AN OVERVIEW COMPARISON OF TANK CLOSURE ACTIVITIES AT CERTAIN DOE SITES

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ABSTRACT

This paper presents a summary-level comparison of the similarities and differences of tank closure programs at the four primary radioactive waste tank sites in the US Department of Energy (DOE) complex. The sites are Hanford, Idaho National Engineering and Environmental Laboratory (INEEL), Oak Ridge Reservation (ORR), and the Savannah River Site (SRS). The depth of our understanding of the closure programs varies with the amount of detailed information each of the four sites has provided to date. This paper was prepared using the best available information, including direct communications with key tank closure personnel at each of the sites. Many of the current schedules are under review for possible acceleration.

INTRODUCTION

DOE currently stores about 340 million liters (90 Mgal) of waste containing more than 700 million curies in 279 tanks at 4 major sites. The tanks were built from the 1940s through the 1980s and have storage capacities ranging from 49,000 L to over 3.7 million liters (13,000 gal to over 1 Mgal). The waste in these tanks is classified as high-level waste (HLW), transuranic (TRU) waste, or mixed waste. Many of the tanks have exceeded or are approaching the end of their design life. Table I provides a comparison of the four sites.

The most prominent characteristic of the Hanford Site tank closure program is the relative enormity of the task. The Hanford Site has 63 percent of all the DOE tanks (80 percent of all the single-shell tanks (SSTs)), 38 percent of the DOE waste volume, and 86 percent of the DOE failed tanks, including 98 percent of all the failed tanks that have leaked to the environment. The considerable subsurface contamination created by these leaks vastly complicates the technical and regulatory aspects of the Hanford Site tank closure program.

Table I. Comparison of Site Physical Systems to Be Closed

Tank Specification	Hanford Site	Savannah River Site	INEEL	ORR
Number of tanks/ areas to close	177/18 tank farms	51/2 tank farms	11[a]/1 tank farm	40[c]/5 tank farms
Tank types	2	4	2	6
Tank sizes, 10^3 gal	55-1,160	750-1,300	300-318	1.5-170
Tank ages, years	15-58	20-50	37-50	3-58
Tank conditions	67 confirmed and assumed leakers, est. 1 Mgal to soil; carbon steel liners	11 leakers, 1 to soil; carbon steel liners	No leakers; stainless steel tanks	No leakers; carbon steel liners
Tank maximum ages in years at closure	More than 75	More than 75	More than 60	More than 60
Site and tank-specific considerations and uncertainties	In-tank hardware; arid climate; well above water table; contaminated vadose zone/ groundwater	In-tank hardware; some tanks in water table; 2 tanks interim closed in 1997	Tanks are stainless steel; in-tank hardware; no secondary containment	Waste not classified as high-level; in-tank chunks of gunite; resin beads in 3 tanks
Waste types	Viscous, alkaline liquid, sludge, salt cake	Viscous, alkaline liquid, sludge, salt cake	Acidic, liquid sodium waste, sludges; calcined powder	Liquids, sludges
Waste volumes, 10^6 gal	54	33	1.4	0.4
Waste radionuclides, 10^6 Ci	200	470	0.52	0.047
Retrieval schedule	SSTs complete by 2018[b] and DSTs by 2028[b]	2019 for Type I, II, and IV; 2024 for Type III	HLW complete 1998; remaining liquid waste by 2012	37 of 40 inactive tanks complete
Closure schedule	SSTs by 2024[b] and DSTs by 2032[b]	2022 for Type I, II, and IV; Type III by 2028; tank farms later	In six phases from 2005 to 2016; tank farms later	Remaining 3 inactive tanks will be closed as soon as funding is approved

[a]Plus an additional 7 calcine bin sets, containing 3.8 million L (24 million Ci) of calcined HLW, and four 30,000 gal stainless tanks in the tank farm facility.
[b]Currently reevaluating retrieval and closure schedules.
[c]Inactive tanks.

DST = double-shell tank.
INEEL = Idaho National Engineering and Environmental Laboratory.
HLW = high-level waste.
ORR = Oak Ridge Reservation.
SST = single-shell tank.

REGULATORY COMPLIANCE STRATEGY - PLANS FOR TANK CLOSURE

Hanford

Closure of Hanford Site tanks will occur under DOE Order 435.1 (1) and the Washington State Hazardous Waste Management Act and its implementing "Dangerous Waste Regulations" in the Washington Administrative Code (2). As defined in the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (3), the tanks will be closed as RCRA treatment, storage, and/or disposal facilities. Compelling evidence compiled to date supports the selection of landfill closure as the planning baseline for the SST farms. This planning basis will allow closure planning to move forward in a manner that is consistent with other 200 Area waste sites, is technically achievable, and is cost effective. However, before making a decision and implementing closure actions, a National Environmental Policy Act analysis of closure alternatives will be conducted and closure plans will be developed for regulatory approval. Spills are to be cleaned up under the requirements of a RCRA corrective action. The closure strategy for SSTs at the Hanford Site also assumes that waste retrieval will remove sufficient waste from the SSTs so that the residual waste following retrieval will be determined to be waste incidental to reprocessing under DOE Order 435.1. The tanks, tank farm ancillary equipment, and contaminated soil will be disposed of in accordance with applicable regulations and agreements.

Idaho National Engineering and Environmental Laboratory

INEEL is pursuing an aggressive program to complete RCRA closure of its 11 stainless steel HLW storage tanks in the Idaho Nuclear Technology and Engineering Center (INTEC) Tank Farm by FY 2016. The goal of clean closure of 11 tanks by FY 2016 is considered "aggressive," because clean closure requires an extensive retrieval and decontamination program that, historically, has not been accomplished in such a short period of time. The State of Idaho Department of Environmental Quality (DEQ) has approved the Idaho Nuclear Waste Management Act/Resource Conservation and Recovery Act Closure Plan for the Idaho Nuclear Technology and Engineering Center Tanks WM-182 and WM-183 (4).

A Tier I closure plan was prepared in accordance with the requirements of DOE Order 435.1 for approval by DOE. This plan was submitted for DOE Headquarters review in January 2002.

The liquid tank waste is stored in acid form with very few solids. None of the tanks have failed; therefore, leakage during waste retrieval and tank decontamination operations does not present the concern that it does at the Hanford Site. INEEL expects to fill the first two tanks with grout by the end of FY 2004.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (5) actions still would be required to close the entire INTEC Tank Farm.

Oak Ridge Reservation

All but 3 of 40 inactive tanks have been closed under the Federal Facility Agreement for the Oak Ridge Reservation (6); 25 of these tanks were closed in FY 2001. Because a CERCLA process governed closures, work proceeded under remediation plans rather than under closure plans for the tanks. Waste characterization plans were developed that preceded and supported the remediation plans. Several remedial action reports have been issued.

According to representatives of the Bechtel Jacobs Company, regulator agreement early in the process was crucial. The regulators agreed to a closure program based on accepted criteria (10^{-6} incidental lifetime cancer risk) and modeling. The disposal unit source-term model was used, and the regulators agreed to accept the results from the modeling. Additionally, the regulators were involved in the sampling and characterization of the residual waste heels. Following a demonstration of multiple-point sampling and analysis from one tank, agreement was reached that the remaining tanks could be characterized using single-point samples.

Savannah River Site

In accordance with the Federal Facility Agreement for the Savannah River Site (7), among DOE, EPA, and the South Carolina Department of Health and Environmental Control, DOE is obligated to close the remaining 22 Type I, II, and IV tanks that do not meet the secondary containment standards by the end of FY 2022. Each of the 22 tanks has a closure commitment date assigned to it. Type III tanks are not required to be removed from service and will remain in use until there is no further need for them, which DOE currently anticipates to occur by the year 2028. The tanks eventually will be closed in place.

After the SRS DOE environmental management mission is complete, Site boundaries should remain unchanged and the land should remain under the ownership of the Federal government either for new Site missions or for continued ecological research as a national environmental research park.

COMPARISON OF CLOSURE APPROACHES - CROSS CUTTING ISSUES

This section summarizes and compares crosscutting issues for the key components of the closure programs at each site.

Closure Decision Status

The level to which each site has progressed in the closure decision process varies.

- The Hanford Site submitted a draft RCRA closure plan to the State of Washington on December 19, 2002. DOE closure plans (Tier I and Tier II), a closure EIS, and performance assessments also will be prepared to support tank farm closures.

- At INEEL, the draft Tier I closure plan is completed, as is the draft performance assessment for the tank farm facility. Both of these currently are being reviewed. The State of Idaho Department of Environmental Quality (DEQ) has approved the Idaho Nuclear Waste Management Act/Resource Conservation and Recovery Act Closure Plan for the Idaho Nuclear Technology and Engineering Center Tanks WM-182 and WM-183.

- ORR has closed 37 out of 40 inactive tanks. Remediation of the last three will be completed in accordance with the approved Record of Decision (ROD) by the end of FY05.

- SRS submitted a Tier I closure plan in 2001. DOE Headquarters is still reviewing the plan.

Waste Retrieval Goals or Residual Volumes

- Hanford: The Tri-Party Agreement currently contains interim retrieval goals of as much tank waste as technically possible with tank waste residues not to exceed 99 percent, or the limit of waste retrieval technology, whichever is less.

- INEEL: Residual volumes are assumed to be approximately 15,000 L (400 gal) of liquid and a solid heel of about 2.5 cm (1 in.) in thickness.

- ORR: Residuals are assumed to include contaminated soils surrounding the tanks.

- SRS: The residuals are estimated to be less than 3,700 L (1,000 gal) of solids in each tank.

Compliance Boundaries

Protection of the general population via the groundwater ingestion pathway is considered at all sites. However, the point of compliance varies considerably among the sites.

- Hanford Site: Compliance boundaries for SST farm closure have been established by the state at the tank farm fence line as the point of compliance consistent with RCRA requirements. Groundwater pathway human health impacts typically are being calculated at multiple points of compliance from the tank farm fence line to the Columbia River shoreline for assessments supporting Hanford Site waste retrieval functions and requirements development and RCRA vadose zone and groundwater corrective-action decision making. Consistent with DOE requirements, groundwater doses for the immobilized low-activity waste performance assessment are being calculated at a location 100 m (330 ft) downgradient from the disposal facility.

- INEEL: The point of compliance was selected as the point of maximum concentration where the unsaturated zone discharges to the saturated zone (generally, beneath the tank farm).

- ORR: The calculations for point of compliance were completed at the White Oak Creek location, approximately 370 m (1,200 ft) south of the North Tank Farm, for a nearby resident.

- SRS: The compliance point for the groundwater ingestion scenario is the point where groundwater discharges to the surface, termed the "seep line." These seep lines vary in distance from the tank farms, ranging from approximately 2 to 5 km (1.2 to 3 mi.).

Compliance Time Frame

The timeframes of compliance also are inconsistent among the sites.

- Hanford Site uses 1,000 years for the composite analysis, 1,000 years for RCRA facility investigations, 1,000 and 10,000 years with calculations of peak dose and time of peak dose for the immobilized low-activity waste performance assessment, and a 10,000-year time frame for the groundwater ingestion scenarios used to evaluate retrieval impacts and the 100- to 500-year period for intruder analyses.

- INEEL uses the 1,000-year compliance period required for composite analyses and performance assessments under DOE Order 435.1, but does additional calculations to determine peak dose and time of peak dose.

- ORR and SRS use a compliance period of 10,000 years, because of 40 CFR 191, “Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High Level and Transuranic Radioactive Wastes,” (8) requirements.

Institutional Control Period

There also are differences among the sites as to how the institutional control period is implemented.

- Hanford Site: The institutional control period currently is being considered as a part of the 200 Areas Central Plateau land-use planning effort and is likely to be at least 100 years for groundwater exposure calculations and 500 years for intruder dose calculations. Discussions regarding industrial use in perpetuity have been held with the state and stakeholders but are not finalized.

- INEEL: The institutional control period is set at 1,000 years, or peak dose. This time period is consistent with 10 CFR 61, “Licensing Requirements for Land Disposal of Radioactive Waste,” (9) and other U.S. Nuclear Regulatory Commission regulations such as 10 CFR 60, “Disposal of Radioactive Waste in Geological Repositories,” (10) for HLW.

- ORR and SRS: ORR and SRS, on the other hand, are assuming institutional controls to be in place in perpetuity. These perpetual controls also influence future land-use scenarios, as the following section describes.

Exposure Scenarios

- Hanford Site: Final closure groundwater pathway dose/risk calculations likely will be developed through consultation with regulators and stakeholders. Multiple scenarios are being used for groundwater pathway dose/risk calculations in support of Hanford Site waste retrieval functions and requirements development and in support of the RCRA vadose zone and groundwater corrective action process for SST past releases. Groundwater dose calculations for the Hanford Site immobilized low-activity waste performance assessment is performed using both an all-pathways scenario and a drinking water ingestion scenario. Inadvertent intruder dose calculations for final Hanford Site closure decisions likely will be based on a well-drilling scenario similar to the driller and post-drilling resident scenarios used in the Tank Waste Remediation System EIS (DOE/EIS-0189) (11), immobilized low-activity waste performance assessment, and waste retrieval functions and requirements retrieval performance evaluations. However, it is possible that institutional controls will be assumed similar to those at SRS if industrial use in perpetuity is agreed to.

- INEEL: INEEL did not assume long-term institutional controls; therefore, the inadvertent intruder well driller and post-well driller scenarios at the end of the institutional control period were evaluated.

- ORR: No intruder scenarios were analyzed. Onsite residents and employees were considered as having the greatest risk, but the risk is from direct radiation resulting from tank dome collapse. An offsite resident (nearby resident) scenario was calculated for ingestion of contaminated drinking water.

- SRS: An indefinitely long institutional control period allows for restricted access to the Site; therefore, the inadvertent intruder scenarios do not apply within the general separations area boundary. Residential use is prohibited, and land use has been restricted to industrial/commercial uses in perpetuity. Therefore, groundwater pathway health impacts for future land-use scenarios within the general separations area boundary are not evaluated.

Waste Incidental to Reprocessing

While most sites are utilizing the DOE Order 435.1 WIR process to recategorize tank waste residuals with an HLW classification to either TRU or LLW, the sites use somewhat different methods.

- At the Hanford Site, it is anticipated that the incidental waste determination will be made using the process set out in DOE Order 435.1.

- INEEL is following the three WIR criteria and using grout averaging to classify residual tank waste as LLW.

- ORR waste did not fall under the Atomic Energy Act of 1954 (12), as amended, definition of HLW; therefore, no WIR process was required.

- SRS is using the alternate requirements for waste classification as DOE may authorize. DOE has the responsibility for classifying its radioactive waste, including the responsibility of determining whether residual waste in the SRS stabilized HLW tank residuals will be managed as LLW by application of the WIR process in DOE Order 435.1. DOE has and will continue to consult with the U.S. Nuclear Regulatory Commission in this determination.

Cumulative Assessments – Exposures to Members of the Public From All Radiation Sources Implementation Strategies

There are differences in how the risks, preclosure and postclosure, are to be distributed over all sources at the sites.

- Hanford: PNNL-11800, Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site (13), was completed and was approved by EM-1; the disposal authorization statement was issued. Future cumulative assessments will be completed using the System Assessment Capability suite of tools (STOMP, CFEST, MASS2, HUMAN, ECEM).[1]

- INEEL: The groundwater pathway is one of the more important pathways, and assigning or apportioning this risk over all contributing sources may be done by integrating the contribution from all sources at one location and assuming that all contribute to the same contaminant plume. (At INEEL the calculated exposures from all radiation sources are stated not to exceed 25 mrem/yr.)

- ORR: ORR is applying the requirements from DOE Order 5400.5[II. Ia], Radiation Protection of the Public and the Environment (14) (i.e., the exposures from all radiation sources shall not cause the effective dose equivalent to be greater than 100 mrem/yr).

- SRS: The apportioning is done differently; the approach takes advantage of a natural groundwater divide, which separates plumes from one tank farm into segments that do not overlap or rejoin. In the SRS case, these individual plumes are called groundwater transport segments. Risk is apportioned over each segment, but not collectively, because the segments diverge.

Closure Costs

The following data have been provided by representatives of the three primary sites (INEEL, Table II; SRS, Table III; ORR, Table IV) where actual closure activities have commenced. The data identify the costs spent to date associated with each site’s particular closure activities. The data do not allow direct site-to-site comparisons of closure costs for two reasons. First, the level of detail provided supporting the cited expenditures is different for each site. For

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[1] System Assessment Capability was formed to examine activities in the groundwater/vadose zone and model or simulate the environmental, health, and socioeconomic impacts of Hanford releases to the soil and groundwater to assess the cumulative environmental effects.

example, one site might have provided a comprehensive listing of all activities viewed as having comprised "closure" and, therefore, as having contributed to the cited cost, while another site might have provided only a total dollar cost with considerably less breakdown. Second, the scope of "closure" is different at each site. For example, at INEEL and ORR, soil remediation costs are not included in the data because those costs are to be picked up by separate projects. At ORR, costs associated with retrieval of tank waste and closing ancillary equipment are not included for the same reason.

Table II. Idaho National Environmental and Engineering Laboratory – Tank Closure Activities and Costs ($K)				
Activity	Total Life Cycle Cost	Before 2000	2000	2001
Project Management	15,889	750	500	443
Closure Plans	11,092		2,292	700
Baseline Heel Samples	5,232	240	592	
Final Heel Samples	6,650			
Conceptual/FS Design	2,911	1,444	1,467	
Mockup Facility*	300	300		
Design	6,145			724
GFE Material	65,576		300	250
Site Preparation	6,440			450
Tank Isolation/Decon Lines	8,446			
Wash Interior Walls	7,756			
Solidify Remaining Heel	7,856			
Fill Vault with Clean Grout	12,500			
Fill Tank with Clean Grout**	8,060			
Project Request Budget	105,853	2,734	5,151	2,567
Approved Budget	14,834	1,650	5,145	2,534

Costs are for multiple tanks if clean grout is used.
* TFA will fund mockup activities.
** Tank fill material will be determined by environmental impact statement record of decision.
This will change to reflect the acceleration goal of closing four tanks by 2004.
Soil remediation costs will be picked up by a different project.

Table III. Savannah River Site -- Detailed Cost Calculations

Year	Tanks Operating	Tank Closure Costs ($ million)
1997	24	4.30
1998	23	4.30
1999	22	4.30
2000	21	8.60
2001	19	4.30
Total Through 2001		25.8

Table IV. Oak Ridge Reservation – Waste Retrieval Cost Summary for Final Cleanout of the Gunite and Associated Tanks

Cost Category	Cost ($ K)										
	Fiscal Year										
	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	%
Project Management	530	132	635	673	804	800	632	767	134	5,107	7.3
Preliminary Design and Technology Selection	535	1,385	2,169	1,809	6,496	414				12,808	18.2
Final Design		237	987	1,461	1,285	243	435	293		4,941	7.0
Materials			50	3,256	1,141	90				4,537	6.5
Site Preparation		152	1,827	3,749	1,511	1,397	947	1,962		11,545	16.4
Operations		338	3,294	2,695	1,036	7,977	8,365	5,826	1,222	30,753	43.8
Closure							56	363	149	568	0.8
EM-50 Retrieval Systems										14,835	
Annual Cost	1,065	2,244	8,962	13,643	12,273	10,921	10,435	9,211	1,505		
Cumulative Cost	1,065	3,309	12,271	25,914	38,187	49,108	59,543	68,754	70,259	85,094	

Does not include soil remediation.
Does not include ancillary equipment.

CONCLUSIONS

The task of cleanup and closure of the Hanford tank farms is complex and offers many challenges. The Hanford tank farms have 177 of the 279 tanks (63 percent) scheduled for closure at the four major DOE sites. Of these 177, there are 67 assumed leaking tanks. There is only one additional assumed leaking tank within the DOE complex. An estimated one Mgal of tank waste has leaked into the environment from assumed leakers at the Hanford site, complicating both retrieval and closure activities. All of the 149 SSTs are beyond their expected design life. The remaining 28 DSTs are still within their expected design life.

The waste at Hanford is very complex and makes retrieval and closure activities considerably more problematic than at the other DOE sites. There are approximately 53 Mgal of waste in the Hanford tanks representing over 60 percent of all the HLW in the DOE complex. This waste is the result of numerous chemical separations processes utilized over several decades. This generated a wide spectrum of chemical and radiological constituents and concentrations. Additionally, tank operations and processes such as cascading and volume reduction further complicate the tracking of the waste constituents.

Coupled with the complexity of waste characteristics, tank life expectancy, and environmental concerns from previous releases, the regulatory environment at the Hanford site is very restrictive. Retrieval goals, cleanup standards, and land-use options remain as issues. Discussions with regulators and stakeholders are currently underway and could provide a clear path forward in the near future.

Some of the Hanford cleanup activities are similar to activities across the DOE complex. However, it is evident that there are major differences between these activities. Volume of waste, characteristics of the waste, previous releases to the environment, tank life expectancy, and regulatory issues present a more complex and difficult situation at the Hanford site than at other DOE sites. A more detailed discussion of these differences can be found in "Tank Closure Activities at U.S. Department of Energy Sites" (15), upon which this paper was based.

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