 hours over the course of a year, during which time he is assumed simply to roam the disposal area without attempting to excavate, drill into, or otherwise develop the site. Thus, the only modes of exposure are:

- External gamma exposures from disposed waste, from residual contamination assumed in surface soils, and from potential overflow from the mixed waste disposal unit.
- Inhalation of resuspended residual contamination.

Intruder-Construction

A person was assumed to occupy the disposal area at the assumed conclusion of the institutional control period and to construct a residence for himself. The construction was assumed to involve the drilling of a culinary water well and the digging of a basement for the house. The construction was assumed to require 500 hours over the course of a year. Radiation exposures were assumed to result from external gamma radiation from any exhumed waste and inhalation of resuspended contaminants. This scenario did not involve consumption of food stuffs grown at the site.

Intruder-Agriculture

Following the construction activities described for the Intruder-Construction scenario, a person was assumed to inhabit the dwelling on the disposal site, grow a vegetable garden, raise crops for animal feed, and raise animals for food and dairy products. Contaminated food was assumed to supply 50 percent of his total dietary needs. The assumed modes of radiation exposure are external gamma exposure for exhumed waste, ingestion of potentially contaminated drinking water, ingestion of contaminated food stuffs, and inhalation of resuspended contamination.

Adjacent Farmer

A individual was assumed to operate a farm about 3,300 ft from the disposal area. Food was assumed to be grown and consumed just as it was in the Intruder-Agriculture scenario, described above. Radioactive contaminants were assumed to be present at his farm because of the migration of residual contamination from the disposal site. The assumed modes of radiation exposure are ingestion of contaminated food stuffs and inhalation of resuspended contamination.

Results

The results of these radiological assessments are summarized in Table I. The largest projected whole body equivalent dose is about 12 mrem/yr to the Adjacent Farmer. This dose results external gamma exposure. The largest critical organ dose is 1.2 mrem/yr to the bone surface. This dose occurs in the Intruder-Construction scenario through dust inhalation. These projected doses satisfy the performance objectives of the State of Texas(7) and the NRC(8).

Because of the extremely arid conditions at the assumed disposal site (11 in/yr) and of the extreme depth to the water table (492 ft), the potential of ground water contamination was estimated to be minimal. Using the UNSAT code(9), it was estimated that well in excess of 100,000 years are required for water from the surface to reach the water table.

OCCUPATIONAL RADIATION DOSE ASSESSMENT

Occupational radiation exposures to workers were projected using the MICROSHIELD code(10) and estimated time-distance-shielding configurations for each waste handling activity at the disposal facility. The results of these projections are presented in Table II by worker category. The annual collective occupational dose from assumed disposal operations totals about 19 person-rem/yr. Given the numbers of each type of worker, the largest individual dose could be as high as about 2 rem/yr for members of the process crew (which places low-gamma Class A waste in canisters) and health physics technicians.

On the basis of the radioactivity disposed annually, these projected dose rates are high, when compared to experience at operating shallow land disposal facilities(11) and to previous estimates for earth mounded concrete bunker disposal facilities (to which the Texas facility is similar)(12). However, very conservative assumptions were made in these evaluations, particularly in the assumption that each waste container handled in the waste Receiving and Storage Building is inspected prior to processing.

ECONOMIC ASSESSMENT

The life cycle costs of the Texas LLW disposal facility were estimated to total \$233 million, in the absence of inflation and without consideration for the time value of money. Of this total, about \$40 million is associated with the facility development and construction and \$164 million with disposal operations. Assuming that disposal charges are levied on the basis of disposal volume alone, the disposal charge was estimated to be \$101 per cubic foot in constant 1988 dollars. The surcharge for closure and long-term maintenance was estimated to be about \$1 per cubic foot.

The closure and maintenance fund was estimated to have a value of about \$10 million at the conclusion of disposal operations and of about \$4 million after site closure activities. At the end of the institutional control period, the value of this fund was estimated to be about \$100 million, assuming there are no unusual maintenance or remedial action requirements.

REFERENCES

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5. American Concrete Institute, "Guide to Durable

TABLE I

Maximum Radiological Doses and Risks by Scenario

		Pathway				
Scenario	Waste Component	External Gamma	Dust Inhalation	Food Consumption	Offsite Atmospheric	Groundwater
IntruderExplorer	Residual Class A					
Year of Maximum Dose		100	100	---	---	---
Maximum Dose (mrem/yr)		3.4E01	1.4E03	---	---	---
Maximum Risk		9.6E08	3.9E10	---	---	---
Dominant Nuclide		Cs137	Am241	---	---	---
Critical Organ		---	Bone Surface		---	---
Organ Dose (mrem/yr)		---	2.6E02	---	---	---
IntruderConstruction	LowGamma A					
Year of Maximum Dose		200	200	---	---	---
Maximum Dose (mrem/yr)		4.6E01	6.7E02	---	---	---
Maximum Risk		1.3E07	1.9E08	---	---	---
Dominant Nuclide		Cs137	Am241	---	---	---
Critical Organ		---	Bone Surface	---	---	---
Organ Dose (mrem/yr)		---	1.2E+00	---	---	---

TABLE I (Continued)

Maximum Radiological Doses and Risks by Scenario

Scenario	Waste Component	External Gamma	Dust Inhalation	Food Consumption	Offsite Atmospheric	Groundwater
IntruderAgriculture	LowGamma A*					
Year of Maximum		Dose	200	200	100	---
Maximum Dose (mrem/yr)		1.7E+00	4.8E02	5.1E02	---	---
Maximum Risk		4.7E07	1.4E08	1.4E08	---	---
Dominant Nuclide		Cs137	Am241	Sr90	---	---
Critical Organ		---	Bone Surface	Thyroid	---	---
Organ Dose		---	8.6E01	4.3E01	---	---
Adjacent Farm	Residual Class A				---	---
Year of Maximum Dose		0	0	0	0	---
Maximum Dose (mrem/yr)		1.2E+01	1.8E03	1.2E01	1.1E04	---
Maximum Risk		3.4E06	5.0E10	3.2E08	3.0E11	---
Dominant Nuclide		Co60	Am241	Cs137	Am241	---
Critical Organ			Bone Surface	Gonads	Bone Surface	---
Organ Dose			3.1E02	9.5E02	1.9E03	---

*Food consumption dose is due to the mixed waste overflow in the retention basin.

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TABLE II

Annual Average Worker Doses By Worker Category

Worker Category	Number Employed	Annual Collective Dose (person • rem/yr)	Average Annual Dose (rem/yr)
Process Crew	3	6.1	2.0
Disposal Drew	3	1.7	0.6
Rigger	1	0.4	0.4
Equipment Operator	3	2.4	1.2
Health Physics Technician	2	3.9	2.0
Quality Assurance Technician	2	2.4	1.2
Supervisor	4	2.1	1.1
TOTAL	19.0		