JEG-02-013

SUMMARY OF HIGH LEVEL WASTE TANK LAY-UP ACTIVITIES SUPPORTING THE TANKS FOCUS AREA, FISCAL YEARS 2001-2002

May 2002

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CONTENTS

1.0 INTRODUCTION 1
2.0 BACKGROUND 1
3.0 SUPPORT TO WVDP 1
4.0 EXTENSION TO OTHER U. S. DEPARTMENT OF ENERGY TANK SITES 2
5.0 CONCLUSIONS AND RECOMMENDATIONS 2
6.0 ANNOTATED BIBLIOGRAPHY 2
7.0 REFERENCES 15

ACRONYMS

BBI	best basis inventory
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOE/ID	DOE Idaho Field Office
DWPF	Defense Waste Processing Facility
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EM	DOE Environmental Management Program
FFA	Federal Facilities Agreement
FSAR	final safety analysis report
FY	fiscal year
HLW	high-level waste
HWMA	*Hazardous Waste Management Act*
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LLLW	liquid low-level waste
LLW	low-level waste
MOU	Memorandum of Understanding
MUST	miscellaneous underground storage tank
ORNL	Oak Ridge National Laboratory
ORP	DOE Office of River Protection
ORR	Oak Ridge Reservation
PNNL	Pacific Northwest National Laboratory
RCRA	*Resource Conservation and Recovery Act*
ROD	Record of Decision
RPP	River Protection Project
SEIS	supplemental environmental impact statement
SRS	DOE Savannah River Site
TDEC	Tennessee Department of Environmental Conservation
TFA	tanks focus area
TFF	tank farm facility
TRU	transuranic
TTG	tank technology guide
TWRS	tank waste remediation system
WAC	waste acceptance criteria
WVDP	West Valley Demonstration Project
WVMA	West Valley Management Area
WVNS	West Valley Nuclear Services
WVNW	West Valley Nuclear Wastes

1.0 INTRODUCTION

This report compiles and summarizes the activities and reports completed in support of the Tanks Focus Area (TFA) under Technical Task Plan RL30WT21 (Subtask A), *Post-Retrieval and Pre-Closure HLW Tank Lay-Up*, from its inception through March 2002. This report presents the chronology and evolution of the task, and provides electronic links to reports where greater detail may be found. In addition, an annotated bibliography of relevant documents, collected during this task, is provided.

2.0 BACKGROUND

The TFA recognized that, for a number of sites, there would likely be an extended period of time between waste retrieval and tank closure due to the issues and uncertainties associated with making final closure decisions. The TFA also recognized the need to develop a strategy for placing tanks that no longer contained any retrievable waste into a safe, stable, and minimum maintenance condition until final closure could occur. This state of pre-final closure (otherwise known as interim closure, operational closure, etc.) was termed tank lay-up. The TFA identified a particular need for this strategy at the West Valley Demonstration Project (WVDP) since the site was nearing the end of its waste retrieval phase. Early in fiscal year (FY) 2001, TFA funded a task through the Pacific Northwest National Laboratory (PNNL) in collaboration with Jacobs Engineering to assist WVDP in tank lay-up planning.

Following completion of the WVDP support task, the TFA reviewed and redirected the task to determine what each of the sites had already done on tank lay-up, then facilitate intersite communication of lessons-learned from these activities. The sites would be visited to review lay-up progress, then periodic, structured dialogue would be set up among the sites, and a virtual library of lay-up related literature was to be established.

By February 2002, each of the four major waste tanks sites [Hanford, Idaho National Environmental and Engineering Laboratory (INEEL), Oak Ridge Reservation (ORR), and Savannah River Site (SRS)] had been visited and evaluated for tank closure status.

In April 2002, following completion of the visits to the major tank sites, the TFA requested the orderly closure of this task.

3.0 SUPPORT TO WVDP

The primary objective of the overall task was to develop and evaluate conceptual strategies for the lay-up of two high-level waste (HLW) storage tanks at WVDP. Working with key staff from West Valley Nuclear Services (WVNS), requirements were developed for laying up the tanks for a 20-year period in a safe and stable condition with minimum capital and operating costs. Results are detailed in Letter Report # 1 (Jacobs, 2001a).

Several tank lay-up options were identified and evaluated for potential application alone, or in combination with one another. In addition, the principal information needs for a final decision on the preferred lay-up strategy were identified. Results are detailed in Letter Report #2

(Jacobs, 2001b). A methodology was then developed to use the tank lay-up requirements as evaluation criteria to down select from the identified lay-up options and arrive at a preferred option (Jacobs, 2001c). Utilizing a team of technical specialists, weighting factors were assigned to the evaluation criteria, and a preferred tank lay-up option was selected and presented to the WVNS staff (Jacobs, 2001d).

4.0 EXTENSION TO OTHER U. S. DEPARTMENT OF ENERGY TANK SITES

A proposal was generated to extend the WVDP tank lay-up strategy development methodology to the other U. S. Department of Energy (DOE) tank sites (JEG-01-005, 2001), and a preliminary assessment was made of the sites' lay-up requirements and considerations (JEG-01-023, 2001).

Visits were made to the major tank sites (Hanford, INEEL, ORR, and SRS) to review the tank lay-up progress, and to determine interest in initiating intersite communication on tank lay-up activities (JEG-02-011). This was the final activity in support of this task before its termination.

5.0 CONCLUSIONS AND RECOMMENDATIONS

As of the date of this report, there is still a wealth of important and useful information on tank closure activities at each of the sites that has not been communicated or made accessible to all the tank sites. Currently, because its tank closure program is maturing, Hanford has the most to gain from what has been tried at other sites. Successful and unsuccessful waste retrieval and tank closure technologies, regulatory and land use strategies, closure costs, and changes to authorization bases are just some of the topics that would be of interest to all tank sites.

Whether as part of a future TFA revival of tank lay-up activities or not, consideration should be given to ways to improve the intersite communication on tank lay-up activities. One way to do this might be to establish a Tank Interim (or Operational) Closure Working Group or incorporate the interim closure concept into an existing tank closure entity. This working group should consider establishing a web-based virtual reference library and stocking it with programmatic, technical, and regulatory tank closure documentation from all the tank sites. In addition, this working group might consider establishing periodic, structured, intersite videoconferences and rotating site meetings.

6.0 ANNOTATED BIBLIOGRAPHY

The following are key documents referenced in the appendices. A brief summary of each document has been provided, and an acronym list may be found at the end of the bibliography.

1. DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C. and Olympia, Washington.

   The Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) analyzes the potential environmental consequences related to TWRS alternatives for

management and disposal of radioactive, hazardous and mixed waste, including Cs/Sr capsules, 177 HLW tanks and 60 miscellaneous underground storage tanks (MUSTs).

2. DOE/EM-0449, 1999, *SRS Tank Closure, a Tanks Focus Area Innovative Technology Summary Report*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

   Summary-level document that describes the closure of Tanks 17 and 20 at the Savannah River Site using grout stabilization.

3. DOE/OR/01-1135&D2, 1993, *Federal Facility Agreement Plans and Schedules for Liquid Low-Level Radioactive Waste Tank Systems at Oak Ridge National Laboratory, Oak Ridge, Tennessee*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

   This document describes the strategy for meeting the Federal Facility Agreement (FFA) requirements at Oak Ridge National Laboratory (ORNL), summarizes the progress made to date, and revises plans and schedules that were submitted in March 1992.

4. DOE/OR/01-1159&D1, 1997, *Waste Characterization Data Manual for the Inactive Liquid low-Level Waste Tank Systems at Oak Ridge National Laboratory, Oak Ridge, Tennessee*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

   This report contains the results of an analysis of the contents of liquid low-level waste (LLLW) tanks that were removed from service per the ORNL FFA.

5. DOE/OR/01-1721&D3, 1999, *Engineering Evaluation/Cost Analysis for the Bethel Valley Main Plant Inactive Liquid Low-Level Radioactive Waste Tanks,* U.S. DOE Office of Environmental Management, Washington, D.C.

   This document provides an engineering evaluation and cost analysis for removing tank contents and either removing or stabilizing the tanks in place. This evaluation and analysis develops, evaluates, and recommends a preferred alternative. These tanks range in size from 700 gallons to 4000 gallons.

6. DOE/OR/01-1725&D1, 1998, *Treatability Study Report on the Gunite and Associated Tanks Waste Removal*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

   This report describes the results of a treatability study conducted on waste removal from the Gunite and Associated Tanks Operable Unit at ORNL. The treatability study on waste removal included the use of a full-scale radioactive tank cleaning system. The study was planned so that the equipment used, if successful, could be transitioned into the remediation without the need to remobilize.

7. DOE/OR/01-1813&D1, 1999, *Action Memorandum for the Bethel Valley Main Plant Inactive Liquid Low-Level Radioactive Waste Tanks*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

This document lists the activities that are included in remediation of the 27 tanks identified, including excavation to expose tank shells/manholes or installation of new risers, removal of liquids and solids, packaging liquids and solids not meeting the on-site waste acceptance criteria (WAC) for disposition, isolation of piping, vents, support connections, etc.

8. DOE/OR/01-1821&D1, 1999, *Removal Action Work Plan for the Bethel Valley Main Plant Inactive Liquid Low-Level Radioactive Waste Tanks*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

This work plan describes the actions that will be taken to remove waste from 11 ORR tanks and stabilization of the tank shells by grouting them in place.

9. DOE/OR/01-1833&D2, 1999, *Action Memorandum Addendum for the Bethel Valley Main Plant Inactive Liquid Low-Level Radioactive Waste Tanks*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

This document adds 16 tanks to Reference 8, above, at ORR.

10. DOE/OR/01-1842&D1, 1999, *Addendum to the Removal Action Work Plan for the Bethel Valley Main Plant Inactive Liquid Low-Level Radioactive Waste Tanks*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

This work plan addendum (to Reference 8, above, at ORR) provides sufficient detail of activities to be conducted to identify regulatory, safety, and logistical issues and to resolve these issues prior to field implementation. The scope of this addendum is sludge removal and in-place stabilization.

11. DOE/OR/02-1591&D3, 1997, *Record of Decision for Interim Action: Sludge Removal from the Gunite and Associated Tanks Operable Unit, Waste Area Grouping 1*, U.S. Department of Energy Office of Environmental Management, Washington, D.C.

This Record of Decision (ROD) presents the selected interim remedial action for removing mixed transuranic (TRU) waste sludge from eight tanks in the Gunite and Associated Tanks Operable Unit at ORNL. The objective of this interim action is to reduce the potential for on- and off-site risk from tank contents.

12. DOE/ORP-2000-06, 2001, *River Protection Project – Project Management Plan*, Rev. 2, U.S. Department of Energy, Office of River Protection, Richland, Washington.

This project management plan describes how the Office of River Protection (ORP) manages the River Protection Project (RPP). Specifically, it summarizes the project

scope, schedule, and cost, describes the ORP organization and responsibilities, describes how ORP will manage, control and integrate the project and its prime contractors, and identifies other documents that further define the project and management systems.

13. DOE/ORP-2000-10, 2001, *River Protection Project Mission Analysis and Requirements Report*, Rev. 1, U.S. Department of Energy, Office of River Protection, Richland, Washington.

    This report describes the RPP mission, the top-level functions that must be conducted to accomplish the mission and the requirements that must be met to achieve these functions. RPP participants will use this report to develop lower-level functions and requirements necessary to conduct work. This report describes the initial state, desired outcome and establishes top-level functions and requirements to reach the end state.

14. HLW-2001-00040, 2001, *Savannah River Site High Level Waste System Plan*, Rev. 12, Savannah River Operations Office, Aiken, South Carolina.

    This HLW system plan documents the operating strategy of the HLW system at SRS to receive, store, treat and dispose of high-level waste. Included is a comparison of scope and funding for the different production cases, a review of the SRS HLW track record, a discussion of key process issues facing the HLW system and recognition of Defense Nuclear Facilities Safety Board (DNFSB) recommendation 2001-1 (03/15/2001).

15. HNF-SD-WM-SAR-067, 1999, *Hanford Tank Waste Remediation System Final Safety Analysis Report*, Rev. 2, Volumes I and II, Lockheed Martin Hanford Corporation, Richland, Washington.

    The Hanford Final Safety Analysis Report (FSAR) documents the results of the safety analyses that establish and evaluate adequacy of the safety basis for Hanford facilities and operations that support the safe, interim storage of tank waste. The FSAR also establishes the envelope within which the TWRS facilities and operations can continue to operate.

16. PNNL-13651, 2001 *Technical Review of Retrieval and Closure Plans for the INEEL INTEC Tank Farm Facility*, UC-721, Pacific Northwest National Laboratory, Richland, Washington.

    This report documents the conclusions of a technical review of retrieval and closure plans for the INEEL Idaho Nuclear Technology and Engineering Center (INTEC) tank farm. The review focused on evaluation of the technical feasibility and appropriateness of the approach selected by INEEL (using a wash ball for residual waste removal and cleaning followed by grout pouring) and the technology gaps that could be addressed through utilization of technologies and performance used at other DOE sites and the private sector.

17. SRS, 2000, *Savannah River Site Closure Plan and Performance Assessment for F- and H-Area High Level Waste Tank Systems*, Preliminary Draft (Rev. 2), Savannah River Operations Office, Aiken, South Carolina.

This plan establishes the general protocol for which DOE intends to close SRS Site F-Area and H-Area HLW tank systems. This plan describes the environmental setting for the HLW tanks and the human and environmental receptors potentially affected by tank closures. In establishing the performance objectives for HLW system closure, DOE has assumed that the residual waste material remaining in the tanks will not be managed as HLW. Per DOE Order 435.1, DOE will demonstrate the residual waste is incidental to reprocessing.

18. DOE/EIS-0217, 1995, *Savannah River Site, Waste Management, Final Environmental Impact Statement*, 2 volumes, U.S. Department of Energy Savannah River Operations Office, Aiken, South Carolina.

The purpose of this EIS is to help DOE decide how to manage radioactive (HLW, LLW, TRU), hazardous and mixed waste stored at SRS.

19. DOE/EIS-0222F, 1999, *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

This document analyzes potential environmental impacts associated with establishing future land use objectives for Hanford.

20. DOE/EIS-0287D, 1999, *Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement*, U.S. Department of Energy, Washington, D.C.

This EIS describes technologies and methods DOE is considering for management of HLW and related wastes and the disposition of HLW generation, storage, and treatment facilities. The document also provides environmental consequences and regulatory issues surrounding the various management alternatives under consideration at INEEL.

21. DOE/EIS-0303D, 2000, *High Level Waste Tank Closure, Draft Environmental Impact Statement*, U.S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

This draft EIS discusses three alternatives (clean and stabilize tanks, clean and remove tanks, and no action alternative). It also considers three options for tank stabilization (fill with grout (preferred), fill with sand, fill with salt stone).

22. DOE-ID, 1991, *Federal Facility Agreement and Consent Order and Action Plan*, U.S. Department of Energy, Idaho Field Office, U.S. Environmental Protection Agency, Region 10, Idaho Department of Health and Welfare, Idaho Falls, Idaho.

In 1992, DOE and the Idaho Department of Health and Welfare signed a consent order to resolve a Notice of Noncompliance issued by the U.S. Environmental Protection Agency (EPA) Region 10. This Consent Order addresses concerns regarding the *Resource Conservation Recovery Act* (RCRA) secondary containment requirements for the INEEL HLW tanks by prescribing dates by which the tanks must be removed from service.

23. DOE/OR-1014, 1992, *Federal Facility Agreement for the Oak Ridge Reservation*, U.S. Department of Energy Oak Ridge Operations Office, Environmental Protection Agency, and the Tennessee Department of Environmental and Conservation, U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, Tennessee.

    The Parties to this Agreement are the EPA, the Tennessee Department of Environmental Conservation (TDEC), and the DOE. The terms of the Agreement apply to and are binding upon the EPA, TDEC, and DOE, their respective agents, employees, and response action contractors and upon all subsequent owners, operators, and lessees of the DOE for the Site. It is a binding agreement that ensures the environmental impacts associated with past and present activities at the Site are thoroughly investigated and that appropriate remedial action is taken as necessary to protect the public health, welfare, and the environment.

24. Ecology, EPA, and DOE, 1989, *Hanford Federal Facilities Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, U.S. Department of Energy, Olympia, Washington.

    The Hanford Federal Facility Agreement and Consent Order, or HHFACO, is an agreement for achieving compliance with *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions. More specifically, the Tri-Party Agreement: 1) defines and ranks CERCLA and RCRA cleanup commitments, 2) establishes responsibilities, 3) provides a basis for budgeting, and 4) reflects a concerted goal of achieving full regulatory compliance and remediation, with enforceable milestones in an aggressive manner. The HFFACO is a legally binding agreement consisting of: 1) The "Legal Agreement" itself which describes the roles, responsibilities and authority of the three agencies, or "Parties", in the cleanup, compliance and permitting processes. It also sets up dispute resolution processes and describes how the agreement will be enforced, and 2) The "Action Plan" to implement the cleanup and permitting efforts which includes milestones (in Appendix D) for initiating and completing specific work and procedures the three agencies will follow.

25. MOU, 1996, *Memorandum of Understanding: Required Percent of Waste Retrieval*, U.S. Department of Energy and Washington State Department of Ecology, Richland, Washington.

    This Memorandum of Understanding (MOU) states that a minimum of 99% of the waste must be retrieved from Hanford HLW tanks.

26. NYSERDA, 1980, *Cooperative Agreement between the U.S. Department of Energy and the New York State Energy Research and Development Authority*, New York State Energy Research and Development Authority, Albany, New York.

This agreement includes, but is not limited to the use of the facilities by DOE for the WVDP, the guarantee for technical assistance from DOE in securing license amendments, and a guarantee of joint submittal of an NRC license amendment, providing DOE with exclusive possession of the Project Premises and facilities necessary to conduct the WVDP.

27. WSRC-OS-94-42, 1993, *Federal Facility Agreement for the Savannah River Site*, Administrative Document Number 89-05-FF, U.S. Department of Energy and South Carolina Department of Health and Environmental Control, Aiken, South Carolina.

This is an agreement between EPA Region IV, DOE, and the South Carolina Department of Health and Environmental Control. This agreement establishes requirements for remediation of SRS. It states that HLW tanks must meet structural integrity requirements or be removed from service.

28. DOE/ID-XXXXX, 2001, *Tier I Closure Plan for the Idaho Nuclear Engineering and Technology Center Tank Farm Facility at the INEEL*, Rev. 0 Draft, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

This document describes and documents the Tier I closure plan methodology used at INEEL to comply with the requirements of DOE Order 435.1 and additional requirements under RCRA.

29. DOE/ID-10802, 2001, *Idaho Hazardous Waste Management Act/Resource Conservation and Recovery Act Closure Plan for Idaho Nuclear Technology and Engineering Center Tanks WM-182 and WM-183*, Rev. 1, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, Idaho.

This document outlines the conceptual closure plan approach for tank closure at INEEL to comply with both the requirements of DOE Order 435.1 and HWMA/RCRA requirements.

30. DOE/ORP-2001-18, 2001, *Single-Shell Tank Closure Plan*, Appendix F, "Complex-Wide Closure Progress and Issues," Rev. 0 Draft, U.S. Department of Energy, Office of River Protection, Richland, Washington.

The purpose of this appendix is to provide a comparative overview of tank closure issues at five sites in the DOE complex. Information on tank waste characteristics and generation, storage tank descriptions, and plans and regulatory drivers for tank closure are included. Much of the information is summarized from the Tanks Focus Area *Multiyear Program Plan FY01-FY05* (PNNL-13339).

31. INEEL/EXT-99-01066, 2000, *Idaho Nuclear Technology and Engineering Center Tank Farm Facility Conceptual DOE and HWMA/RCRA Closure Approach (FINAL)*, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

This document outlines the conceptual approach for closure of the INTEC tank farm facility (TFF) located at the INEEL. The conceptual approach uses SRS documentation as the foundation for development of closure documentation.

32. INEEL/EXT-2001-XX, 2000, *Performance Assessment for the Tank Farm Facility at the Idaho National Engineering and Environmental Laboratory*, Draft, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

This report documents the projected radiological dose impacts associated with closure of the TFF at the INTEC at INEEL. This assessment was conducted to support the DOE/ID Tier 1 Closure Plan for the TFF.

33. DOE/EIS-0226-D, 1996, *Draft Environmental Impact Statement for Completion of the West Valley Demonstration Project and Closure of Long-Term Management of Facilities at the Western New York Nuclear Service Center*, U.S. Department of Energy, New York State Energy Research and Development Authority, New York.

This document analyzes alternatives of no action, complete removal and off-site disposal, complete removal and on-site storage, in-place stabilization and on-site disposal and discontinues operations.

34. Fussner, R. J., 2001, communication record of personal communication with Robert J. Fussner, West Valley Nuclear Services Company, Inc., West Valley, New York.

This memorandum discusses the regulatory implications of West Valley HLW lay-up options.

35. Wallon, D. V., 2001, communication record of personal communication with Doug V. Wallon, West Valley Nuclear Services Company, Inc., West Valley, New York.

This communication record discusses the presence of a “bathtub ring” of dried solids on the walls and internal structures of tank 8D-2.

36. WVDP-141, 1992, *Resource Conservation and Recovery Act Closure Plan for the High Level Waste Process Tanks: Tanks 8D-1 & 2*, West Valley Nuclear Services Company, Inc., West Valley, New York.

This plan describes potential closure concepts for two high-level mixed waste tanks. It is intended to meet the RCRA/State of New York hazardous waste requirements only.

37. WVNW, 1987, *Stipulation of Compromise with the Coalition on West Valley Nuclear Wastes*, U.S. District Court, Western District of New York.

This Stipulation of Compromise is an agreement between DOE and the entity Coalition on West Valley Nuclear Wastes (WVNW), resulting from litigation relating to on-site disposal of low-level radioactive waste generated by implementation of the WVDP. The agreement sets forth the stipulation agreement that related to the scope of the WVDP EIS.

38. *West Valley Demonstration Project Act*, 42 USC 2021a, et seq.

The WVDP Act authorized DOE to demonstrate that liquid from the reprocessing of spent nuclear fuel could be safely managed.

39. Chang, J.Y., D.C. Meess, S.M. Barnes, and F.W. Damerow, 1998, *Corrosion Monitoring and Control for Tanks 8D-1, 8D-2 and the Vitrification Melter*, Volume 1, The Fifth Annual Technical Review Meeting at West Valley, New York, September 21-22.

This report documents issues that were discussed and recommendations to continue to mitigate HLW tank external corrosion. Corrosion rate was monitored and four recommendations were documented.

40. Chang, J.Y., D.C. Meess, and S.M. Barnes, 1999, *Corrosion Monitoring and Control for Tanks 8D-1, 8D-2 and the Vitrification Melter*, Volume 2, The Sixth Annual Technical Review Meeting at West Valley, New York, September 21-22.

This report continues to document issues that were discussed and recommendations to continue to mitigate HLW tank external corrosion. Corrosion rate was monitored and four recommendations were documented.

41. EML-609, 2000, *West Valley Demonstration Project Waste Management Area #3 – Closure Alternative I*, Environmental Measurements Laboratory, New York, New York.

West Valley Management Area (WVMA) identified five potential closure alternatives. This report focuses on HLW storage area (tanks 8D-1 and 8D-1), closure alternative I (complete removal of all structures, systems, components and release of the area for unrestricted use).

42. Meess, D.C. and J.Y. Chang, 1997, *Corrosion Monitoring and Control for Tanks 8D-1 & 8D-2*, The Fourth Annual Technical Review Meeting at West Valley, New York, September 8-9.

This report documents issues that were discussed and recommendations to continue to mitigate HLW tank external corrosion. Testing and corrosion mitigation methods are discussed.

43. SCFA, 1994, *Subsurface Contaminants Focus Area, Fact Sheet on Close-Coupled Jet Grout Barrier.*

The web access page is located at: http://www.envnet.org/scfa/archive/stc/jetgrout.htm, accessed on March 21, 2001. As of May 16, 2002, this web site was not available.

This fact sheet describes the use of close-coupled jet grout barriers injected beneath an existing waste site to form a relatively impermeable barrier.

44. SCFA, 1997, *Subsurface Contaminants Focus Area, Fact Sheet on Viscous Liquid Barrier.*

The web access page is located at: http://www.envnet.org/scfa/prodlines/stcr/factsheets/visliq.htm, accessed on March 21, 2001. As of May 16, 2002, the web site is not available.

This Fact Sheet describes viscous liquid barriers as inert liquids that increase their viscosity after being injected into the soil, forming an impermeable barrier. The fact sheet lists a successful demonstration at Brookhaven National Laboratory in FY 97.

45. USEPA, 1999, *United States Environmental Protection Agency, Innovative Freeze Barrier Installation at ORNL*, access page located at: http://www.epa.gov/tio/products/newsltrs/ttrend/tt0299.htm, accessed on March 21, 2001.

This report discusses the successful application of a cryogenic freeze barrier that was installed to isolate a settling pond adjacent to en experimental reactor at ORNL.

46. Williams, A.C., 2001, *Expectations for High-Level Waste (HLW) Removal from the Waste Tank Farm* (letter to Robert Campbell, President, West Valley Nuclear Services Company, February 7), West Valley Demonstration Project, Ohio Field Office, U.S. Department of Energy, West Valley, New York.

This letter documents expectations from DOE-Ohio Field Office to West Valley Nuclear Services on removal of HLW from the West Valley tank farm. These expectations include residue removal of HLW until 10 CFR 61 limits are not exceeded and the West Valley Management Area (WVMA) performance assessment can be satisfied. It also discusses the expectation on removal of fixed contamination.

47. WVNS-DC-065, 1995, *Design Criteria – Inert Gas System for HLW Tanks 8D-1 and 8D-2 Vaults*, West Valley Nuclear Services, West Valley, New York.

This document provides design criteria for an inert gas supply system to reduce the rate of external corrosion of two HLW tanks.

48. 60 FR 18589, 1995, "Record of Decision for the Defense Waste Processing Facility at the Savannah River Site, Aiken, South Carolina," *Federal Register*, April 12.

This ROD states that DOE has determined that the best method for immobilizing high-level waste at Savannah River is to complete construction, startup testing and operation of their Defense Waste Processing Facility (DWPF), as designed, including safety modifications.

49. 60 FR 55249, 1995, "Record of Decision for Savannah River Site Waste Management," *Federal Register*, October 30.

DOE determined, within this ROD, that the most appropriate method for managing low-level radioactive, low-level mixed, and TRU wastes at Savannah River is to implement a moderate treatment configuration alternative, consisting of operation of existing facilities, new recycling initiatives, consolidated incineration facility operation, LLW volume reduction and operation of a mobile sort facility.

50. 62 FR 8693, 1997, "Record of Decision for the Tank Waste Remediation System, Hanford Site, Richland, Washington," *Federal Register*, February 26.

This ROD was issued by DOE to adopt a comprehensive land use plan for Hanford to facilitate decision-making about the site's uses and facilities over at least the next 50 years.

51. 64 FR 61615, 1999, "Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement, *Federal Register*, November 12, 1999.

This ROD addresses actions by DOE to manage and dispose of radioactive, hazardous and mixed wastes within the TWRS program at Hanford.

52. BBI, 2001, *Best Basis Inventory*, access page located at: http://twins.pnl.gov:8001/twins.htm, as of May 2001.

This inventory report provides the best basis inventory of Hanford HLW tanks, on an individual tank basis.

53. Cory, W. N., 1998, "Second Modification to Consent Order," Idaho Department of Health and Welfare, Division of Environmental Quality, Boise, Idaho.

The Consent Order, developed by the state, requires DOE-Idaho Operations Office to cease use of the five pillar and panel vault tanks by 2009 and to cease use of the remaining six tanks by 2015. An August 1998 modification to the Consent Order accelerated these dates to 2003 and 2012, respectively.

54. DOE/EIS-0082S, 1994, *Final Supplemental Environmental Impact Statement - Defense Waste Processing Facility*, U.S. Department of Energy, Savannah River Operations Office, Aiken, South Carolina.

DOE prepared this SEIS to examine the impacts of completing construction and operating the DWPF at SRS. This document assisted DOE in deciding how to proceed with the DWPF project, given changes since 1982.

55. DOE/EM-0362, 1998, *Accelerating Cleanup: Paths to Closure*, U.S. Department of Energy, Washington, D.C.

The Hanford Site underwent a concerted effort between 1994 and 1996 to accelerate the cleanup of the Site. These efforts are reflected in the current Site Baseline. This document describes the current Site Baseline and suggests strategies for further improvements in scope, schedule, and cost. The Environmental Management program (EM) decided to change the name of the draft "strategy" and the document describing it in response to a series of stakeholder concerns, including the practicality of achieving widespread cleanup by 2006. Also, EM was concerned that calling the document a "plan" could be misconstrued to be a proposal by DOE or a decision-making document. The change in name, however, does not diminish the 2006 vision. To that end, *Paths to Closure* retains a focus on 2006, which serves as a point in time around which objectives and goals are established.

56. DOE/RL-00-01, 1994, *Recommendation 93-5 Implementation Plan*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Recommendation 93-5 noted that there was insufficient information to ensure Hanford wastes could be safely stored, associated operations could be conducted safely and future disposal data requirements could be met. As a result, a characterization and safety strategy evolved.

57. DOE/RL-97-57, Draft, *Accelerating Cleanup Paths to Closure Hanford Site,* U.S. Department of Energy, Richland Operations Office, Richland, Washington.

This draft document is a vision for 2006 that includes a baseline and the results that could be achieved if the site's stretch and breakthrough goals are achieved.

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FUNCTIONS AND REQUIREMENTS FOR WEST VALLEY DEMONSTRATION PROJECT TANK LAY-UP

1.0 INTRODUCTION

This letter report documents completion of Milestone A.1-1, "Issue Functions and Requirements for WVDP Tank Lay-up," in Technical Task Plan TTP RL30WT21A – "Post-Retrieval and Pre-Closure HLW Tank Lay-Up." This task is a collaborative effort among Pacific Northwest National Laboratory, Jacobs Engineering Group Inc., and West Valley Nuclear Services (WVNS). Because of the site-specific nature of this task, the involvement of WVNS personnel is critical to the success of this task.

The primary objective of the overall task is to develop and evaluate conceptual strategies for preclosure lay-up of the two high-level waste (HLW) storage tanks at the West Valley Demonstration Project (WVDP). Decision criteria will be developed to support selection of a strategy for safe lay-up of the HLW tanks. The lay-up strategies will be evaluated with respect to the decision criteria to provide WVDP with a defensible decision process.

The subtasks identified in the work plan for the overall task are described below. This letter report documents completion of subtasks 1 and 2 that correspond with completion of Milestone A.1-1 in the Technical Task Plan.

Subtask 1 – Review WVDP Information Package. WVDP personnel have conducted preliminary evaluations for tank lay-up. These evaluations have resulted in three fundamental concepts for lay-up: (1) a wet lay-up with a small amount of corrosion-inhibiting liquid in the tanks, (2) dry lay-up, and (3) dry lay-up with several feet of stabilizing material in the bottom of the tank. This subtask involves coordination with WVDP personnel to identify and review available data and information from WVDP on the HLW tanks, environmental conditions, and tank lay-up concepts. Task completed.

Subtask 2 – Develop Tank Lay-Up Functions and Requirements. Functions and requirements will be developed at a level of detail sufficient to support development of the conceptual tank lay-up descriptions. The functions and requirements will identify the objectives of laying up the tanks and the tank lay-up system requirements. The system requirements will identify what is required of the tank lay-up concepts to support the objective of placing the tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options. Task completed with this letter report.

Subtask 3 – Identify and Evaluate Areas of Technical Concern. In parallel with development of decision criteria, technical areas of concern will be identified and prioritized in consultation with WVDP personnel to ensure that the issues identified correspond to WVDP needs and are relevant to the identified lay-up strategies. A select number of the higher-priority technical concerns will be evaluated by subject matter experts to the extent necessary to factor the concerns into the decision criteria process.

Subtask 4 – Develop Conceptual Description of Tank Lay-Up Options. The three concepts identified for tank lay-up in Subtask 1 will be further developed to the extent necessary to support an evaluation of the concepts against evaluation criteria (performance measures)

developed under Subtask 2. Any additional concept development will be conducted in conjunction with WVDP personnel to ensure that site-specific issues are addressed. Combinations of concepts will also be identified for further evaluation if appropriate.

Subtask 5 - Develop Decision Plan. Performance objectives along with specific criteria will be developed to provide a means for evaluating tank lay-up strategies. The objective of the decision criteria process is to provide a technically defensible methodology for evaluating tank lay-up strategies to allow WVDP to move forward with the selection of an approach for implementation. Examples of performance objectives or attributes that will be considered include (1) minimizing monitoring and maintenance costs, (2) meeting environmental regulations for tank closure, (3) protecting worker health and safety, and (4) addressing stakeholder concerns.

2.0 WEST VALLEY DEMONSTRATION PROJECT BACKGROUND AND OVERVIEW

2.1 SITE HISTORY

The WVDP is located about 30 miles south of Buffalo, New York, on the site of a former commercial spent fuel reprocessing facility which operated from 1966 to 1972. Approximately 640 metric tons of commercial and defense fuels were reprocessed at the site using the plutonium-uranium extraction (PUREX) and the thorium extraction (THOREX) processes. The former site operator, Nuclear Fuel Services, Inc., halted reprocessing operations in 1972 to evaluate the potential for facility expansion. In 1976, Nuclear Fuel Services, Inc. notified New York State that it would withdraw from operating the facility in 1980 when its lease expired. In 1980, the *West Valley Demonstration Project Act* (WVDPA) was signed, directing the U.S. Department of Energy (DOE) to (1) solidify and develop suitable containers for the site's high-level radioactive waste, (2) transport the solidified waste to a federal repository, and (3) dispose of the low-level radioactive and transuranic wastes created during reprocessing operations. In 1982 DOE took control of the site working closely with the New York State Energy Research and Development Authority. A private company, WVNS, was awarded the operations contract and has been the primary contractor since February 1982. New York State owns both the site and the waste. Under the WVDPA, the DOE is responsible for management of the project and funds 90% of the cleanup costs while working with New York State Energy Research and Development Authority, which funds the remaining 10%.

Approximately 2,000,000 L (550,000 gal) of neutralized high-level PUREX radioactive waste remained on the site in an underground carbon steel storage tank designated as 8D-2 in 1982. This waste consisted of insoluble hydroxides and other salts that precipitated out of the solution to form a bottom sludge layer, and a liquid top layer rich in sodium nitrate and nitrite (supernate). In addition, approximately 31,000 L (8,000 gal) of acidic THOREX waste remained in an underground stainless steel storage tank designated 8D-4.

2.2 HIGH-LEVEL WASTE STORAGE TANKS AND VAULTS

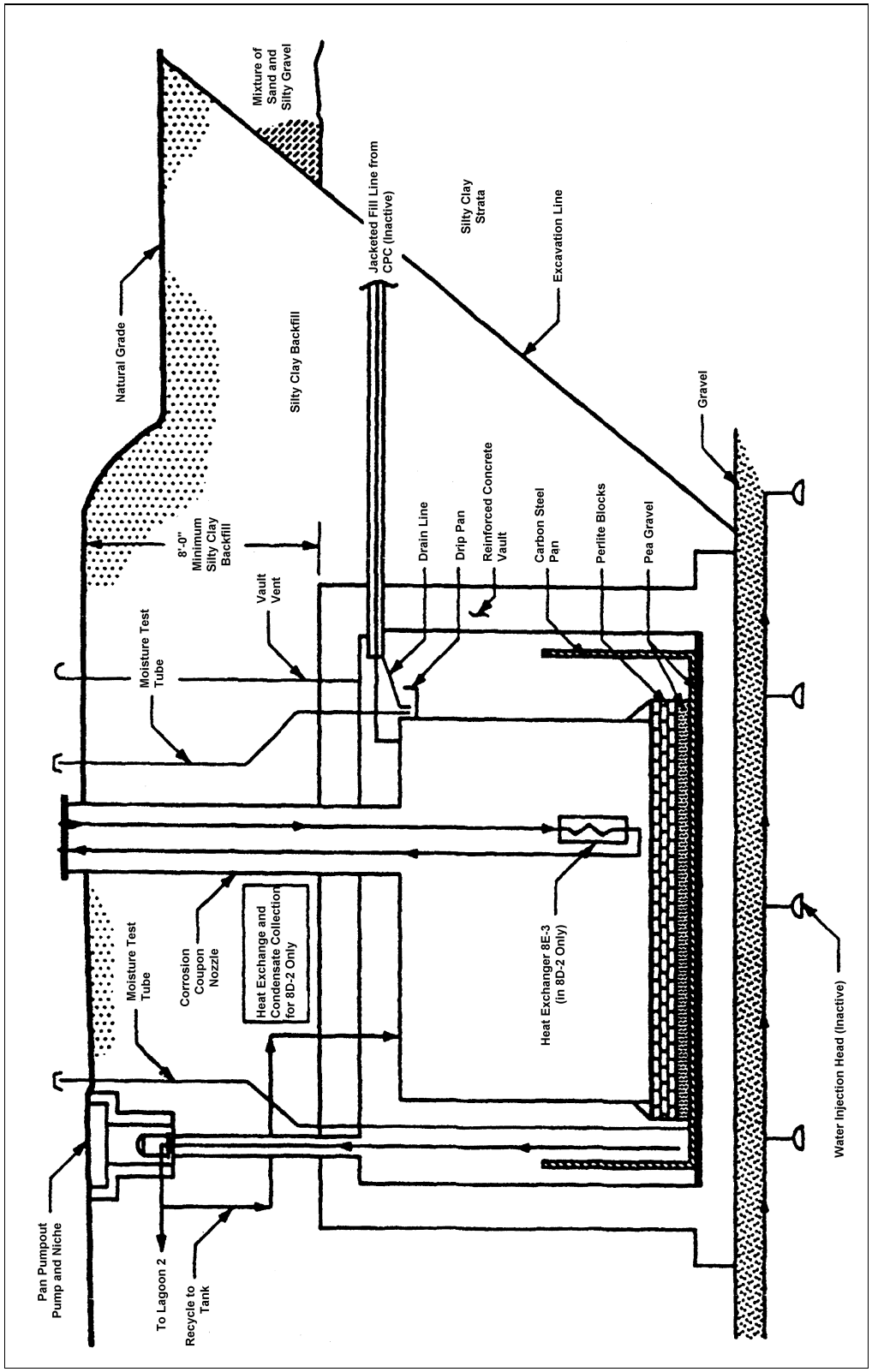
Underground waste storage tanks 8D-1 and 8D-2 are identical 2,800,000-L (760,000-gal) capacity, carbon steel storage tanks each contained within a secondary containment pan and a concrete vault. Figure 1 is a schematic of the tank and vault configuration. Each tank is 21 m (70 ft) in diameter and 8.2 m (27 ft) high with wall thicknesses ranging from 1.3 to 1.7 cm (0.5 to 0.65 in.). The bottom floor plates are 1.7 cm (0.65 in.) thick and the tank roof plates are 1.1 cm (0.43 in.) thick. These tanks have a complex internal gridwork comprised of a network of wide flange beams supported underneath by vertical plates of varying lengths and widths.
These girders attach to the tank bottom by rods held on with reinforcing disks. Forty-five 22-cm (8.6-in.) diameter pipe columns in each tank connect the beams to the tank top and provide support to the roof. Figure 2 shows the arrangement of the girders and support columns in the tanks. Various air circulators, thermowells, and level/density probes also reside within the tanks. Waste mobilization and removal efforts have been uniquely challenging because of internal tank configuration and the presence of internal structures. The internal structures act to disperse the mobilization pumps' mixing jets, which results in nonuniform cleaning/mixing radii and "dead zones" where the low local velocity causes the solids to fall out of suspension and deposit on tank surfaces.

There is an annular air space of 76 cm (30 in.) between the tank and vault wall. Each tank rests directly on a 30-cm (12-in.) layer of perlite blocks and the perlite blocks rest on a 7.5-cm (3-in.) layer of pea gravel within the carbon steel secondary containment pan. The secondary containment pan is approximately 1.5 m (5 ft) deep. There is another 7.5-cm (3-in.) layer of pea gravel between the pan and the vault floor. The bottom of the vault is 70-cm (27 in.) thick except for a thicker ring under the columns that support the vault roof. There are six 1.2-m (4-ft) diameter columns that pass through each tank to support the vault roof. These columns pass through carbon steel tubes constructed of 1-cm (0.4-in.) plate welded to the top plate and floor plate. Figure 3 provides additional detail on the construction of the tanks, including the gravel base below the vaults and the superstructure above the tanks to support the sludge mobilization pumps.

Long-shafted centrifugal mobilization pumps are installed in tanks 8D-1 and 8D-2 to mix settled solids with the liquid supernate. These pumps are each 15 m (50 ft) in length with a single impeller to draw the slurry up into the pump suction and a strainer device to keep out larger debris. The suction is positioned from 2.5 to 3.8 cm (1 to 1.5 in.) from the tank bottom with discharge jets approximately 13 cm (7 in.) above the tank bottom. Two tangential nozzles are used to discharge liquid from the volute above the suction.

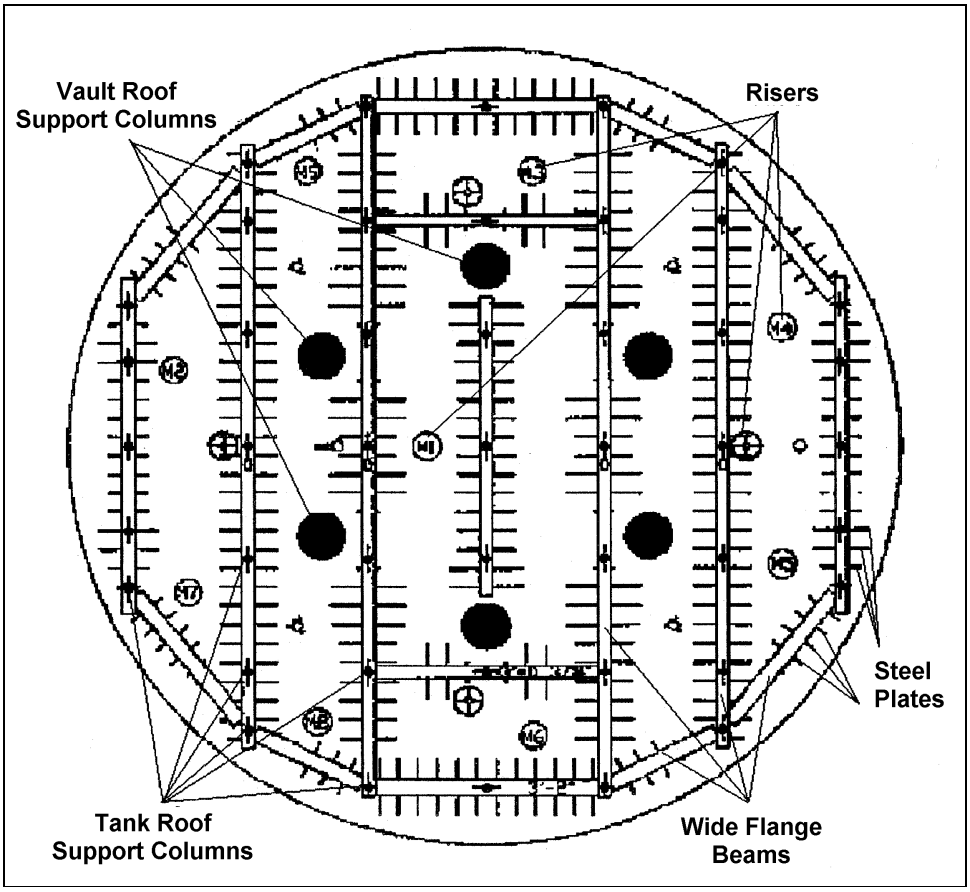
Additionally, one long-shafted vertical turbine transfer pump is installed in tanks 8D-1 and 8D-2. This pump is approximately 12-m (40-ft) long with a radial inlet suction and two concentric strainers about 2.5 to 3.8 cm (1 to 1.5 in.) above the tank bottom. The pump is additionally equipped with instrumentation to allow remote operation and performance monitoring and with vibration sensors to monitor pump wear.

Figure 1. Schematic of Waste Tanks 8D-1 and 8D-2



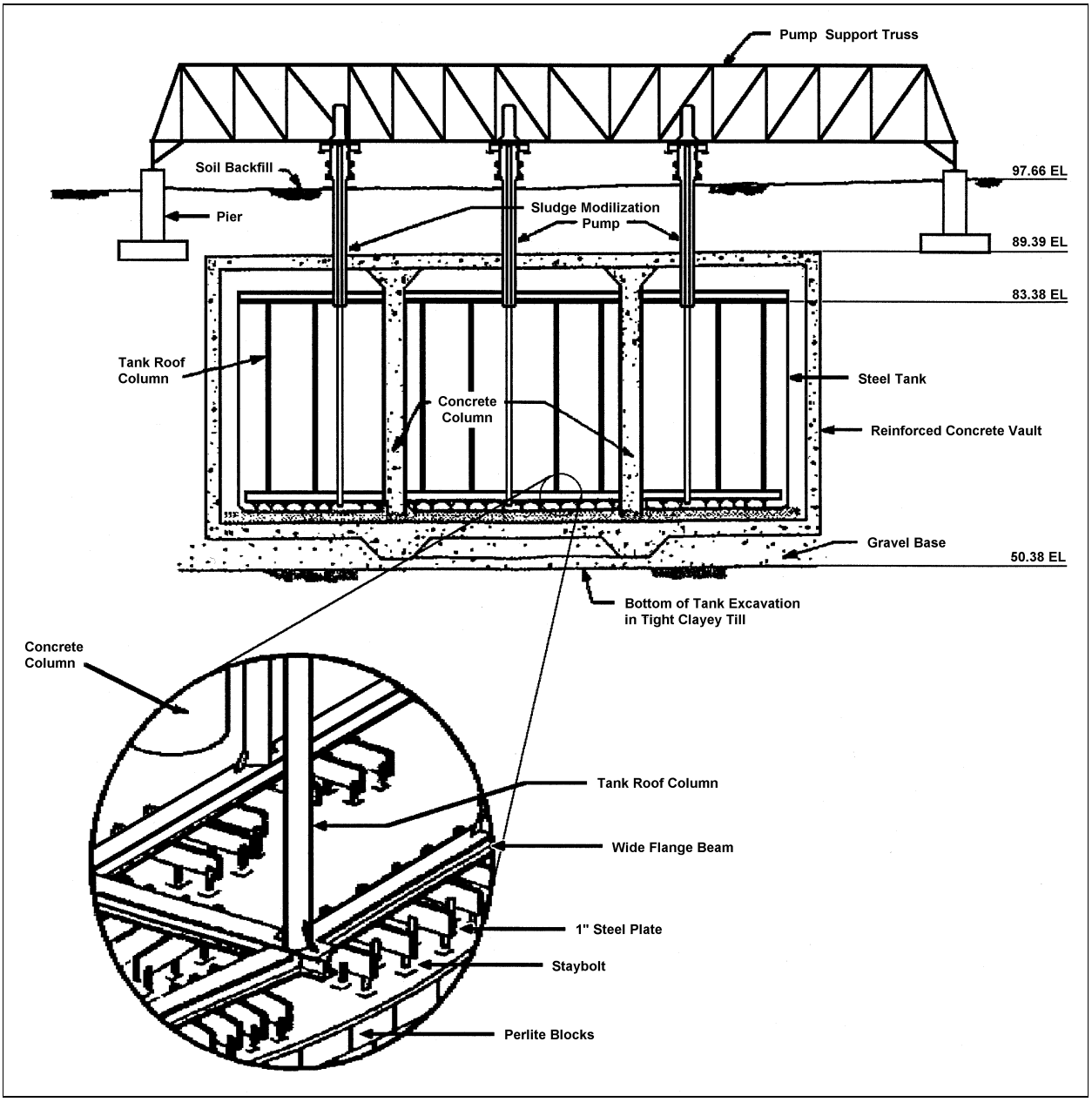
Source: WVDP-141.

Figure 2. High-Level Waste Storage Tank Interior Structure



Source: EML-609.

Figure 3. High-Level Waste Tank Cross-Section with Details of Bottom Gridwork



Source: EML-609.

A 70-m (230-ft) long seismically designed concrete transfer trench connects the tanks to the vitrification facility. Transfer piping within the trench is 6.4-cm (2.5-in.) diameter stainless steel inside a 10-cm (4-in.) diameter stainless steel secondary containment pipe. The trench is equipped with leak detectors, radiation probe penetrations, high-point vents, and exterior valving for monitoring and safety control functions.

A dewatering well between the tanks is used for periodic pumping of water from outside the vaults. The water outside the vaults is never completely removed. The hydraulic pressure of the water is considered secondary containment for any potential leaks into the vault. No records are currently kept on the volume of groundwater pumped. Liquid can also be pumped from the secondary containment pans (see Figure 1). Water is currently pumped from outside the vaults on a weekly basis and pumping from the containment pans is necessary only one to four times per year. There is currently very little ingress of water into the vaults, but the humidity is always at or near 100%.

There has been no leakage of waste from the tanks. However, very small amounts of contamination have been detected in water pumped from inside the tank 8D-2 vault. The contamination is believed to be from small leaks during transfers of waste from the process building that were washed into the vault by water percolation from the surface. This conclusion is supported by the discovery of contaminated soil when new penetrations were added to the vault and tank (Fussner 2001).

2.3 WASTE PRETREATMENT

Pretreatment to remove chemical compounds (e.g., sodium sulfate) that have a detrimental effect on the final vitrified HLW form began in 1988. The supernate in HLW tank 8D-2 was processed using ion-exchange columns containing zeolite located inside spare HLW tank 8D-1. Ion exchange removed greater than 99.9% of the radioactive materials (mostly cesium-137). The resultant effluent salt solution was concentrated and blended with cement and is stored as low-level waste in a shielded, aboveground, onsite facility. Supernate processing was completed in 1990 producing slightly over 10,000 drums.

Without pretreatment of the HLW the quantity of vitrified waste would have been about 10 times the current estimated projection of 300 glass-filled canisters. The remaining waste (mostly solids from tank sludge and zeolite ion-exchange media) was mobilized by mixing pumps and transferred to the vitrification facility for solidification into glass logs.

2.4 HIGH-LEVEL WASTE MOBILIZATION AND TRANSFER

Mobilization pumps were installed mix and wash the sludge portion of the waste. This washing process included the addition of water to the tank to dissolve additional interstitial sulfates. Salt/sulfate removal was necessary to reduce the amount of these compounds processed into glass and the resulting quantity of canisters produced during the vitrification campaign. The wash water was then processed similarly to the supernate; however, titanium-coated zeolite was used in the ion-exchange columns. The titanium-coated zeolite adequately captured cesium-137 and also captured plutonium and strontium that had dissolved during the washing process. Sludge washing created 2,900,000 l (765,000 gal) of liquid that was processed as

supernate liquids, then evaporated, mixed with cement, and placed in 8,033 265-L (70-gal) steel drums.

During 1995 the acidic THOREX waste (85,000 kg or 94 tons, containing 40% water and 50% nitrates of thorium, iron, and aluminum) in tank 8D-4, leftover from past fuel reprocessing, was combined with the waste in tank 8D-2 and chemically neutralized. The resulting THOREX sludges and the PUREX sludge were then washed and processed. The net effect of the wash was an additional 1,100,000 L (300,000 gal) of liquid waste solidified into 1,451 drums.

The processing of liquid from washing the PUREX-based sludge and the additional THOREX waste was completed in 1995, resulting in a total of 6,400,000 L (1,700,000 gal) of liquid being processed and a total of 19,877 drums of cement-based waste produced and stored onsite.
The spent zeolite from the ion-exchange process in tank 8D-1 was then transferred to tank 8D-2. The zeolite particles were size-reduced with an in-line grinder during transfer operations.
The remaining zeolite and sludge mixture is the feed for the vitrification process providing 17% of the glass chemical composition. The waste consists of insoluble metal hydroxides with ferric hydroxide being the major constituent. The sludge mass was estimated at 100,000 kg (220,000 lb) with a specific gravity of 3.35. Based on sludge sampling and analysis, the particle size of the sludge was generally less than 100 microns. The predominant radionuclides in the sludge are strontium-90 and isotopes of thorium and uranium.

From June 1996 through September 1998 over 102 transfers of waste from tank 8D-2 to the vitrification facility were completed. These transfers made up 58 batches of feed for the melter containing 10,300,000 curies of cesium-137 and strontium-90, and comprised approximately 88% of the initial HLW tank inventory. Other liquids from laboratory analysis of samples, distillates from waste concentration in the vitrification facility, and clean water used to lubricate and cool the mobilization pump driveline bearings were added to tank 8D-2 during this period. Volume reduction of some of the excess liquid was performed in the Integrated Radwaste Treatment System. Some portion of the liquid was decanted back to tank 8D-1. Both operations were critical to maintaining the HLW concentration in the primary waste tank supplying the vitrification facility.

From October 1, 1998 to December 31, 1999, 24 transfers of waste from tank 8D-2 to the vitrification facility were completed. These transfers made up 3 feed batches and contained approximately 460,000 curies of cesium-137 and 160,000 curies of strontium-90 for a total of 620,000 curies.

As of March 2001 the total contents of tank 8D-1 and tank 8D-2 are estimated to be approximately 2,300,000 L (600,000 gal) of liquid waste with about 19,300 kg (42,500 lb) of dissolved chemical species consisting primarily of sodium nitrate, sodium nitrite, sodium carbonate and sodium formate. This liquid also contains about 30,000 curies of radioactive species, primarily cesium-137 and small quantities of hazardous chemical constituents such as chromium and mercury. In addition to the liquid and residual solids in the bottom of the tanks, there is a “bathtub ring” of dried solids on the walls and internal structures of tank 8D-2 (Wallon 2001).

Most of this liquid will be removed from the tanks and additional cleaning of the internal surfaces will be completed prior to lay-up. The residual waste will then be characterized. Options for final treatment of the current inventory of sodium waste are being evaluated. Methods for removal of the 'bathtub ring' are also being evaluated.

2.5 HYDROLOGY OF SITE

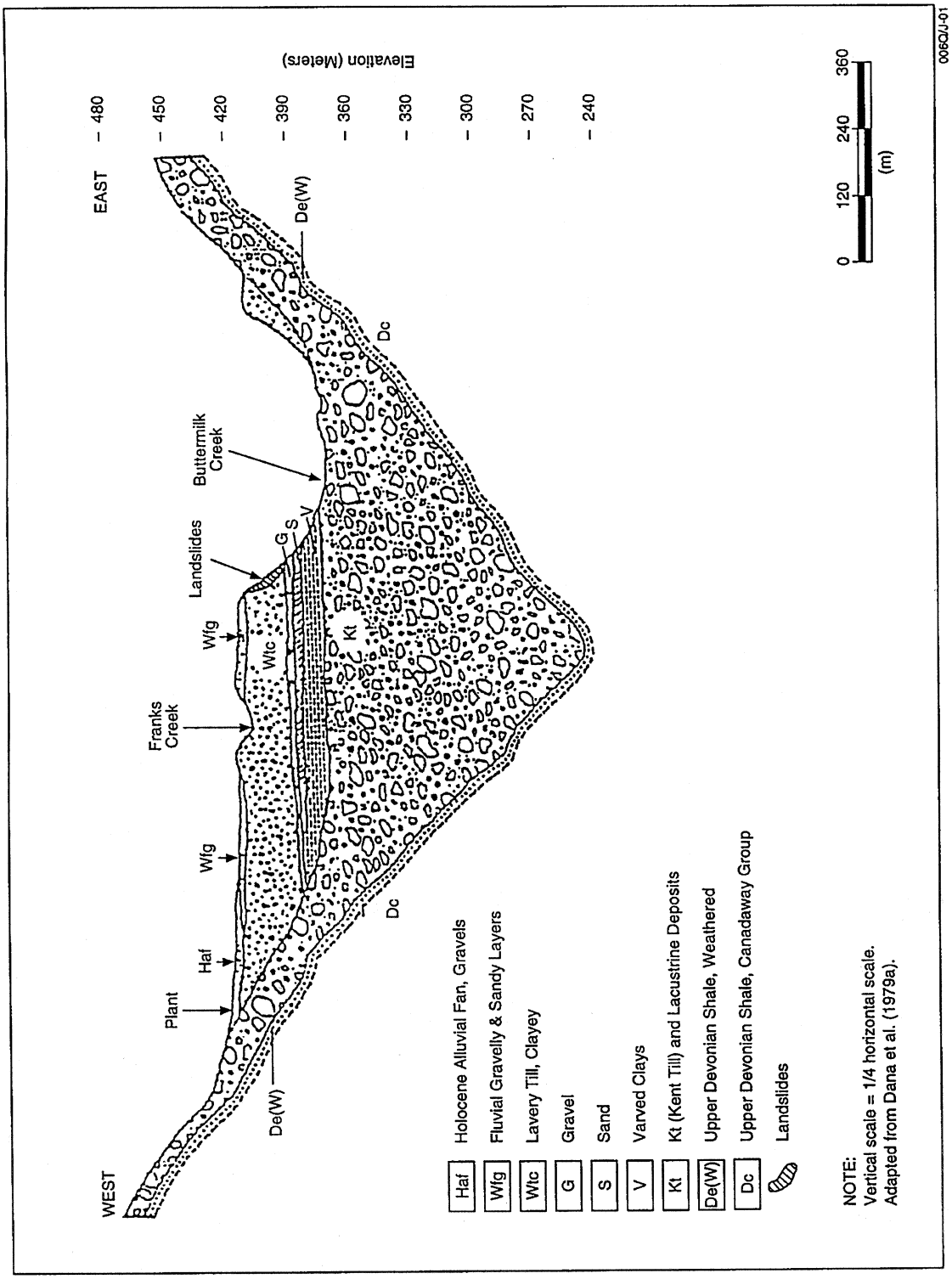
The WVDP facilities are located within a U-shaped bedrock valley filled with approximately 150 m (500 ft) of Pleistocene glacial deposits that form a till plain. A cross-sectional view of the deposits within the valley is shown in Figure 4. There is a sand and gravel layer above a layer of unweathered lavery till. The unsaturated zone is within the sand and gravel layer that has a maximum thickness of 12.5 m (41 ft). Groundwater flow in the sand and gravel layer is predominantly to the east-northeast toward Franks Creek and Erdman Brook. Figure 5 provides additional detail of the geological cross-section in the area of the WVNS facilities and tank farm.

Recharge of the groundwater system within the bedrock valley is primarily from precipitation within the watershed and not from subsurface flow from regional drainages. The water table in the area of the facilities varied between 0.3 to 1.5 m (1 to 5 ft) below the surface from 1990 to 1992. From 1981 to 1992 the depth to groundwater ranged from 1.2 to 3 m (4 to 10 ft). Water levels are typically higher in fall through spring and lower during the summer. The average annual recharge has been estimated at 40% of the annual precipitation with 60% lost to runoff. A geological survey in 1987 estimated that springs and seeps account for 36% of the total annual discharge from the sand and gravel layer while evapotranspiration to the surface accounts for 30% and drainage to streams accounts for 19%. Vertical downward flow to the lavery till was estimated at only 1%. Figure 6 shows the hyrologic cycle for the site. The WVNS site is on the western edge of the bedrock valley.

2.6 STATUS OF THE WEST VALLEY DEMONSTRATION PROJECT ENVIRONMENTAL IMPACT STATEMENT

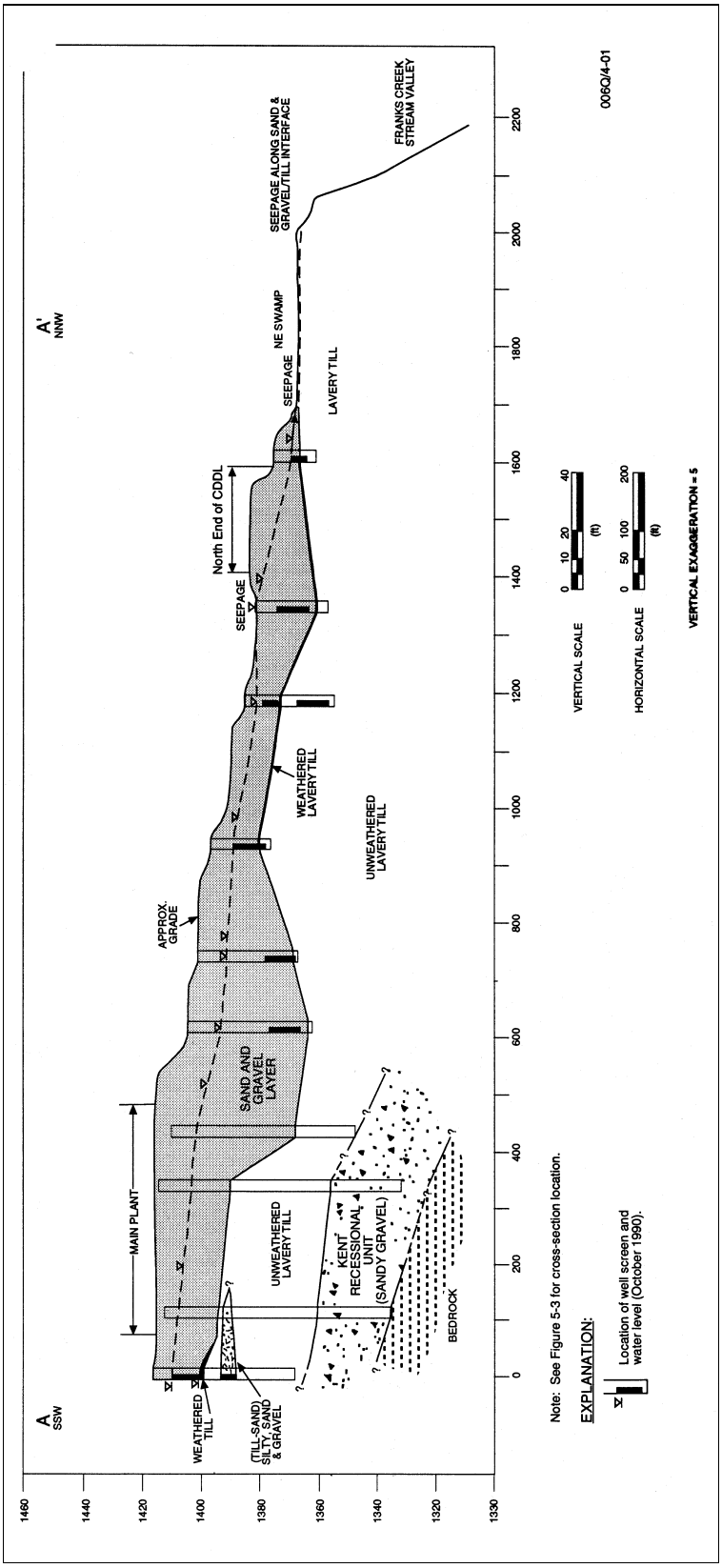
DOE is planning to separate the environmental impact statement (EIS) for completion of closure of the WVDP into two separate EISs. The first EIS will cover only waste management and decontamination. DOE expects to complete this EIS in about 18 months. The second EIS will cover final decommissioning and may take up to five years to complete. This approach has been proposed to expedite continued management of the waste and decontamination activities in advance of the final EIS and Record of Decision on final site closure. DOE believes the two-EIS approach fulfills the requirements of the "1987 Stipulation of Compromise with the Coalition on West Valley Nuclear Wastes" (WVNW 1987), requirements under the WVDPA and *National Environmental Policy Act of 1969* requirements. Final closure of the WVDP site may take 10 to 15 years.

Figure 4. Cross-Section of the Buried Bedrock Valley



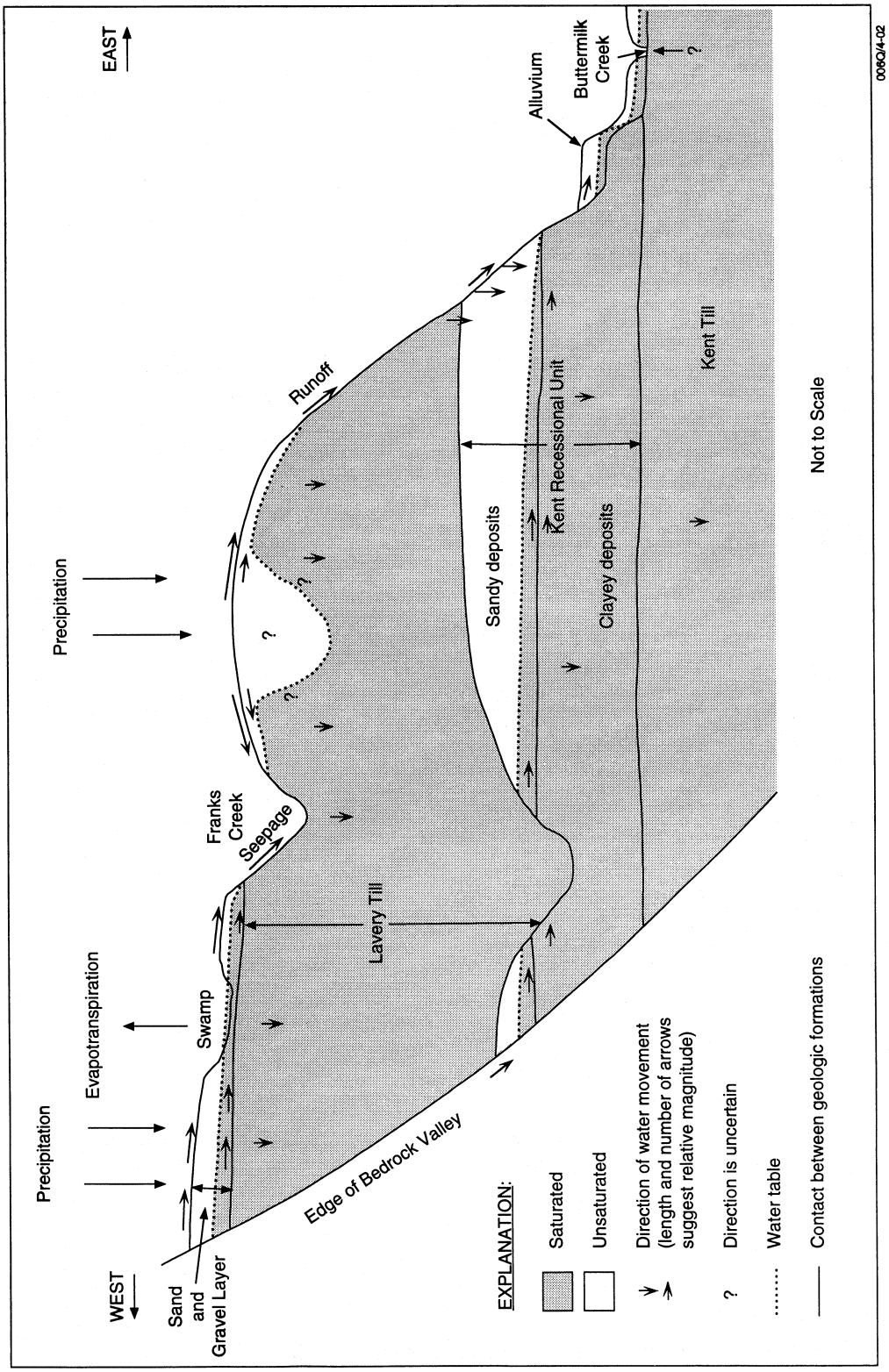
Source: DOE/EIS-0226-D.

Figure 5. Geologic Cross-Section through the North Plateau



Source: DOE/EIS-0226-D.

Figure 6. Idealized Cross-Section Showing Hydrologic Cycle, Distribution of Saturated and Unsaturated Zones, and General Directions of Water Movement



Source: DOE/EIS-0226-D.

3.0 FUNCTIONS AND REQUIREMENTS FOR TANK LAY-UP

The primary function of the tank and auxiliary systems is to contain the waste and prevent releases to the environment. The primary objective for temporary tank lay-up is to put the tank into a safe and stable configuration with minimum capital and operating costs for up to a 20-year period of time. The requirements for the tank system to continue to perform this function during the lay-up period are primarily subjective. It is not possible to construct specific, objective functional requirements. Therefore, the requirements listed below will serve as the evaluation criteria for identifying the preferred option. Some of the requirements identified below are firm requirements (e.g., safety) while others are more value based. Weighting factors will be developed as part of the decision plan to provide a means for ranking alternative lay-up strategies. The weighting factors can be used as a way to vary the importance or influence of the different requirements on the evaluation of lay-up strategies.

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period. Effluent releases must be maintained within permitted limits. This will require maintaining gaseous and liquid treatment capabilities for tank ventilation and potential treatment of liquids pumped from inside or around the vaults.

- **Prevent release of tank contents to the groundwater** – There shall be no release of any amount of the tank contents to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.

- **Ensure acceptable risk to workers and the public** – The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable. However, the selected option should result in a reduced risk to workers and the public during the lay-up period.

- **Maintain integrity of the tanks** – The ability of the tanks to continue to contain the waste residual must be maintained. Further corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up** – The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control construction and operating costs** – The cost of installing new equipment and the continued operating costs are considerations for selecting a preferred option. Construction and operating costs must be within projected budgets.

- **Utilize accepted methods and technologies** – The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation** – Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be avoided.

- **Preserve future options for decontamination and final closure** – The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude either of the currently identified final closure options of in-place stabilization and complete removal.

- **Gain acceptance for lay-up** – The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.

- **Reduce monitoring and surveillance** – Reductions in monitoring and surveillance, consistent with requirements, is desired.

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WEST VALLEY HIGH-LEVEL WASTE TANK LAY-UP STRATEGIES

April 16, 2001

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CONTENTS

1.0 INTRODUCTION 1

2.0 OBJECTIVES 1

3.0 ASSUMPTIONS 1

4.0 FUNCTIONS AND REQUIREMENTS FOR TANK LAY-UP 1

5.0 ALTERNATIVE LAY-UP STRATEGIES 3
- 5.1 CURRENT SYSTEM 3
- 5.2 OTHER POTENTIAL OPTIONS 3
  - 5.2.1 Cathodic Protection for External Tank Surfaces 4
  - 5.2.2 Vault Drying System 4
  - 5.2.3 Drying Systems in Both the Vaults and Tanks 4
  - 5.2.4 Seal Annulus and Maintain Nitrogen Blanket 4
  - 5.2.5 Oxygen Removal Capability 4
  - 5.2.6 Argon or Other High Density Inert Gas Instead of Nitrogen 5
  - 5.2.7 Groundwater Interceptor Trench 5
  - 5.2.8 Infiltration Barrier Above the Vaults 5
  - 5.2.9 Enhanced Pumping of Groundwater 7
  - 5.2.10 Barrier Around the Vaults 7
  - 5.2.11 Corrosion Inhibitors in the Water Outside the Tanks 8
  - 5.2.12 Radionuclide/Hazardous Material Sorbents to the Annulus 9
  - 5.2.13 Low Strength Grout in Tanks to Stabilize Residual Heels 9
  - 5.2.14 Fixative to Prevent Suspension of Internal Contamination 9
  - 5.2.15 Corrosion Monitors in Key Locations 9
  - 5.2.16 Radiation/Contamination Monitors for Early Detection of Any Leakage 10
  - 5.2.17 Complete Removal of All Residual Waste 10
- 5.3 OPTIONS IDENTIFIED AND DISCARDED AS NOT VIABLE 10
  - 5.3.1 Fill Annulus with Material Impervious to Water 10
  - 5.3.2 Add a Coating to the Tank and/or Vault Wall 10
  - 5.3.3 Assess Worst-Case Impact of Credible Leak 10
- 5.4 STRATEGIES TO BE CONSIDERED 11
  - 5.4.1 Current System (see Section 5.1) 11
  - 5.4.2 Cathodic Protection (see Section 5.2.1) 11
  - 5.4.3 Vault Drying (see Section 5.2.2) 11
  - 5.4.4 Vault & Tank Drying (see Section 5.2.3) 11
  - 5.4.5 Nitrogen Blanket (see Section 5.2.4) 11
  - 5.4.6 Nitrogen Blanket with Oxygen Removal (see Section 5.2.5) 11
  - 5.4.7 Argon Blanket (see Section 5.2.6) 11
  - 5.4.8 Argon Blanket with Cathodic Protection 11
  - 5.4.9 Interceptor Trench (see Section 5.2.7)/Drying 11
  - 5.4.10 Trench/Infiltration Barrier (see Section 5.2.8)/Drying 13
  - 5.4.11 Infiltration Barrier/Drying/Enhanced Pumping (see Section 5.2.9) 13
  - 5.4.12 Groundwater Barrier (5.2.10)/Drying 13

5.4.13 Infiltration Barrier/Drying 13
5.4.14 Corrosion Inhibitors in Containment Pan (see Section 5.2.11) 13
5.4.15 Sorbents in Annulus (see Section 5.2.12) 13
5.4.16 Sorbents with Cathodic Protection..... 13
5.4.17 Low Strength Grout (see Section 5.2.13)..... 13
5.4.18 Low Strength Grout/Drying..... 13
5.4.19 Contamination Fixative (see Section 5.2.14)..... 14
5.4.20 Monitors (see Sections 5.2.15 and 5.2.16)..... 14
5.4.21 Waste Removal (see Section 5.2.17) 14

6.0 INFORMATION NEEDS TO SUPPORT LAY-UP DECISION 14

7.0 REFERENCES 15

FIGURES

1. Aerial Photograph of the West Valley Demonstration Project Facilities 6
2. Cross-Section of Tank and Superstructure 6
3. Diagram of a Viscous Liquid Barrier..... 8

TABLES

1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up 12

LIST OF TERMS

GCL	geosynthetic clay liner
HLW	high-level waste
PSX	polysiloxane
WVDP	West Valley Demonstration Project

WEST VALLEY HIGH-LEVEL WASTE TANK LAY-UP STRATEGIES

1.0 INTRODUCTION

This report documents completion of Milestone A.2-1, "Issue Tank Lay-Up Strategies for WVDP," in Technical Task Plan RL30WT21A, "Post-Retrieval and Pre-Closure HLW Tank Lay-Up." This task is a collaborative effort among Pacific Northwest National Laboratory, Jacobs Engineering Group Inc., and West Valley Nuclear Services. The primary objective of the overall task is to develop and evaluate conceptual strategies for preclosure lay-up of the two large high-level waste (HLW) storage tanks at the West Valley Demonstration Project (WVDP).

Functions and requirements for tank lay-up were developed and previously documented in "Functions and Requirements for WVDP Lay-Up" (Henderson 2001 [Letter Report #1]). These functions and requirements will serve as decision criteria to support selection of a strategy for safe and cost-effective lay-up of the HLW tanks.

2.0 OBJECTIVES

This report has two objectives:

- Summarize the lay-up strategies already identified and summarize any new strategies
- Describe information or development needs to support prioritization of the lay-up strategies against the decision criteria.

3.0 ASSUMPTIONS

The following assumptions apply to the assessment of alternatives for WVDP tank lay-up.

- Current environmental permits will continue.
- HLW will be removed and the tanks will be decontaminated to meet the limits in 10 CFR 61 (Williams 2001).
- The residual waste will be characterized.
- Gaseous and liquid effluent treatment systems will be maintained.

4.0 FUNCTIONS AND REQUIREMENTS FOR TANK LAY-UP

The primary function of the tanks and auxiliary systems is to contain the waste and prevent releases to the environment. The primary objective for temporary tank lay-up is to put the tanks and vaults into a safe and stable configuration with minimum capital and operating costs for up to a 20-year period of time. The requirements listed below will serve as the evaluation criteria for identifying the preferred strategy. Development of these requirements was previously reported (Letter Report #1). Some of the requirements identified below are firm requirements (e.g., safety) while others are more value based. Weighting factors will be developed as part of

the decision plan to provide a means for ranking alternative lay-up strategies. The weighting factors can be used as a way to vary the importance or influence of each requirement.

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period. Effluent releases must be maintained within permitted limits. This will require maintaining gaseous and liquid treatment capabilities for tank ventilation and potential treatment of liquids pumped from inside or around the vaults.

- **Prevent release of tank contents to the groundwater** – There shall be no release of any amount of the tank contents to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.

- **Ensure acceptable risk to workers and the public** – The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable. However, the selected option should result in a reduced risk to workers and the public during the lay-up period.

- **Maintain integrity of the tanks** – The ability of the tanks to continue to contain the waste residual must be maintained. Further corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up** – The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control construction and operating costs** – The cost of installing new equipment and the continued operating costs are considerations for selecting a preferred option. Construction and operating costs must be within projected budgets.

- **Utilize accepted methods and technologies** – The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation** – Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be avoided.

- **Preserve future options for decontamination and final closure** – The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude either of the currently identified final closure options of in-place stabilization and complete removal.

- **Gain acceptance for lay-up** – The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.

- **Reduce monitoring and surveillance** – Reductions in monitoring and surveillance, consistent with requirements, is desired.

Additional requirements or criteria for selecting a preferred strategy for lay-up may be identified when the alternative strategies are ranked.

5.0 ALTERNATIVE LAY-UP STRATEGIES

Several alternative actions were identified to provide for continued safe storage of the residual waste in the tanks prior to final closure. The lay-up strategy selected must provide for placing the tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options. Several alternative approaches are discussed in the following sections. Some of the options identified were deemed not viable for serious consideration. The preferred strategy for lay-up will likely be some combination of options.

5.1 CURRENT SYSTEM

The historical methods of corrosion control have been to periodically remove water from the containment pan, control the pH and nitrite/nitrate ratio of the liquid inside the tanks, and maintain a nitrogen purge inside the vaults. The corrosion-monitoring program has confirmed that the rate of internal pitting corrosion has been maintained with a program of pH control and nitrite/nitrate ratio control (Chang 1999). The corrosion rate of the tank internals has been controlled in the range of 0.013 to 0.025 mm/yr (0.5 to 1.0 mpy[1]) (Chang 1999).

Pumps are currently used to remove water from outside and inside the tank vaults. However, there will continue to be a concern that corrosion to the external surfaces of the tanks could eventually result in penetrations. Corrosion of the external tank walls is primarily from the wet conditions inside the vaults. General corrosion rates determined from corrosion coupons are generally less than 3 mpy and the highest measured rate is 0.188 mm/yr (7.4 mpy) (Chang 1999). The external pitting corrosion rate has been estimated at up to 0.3 ± 0.075 mm/yr (12 ± 3 mpy) (Chang 1998). If this rate has been experienced since the tanks were built, there may be little remaining corrosion allowance at locations prone to pitting.

The nitrogen inerting system has been in operation since August 1996. The oxygen concentration has been maintained at about 13.5% to 15.5%; oxygen concentration in air is 21%. Using this system has resulted in an estimated decrease in the external corrosion rate of tank 8D-1 by about 33% (Chang 1999). The nitrogen inerting system also reduces the concentration of other impurities in the gas surrounding the tanks, such as sulfur dioxide, that can also accelerate corrosion.

5.2 OTHER POTENTIAL OPTIONS

There are several options that can be considered to ensure safe and cost-effective storage of residual waste remaining in the tanks during the lay-up period. These enhancements include all the options previously identified by West Valley Nuclear Services. These options are individual components that can be selected and combined to create an integrated lay-up strategy as described in Section 5.4. They are described in the following sections.

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[1]Note: mpy = mils per year; a mil is 1/1000 of an inch.

5.2.1 Cathodic Protection for External Tank Surfaces

Addition of cathodic protection to the tanks has been assessed. One alternative method for cathodic protection identified is to use the containment pan as the sacrificial anode.
The tank 8D-2 containment pan is known to have a hole in it, so use as a sacrificial anode would be reasonable since its original purpose is already compromised. There are several technical and engineering issues that must be resolved before this option could be selected. These include (1) galvanic corrosion on the bottom of the tank, (2) runaway voltage with the impressed current system, (3) protection of welds, (4) assurance that no electrical shorts are present, e.g., pan pump, dip tubes, etc (Chang 1999).

5.2.2 Vault Drying System

General textbook corrosion rates of carbon steel in water are generally 0.075 to 0.20 mm/yr (3 to 8 mpy) and pitting corrosion rates are generally 2.5 to 3.5 times the general corrosion rate. External tank corrosion could be virtually eliminated if the tank surfaces were kept dry.
The criterion would be to maintain the relative humidity below 30% in the air surrounding the tanks (Chang 1998). The drying system would include a dehumidifier and heater for air forced into the vaults. The exhaust air leaving the vaults would pass through high-efficiency particulate air filters.

5.2.3 Drying Systems in Both the Vaults and Tanks

An additional enhancement to also reduce corrosion inside the tanks is to install drying systems both inside the vaults and inside the tanks. Drying the inside of the tanks could result in contamination of the exhaust air by particles of dried solids in the tanks being suspended by the airflow through the tanks. However, once all the liquid inside the tanks was evaporated, only a very low flow of heated, dehumidified air would be required to maintain low humidity inside the tanks. Keeping the tank internals the same temperature, as the external surfaces would also prevent condensation of water on the tanks' external walls.

5.2.4 Seal Annulus and Maintain Nitrogen Blanket

The current nitrogen inerting system has not been effective in maintaining the desired concentration of oxygen in the vault below 0.9% as specified in the design criteria (WVNS-DC-065). Sealing the vault as well as possible and then adding additional amounts of cold nitrogen to displace air from the vault should result in a more effective blanket and lower oxygen concentrations.

5.2.5 Oxygen Removal Capability

This option could be used in combination with either of the two preceding options. Recirculated blanket gas could be passed through a device to remove oxygen. Such a system would be efficient only if air in-leakage is significantly reduced.

5.2.6 Argon or Other High Density Inert Gas Instead of Nitrogen

Using Argon instead of Nitrogen as the blanket gas would be more effective in displacing air because Argon is heavier than air. This option has been considered in the past, as early as 1997 (Meess 1997).

5.2.7 Groundwater Interceptor Trench

One of the primary methods of preventing or significantly reducing corrosion on the outside of the tanks is to maintain very low humidity in the vaults. In order to do this, the ingress of water into the vaults must be prevented. The principal source of water into the vaults appears to be from percolation of rainwater and snowmelt through the soil layer above the vaults and groundwater flow in the soil/sand layer above the compacted clay layer. One method to significantly reduce this infiltration is to divert runoff and groundwater flow. This could be accomplished by installing an interceptor trench down to the compacted clay layer upgradient of the tanks. This trench would be filled with coarse gravel and perforated pipe would be installed at the bottom of the trench to collect and remove excess water. The trench would be connected to a culvert to carry water to an appropriate location downgradient from the tanks and vaults. This would be a totally passive system. Pumping of water from the vaults and the well between the vaults could be eliminated or significantly reduced.

5.2.8 Infiltration Barrier Above the Vaults

A principal source of water ingress into the tank vaults appears to be from infiltration from above the vaults. A cover to divert rainwater away from the area would be effective in preventing this water from entering the vaults. This barrier could be a clay cap, a membrane, a roof or some other cover. Installation of a barrier above the vaults is complicated by the superstructure that was installed to support the mobilization pumps and penetrations into the soil above the tanks and vaults. Figure 1 is an aerial photograph showing the super-structure. Figure 2 is a cross-section showing penetrations through the soil (EML-609).

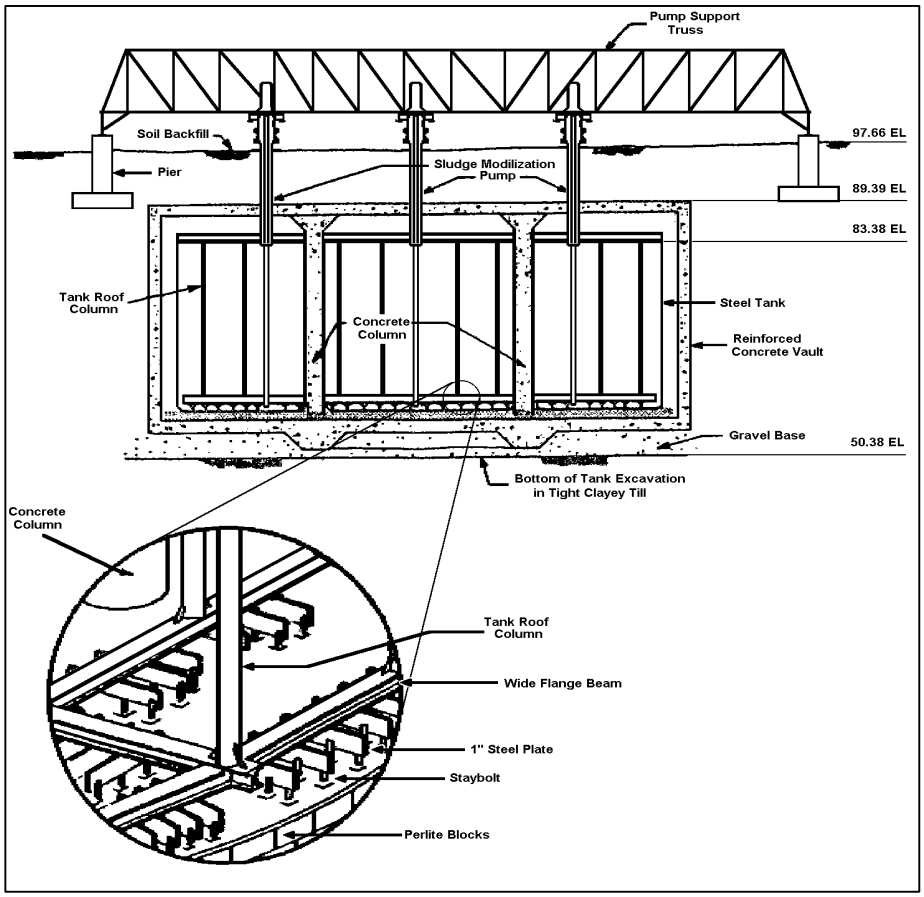
Grout was added around the penetrations into the tank 8D-2 vault and this significantly reduced water intrusion (from about 1,900 L/day [500 gal/day] to about 45 L/day [12 gal/day]). However, this increased the water intrusion into the tank 8D-1 vault from 190 to 1,900 L/day (50 to 500 gal/day). Grout was then added around the tank 8D-1 vault accessway with similar results.

One alternative cover layer is a capillary layer barrier, which consists of a fine-over-coarse soil arrangement. The capacity of capillary barriers to laterally divert downward moving water is the key to their success. Another alternative is a dry barrier, in which atmospheric air is circulated through a coarse layer within the cover to remove water vapor. Yet another approach is a geosynthetic clay liner (GCL) cover. This is a barrier manufactured with a thin layer of bentonite clay supported by geotextiles and/or geomembranes. A 5 mm (0.2 in.) thick GCL has the same hydraulic conductivity as a 1 m (40 in.) thick compacted soil layer.

A geomembrane can also be used on top of compacted soil or a GCL. Geomembranes are available in a variety of materials, such as polyvinyl chloride, very-low-density polyethylene, and linear-low-density polyethylene.

Figure 1. Aerial Photograph of the West Valley Demonstration Project Facilities

Figure 2. Cross-Section of Tank and Superstructure



Another choice of a barrier is to construct a roof over the vaults. This roof could also serve as a cover during final closure of the tanks. Gutters and drains would also be needed on the adjacent buildings to divert that water downgrade from the tank farm area.

Addition of a cover barrier would be simplified with prior removal of the superstructure. This would first require removal of the mobilization pumps or abandoning the pumps in place. A roof could possibly be built on or above the superstructure.

5.2.9 Enhanced Pumping of Groundwater

To ensure that water will not infiltrate into the vaults from groundwater around and below the vaults, the capability to pump water from the gravel bed below the vaults could be maintained or enhanced. Water is currently pumped from a well between the vaults, but the water table is not pumped to below the bottom of the vaults. The hydrology is not known well enough to determine the volume of water that would need to be pumped to maintain the water table below the level of the vaults. More frequent operation of the current system or additional wells and pumps may be needed. Elimination of surface water infiltration and possibly also a reduction in groundwater flow (as described in the preceding sections) may be necessary for this option to be effective.

5.2.10 Barrier Around the Vaults

A solid barrier to groundwater flow could be installed if more positive exclusion of groundwater from the vaults is needed. This barrier could be a solid grout wall, a frozen soil barrier, or a viscous liquid barrier.

Jet Grout Barriers have been demonstrated at the Hanford 400 Area and at Brookhaven National Laboratory. At Hanford, a cone-shaped barrier was placed around a simulated waste form. The barrier material was cement and a high-molecular polymer. The barrier integrity was verified using nonintrusive geophysical techniques. At Brookhaven, a v-shaped cementitious barrier was emplaced beneath a mixed waste pit approximately 6 m (20 ft) wide by 12 m (40 ft) long and 6 m (20 ft) deep (SCFA 1994).

Another type of barrier is a frozen soil barrier. Frozen soil barrier technology consists of installing subsurface heat transfer devices around a contaminant source to freeze soil pore water, which creates a frozen soil boundary that is impervious to groundwater movement. The frozen soil barrier isolates the contaminant source from the surrounding groundwater, preventing transport of contaminants to adjacent areas. The barrier is maintained in situ until the source of contamination is physically removed, treated, decayed to acceptable levels, or otherwise remediated. At that point, the system is powered down and the frozen barrier eventually thaws. If the barrier is removed prior to remediation, the site will return to its pre-barrier configuration, as will the mechanism of contaminant transport from the source.

Demonstration of an innovative frozen soil barrier technology for containment of subsurface radioactive contaminants was conducted at Oak Ridge National Laboratory in Oak Ridge, Tennessee, from September 1996 through September 1998. Groundwater monitoring and dye tracer results indicate that the frozen soil barrier hydraulically isolates a hazardous waste area from the surrounding area. The project cost approximately $1,809,000, including design,

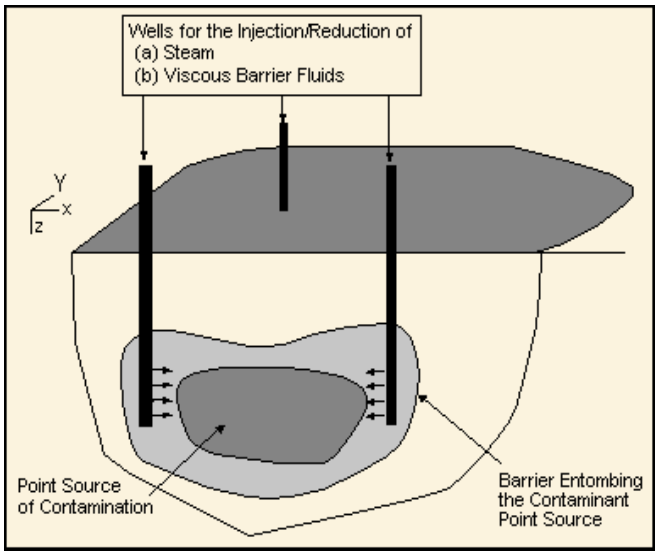
installation, startup, system operation, engineering oversight, site infrastructure upgrades, and pre- and post-barrier verification studies. The system requires approximately 288 kilowatt-hours of electrical power per day to maintain the frozen soil barrier (USEPA 1999).

Another barrier system uses inert liquids that increase their viscosity after being injected into the soil to form an impermeable wall. These barriers are similar to frozen soil barriers in that they surround and contain a plume. Unlike frozen soil barriers, viscous liquid barriers are a gel-like mass rather than a wall of frozen subsurface moisture.

The U.S. Department of Energy has investigated three types of viscous liquid barrier materials (SCFA 1997). The first type of fluid is a member of the polybutene, or PB, family.
The viscosity of PB is temperature sensitive. It is practically solid at surrounding groundwater temperatures. PB will not dissolve in water and is impermeable to water and gases. Installation of PB barriers requires heating the soil. The liquid is injected at the same temperature as the soil, then the barrier forms as the soil cools. The second fluid is polysiloxane (PSX). PSX is a silicon-based polymer that is unaffected by the chemistry of the aquifer. The viscosity increase in PSX is the result of mixing with other substances and temperature control. The third barrier fluid is colloidal silica. Colloidal silica is a silicon-based grout that is installed using a cooling process, or gelation. The pH, temperature, and the chemistry of the soil and groundwater affect the time required for colloidal silica to gel.

A viscous liquid barrier could be placed completely around the tanks and vaults to totally entomb them. This would prevent any water intrusion during the temporary lay-up period. Figure 3 is a graphic showing a viscous liquid barrier (SCFA 1997).

Figure 3. Diagram of a Viscous Liquid Barrier



5.2.11 Corrosion Inhibitors in the Water Outside the Tanks

Adding corrosion inhibitors to water in the containment pans may reduce the corrosion on the outer walls. Corrosion inhibitors would not be effective for reducing corrosion in the high humidity vapor space above the liquid level.

5.2.12 Radionuclide/Hazardous Material Sorbents to the Annulus

An ion exchange and/or sorbent material could be added to the secondary containment pan and/or the vault to capture the radioactive species before they could migrate outside the vault. Additional information would be required to determine if a combination of materials could be selected which would be effective for all the species of concern.

5.2.13 Low Strength Grout in Tanks to Stabilize Residual Heels

This option provides a method for temporarily fixing the residual waste in the tank. Nearly all the residual liquid would have to be removed before the grout was added. A low strength grout would be necessary so that it could be removed in the future if final closure requires additional decontamination of the tanks or complete removal of the tanks.

5.2.14 Fixative to Prevent Suspension of Internal Contamination

Another option for temporary stabilization of the residual material in the tank would be to spray a coating to prevent any suspension of contamination. This option could be used in combination with the option to keep the inside of the tanks dry to prevent corrosion or to reduce contaminated solids suspension if the tank contents are allowed to dry during the lay-up period. In fact, the tank contents would first have to be dry before a fixative could be applied.

5.2.15 Corrosion Monitors in Key Locations

Continuous corrosion monitors could be installed in the tanks and vaults. These monitors would provide an indication of accelerated corrosion due to unexpected changes.

The electrochemical noise probe is being developed as a corrosion-monitoring tool for HLW tanks. This technique can provide real-time, on-line measurements of the corrosion processes in the tank, including the most probable processes of pitting and stress corrosion cracking. Development of the electrochemical noise probe was initiated at Hanford (3 units have been deployed) and is being adapted for the Savannah River Site. Development and deployment of a stainless steel probe for application at the Oak Ridge Reservation is planned. Data from the currently installed probes is being analyzed to validate the electrochemical noise corrosion probe as an alternative for monitoring HLW tank corrosion. An electrochemical noise probe may be an acceptable method for monitoring the corrosion of the WVDP tanks during the lay-up period (PNNL-13339).

A corrosion species monitor is being developed by the U.S. Department of Energy Characterization, Monitoring and Sensor Technology Crosscutting Program as a technique for real-time, on-line monitoring of waste chemistry. A robust, in situ probe that uses Raman spectroscopy for analysis is capable of measuring the nitrite/nitrate concentration and the hydroxide concentration. EIC Laboratories are developing the Raman probe. The corrosion species monitor will be combined with an electrochemical noise corrosion probe (see above) for deployment at the Savannah River Site.

Depending on the composition of waste in the WVDP carbon-steel tanks, the tanks may be susceptible to nitrate ion-induced corrosion cracking. Monitoring and maintaining adequate

nitrite/nitrate ratio and hydroxide ion levels prevents this degradation. Sensors that could monitor all three species could reduce the costs of current baseline sampling and laboratory analysis methods and could minimize the addition of corrosion inhibitor solution.

5.2.16 Radiation/Contamination Monitors for Early Detection of Any Leakage

Radiation and/or contamination monitors in the tanks or vaults would indicate changes in conditions and possible leaks. There are several monitors on the market that could be installed to give early warning of a tank failure. A gamma monitor would need to be shielded from the background radiation inside the tank, or an alpha and/or beta monitor could be used.

5.2.17 Complete Removal of All Residual Waste

Very aggressive decontamination could be employed prior to temporary tank lay-up. Removal of all but a very small amount of residual contamination may preclude the need for any further action prior to final closure. This option might have a lower lay-up cost than other options that require continued operation of equipment (such as the nitrogen purge system) and surveillance. However, the criteria for what constitutes adequate decontamination are not established and any residual contamination could present a risk to the environment.

5.3 OPTIONS IDENTIFIED AND DISCARDED AS NOT VIABLE

5.3.1 Fill Annulus with Material Impervious to Water

A waterproof material, such as that used for a viscous liquid barrier, could be injected into the annulus. To be effective, the vault would probably need to be dried before the material is added. Verification of effective application to the entire tank surface would be difficult, especially the bottom of the tank. Assurance that moisture would not migrate between the material and the tank wall would also be difficult.

5.3.2 Add a Coating to the Tank and/or Vault Wall

A coating could be applied to the exterior tank wall to protect the metal surfaces from moisture. This would require cleaning of rust and other corrosion products from the walls and drying the walls before applying the coating. This disruption of the surface could actually cause a leak. Also, application to the bottom of the tank would not be possible.

5.3.3 Assess Worst-Case Impact of Credible Leak

An assessment of the impact of a credible loss of material from the tanks could be assessed. The fate and transport of residuals into the environment could be modeled assuming tank failure. This might determine that the risk is acceptable. However, this option is unlikely to achieve regulatory and stakeholder acceptance.

5.4 STRATEGIES TO BE CONSIDERED

There are many combinations of the options described above that would constitute reasonable strategies for tank lay-up. The combinations recommended for consideration are listed below and are depicted on Table 1 on the next page. There may be other options and combinations of options that can be considered when the final ranking is done. The options are categorized as "wet" or "dry." The "dry" options would result in preventing further corrosion of the tanks during the lay-up period. The "wet" options would result in some amount of continued corrosion, but with reasonable assurance of no loss of radioactive material to the environment.

5.4.1 Current System (see Section 5.1)

5.4.2 Cathodic Protection (see Section 5.2.1)

5.4.3 Vault Drying (see Section 5.2.2)

5.4.4 Vault & Tank Drying (see Section 5.2.3)

5.4.5 Nitrogen Blanket (see Section 5.2.4)

5.4.6 Nitrogen Blanket with Oxygen Removal (see Section 5.2.5)

Oxygen removal from the gas surrounding the tanks to a low level (the original design criterion for the nitrogen purge was less than 0.9% oxygen) may provide adequate protection without additional measures taken to keep the vaults dry. An efficient nitrogen blanket (recirculating system) would be required for this option.

5.4.7 Argon Blanket (see Section 5.2.6)

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults. Proper use of an argon blanket should not require additional capability for oxygen removal.

5.4.8 Argon Blanket with Cathodic Protection

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults in combination with cathodic protection for additional assurance of corrosion control.

5.4.9 Interceptor Trench (see Section 5.2.7)/Drying

Installation of an interceptor trench would enhance the ability to keep the vaults at < 30% relative humidity. The clay layer surrounding the vaults has a very low permeability to water flow, so a trench to that depth would be very effective in collecting surface water runoff and groundwater in the upper sand/soil layer and diverting it downgrade from the tanks and vaults.

Table 1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up

Strategy	Dry or Wet Option	Nitrogen Inerting	pH Control	Cathodic Protection	Vault Drying	Tank Drying	Nitrogen Blanket	Ar Inerting	Oxygen Removal	Intercep-tor Trench	Ground-water Barrier	Infiltra-tion Barrier	Enhanced Pumping	Corrosion Inhibitors	Sorbents in Annulus	Low Strength Grout	Contami-nation Fixative	Corrosion Monitors	Radiation/ Contami-nation Monitors	Complete Waste Removal
Current System	Wet	X	X																	
Cathodic Protection	Wet	X	X	X																
Vault Drying	Dry		X		X															
Vault & Tank Drying	Dry				X	X														
Nitrogen Blanket	Wet		X				X													
Nitrogen Blanket w/Oxygen Removal	Wet		X				X		X											
Argon Blanket	Wet		X					X												
Argon Blanket w/Cathodic Protection	Wet		X	X				X												
Interceptor Trench/Drying	Dry		X		X					X										
Trench/Infiltration Barrier/Drying	Dry		X		X					X		X								
Trench/Infiltration Barrier/Drying/Enhanced Pumping	Dry		X		X					X		X	X							
Groundwater Barrier/Drying	Dry		X		X						X									
Infiltration Barrier/Drying	Dry		X		X							X								
Corrosion Inhibitors in Vault	Wet	X	X											X						
Sorbents in Annulus	Wet	X	X												X					
Sorbents with Cathodic Protection	Wet	X	X	X											X					
Low Strength Grout	Wet	X														X				
Low Strength Grout/Drying	Dry				X	X										X				
Contamination Fixative/Drying	Dry				X	X											X			
Monitors	Wet		X															X	X	
Waste Removal	Wet																			X

5.4.10 Trench/Infiltration Barrier (see Section 5.2.8)/Drying

To increase the effectiveness of a trench, a domed clay cap, roof or some other cover barrier could be added above the vaults to divert rainwater and snowmelt to the trench rather than infiltrating through the soil to the vaults.

5.4.11 Infiltration Barrier/Drying/Enhanced Pumping (see Section 5.2.9)

If the combination of a trench, infiltration barrier and drying system was not effective, then additional pumping of water from inside and below the vaults could be instituted. The need for additional pumping is unlikely.

5.4.12 Groundwater Barrier (5.2.10)/Drying

A barrier around the vaults may be a more positive means to preclude water intrusion than would an interceptor trench. However this would be a much more costly approach and may not be necessary. Also, ponding (perched water) could accumulate behind the barrier.

5.4.13 Infiltration Barrier/Drying

A barrier above the tanks would be very effective in preventing water intrusion into the vaults. The combination of a barrier above the vaults and a drying system (no interceptor trench or barrier) may be adequate for keeping the vault humidity within an acceptable level. This is dependent on the amount of water that could infiltrate the vaults from groundwater flow alone, which appears to be quite small.

5.4.14 Corrosion Inhibitors in Containment Pan (see Section 5.2.11)

5.4.15 Sorbents in Annulus (see Section 5.2.12)

5.4.16 Sorbents with Cathodic Protection

This would be a relatively low cost option of adding a cathodic protection system and also sorbents for added protection in the unlikely event of a leak. However, reliable corrosion control with cathodic protection alone is uncertain.

5.4.17 Low Strength Grout (see Section 5.2.13)

5.4.18 Low Strength Grout/Drying

This would be the combination of adding a low strength grout and a drying system for the tanks and vaults. The drying system would be very effective in reducing corrosion and the grout would stabilize the radionuclides and reduce or possibly prevent leakage even if a penetration in the tank wall developed.

5.4.19 Contamination Fixative (see Section 5.2.14)

This would be the combination of a fixative and a drying system for the tanks and vaults. The drying system would be very effective in reducing corrosion and the fixative would stabilize the radionuclides and dispersion into the off-gas system.

5.4.20 Monitors (see Sections 5.2.15 and 5.2.16)

5.4.21 Waste Removal (see Section 5.2.17)

6.0 INFORMATION NEEDS TO SUPPORT LAY-UP DECISION

Several options for temporary lay-up of the tanks have been previously proposed and partially assessed. Other options have only recently been proposed. The principal information needs for a final decision on the preferred approach are listed below.

- A better estimate of the remaining corrosion allowance for the tanks.
- An estimate of the maximum rate of surface runoff from rain and/or snowmelt to establish the size of an interceptor trench in order to determine a cost estimate for that option. Are there existing storm sewers or other drainage systems?
- Data to establish if pumping from below the vaults alone would reduce water infiltration into the vaults low enough for a drying system to be effective.
- Determination of whether maintaining a liquid inventory inside the tanks with continued chemistry adjustments is adequate to control internal corrosion.
- Determination of whether effective control of the oxygen concentration in the gas in the annuli alone can control external corrosion within an acceptable rate. If so, is an oxygen removal system needed or will a better inert gas system suffice?
- Determine if a system to maintain the vaults and all external surfaces of the tanks dry is necessary to ensure an acceptable corrosion rate.
- Determine if a tank wall penetration must be prevented during lay-up or if small penetrations that would not result in releases outside the tanks or vaults would be acceptable.
- Resolution of the technical and engineering issues related to cathodic protection (see Section 5.1.2).
- Determination of the acceptability of using argon rather than nitrogen due to the higher cost and safety concerns.
- Determination of whether the pumps in the catch pans need to be relocated to be at the lowest point.
- Determine if sorbent material(s) could capture leaking radionuclides.

- Estimates of the expected life of potential groundwater barrier systems.
- A more detailed assessment of adding corrosion inhibitors to the water in the vault.
- Feasibility of decontamination prior to lay-up precluding the need for any further preparation for lay-up.
- Updates to existing preliminary cost estimates and new preliminary cost estimates for several options, including:
  - Installation of an interceptor trench or an underground barrier
  - Installation of an infiltration barrier
  - Addition of a roof above the vaults and tanks
  - Installation and operation of an oxygen removal system
  - Continuous corrosion monitoring of tanks' external surfaces.

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DECISION PLAN FOR WEST VALLEY HIGH-LEVEL WASTE TANK LAY-UP

May 25, 2001

Prepared for
Tanks Focus Area

Prepared by
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CONTENTS

1.0 INTRODUCTION 1

2.0 OBJECTIVES 1

3.0 EVALUATION CRITERIA FOR SELECTION OF PREFERRED OPTION 1

4.0 ALTERNATIVE LAY-UP STRATEGIES 2
- 4.1 CURRENT SYSTEM 2
- 4.2 CATHODIC PROTECTION FOR EXTERNAL TANK SURFACES 3
- 4.3 VAULT DRYING SYSTEM 3
- 4.4 VAULT AND TANK DRYING 3
- 4.5 NITROGEN BLANKET 4
- 4.6 NITROGEN BLANKET WITH OXYGEN REMOVAL 4
- 4.7 ARGON OR OTHER HIGH DENSITY INERT GAS INSTEAD OF NITROGEN 4
- 4.8 ARGON BLANKET WITH CATHODIC PROTECTION 4
- 4.9 INTERCEPTOR TRENCH/DRYING 4
- 4.10 TRENCH/INFILTRATION BARRIER/DRYING 5
- 4.11 INFILTRATION BARRIER/DRYING/ENHANCED PUMPING 5
- 4.12 GROUNDWATER BARRIER/DRYING 5
- 4.13 INFILTRATION BARRIER/DRYING 5
- 4.14 CORROSION INHIBITORS IN THE WATER OUTSIDE THE TANKS 6
- 4.15 SORBENTS IN ANNULUS 6
- 4.16 SORBENTS WITH CATHODIC PROTECTION 6
- 4.17 LOW STRENGTH GROUT 6
- 4.18 LOW STRENGTH GROUT/DRYING 6
- 4.19 CONTAMINATION FIXATIVE 6
- 4.20 MONITORS 6
- 4.21 WASTE REMOVAL 7

5.0 UNCERTAINTY OF STRATEGIES 7

6.0 DECISION PLAN METHODOLOGY 9
- 6.1 TEAM SCORES 12
- 6.2 SENSITIVITY ANALYSIS 18
  - 6.2.1 Variations in Team Scoring 18
  - 6.2.2 Sensitivity of Weighting Factors 18

7.0 CONCLUSIONS AND RECOMMENDATIONS 21

8.0 REFERENCES 26

TABLES

1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up 8
2. Team Scoring Sheet 10
3. Team Rankings 14
4. Combined Rankings of Team Members 16
5. Weighting Factor Averages 17
6. Comparison of Scoring Averages 19
7. Ranking Comparisons 20
8. Rankings Using Alternate Weighting Factors 23
9. Combined Rankings by Weighting Factors 25

1.0 INTRODUCTION

This report documents completion of Milestone A.3-1, "Issue Decision Plan for WVDP Tank Lay-Up," in Technical Task Plan RL30WT21A, "Post-Retrieval and Pre-Closure HLW Tank Lay-Up." This task is a collaborative effort among Pacific Northwest National Laboratory, Jacobs Engineering Group Inc., and West Valley Nuclear Services. The primary objective of the overall task is to develop and evaluate conceptual strategies for preclosure lay-up of the two large high-level waste storage tanks at the West Valley Demonstration Project.

Functions and requirements for tank lay-up were developed and previously documented in *Functions and Requirements for WVDP Lay-Up* (Henderson 2001a [Letter Report #1]). These functions and requirements served as the basis for criteria to evaluate potential lay-up options documented in *West Valley High-Level Waste Tank Lay-Up Strategies* (Henderson 2001b [Letter Report #2]).

2.0 OBJECTIVES

This report has two objectives:

- Present a methodology for selecting a preferred strategy for West Valley Demonstration Project tank lay-up.
- Present the results of an example application of the methodology including a sensitivity analysis.

3.0 EVALUATION CRITERIA FOR SELECTION OF PREFERRED OPTION

The following selection criteria were previously developed for evaluating options for tank lay-up (Letter Report #1). Two criteria were expanded into subcriteria for the scoring methodology.

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period.
- **Prevent release of tank contents to the groundwater** – There shall be no release of radioactive or hazardous materials to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.
- **Ensure acceptable risk to workers and the public**
  - Short-Term Risk: The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable.
  - Long-Term Risk: The selected option should result in a reduced risk to workers and the public during the lay-up period.
- **Maintain integrity of the tanks** – The ability of the tanks to continue to contain the waste residual must be maintained. Corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up** – The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control costs**

  - Capital costs of new equipment or modifications to existing systems.
  - Routine operating costs during the lay-up period.

- **Utilize accepted methods and technologies** – The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation** – Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be generally avoided.

- **Preserve future options for decontamination and final closure** – The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude candidate final closure options, such as in-place stabilization or complete tank removal.

- **Gain acceptance for lay-up** – The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.

- **Reduce monitoring and surveillance** – Reductions in monitoring and surveillance, consistent with requirements, is desired.

4.0 ALTERNATIVE LAY-UP STRATEGIES

Several alternative actions were identified to provide for continued safe storage of the residual waste in the tanks prior to final closure (Letter Report #2). The lay-up strategy selected must provide for placing the tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options.

4.1 CURRENT SYSTEM

The historical methods of corrosion control have been to periodically remove water from the containment pan, control the pH and nitrite/nitrate ratio of the liquid inside the tanks, and maintain a nitrogen purge inside the vaults. The corrosion rate of the tank internals is believed to be controlled in the range of 0.013 to 0.025 mm/yr (0.5 to 1.0 mpy[1]) (Chang et al. 1999). However, pH and nitrate limits have not been rigorously maintained since waste retrieval operations began, decreasing the level of the confidence of corrosion control.

[1]Note: mpy = mils per year; a mil is 1/1000 of an inch.

Pumps are currently used to remove water from outside and inside the tank vaults. However, there will continue to be a concern that corrosion to the external surfaces of the tanks could eventually result in penetrations during the lay-up period. Corrosion of the external tank walls is primarily from the wet conditions inside the vaults. General corrosion rates determined from corrosion coupons are generally less than 3 mpy and the highest measured rate is 0.188 mm/yr (7.4 mpy) (Chang et al. 1999). The external pitting corrosion rate has been estimated at up to 0.3 ± 0.075 mm/yr (12 ± 3 mpy) (Chang et al. 1998). If this rate has been experienced since the tanks were built, there may be little remaining corrosion allowance at locations prone to pitting.

The nitrogen inerting system has been in operation since August 1996. The oxygen concentration in the vault exhaust gas has been maintained at about 13.5% to 15.5% (oxygen concentration in air is 21%) even though the system was originally designed to maintain the oxygen concentration below 0.99% (WVNS-DC-065). Assuming an even distribution of nitrogen in the vaults, use of the system has resulted in an estimated decrease in the external corrosion rate of tank 8D-1 by about 33% (Chang et al. 1999). The nitrogen inerting system also reduces the concentration of other impurities in the gas surrounding the tanks, such as sulfur dioxide, that can also accelerate corrosion.

4.2 CATHODIC PROTECTION FOR EXTERNAL TANK SURFACES

Addition of cathodic protection to the tanks has been assessed. One alternative method for cathodic protection identified is to use the containment pan as the sacrificial anode.
The tank 8D-2 containment pan is known to have a hole in it, so use as a sacrificial anode would be reasonable since its original purpose is already compromised. There are several technical and engineering issues that must be resolved before this option could be selected. These include (1) galvanic corrosion on the bottom of the tank; (2) runaway voltage with the impressed current system; (3) protection of welds; and (4) assurance that no electrical shorts are present (e.g., pan pump, dip tubes) (Chang et al. 1999).

4.3 VAULT DRYING SYSTEM

General textbook corrosion rates of carbon steel in water are generally 0.075 to 0.20 mm/yr (3 to 8 mpy) and pitting corrosion rates are generally 2.5 to 3.5 times the general corrosion rate. External tank corrosion could be virtually eliminated if the tank surfaces were kept dry.
The criterion would be to maintain the relative humidity below 30% in the air surrounding the tanks (Chang et al. 1998). The drying system would include a dehumidifier and heater for air forced into the vaults. The exhaust air leaving the vaults would pass through high-efficiency particulate air filters.

4.4 VAULT AND TANK DRYING

An additional enhancement to also reduce corrosion inside the tanks is to install drying systems both inside the vaults and inside the tanks. Drying the inside of the tanks could result in contamination of the exhaust air by particles of dried solids in the tanks being suspended by the airflow through the tanks. However, once all the liquid inside the tanks was evaporated, only a very low flow of heated, dehumidified air would be required to maintain low humidity inside the

tanks. Keeping the tank internals the same temperature as the external surfaces would also prevent condensation of water on the tanks' external walls.

4.5 NITROGEN BLANKET

The current nitrogen inerting system has not been effective in maintaining the desired concentration of oxygen in the vault below 0.9% as specified in the design criteria (WVNS-DC-065). Sealing the vault as well as possible and then adding additional amounts of cold nitrogen to displace air from the vault should result in a more effective blanket and lower oxygen concentrations.

4.6 NITROGEN BLANKET WITH OXYGEN REMOVAL

Oxygen removal from the gas surrounding the tanks to a low level (the original design criterion for the nitrogen purge was less than 0.9% oxygen) may provide adequate protection without additional measures taken to keep the vaults dry. An efficient nitrogen blanket (recirculating system) would also be required for this option. Recirculated blanket gas could be passed through a device to remove oxygen. Such a system would be efficient only if air in-leakage is significantly reduced.

4.7 ARGON OR OTHER HIGH DENSITY INERT GAS INSTEAD OF NITROGEN

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults because argon is heavier than air. Proper use of an argon blanket should not require additional capability for oxygen removal. This option has been considered in the past, as early as 1997 (Meess and Chang 1997).

4.8 ARGON BLANKET WITH CATHODIC PROTECTION

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults in combination with cathodic protection for additional assurance of corrosion control.

4.9 INTERCEPTOR TRENCH/DRYING

One of the primary methods of preventing or significantly reducing corrosion on the outside of the tanks is to maintain very low humidity in the vaults. In order to do this, the ingress of water into the vaults must be prevented. The principal source of water into the vaults appears to be from percolation of rainwater and snowmelt through the soil layer above the vaults and groundwater flow in the soil/sand layer above the compacted clay layer. One method to significantly reduce this infiltration is to divert runoff and groundwater flow. This could be accomplished by installing an interceptor trench down to the compacted clay layer upgradient of the tanks. This trench would be filled with coarse gravel and perforated pipe would be installed at the bottom of the trench to collect and remove excess water. The trench would be connected to a culvert to carry water to an appropriate location downgradient from the tanks and vaults. This would be a totally passive system. Pumping of water from the vaults and the well between the vaults could be eliminated or significantly reduced.

4.10 TRENCH/INFILTRATION BARRIER/DRYING

To increase the effectiveness of a trench, a domed clay cap, roof or some other cover barrier could be added above the vaults to divert rainwater and snowmelt to the trench rather than infiltrating through the soil to the vaults.

A principal source of water ingress into the tank vaults appears to be from infiltration from above the vaults. A cover to divert rainwater away from the area would be effective in preventing this water from entering the vaults. This barrier could be a clay cap, a membrane, a roof or some other cover. Installation of a barrier above the vaults is complicated by the superstructure that was installed to support the mobilization pumps and penetrations into the soil above the tanks and vaults.

4.11 INFILTRATION BARRIER/DRYING/ENHANCED PUMPING

To ensure that water will not infiltrate into the vaults from groundwater around and below the vaults, the capability to pump water from the gravel bed below the vaults could be maintained or enhanced. Water is currently pumped from a well between the vaults, but the water table is not pumped to below the bottom of the vaults. The hydrology is not known well enough to determine the volume of water that would need to be pumped to maintain the water table below the level of the vaults. More frequent operation of the current system or additional wells and pumps may be needed. Elimination of surface water infiltration and possibly also a reduction in groundwater flow (as described in the preceding sections) may be necessary for this option to be effective.

If the combination of a trench, infiltration barrier and drying system was not effective, then additional pumping of water from inside and below the vaults could be instituted. The need for additional pumping is unlikely.

4.12 GROUNDWATER BARRIER/DRYING

A solid barrier to groundwater flow could be installed if more positive exclusion of groundwater from the vaults is needed. This barrier could be a solid grout wall, a frozen soil barrier, or a viscous liquid barrier.

A barrier around the vaults may be a more positive means to preclude water intrusion than would an interceptor trench. However this would be a much more costly approach and may not be necessary. Also, ponding (perched water) could accumulate behind the barrier.

4.13 INFILTRATION BARRIER/DRYING

A barrier above the tanks would be very effective in preventing water intrusion into the vaults. The combination of a barrier above the vaults and a drying system (no interceptor trench or barrier) may be adequate for keeping the vault humidity within an acceptable level. This is dependent on the amount of water that could infiltrate the vaults from groundwater flow alone, which appears to be quite small.

4.14 CORROSION INHIBITORS IN THE WATER OUTSIDE THE TANKS

Adding corrosion inhibitors to water in the containment pans may reduce the corrosion on the outer walls below the liquid level. Corrosion inhibitors would not be effective for reducing corrosion in the high humidity vapor space above the liquid level.

4.15 SORBENTS IN ANNULUS

An ion exchange and/or sorbent material could be added to the secondary containment pan and/or the vault to capture the radioactive species before they could migrate outside the vault. Additional information would be required to determine if a combination of materials could be selected which would be effective for all the species of concern.

4.16 SORBENTS WITH CATHODIC PROTECTION

This would be a relatively low cost option of adding a cathodic protection system and also sorbents for added protection in the unlikely event of a leak. However, reliable corrosion control with cathodic protection alone is uncertain.

4.17 LOW STRENGTH GROUT

The objective of this option is to provide a method for temporarily fixing the residual waste in the tank. Nearly all the residual liquid would have to be removed before the grout was added. A low strength grout would be necessary so that it could be removed in the future if final closure requires additional decontamination of the tanks or complete removal of the tanks. Adequate mixing of the grout with the residual waste has not been demonstrated.

4.18 LOW STRENGTH GROUT/DRYING

This would be the combination of adding a low strength grout and a drying system for the tanks and vaults. The drying system would be very effective in reducing corrosion and the grout would stabilize the radionuclides and reduce or possibly prevent leakage even if a penetration in the tank wall developed.

4.19 CONTAMINATION FIXATIVE

Another option for temporary stabilization of the residual material in the tank would be to spray a coating to prevent any suspension of contamination. This option could be used in combination with the option to keep the inside of the tanks dry to prevent corrosion or to reduce contaminated solids suspension if the tank contents are allowed to dry during the lay-up period. In fact, the tank contents would first have to be dry before a fixative could be applied. The drying system would reduce corrosion and the fixative would stabilize the radionuclides and prevent dispersion into the off-gas system.

4.20 MONITORS

Radiation and/or contamination monitors in the tanks or vaults would indicate changes in conditions and possible leaks. There are several monitors on the market that could be installed to

give early warning of a tank failure. A gamma monitor would need to be shielded from the background radiation inside the tank, or an alpha and/or beta monitor could be used.

Continuous corrosion monitors could also be installed in the tanks and vaults. These monitors would provide an indication of accelerated corrosion due to unexpected changes.

Depending on the composition of waste in the West Valley Demonstration Project carbon-steel tanks, the tanks may be susceptible to nitrate ion-induced stress corrosion cracking. Monitoring and maintaining adequate nitrite/nitrate ratio and hydroxide ion levels prevents this degradation. Sensors that could monitor all three species could reduce the costs of current baseline sampling and laboratory analysis methods and could minimize the addition of corrosion inhibitor solution. Savannah River Site personnel are currently evaluating a Raman spectroscopy-based method for in situ analysis of OH^-, NO_2^-, and NO_3^-.

4.21 WASTE REMOVAL

Very aggressive decontamination could be employed prior to temporary tank lay-up. Removal of all but a very small amount of residual contamination may preclude the need for any further action prior to final closure. This option might have a lower lay-up cost than other options that require continued operation of equipment (such as the nitrogen purge system) and surveillance. However, the criteria for what constitutes adequate decontamination are not established and any residual contamination could present a risk to the environment.

Table 1 is a summary of the lay-up strategies considered for the West Valley Demonstration Project tanks.

5.0 UNCERTAINTY OF STRATEGIES

Several of the strategies for temporary lay-up of the tanks have been previously proposed and partially assessed. Other options have only recently been proposed. The effectiveness and acceptability of several of the options are not fully developed. The principal information needs identified to reduce the uncertainties are listed below.

- A better estimate of the remaining corrosion allowance for the tanks.
- An estimate of the maximum rate of surface runoff from rain and/or snowmelt to establish the size of an interceptor trench in order to determine a cost estimate for that option. Are there existing storm sewers or other drainage systems?
- Data and analysis to establish if pumping from below the vaults alone would reduce groundwater infiltration into the vaults to a rate low enough for a drying system to be effective.
- Determination of whether maintaining a liquid inventory inside the tanks with continued chemistry adjustments is adequate to control internal corrosion.

Table 1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up

Strategy	Dry or Wet Option	Nitrogen Inerting	pH Control	Cathodic Protection	Vault Drying	Tank Drying	Nitrogen Blanket	Ar Inerting	Oxygen Removal	Intercep-tor Trench	Ground-water Barrier	Infiltra-tion Barrier	Enhanced Pumping	Corrosion Inhibitors	Sorbents in Annulus	Low Strength Grout	Contami-nation Fixative	Corrosion Monitors	Radiation/Contami-nation Monitors	Complete Waste Removal
Current System	Wet	X	X																	
Cathodic Protection	Wet	X	X	X																
Vault Drying	Dry		X		X															
Vault & Tank Drying	Dry				X	X														
Nitrogen Blanket	Wet		X				X													
Nitrogen Blanket w/Oxygen Removal	Wet		X				X		X											
Argon Blanket	Wet		X					X												
Argon Blanket w/Cathodic Protection	Wet		X	X				X												
Interceptor Trench/Drying	Dry		X		X					X										
Trench/Infiltration Barrier/Drying	Dry		X		X					X		X								
Trench/Infiltration Barrier/Drying/Enhanced Pumping	Dry		X		X					X		X	X							
Groundwater Barrier/Drying	Dry		X		X						X									
Infiltration Barrier/Drying	Dry		X		X							X								
Corrosion Inhibitors in Vault	Wet	X	X											X						
Sorbents in Annulus	Wet	X	X												X					
Sorbents with Cathodic Protection	Wet	X	X	X											X					
Low Strength Grout	Wet	X														X				
Low Strength Grout/Drying	Dry				X	X										X				
Contamination Fixative/Drying	Dry				X	X											X			
Monitors	Wet		X															X	X	
Waste Removal	Wet																			X

- Determination of whether effective control of the oxygen concentration in the gas in the annuli alone can control external corrosion within an acceptable rate. If so, is an oxygen removal system needed or will a better inert gas system suffice?

- Determine if a system to maintain the vaults and all external surfaces of the tanks in a dry condition is necessary to ensure an acceptable corrosion rate. The primary concern is keeping the bottoms of the tanks dry.

- Determine if a tank wall penetration must be prevented during lay-up or if small penetrations that would not result in releases outside the tanks or vaults would be acceptable.

- Resolution of the technical and engineering issues related to cathodic protection.

- Determination of the acceptability of using argon rather than nitrogen due to the higher cost and safety concerns.

- Determination of whether the pumps in the catch pans need to be relocated to be at the lowest point.

- Determine if sorbent material(s) could capture all leaking radionuclides of concern.

- Estimates of the expected life of potential groundwater barrier systems.

- A more detailed assessment of adding and maintaining corrosion inhibitors in the water in the vault.

- Feasibility of decontamination prior to lay-up precluding the need for any further preparation for lay-up.

- Updates to existing preliminary cost estimates and new preliminary cost estimates for several options, including:

  - Installation of an interceptor trench or an underground barrier
  - Installation of an infiltration barrier
  - Addition of a roof above the vaults and tanks
  - Installation and operation of an oxygen removal system
  - Continuous corrosion monitoring of tanks' external surfaces.

6.0 DECISION PLAN METHODOLOGY

A methodology for ranking the strategies was developed. The methodology consists of scoring each strategy with each of the selection criteria. The scoring matrix is shown as Table 2.

A team was selected with a broad range of experience to provide scores on the matrix which were used to demonstrate the methodology. These sample scores provided a starting point for demonstrating the methodology. The ranking of strategies resulting from these scores are reported only to demonstrate the methodology and are not intended as a recommendation of preferred strategies. This methodology can be used by West Valley Nuclear Services and the U.S. Department of Energy to determine the preferred path forward.

Table 2. Team Scoring Sheet (2 Sheets)

Evaluation Criteria------>	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->															
STRATEGY															**SCORE**
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	
Current System															
Cathodic Protection															
Vault Drying															
Vault & Tank Drying															
Nitrogen Blanket															
Nitrogen Blanket w/Oxygen Removal															
Argon Blanket															
Argon Blanket w/Cathodic Protection															
Interceptor Trench/Drying															
Trench/Infiltration Barrier/Drying															
Trench/Infiltration Barrier/ Drying/Enhanced Pumping															
Groundwater Barrier/Drying															
Infiltration															

Table 2. Team Scoring Sheet (2 Sheets)

Evaluation Criteria------>	**Compliance with Regulations and Permits**	**Prevent Release of Contents**	**Acceptable Risk (Short Term)**	**Acceptable Risk (Long Term)**	**Maintain Tank Integrity**	**Safe Operating Envelope**	**Capital Cost**	**Operating Cost**	**Proven Methods and Technologies**	**Minimize Secondary Waste**	**Preserve Closure Options**	**Regulatory and Stakeholder Acceptance**	**Reduced Monitoring and Surveillance**	**Certainty of Strategy**	
Weighting Factor (1-5) --->															
STRATEGY															**SCORE**
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	
Barrier/Drying															
Corrosion Inhibitors in Vault															
Sorbents in Annulus															
Sorbents with Cathodic Protection															
Low Strength Grout															
Low Strength Grout/Drying															
Contamination Fixative/Drying															
Monitors															
Waste Removal															

The scoring team consisted of three personnel from the Richland Jacobs Engineering Office, three from the Denver Jacobs Engineering Office and three from PNNL. The disciplines represented were: (1) Chemist, (2) Chemical Engineer, (3) Civil Engineer, (4) Environmental Engineer, (5) Corrosion Engineer, (6) Hydrogeologist, (7) Mechanical Engineer, and (8) Regulatory Specialist (two). The scores provided by each team member are in the Attachment.

6.1 TEAM SCORES

The individual team rankings resulting from the scoring sheets are shown in Table 3. Team member B did not provide weighting factors, so the averages of the weighting factor scores from the other team members were used to determine scores for team member B. There are some interesting results from the individual scoring sheets. Note that team member A scored the grout options last, while team members F and G ranked them first. This may demonstrate a lack of understanding of this option by one or more of the team members. Scoring was completed on an individual basis and compiled for this report without a meeting to develop consensus for the weighting factors or scores. When the actual ranking of strategies is done, a meeting of all parties should be convened to discuss the scores and rankings and resolve such differences. The ranking from the raw scores and sensitivity analysis should merely serve as the starting point for the discussion.

The results shown in Table 3 indicate that the team members favored the strategy of using an interceptor trench, infiltration barrier and vault drying. This may be a result of this strategy being one of the more extensive in terms of the number of actions taken to prevent water from entering the vaults. The addition of enhancement pumping to these three actions also scored high. The options of using grout to stabilize the tank contents also scored well. The waste removal option also scored in the top five.

A combined ranking of the strategies from the team member rankings is shown in Table 4. The combined ranking is based on assigning a score of 5 to each #1 ranking, a score of 4 to each #2 ranking, etc. down to a score of 1 for each #5 ranking. Table 4 shows that the strategy of installing an interceptor trench in combination with an infiltration barrier and vault drying is clearly preferred. There is very little difference in the scores for the strategies ranked second through fifth. There are a number of strategies that ranked low indicating that there was little confidence by any of the team members that the strategies as described would meet the tank lay-up goals. The bottom 1/3 of the strategies could be eliminated from further consideration or the strategies could be reconfigured to combine elements into a strategy or strategies oriented at meeting the tank lay-up goals.

The scores provided by the team for weighting factors for each criterion are shown in Table 5. Table 5 also shows the variation in scores (range) and a calculated average (mean) and median for each criterion. There was a very wide disparity in several of the weighting factors. The range for some was from 1 to 5. Again, this is something that should be discussed by team members to understand the basis for the differences. The criterion that scored highest was Prevent Release of Tank Contents. Other criteria that scored high were:

- Acceptable Long Term Risk

- Maintain Tank Integrity
- Acceptable Short Term Risk
- Safe Operating Envelope
- Preserve Closure Options.

Table 3. Team Member Rankings (2 Sheets)

A	B	C	D	E	F	G	H	I
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Waste Removal	Waste Removal	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Interceptor Trench/Drying	Low Strength Grout/Drying	Low Strength Grout/Drying	Trench/Infiltration Barrier/Drying	Interceptor Trench/Drying
Trench/Infiltration Barrier/Drying	Vault Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout/Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout	Low Strength Grout	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Contamination Fixative/Drying
Groundwater Barrier/Drying	Vault & Tank Drying	Low Strength Grout	Current System	Nitrogen Blanket	Contamination Fixative/Drying	Vault & Tank Drying	Vault & Tank Drying	Vault Drying
Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Corrosion Inhibitors in Vault	Low Strength Grout	Sorbents in Annulus	Monitors	Waste Removal	Waste Removal	Trench/Infiltration Barrier/Drying
Vault & Tank Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Cathodic Protection	Waste Removal	Low Strength Grout	Groundwater Barrier/Drying	Current System	Low Strength Grout/Drying	Infiltration Barrier/Drying
Interceptor Trench/Drying	Sorbents with Cathodic Protection	Current System	Trench/Infiltration Barrier/Drying	Infiltration Barrier/Drying	Interceptor Trench/Drying	Infiltration Barrier/Drying	Interceptor Trench/Drying	Vault & Tank Drying
Corrosion Inhibitors in Vault	Sorbents in Annulus	Low Strength Grout/Drying	Infiltration Barrier/Drying	Monitors	Trench/Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Infiltration Barrier/Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping
Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket w/Oxygen Removal	Vault & Tank Drying	Vault Drying	Current System	Sorbents with Cathodic Protection	Argon Blanket w/Cathodic Protection	Vault Drying	Waste Removal
Argon Blanket w/Cathodic Protection	Nitrogen Blanket	Sorbents in Annulus	Groundwater Barrier/Drying	Low Strength Grout/Drying	Argon Blanket w/Cathodic Protection	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Groundwater Barrier/Drying	Corrosion Inhibitors in Vault
Cathodic Protection	Monitors	Vault Drying	Vault & Tank Drying	Argon Blanket	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Contamination Fixative/Drying	Contamination Fixative/Drying	Groundwater Barrier/Drying
Sorbents in Annulus	Low Strength Grout/Drying	Nitrogen Blanket	Corrosion Inhibitors in Vault	Sorbents with Cathodic Protection	Current System	Cathodic Protection	Nitrogen Blanket w/Oxygen Removal	Low Strength Grout/Drying
Vault Drying	Low Strength Grout	Argon Blanket	Argon Blanket w/Cathodic Protection	Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket w/Oxygen Removal	Vault Drying	Nitrogen Blanket	Current System

Table 3. Team Member Rankings (2 Sheets)

A	B	C	D	E	F	G	H	I
Sorbents with Cathodic Protection	Interceptor Trench/Drying	Argon Blanket w/Cathodic Protection	Interceptor Trench/Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Vault Drying	Sorbents with Cathodic Protection	Low Strength Grout	Low Strength Grout
Monitors	Infiltration Barrier/Drying	Sorbents with Cathodic Protection	Contamination Fixative/Drying	Corrosion Inhibitors in Vault	Waste Removal	Monitors	Corrosion Inhibitors in Vault	Nitrogen Blanket w/Oxygen Removal
Current System	Groundwater Barrier/Drying	Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket	Waste Removal	Argon Blanket	Nitrogen Blanket w/Oxygen Removal	Current System	Nitrogen Blanket
Argon Blanket	Current System	Infiltration Barrier/Drying	Cathodic Protection	Cathodic Protection	Vault & Tank Drying	Groundwater Barrier/Drying	Cathodic Protection	Monitors
Nitrogen Blanket	Corrosion Inhibitors in Vault	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Argon Blanket	Vault & Tank Drying	Nitrogen Blanket	Corrosion Inhibitors in Vault	Argon Blanket	Cathodic Protection
Contamination Fixative/Drying	Contamination Fixative/Drying	Contamination Fixative/Drying	Nitrogen Blanket w/Oxygen Removal	Groundwater Barrier/Drying	Infiltration Barrier/Drying	Sorbents in Annulus	Sorbents with Cathodic Protection	Sorbents with Cathodic Protection
Waste Removal	Cathodic Protection	Monitors	Sorbents with Cathodic Protection	Vault Drying	Sorbents in Annulus	Interceptor Trench/Drying	Monitors	Sorbents in Annulus
Low Strength Grout/Drying	Argon Blanket w/Cathodic Protection	Interceptor Trench/Drying	Monitors	Argon Blanket w/Cathodic Protection	Cathodic Protection	Argon Blanket	Argon Blanket w/Cathodic Protection	Argon Blanket
Low Strength Grout	Argon Blanket	Groundwater Barrier/Drying	Sorbents in Annulus	Contamination Fixative/Drying	Corrosion Inhibitors in Vault	Nitrogen Blanket	Sorbents in Annulus	Argon Blanket w/Cathodic Protection

Table 4. Combined Rankings of Team Members

Sorted by Rankings Score	Ranked #1	Ranked #2	Ranked #3	Ranked #4	Ranked #5	Rankings Score
Trench/Infiltration Barrier/Drying	1	3	2	0	0	23
Trench/Infiltration Barrier/Drying/ Enhanced Pumping	2	1	0	1	0	16
Low Strength Grout/Drying	2	1	0	0	1	15
Waste Removal	2	0	0	2	1	15
Low Strength Grout	0	2	1	1	1	14
Interceptor Trench/Drying	2	0	0	0	0	10
Vault & Tank Drying	0	0	3	0	1	10
Contamination Fixative/Drying	0	1	1	0	0	7
Vault Drying	0	1	1	0	0	7
Current System	0	0	1	0	1	4
Groundwater Barrier/Drying	0	0	1	0	1	4
Infiltration Barrier/Drying	0	0	0	1	1	3
Nitrogen Blanket	0	0	1	0	0	3
Corrosion Inhibitors in Vault	0	0	0	1	0	2
Monitors	0	0	0	1	0	2
Sorbents in Annulus	0	0	0	1	0	2
Cathodic Protection	0	0	0	0	1	1
Argon Blanket						0
Argon Blanket w/Cathodic Protection						0
Nitrogen Blanket w/Oxygen Removal						0
Sorbents with Cathodic Protection						0

Table 5. Weighting Factor Averages

Evaluation Criteria---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy
Team Member														
B	Did not supply weightings													
C	Did not weight from 1-5													
A	1	5	4	4	5	3	4	3	4	5	4	2	3	4
D	2	3	5	5	4	5	3	3	2	1	4	3	2	5
E	5	5	5	5	4	5	3	3	4	3	4	4	3	4
F	4	5	4	4	4	4	3	3	3	4	4	4	2	3
G	4	5	4	5	3	4	2	3	4	3	4	4	1	4
H	5	5	4	4	5	5	3	2	4	2	5	4	3	4
I	5	5	2	3	5	2	2	4	3	4	3	3	2	2
Mean (Average)	3.7	4.7	4.0	4.3	4.3	4.0	2.9	3.0	3.4	3.1	4.0	3.4	2.3	3.7
Median	4.0	5.0	4.0	4.0	4.0	4.0	3.0	3.0	4.0	3.0	4.0	4.0	2.0	4.0
Range	1-5	3-5	2-5	3-5	3-5	2-5	2-4	2-4	2-4	1-5	3-5	2-4	1-3	2-5

6.2 SENSITIVITY ANALYSIS

6.2.1 Variations in Team Scoring

The average scores for weighting factors were then used for a sensitivity analysis of the scores. The scores resulting from using the average weighting factors and each team member's scores for each strategy are shown in the Attachment (Table A-10). Scores that are particularly higher or lower than other team member scores are noted. The individual scores are light-shaded if that is the only score that is higher than all other scores and dark-shaded if that is the only score lower than all other scores. The total score is light-shaded if it is more than 20 points higher than the next lower score and is dark-shaded if it is more than 20 points lower than the next lowest score.

The high and low scores in Table A-10 were then adjusted to determine the effect on the rankings. The high scores (light) were adjusted to be equal to the next lowest score and the low scores (dark) were adjusted to be equal to the next highest score. The adjusted scores are shown in Table A-11.

The differences in average scores are shown in Table 6. The differences are small as would be expected due to the fairly large number of team members (nine).

A comparison in the rankings of the strategies using the averages of unadjusted scores and by adjusting the high and low scores is shown in Table 7. Again, there is little difference caused by individual scores being significantly different than scoring by other team members.

As long as there is a relatively large number of people scoring the strategies, average weighting factors and an average score for each criteria can be used to determine a ranking order from the scoring sheets. The high and low scores should not be discarded, but should be discussed.

6.2.2 Sensitivity of Weighting Factors

The effect of assigning higher or lower weighting factors to key criteria was assessed. The criteria were grouped as follows:

1. Risk Weight Factors
    a. Acceptable Risk (Short Term)
    b. Acceptable Risk (Long Term)
2. Safety / Compliance Factors
    a. Compliance with Regulations and Permits
    b. Prevent Release of Contents
    c. Maintain Tank Integrity

Table 6. Comparison of Scoring Averages

	Score using Average Weighting Factor and Individual Scores	Score using Average Weighting Factor and Average of Individual Scores	Combined Average Using All Scores (from Table A-10)	Combined Average With Adjusted Scores (from Table A-11)	Change in Combined Average from Using All Scores to Using Adjusted Scores
Argon Blanket	139.7	139.0	139.3	139.8	0.36%
Argon Blanket w/Cathodic Protection	145.1	145.3	145.2	145.5	0.21%
Cathodic Protection	148.6	148.3	148.4	147.2	-0.81%
Contamination Fixative/Drying	151.0	151.6	151.3	152.2	0.59%
Corrosion Inhibitors in Vault	152.7	153.3	153	149.3	-2.42%
Current System	151.5	151.8	151.7	153.1	0.92%
Groundwater Barrier/Drying	150.3	150.4	150.3	149.1	-0.80%
Infiltration Barrier/Drying	160.7	160.8	160.8	158.3	-1.55%
Interceptor Trench/Drying	155.4	155.6	156.5	155.6	-0.58%
Low Strength Grout	158.6	159.3	159	158.7	-0.19%
Low Strength Grout/Drying	167.9	168.7	168.3	167.7	-0.36%
Monitors	141.4	142.0	141.7	142	0.21%
Nitrogen Blanket	147.7	146.9	147.3	146.2	-0.75%
Nitrogen Blanket w/Oxygen Removal	145.6	145.1	145.4	146.5	0.76%
Sorbents in Annulus	136.3	135.4	135.4	137.7	1.70%
Sorbents with Cathodic Protection	139.8	140.0	139.9	142.4	1.79%
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	163.6	164.1	163.8	163.2	-0.37%
Trench/Infiltration Barrier/Drying	174.1	173.8	173.9	171.8	-1.21%
Vault & Tank Drying	166.0	167.3	166.6	166	-0.36%
Vault Drying	157.9	158.2	158	158.3	0.19%
Waste Removal	172.4	174.0	173.2	168.8	-2.54%

Table 7. Ranking Comparisons

Combined Average Using All Scores (from Table A-10)	Ranking from Averages	Combined Average With Adjusted Scores (from Table A-11)	Ranking from Adjusted Averages
173.9	Trench/Infiltration Barrier/Drying	171.8	Trench/Infiltration Barrier/Drying
173.2	Waste Removal	168.8	Waste Removal
168.3	Low Strength Grout/Drying	167.7	Low Strength Grout/Drying
166.6	Vault & Tank Drying	166	Vault & Tank Drying
163.8	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	163.2	Trench/Infiltration Barrier/ Drying/Enhanced Pumping
160.8	Infiltration Barrier/Drying	158.7	Low Strength Grout
159	Low Strength Grout	158.3	Infiltration Barrier/Drying
158	Vault Drying	158.3	Vault Drying
156.5	Interceptor Trench/Drying	155.6	Interceptor Trench/Drying
153	Corrosion Inhibitors in Vault	153.1	Current System
151.7	Current System	152.2	Contamination Fixative/Drying
151.3	Contamination Fixative/Drying	149.3	Corrosion Inhibitors in Vault
150.3	Groundwater Barrier/Drying	149.1	Groundwater Barrier/Drying
148.4	Cathodic Protection	147.2	Cathodic Protection
147.3	Nitrogen Blanket	146.5	Nitrogen Blanket w/Oxygen Removal
145.4	Nitrogen Blanket w/Oxygen Removal	146.2	Nitrogen Blanket
145.2	Argon Blanket w/Cathodic Protection	145.5	Argon Blanket w/Cathodic Protection
141.7	Monitors	142.4	Sorbents with Cathodic Protection
139.9	Sorbents with Cathodic Protection	142	Monitors
139.3	Argon Blanket	139.8	Argon Blanket
135.4	Sorbents in Annulus	137.7	Sorbents in Annulus

d. Safe Operating Envelope

e. Regulatory and Stakeholder Acceptance

3. Certainty

a. Certainty of Strategy

4. Cost

a. Capital Cost

b. Operating Cost

5. No Weight

This is a case where all the criteria are weighted the same.

The rankings from these cases can be compared to the base case using the average of the weighting factors scored by the team. The results of this analysis are shown in Table A-12. A summary of the results of the weighting factor sensitivity analysis is shown in Table 8. The strategies that scored highest with the average weighting factors generally scored highest in these sensitivity cases. The only significant difference is when the major criterion is cost; in this case, the current system scores highest. However, the current system may not result in lowest total life cycle cost.

Finally, a combined ranking from the results of the weighting factor comparisons was developed. This is shown in Table 9. The strategy including an interceptor trench, infiltration barrier and vault drying was still the favorite and relatively insensitive to weighting the different criteria more heavily.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The methodology developed for ranking the potential strategies for lay-up of the WVDP tanks will provide a basis for a decision on the preferred path forward. The methodology will provide a consensus ranking even with wide variations in scores from individual team members as long as the number of team members is large enough. A minimum of eight team members is recommended, and 10-12 would be better. The team members should represent a broad spectrum of technical experts and decision makers.

The current uncertainties associated with several strategies will tend to result in more costly and involved strategies to be favored. Strategy specific performance data could result in simpler strategies. Also, there may be other strategies and criteria identified during the process that will be ranked higher than most or all of the strategies identified in this report. In the absence of performance data for the strategies there is a tendency to rank the strategies on a relative basis because the minimum but sufficient effort to meet the tank lay-up goals is unknown.

All the strategies and criteria should be presented to the team members to ensure a common understanding. All available information should be provided to the team members at this time. The team should then determine if additional strategies should be scored and if the decision

criteria should be modified. Any changes to the strategies or criteria should be done before the scoring starts. Orientation, scoring, and discussions should be in a facilitated session or sessions.

A difficulty in evaluating the lay-up strategies for the WVDP tanks is that there is incomplete information on the cost and performance for several of the identified strategies. A recommended path forward would be to reevaluate the strategies identified in this report based on the example ranking and eliminate or reconfigure the strategies that were ranked at or near the bottom. Preconceptual engineering data should be developed for the remaining strategies to facilitate scoring and ranking using this methodology. The team members should be consulted to identify any additional information needs to support making informed decisions. The initial rankings will have to be made based on the available information.

Once each team member scores the alternatives, the scores can be combined as described in this report and the team members can then be reconvened to discuss the results. Any wide variations among scores should be discussed to ensure there are no errors. This discussion will also help team members share their points of view and expertise or experience on the strategies. The discussion can then focus on the composite ranking to determine if there is consensus. The team members should be allowed to discuss if they feel the list should be modified based on the information shared. The team should develop a final, consensus ranked list of the top five strategies. The team and WVDP and DOE management should then decide whether to proceed with conceptual design of the top one or two strategies or specify the additional information needed to make a final decision.

Table 8. Rankings Using Alternate Weighting Factors (2 Sheets)

No Weighting	Average	Safety/ Compliance	Risk	Certainty	Cost
Trench/Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout/Drying	Low Strength Grout/Drying	Trench/Infiltration Barrier/Drying	Current System
Waste Removal	Waste Removal	Trench/Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout/Drying	Infiltration Barrier/Drying
Low Strength Grout/Drying	Low Strength Grout/Drying	Waste Removal	Waste Removal	Waste Removal	Low Strength Grout
Vault & Tank Drying	Vault & Tank Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Low Strength Grout	Vault & Tank Drying	Vault Drying
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Vault & Tank Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Current System	Trench/Infiltration Barrier/Drying
Low Strength Grout	Low Strength Grout	Low Strength Grout	Vault & Tank Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Waste Removal
Vault Drying	Vault Drying	Contamination Fixative/Drying	Vault Drying	Infiltration Barrier/Drying	Corrosion Inhibitors in Vault
Infiltration Barrier/Drying	Infiltration Barrier/Drying	Interceptor Trench/Drying	Contamination Fixative/Drying	Low Strength Grout	Cathodic Protection
Current System	Interceptor Trench/Drying	Infiltration Barrier/Drying	Infiltration Barrier/Drying	Vault Drying	Vault & Tank Drying
Interceptor Trench/Drying	Current System	Vault Drying	Interceptor Trench/Drying	Interceptor Trench/Drying	Nitrogen Blanket
Contamination Fixative/Drying	Contamination Fixative/Drying	Groundwater Barrier/Drying	Current System	Corrosion Inhibitors in Vault	Interceptor Trench/Drying
Corrosion Inhibitors in Vault	Corrosion Inhibitors in Vault	Nitrogen Blanket w/Oxygen Removal	Corrosion Inhibitors in Vault	Contamination Fixative/Drying	Low Strength Grout/Drying
Groundwater Barrier/Drying	Groundwater Barrier/Drying	Argon Blanket w/Cathodic Protection	Monitors	Groundwater Barrier/Drying	Monitors

Table 8. Rankings Using Alternate Weighting Factors (2 Sheets)

No Weighting	Average	Safety/ Compliance	Risk	Certainty	Cost
Cathodic Protection	Cathodic Protection	Cathodic Protection	Groundwater Barrier/Drying	Monitors	Sorbents in Annulus
Nitrogen Blanket	Nitrogen Blanket w/Oxygen Removal	Corrosion Inhibitors in Vault	Nitrogen Blanket w/Oxygen Removal	Cathodic Protection	Contamination Fixative/Drying
Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket	Sorbents with Cathodic Protection	Argon Blanket w/Cathodic Protection	Nitrogen Blanket	Groundwater Barrier/Drying
Argon Blanket w/Cathodic Protection	Argon Blanket w/Cathodic Protection	Current System	Nitrogen Blanket	Nitrogen Blanket w/Oxygen Removal	Sorbents with Cathodic Protection
Monitors	Monitors	Nitrogen Blanket	Sorbents with Cathodic Protection	Argon Blanket w/Cathodic Protection	Argon Blanket
Sorbents with Cathodic Protection	Sorbents with Cathodic Protection	Argon Blanket	Cathodic Protection	Argon Blanket	Nitrogen Blanket w/Oxygen Removal
Argon Blanket	Argon Blanket	Sorbents in Annulus	Sorbents in Annulus	Sorbents with Cathodic Protection	Argon Blanket w/Cathodic Protection
Sorbents in Annulus	Sorbents in Annulus	Monitors	Argon Blanket	Sorbents in Annulus	Trench/Infiltration Barrier/ Drying/Enhanced Pumping

Table 9. Combined Rankings by Weighting Factors

Sorted by Rankings Score	Ranked #1	Ranked #2	Ranked #3	Ranked #4	Ranked #5	Rankings Score
Trench/Infiltration Barrier/Drying	3	2	0	0	1	24
Low Strength Grout/Drying	2	0	2	0	0	16
Waste Removal	0	2	2	0	0	14
Interceptor Trench/Drying	2	0	0	0	0	10
Contamination Fixative/Drying	0	1	1	0	0	7
Vault Drying	0	1	1	0	0	7
Current System	1	0	0	0	1	6
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	0	0	0	1	3	5
Vault & Tank Drying	0	0	0	2	1	5
Low Strength Grout	0	0	0	1	0	2
Argon Blanket						0
Argon Blanket w/Cathodic Protection						0
Cathodic Protection						0
Corrosion Inhibitors in Vault						0
Groundwater Barrier/Drying						0
Infiltration Barrier/Drying						0
Monitors						0
Nitrogen Blanket						0
Nitrogen Blanket w/Oxygen Removal						0
Sorbents in Annulus						0
Sorbents with Cathodic Protection						0

8.0 REFERENCES

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ATTACHMENT

WEST VALLEY DEMONSTRATION PROJECT DECISION PLAN METHODOLOGY RESULTS

TABLES

A-1. Team Member A Scoring Sheet A-1
A-2. Team Member B Scoring Sheet A-2
A-3. Team Member C Scoring Sheet A-3
A-4. Team Member D Scoring Sheet A-4
A-5. Team Member E Scoring Sheet A-5
A-6. Team Member F Scoring Sheet A-6
A-7. Team Member G Scoring Sheet A-7
A-8. Team Member H Scoring Sheet A-8
A-9. Team Member I Scoring Sheet A-9
A-10. Average Scores for Each Strategy A-10
A-11. Adjusted Average Scores for Each Strategy A-18
A-12. Scores with Alternative Weighting Factors A-26

Table A-1. Team Member A Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	1	5	4	4	5	3	4	3	4	5	4	2	3	4	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*255*
Current System	5	1	3	2	1	3	5	5	2	2	3	1	3	5	140
Cathodic Protection	5	3	3	2	3	3	3	4	3	2	4	3	2	3	150
Vault Drying	5	2	2	2	3	2	3	4	3	3	4	3	3	3	146
Vault & Tank Drying	5	3	3	3	4	3	2	3	3	3	4	3	3	3	160
Nitrogen Blanket	5	2	2	2	3	2	3	4	3	3	3	3	2	2	135
Nitrogen Blanket w/Oxygen Removal	5	3	3	3	4	3	2	3	3	3	3	3	3	2	152
Argon Blanket	5	3	2	2	3	2	3	4	3	3	3	3	2	2	140
Argon Blanket w/Cathodic Protection	5	3	3	3	4	3	2	3	3	3	3	3	3	2	152
Interceptor Trench/Drying	5	3	3	3	3	3	3	4	4	4	2	3	3	2	159
Trench/Infiltration Barrier/Drying	5	3	4	4	5	4	2	2	4	4	2	4	4	2	175
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	4	5	5	5	5	1	3	4	4	2	5	5	2	195
Groundwater Barrier/Drying	5	3	3	3	4	3	3	4	4	4	2	3	3	3	168
Infiltration Barrier/Drying	5	3	3	3	4	3	3	4	4	4	2	3	3	3	168
Corrosion Inhibitors in Vault	5	3	3	3	3	3	4	4	3	2	3	3	2	3	154
Sorbents in Annulus	5	4	3	3	2	3	3	4	4	2	3	3	2	2	150
Sorbents with Cathodic Protection	5	3	3	3	3	3	2	4	4	2	3	3	2	2	146
Low Strength Grout	5	2	3	3	2	3	3	4	2	1	2	2	3	2	124
Low Strength Grout/Drying	5	3	3	3	2	3	2	3	3	1	2	2	3	2	126
Contamination Fixative/Drying	5	2	3	3	2	3	2	3	2	2	3	3	3	3	132
Monitors	5	1	4	3	1	4	3	2	4	3	4	3	1	4	145
Waste Removal	5	2	1	1	2	1	2	4	4	2	5	5	3	2	129

Table A-2. Team Member B Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5)* --->	3.7	4.7	4.0	4.3	4.3	4.0	2.9	3.0	3.4	3.1	4.0	3.4	2.3	3.7	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*254*
Current System	4	2	3	1	1	3	4	2	4	3	4	2	1	2	130
Cathodic Protection	4	3	3	2	3	3	4	3	3	4	4	3	3	2	158
Vault Drying	4	3	4	3	3	3	3	3	2	3	4	4	2	2	158
Vault & Tank Drying	3	4	4	3	4	3	3	2	2	3	3	4	3	2	159
Nitrogen Blanket	4	2	4	2	2	3	4	2	3	4	4	3	2	2	148
Nitrogen Blanket w/Oxygen Removal	4	3	4	2	1	3	3	2	2	4	4	3	2	2	142
Argon Blanket	4	2	3	2	1	3	3	3	3	4	4	3	2	2	140
Argon Blanket w/Cathodic Protection	4	3	3	3	2	3	3	3	3	4	4	3	2	2	153
Interceptor Trench/Drying	3	2	2	2	2	2	2	3	2	3	4	4	2	1	123
Trench/Infiltration Barrier/Drying	3	2	2	2	2	2	2	3	2	3	4	4	2	1	123
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3	2	2	2	2	2	1	3	2	2	4	3	2	2	117
Groundwater Barrier/Drying	3	3	2	2	2	2	2	3	2	3	4	4	2	2	131
Infiltration Barrier/Drying	3	3	2	2	2	3	2	3	2	3	4	4	2	2	135
Corrosion Inhibitors in Vault	3	3	3	2	2	3	4	4	2	4	4	2	2	2	144
Sorbents in Annulus	3	2	2	1	2	3	4	4	2	4	4	2	2	1	127
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	3	3	4	4	2	2	2	142
Low Strength Grout	3	2	3	3	2	3	1	4	2	1	2	2	2	2	118
Low Strength Grout/Drying	3	3	4	4	3	3	1	3	3	1	2	3	3	2	141
Contamination Fixative/Drying	3	2	2	2	2	2	3	3	2	3	4	3	2	1	122
Monitors	3	1	3	3	0	4	4	4	3	3	4	2	3	1	133
Waste Removal	4	4	3	4	3	3	1	2	4	1	4	4	4	4	167

* - Team member B did not score weighting factors, so averages from the other team members were used

Table A-3. Team Member C Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	2	3	5	5	4	5	3	3	2	1	4	3	2	5	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*235*
Current System	3	1	4	3	1	5	5	4	5	3	4	3	3	2	154
Cathodic Protection	2	2	3	2	2	4	3	4	2	3	4	2	2	2	127
Vault Drying	3	2	4	3	2	3	3	3	4	2	4	4	3	2	142
Vault & Tank Drying	3	3	3	3	3	2	3	3	4	2	4	4	3	2	139
Nitrogen Blanket	3	2	3	3	2	3	3	3	2	2	4	3	2	2	128
Nitrogen Blanket w/Oxygen Removal	3	3	3	3	3	2	2	2	2	2	4	3	1	2	122
Argon Blanket	3	2	3	2	2	3	3	3	2	3	4	3	2	2	124
Argon Blanket w/Cathodic Protection	3	3	3	3	3	3	2	3	2	3	4	3	2	3	138
Interceptor Trench/Drying	3	3	2	3	3	3	2	3	3	1	4	4	3	2	133
Trench/Infiltration Barrier/Drying	4	4	1	4	4	3	1	3	3	1	4	4	3	4	149
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	5	1	5	5	3	1	2	3	1	4	4	1	5	161
Groundwater Barrier/Drying	4	4	2	3	3	3	1	3	3	1	4	4	3	3	140
Infiltration Barrier/Drying	4	2	2	3	3	3	2	3	4	2	4	4	3	4	145
Corrosion Inhibitors in Vault	3	3	4	1	2	3	4	4	5	3	4	3	2	2	139
Sorbents in Annulus	2	1	4	1	1	3	4	3	1	3	2	2	2	1	100
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	2	1	3	2	2	2	1	105
Low Strength Grout	3	2	3	3	3	4	4	4	4	4	1	4	4	4	154
Low Strength Grout/Drying	3	4	3	4	4	3	3	3	4	3	1	4	5	4	159
Contamination Fixative/Drying	3	3	3	3	2	3	4	2	4	3	2	2	3	3	132
Monitors	1	1	4	1	1	1	4	4	5	4	4	1	2	1	105
Waste Removal	5	5	1	5	1	4	1	2	1	1	5	5	4	4	154

Table A-4. Team Member D Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	5	5	5	5	4	5	3	3	4	3	4	4	3	4	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*285*
Current System	5	3	5	2	2	4	5	4	4	3	4	4	1	2	198
Cathodic Protection	5	3	5	3	3	4	3	3	2	3	4	3	1	2	186
Vault Drying	4	3	4	3	3	3	3	3	3	3	4	3	1	2	175
Vault & Tank Drying	4	3	4	3	4	3	3	4	3	3	4	3	1	3	186
Nitrogen Blanket	5	3	5	3	3	4	3	4	4	3	4	4	2	3	208
Nitrogen Blanket w/Oxygen Removal	5	3	5	3	3	4	3	4	2	3	4	3	2	2	192
Argon Blanket	5	3	5	3	3	3	2	3	3	3	4	4	2	3	193
Argon Blanket w/Cathodic Protection	5	3	5	3	3	3	2	2	2	3	4	3	1	2	175
Interceptor Trench/Drying	5	3	5	3	3	4	4	4	4	3	4	4	2	3	211
Trench/Infiltration Barrier/Drying	4	3	5	3	3	4	3	4	4	4	4	4	2	4	210
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	3	5	3	3	4	3	3	2	4	4	4	2	2	191
Groundwater Barrier/Drying	4	3	5	3	3	3	2	2	2	3	4	4	2	2	177
Infiltration Barrier/Drying	4	3	5	3	3	3	4	4	4	3	4	4	2	3	201
Corrosion Inhibitors in Vault	5	3	4	3	3	4	4	3	2	3	4	4	2	2	191
Sorbents in Annulus	5	3	5	3	3	4	3	4	3	3	4	4	2	3	204
Sorbents with Cathodic Protection	5	3	5	3	3	4	3	3	2	3	4	4	2	2	193
Low Strength Grout	5	4	5	3	3	4	3	4	3	3	2	4	3	3	204
Low Strength Grout/Drying	4	4	5	3	3	4	3	3	3	3	2	4	3	3	196
Contamination Fixative/Drying	5	3	4	3	3	3	3	3	2	3	2	4	2	2	175
Monitors	5	3	5	3	3	4	3	3	3	3	4	4	2	3	201
Waste Removal	4	4	4	3	4	3	2	3	3	4	4	3	2	2	187

Table A-5. Team Member E Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	4	5	4	4	4	4	3	3	3	4	4	4	2	3	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*255*
Current System	2	2	2	2	2	3	4	3	4	4	4	1	1	3	134
Cathodic Protection	2	2	1	2	2	1	3	3	3	4	4	1	1	2	113
Vault Drying	2	2	2	2	2	2	4	3	4	3	4	1	1	3	126
Vault & Tank Drying	1	2	2	2	2	2	3	3	3	3	4	2	1	3	120
Nitrogen Blanket	2	2	2	2	2	2	4	3	4	3	4	1	1	1	120
Nitrogen Blanket w/Oxygen Removal	2	2	2	2	2	2	4	3	4	3	4	2	1	2	127
Argon Blanket	2	2	2	2	2	2	3	3	3	3	4	2	1	2	121
Argon Blanket w/Cathodic Protection	2	2	2	4	3	2	4	3	2	3	4	2	2	2	135
Interceptor Trench/Drying	3	2	2	3	3	3	4	3	3	3	4	2	2	2	142
Trench/Infiltration Barrier/Drying	2	1	3	3	3	3	5	3	3	3	4	2	2	2	140
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	3	3	3	2	3	3	2	3	3	4	2	1	2	135
Groundwater Barrier/Drying	2	3	2	3	3	3	5	4	3	3	4	2	2	1	146
Infiltration Barrier/Drying	0	1	2	1	3	3	5	4	3	3	4	2	2	1	120
Corrosion Inhibitors in Vault	0	1	4	1	1	1	1	1	3	3	4	1	1	1	85
Sorbents in Annulus	2	2	2	2	2	2	4	4	2	3	4	2	1	0	118
Sorbents with Cathodic Protection	2	3	2	3	3	3	4	4	2	3	4	2	1	1	138
Low Strength Grout	4	4	4	4	3	3	3	2	4	4	3	2	2	3	168
Low Strength Grout/Drying	4	4	3	4	4	4	4	3	4	4	3	3	2	3	182
Contamination Fixative/Drying	3	3	3	3	3	4	4	3	3	4	3	2	2	2	155
Monitors	2	2	4	3	3	3	4	4	3	3	4	2	1	2	147
Waste Removal	4	2	5	3	0	3	5	0	2	1	2	1	5	2	123

Table A-6. Team Member F Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	2	2	1	1	1	1	2	3	1	1	1	3	2	1	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*110*
Current System	3	1	3	1	1	3	5	4	3	4	5	2	3	1	63
Cathodic Protection	3	2	3	2	2	3	4	3	3	4	5	3	2	2	64
Vault Drying	3	2	3	3	3	3	3	2	2	3	5	3	2	2	59
Vault & Tank Drying	3	3	3	4	4	3	3	1	3	3	4	3	1	4	60
Nitrogen Blanket	3	2	3	2	1	2	4	2	2	4	5	3	2	1	57
Nitrogen Blanket w/Oxygen Removal	3	2	3	2	1	2	3	1	2	3	5	3	2	1	51
Argon Blanket	3	2	3	2	2	2	3	2	2	4	5	3	2	1	56
Argon Blanket w/Cathodic Protection	3	2	3	2	2	2	3	2	1	3	5	3	2	2	55
Interceptor Trench/Drying	1	2	2	1	2	2	2	2	2	3	3	2	2	2	43
Trench/Infiltration Barrier/Drying	4	5	3	5	4	3	1	3	2	4	5	4	3	4	77
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	2	3	2	2	2	3	1	4	1	5	2	2	2	48
Groundwater Barrier/Drying	1	2	2	1	2	2	1	1	1	3	3	1	1	1	31
Infiltration Barrier/Drying	1	2	3	2	2	2	3	3	3	3	3	2	2	2	51
Corrosion Inhibitors in Vault	3	2	3	2	2	2	4	4	3	4	5	3	2	2	66
Sorbents in Annulus	2	3	3	3	1	2	3	4	2	3	3	2	3	3	60
Sorbents with Cathodic Protection	2	3	3	3	2	2	3	3	1	3	3	2	2	3	55
Low Strength Grout	4	4	4	4	2	3	3	5	3	1	1	3	4	4	76
Low Strength Grout/Drying	4	5	4	5	3	3	2	1	3	2	1	3	2	4	63
Contamination Fixative/Drying	3	4	3	3	3	3	1	1	1	1	2	2	1	3	46
Monitors	2	1	2	1	1	3	2	2	2	4	5	3	1	1	46
Waste Removal	4	5	5	5	5	4	1	4	3	1	4	5	5	4	88

Table A-7. Team Member G Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	4	5	4	5	3	4	2	3	4	3	4	4	1	4	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*250*
Current System	4	3	3	2	2	3	4	3	3	5	5	2	2	3	157
Cathodic Protection	4	2	3	2	2	4	2	4	2	5	5	2	2	2	147
Vault Drying	3	3	3	3	2	3	4	3	2	4	5	2	2	2	147
Vault & Tank Drying	3	4	3	4	3	3	3	2	2	4	5	3	2	3	163
Nitrogen Blanket	3	2	2	2	2	2	3	4	1	5	5	2	2	2	129
Nitrogen Blanket w/Oxygen Removal	3	3	2	3	3	2	2	3	2	4	5	3	2	2	142
Argon Blanket	3	3	1	3	3	1	2	3	2	5	5	2	2	2	133
Argon Blanket w/Cathodic Protection	3	4	1	3	4	2	1	2	3	5	5	3	2	3	152
Interceptor Trench/Drying	2	3	3	3	3	3	3	3	2	1	5	2	1	2	134
Trench/Infiltration Barrier/Drying	2	4	3	4	4	3	2	3	2	1	5	3	1	3	153
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	4	3	4	4	3	1	2	2	1	5	4	1	3	152
Groundwater Barrier/Drying	3	2	3	2	2	3	2	3	2	4	5	2	2	3	137
Infiltration Barrier/Drying	3	3	3	3	3	3	2	3	3	4	5	3	2	2	154
Corrosion Inhibitors in Vault	3	2	3	3	3	2	4	4	3	2	4	2	1	2	137
Sorbents in Annulus	3	2	3	3	3	2	4	4	2	3	4	3	1	1	136
Sorbents with Cathodic Protection	3	2	3	4	3	2	2	3	3	3	4	3	2	3	147
Low Strength Grout	4	4	4	4	4	4	4	5	3	1	1	3	3	3	169
Low Strength Grout/Drying	4	5	3	5	5	3	3	3	3	1	1	4	3	4	174
Contamination Fixative/Drying	3	4	3	4	4	3	2	3	2	3	2	3	2	2	148
Monitors	4	2	4	2	1	4	4	4	2	5	5	2	1	1	147
Waste Removal	1	5	1	5	1	5	1	5	1	5	5	4	5	1	162

Table A-8. Team Member H Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	SCORE
Weighting Factor-->	5	5	4	4	5	5	3	2	4	2	5	4	3	4	
STRATEGY															
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*275*
Current System	3	2	5	2	2	2	5	4	5	3	5	2	1	2	166
Cathodic Protection	3	3	3	3	2	3	4	4	3	3	5	3	1	2	165
Vault Drying	2	4	4	4	3	4	3	3	4	3	5	4	3	2	192
Vault & Tank Drying	2	4	4	5	4	5	2	3	4	4	4	5	3	3	208
Nitrogen Blanket	3	3	4	3	3	4	4	4	4	3	5	3	1	2	183
Nitrogen Blanket w/Oxygen Removal	3	4	4	3	3	4	2	3	3	3	5	4	2	2	183
Argon Blanket	2	4	4	1	3	2	3	3	3	3	5	2	1	2	152
Argon Blanket w/Cathodic Protection	2	4	3	2	3	2	3	2	3	3	5	2	1	2	150
Interceptor Trench/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	196
Trench/Infiltration Barrier/Drying	2	5	2	5	5	5	1	3	4	4	5	5	4	4	219
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	5	2	5	5	5	1	2	4	2	5	5	4	4	213
Groundwater Barrier/Drying	2	4	4	4	4	4	2	3	3	4	5	4	3	2	192
Infiltration Barrier/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	196
Corrosion Inhibitors in Vault	3	3	4	2	3	3	4	4	3	2	5	3	2	2	171
Sorbents in Annulus	2	3	4	2	2	2	3	4	2	2	4	3	2	2	144
Sorbents with Cathodic Protection	2	4	3	3	2	3	2	4	2	2	4	3	2	2	151
Low Strength Grout	3	4	4	3	2	3	4	4	3	3	4	3	3	2	175
Low Strength Grout/Drying	2	4	4	4	5	4	3	3	3	4	3	4	4	3	197
Contamination Fixative/Drying	2	4	4	4	4	4	3	3	3	3	3	3	4	3	186
Monitors	3	2	4	2	2	2	3	3	4	3	5	2	1	2	150
Waste Removal	4	5	2	4	3	5	1	5	2	2	5	5	5	3	206

Table A-9. Team Member I Scoring Sheet

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->	5	5	2	3	5	2	2	4	3	4	3	3	2	2	
STRATEGY															SCORE
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*225*
Current System	5	4	3	3	4	3	5	2	5	2	5	4	2	3	164
Cathodic Protection	4	2	3	2	2	4	3	3	2	5	5	2	2	2	133
Vault Drying	5	4	4	4	4	5	4	4	4	5	5	4	3	4	192
Vault & Tank Drying	5	5	3	4	4	5	4	4	4	3	5	4	3	4	187
Nitrogen Blanket	4	3	3	2	2	3	3	3	2	5	5	3	3	2	141
Nitrogen Blanket w/Oxygen Removal	4	3	2	2	3	2	3	2	3	5	5	3	3	3	143
Argon Blanket	4	3	2	2	2	2	2	2	3	5	5	2	2	2	129
Argon Blanket w/Cathodic Protection	3	3	3	2	2	3	3	2	2	5	5	2	2	2	127
Interceptor Trench/Drying	4	5	5	5	4	5	4	4	5	5	5	4	3	4	200
Trench/Infiltration Barrier/Drying	4	5	5	5	4	5	3	4	5	5	2	5	2	4	190
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	5	5	5	4	5	3	4	5	2	5	3	2	4	181
Groundwater Barrier/Drying	4	4	4	3	4	4	2	4	4	4	5	3	3	3	169
Infiltration Barrier/Drying	5	4	5	5	4	4	3	4	4	5	4	4	3	3	188
Corrosion Inhibitors in Vault	5	3	4	3	3	4	5	5	5	5	5	2	2	2	174
Sorbents in Annulus	4	3	4	3	1	2	3	3	2	4	5	2	2	2	130
Sorbents with Cathodic Protection	5	2	3	3	2	2	3	3	2	4	5	2	2	2	133
Low Strength Grout	5	4	5	4	2	5	2	4	4	1	4	2	2	2	149
Low Strength Grout/Drying	5	4	5	4	5	5	2	4	4	1	4	3	2	3	169
Contamination Fixative/Drying	5	5	5	5	5	4	3	4	3	4	5	4	2	4	194
Monitors	5	1	5	1	1	5	4	4	3	5	5	2	1	2	138
Waste Removal	5	5	5	5	1	5	1	5	5	1	5	5	4	5	179

Table A-10. Average Scores for Each Strategy

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy			
Team Member																	
A	1	5	4	4	5	3	4	3	4	5	4	2	3	4			
B	Did not supply weightings																
C	Did not weight from 1-5																
D	2	3	5	5	4	5	3	3	2	1	4	3	2	5			
E	5	5	5	5	4	5	3	3	4	3	4	4	3	4			
F	4	5	4	4	4	4	3	3	3	4	4	4	2	3			
G	4	5	4	5	3	4	2	3	4	3	4	4	1	4			
H	5	5	4	4	5	5	3	2	4	2	5	4	3	4			
I	5	5	2	3	5	2	2	4	3	4	3	3	2	2			
Average Weighting Factor	**3.7**	**4.7**	**4.0**	**4.3**	**4.3**	**4.0**	**2.9**	**3.0**	**3.4**	**3.1**	**4.0**	**3.4**	**2.3**	**3.7**			
STRATEGY															**TEAM MEMBER**	**SCORE**	
Argon Blanket	5	3	2	2	3	2	3	4	3	3	3	3	2	2	A	140	
Argon Blanket	4	2	3	2	1	3	3	3	3	4	4	3	2	2	B*	140	
Argon Blanket	3	2	3	2	2	2	3	2	2	4	5	3	2	1	C*	130	
Argon Blanket	3	2	3	2	2	3	3	3	2	3	4	3	2	2	D	124	
Argon Blanket	5	3	5	3	3	3	2	3	3	3	4	4	2	3	E	193	
Argon Blanket	2	2	2	2	2	2	3	3	3	3	4	2	1	2	F	121	
Argon Blanket	3	3	1	3	3	1	2	3	2	5	5	2	2	2	G	133	
Argon Blanket	2	4	4	1	3	2	3	3	3	3	5	2	1	2	H	152	
Argon Blanket	4	3	2	2	2	2	2	2	3	5	5	2	2	2	I	129	
Note: *Average weighting factors from other team members were used															**Average Score**	**140.2**	**Combined Average**
Average Score	**3.4**	**2.7**	**2.8**	**2.1**	**2.3**	**2.2**	**2.7**	**2.9**	**2.7**	**3.7**	**4.3**	**2.7**	**1.8**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**139.3**	**139.8**
Argon Blanket w/Cathodic Protection	5	3	3	3	4	3	2	3	3	3	3	3	3	2	A	152	
Argon Blanket w/Cathodic Protection	4	3	3	3	2	3	3	3	3	4	4	3	2	2	B*	153	
Argon Blanket w/Cathodic Protection	3	2	3	2	2	2	3	2	1	3	5	3	2	2	C*	127	
Argon Blanket w/Cathodic Protection	3	3	3	3	3	3	2	3	2	3	4	3	2	3	D	138	
Argon Blanket w/Cathodic Protection	5	3	5	3	3	3	2	2	2	3	4	3	1	2	E	175	
Argon Blanket w/Cathodic Protection	2	2	2	4	3	2	4	3	2	3	4	2	2	2	F	135	
Argon Blanket w/Cathodic Protection	3	4	1	3	4	2	1	2	3	5	5	3	2	3	G	152	
Argon Blanket w/Cathodic Protection	2	4	3	2	3	2	3	2	3	3	5	2	1	2	H	150	
Argon Blanket w/Cathodic Protection	3	3	3	2	2	3	3	2	2	5	5	2	2	2	I	127	
															Average Score	**145.5**	**Combined Average**
Average (Mean)	**3.3**	**3.0**	**2.9**	**2.8**	**2.9**	**2.6**	**2.6**	**2.4**	**2.3**	**3.6**	**4.3**	**2.7**	**1.9**	**2.2**	**Score Using Avg. Wt. And Avg. Score**	**145.4**	**145.5**

Table A-10. Average Scores for Each Strategy

Cathodic Protection	5	3	3	2	3	3	3	4	3	2	4	3	2	3	A	150	
Cathodic Protection	4	3	3	2	3	3	4	3	3	4	4	3	3	2	B*	158	
Cathodic Protection	3	2	3	2	2	3	4	3	3	4	5	3	2	2	C*	147	
Cathodic Protection	2	2	3	2	2	4	3	4	2	3	4	2	2	2	D	127	
Cathodic Protection	5	3	5	3	3	4	3	3	2	3	4	3	1	2	E	186	
Cathodic Protection	2	2	1	2	2	1	3	3	3	4	4	1	1	2	F	113	
Cathodic Protection	4	2	3	2	2	4	2	4	2	5	5	2	2	2	G	147	
Cathodic Protection	3	3	3	3	2	3	4	4	3	3	5	3	1	2	H	165	
Cathodic Protection	4	2	3	2	2	4	3	3	2	5	5	2	2	2	I	133	
															Average Score	**147.4**	**Combined Average**
Average (Mean)	**3.6**	**2.4**	**3.0**	**2.2**	**2.3**	**3.2**	**3.2**	**3.4**	**2.6**	**3.7**	**4.4**	**2.4**	**1.8**	**2.1**	**Score Using Avg. Wt. And Avg. Score**	**147.0**	**147.2**
Contamination Fixative/Drying	5	2	3	3	2	3	2	3	2	2	3	3	3	3	A	132	
Contamination Fixative/Drying	3	2	2	2	2	2	3	3	2	3	4	3	2	1	B*	122	
Contamination Fixative/Drying	3	4	3	3	3	3	1	1	1	1	2	2	1	3	C*	120	
Contamination Fixative/Drying	3	3	3	3	2	3	4	2	4	3	2	2	3	3	D	132	
Contamination Fixative/Drying	5	3	4	3	3	3	3	3	2	3	2	4	2	2	E	175	
Contamination Fixative/Drying	3	3	3	3	3	4	4	3	3	4	3	2	2	2	F	155	
Contamination Fixative/Drying	3	4	3	4	4	3	2	3	2	3	2	3	2	2	G	148	
Contamination Fixative/Drying	2	4	4	4	4	4	3	3	3	3	3	3	4	3	H	186	
Contamination Fixative/Drying	5	5	5	5	5	4	3	4	3	4	5	4	2	4	I	194	
															Average Score	**151.6**	**Combined Average**
Average (Mean)	**3.6**	**3.3**	**3.3**	**3.3**	**3.1**	**3.2**	**2.8**	**2.8**	**2.4**	**2.9**	**2.9**	**2.9**	**2.3**	**2.6**	**Score Using Avg. Wt. And Avg. Score**	**152.8**	**152.2**
Corrosion Inhibitors in Vault	5	3	3	3	3	3	4	4	3	2	3	3	2	3	A	154	
Corrosion Inhibitors in Vault	3	3	3	2	2	3	4	4	2	4	4	2	2	2	B*	144	
Corrosion Inhibitors in Vault	3	2	3	2	2	2	4	4	3	4	5	3	2	2	C*	146	
Corrosion Inhibitors in Vault	3	3	4	1	2	3	4	4	5	3	4	3	2	2	D	139	
Corrosion Inhibitors in Vault	5	3	4	3	3	4	4	3	2	3	4	4	2	2	E	191	
Corrosion Inhibitors in Vault	0	1	4	1	1	1	1	1	3	3	4	1	1	1	F	85	
Corrosion Inhibitors in Vault	3	2	3	3	3	2	4	4	3	2	4	2	1	2	G	137	
Corrosion Inhibitors in Vault	3	3	4	2	3	3	4	4	3	2	5	3	2	2	H	171	
Corrosion Inhibitors in Vault	5	3	4	3	3	4	5	5	5	5	5	2	2	2	I	174	
															Average Score	**149.0**	**Combined Average**
Average (Mean)	**3.3**	**2.6**	**3.6**	**2.2**	**2.4**	**2.8**	**3.8**	**3.7**	**3.2**	**3.1**	**4.2**	**2.6**	**1.8**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**149.5**	**149.3**

Table A-10. Average Scores for Each Strategy

Current System	5	1	3	2	1	3	5	5	2	2	3	1	3	5	A	140	
Current System	4	2	3	1	1	3	4	2	4	3	4	2	1	2	B*	130	
Current System	3	1	3	1	1	3	5	4	3	4	5	2	3	1	C*	135	
Current System	3	1	4	3	1	5	5	4	5	3	4	3	3	2	D	154	
Current System	5	3	5	2	2	4	5	4	4	3	4	4	1	2	E	198	
Current System	2	2	2	2	2	3	4	3	4	4	4	1	1	3	F	134	
Current System	4	3	3	2	2	3	4	3	3	5	5	2	2	3	G	157	
Current System	3	2	5	2	2	2	5	4	5	3	5	2	1	2	H	166	
Current System	5	4	3	3	4	3	5	2	5	2	5	4	2	3	I	164	
															Average Score	**153.1**	**Combined Average**
Average (Mean)	**3.8**	**2.1**	**3.4**	**2.0**	**1.8**	**3.2**	**4.7**	**3.4**	**3.9**	**3.2**	**4.3**	**2.3**	**1.9**	**2.6**	**Score Using Avg. Wt. And Avg. Score**	**153.1**	**153.1**
Groundwater Barrier/Drying	5	3	3	3	4	3	3	4	4	4	2	3	3	3	A	168	
Groundwater Barrier/Drying	3	3	2	2	2	2	2	3	2	3	4	4	2	2	B*	131	
Groundwater Barrier/Drying	1	2	2	1	2	2	1	1	1	3	3	1	1	1	C*	82	
Groundwater Barrier/Drying	4	4	2	3	3	3	1	3	3	1	4	4	3	3	D	140	
Groundwater Barrier/Drying	4	3	5	3	3	3	2	2	2	3	4	4	2	2	E	177	
Groundwater Barrier/Drying	2	3	2	3	3	3	5	4	3	3	4	2	2	1	F	146	
Groundwater Barrier/Drying	3	2	3	2	2	3	2	3	2	4	5	2	2	3	G	137	
Groundwater Barrier/Drying	2	4	4	4	4	4	2	3	3	4	5	4	3	2	H	192	
Groundwater Barrier/Drying	4	4	4	3	4	4	2	4	4	4	5	3	3	3	I	169	
															Average Score	**149.1**	**Combined Average**
Average (Mean)	**3.1**	**3.1**	**3.0**	**2.7**	**3.0**	**3.0**	**2.2**	**3.0**	**2.7**	**3.2**	**4.0**	**3.0**	**2.3**	**2.2**	**Score Using Avg. Wt. And Avg. Score**	**149.0**	**149.1**
Infiltration Barrier/Drying	5	3	3	3	4	3	3	4	4	4	2	3	3	3	A	168	
Infiltration Barrier/Drying	3	3	2	2	2	3	2	3	2	3	4	4	2	2	B*	135	
Infiltration Barrier/Drying	1	2	3	2	2	2	3	3	3	3	3	2	2	2	C*	118	
Infiltration Barrier/Drying	4	2	2	3	3	3	2	3	4	2	4	4	3	4	D	145	
Infiltration Barrier/Drying	4	3	5	3	3	3	4	4	4	3	4	4	2	3	E	201	
Infiltration Barrier/Drying	0	1	2	1	3	3	5	4	3	3	4	2	2	1	F	120	
Infiltration Barrier/Drying	3	3	3	3	3	3	2	3	3	4	5	3	2	2	G	154	
Infiltration Barrier/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	H	196	
Infiltration Barrier/Drying	5	4	5	5	4	4	3	4	4	5	4	4	3	3	I	188	
															Average Score	**158.4**	**Combined Average**
Average (Mean)	**3.0**	**2.8**	**3.1**	**2.9**	**3.1**	**3.1**	**2.9**	**3.4**	**3.4**	**3.4**	**3.9**	**3.3**	**2.4**	**2.6**	**Score Using Avg. Wt. And Avg. Score**	**158.1**	**158.3**

Table A-10. Average Scores for Each Strategy

Interceptor Trench/Drying	5	3	3	3	3	3	3	4	4	4	2	3	3	2	A	159	
Interceptor Trench/Drying	3	2	2	2	2	2	2	3	2	3	4	4	2	1	B*	123	
Interceptor Trench/Drying	1	2	2	1	2	2	2	2	2	3	3	2	2	2	C*	101	
Interceptor Trench/Drying	3	3	2	3	3	3	2	3	3	1	4	4	3	2	D	133	
Interceptor Trench/Drying	5	3	5	3	3	4	4	4	4	3	4	4	2	3	E	211	
Interceptor Trench/Drying	3	2	2	3	3	3	4	3	3	3	4	2	2	2	F	142	
Interceptor Trench/Drying	2	3	3	3	3	3	3	3	2	1	5	2	1	2	G	134	
Interceptor Trench/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	H	196	
Interceptor Trench/Drying	4	5	5	5	4	5	4	4	5	5	5	4	3	4	I	200	
															Average Score	**155.4**	**Combined Average**
Average (Mean)	**3.1**	**3.0**	**3.0**	**3.0**	**3.0**	**3.2**	**2.9**	**3.2**	**3.2**	**3.0**	**4.0**	**3.2**	**2.3**	**2.3**	**Score Using Avg. Wt. And Avg. Score**	**155.7**	**155.6**
Low Strength Grout	5	2	3	3	2	3	3	4	2	1	2	2	3	2	A	124	
Low Strength Grout	3	2	3	3	2	3	1	4	2	1	2	2	2	2	B*	118	
Low Strength Grout	4	4	4	4	2	3	3	5	3	1	1	3	4	4	C*	163	
Low Strength Grout	3	2	3	3	3	4	4	4	4	4	1	4	4	4	D	154	
Low Strength Grout	5	4	5	3	3	4	3	4	3	3	2	4	3	3	E	204	
Low Strength Grout	4	4	4	4	3	3	3	2	4	4	3	2	2	3	F	168	
Low Strength Grout	4	4	4	4	4	4	4	5	3	1	1	3	3	3	G	169	
Low Strength Grout	3	4	4	3	2	3	4	4	3	3	4	3	3	2	H	175	
Low Strength Grout	5	4	5	4	2	5	2	4	4	1	4	2	2	2	I	149	
															Average Score	**158.2**	**Combined Average**
Average (Mean)	**4.0**	**3.3**	**3.9**	**3.4**	**2.6**	**3.6**	**3.0**	**4.0**	**3.1**	**2.1**	**2.2**	**2.8**	**2.9**	**2.8**	**Score Using Avg. Wt. And Avg. Score**	**159.3**	**158.7**
Low Strength Grout/Drying	5	3	3	3	2	3	2	3	3	1	2	2	3	2	A	126	
Low Strength Grout/Drying	3	3	4	4	3	3	1	3	3	1	2	3	3	2	B*	141	
Low Strength Grout/Drying	4	5	4	5	3	3	2	1	3	2	1	3	2	4	C*	160	
Low Strength Grout/Drying	3	4	3	4	4	3	3	3	4	3	1	4	5	4	D	159	
Low Strength Grout/Drying	4	4	5	3	3	4	3	3	3	3	2	4	3	3	E	196	
Low Strength Grout/Drying	4	4	3	4	4	4	4	3	4	4	3	3	2	3	F	182	
Low Strength Grout/Drying	4	5	3	5	5	3	3	3	3	1	1	4	3	4	G	174	
Low Strength Grout/Drying	2	4	4	4	5	4	3	3	3	4	3	4	4	3	H	197	
Low Strength Grout/Drying	5	4	5	4	5	5	2	4	4	1	4	3	2	3	I	169	
															Average Score	**167.1**	**Combined Average**
Average (Mean)	**3.8**	**4.0**	**3.8**	**4.0**	**3.8**	**3.6**	**2.6**	**2.9**	**3.3**	**2.2**	**2.1**	**3.3**	**3.0**	**3.1**	**Score Using Avg. Wt. And Avg. Score**	**168.2**	**167.7**

Table A-10. Average Scores for Each Strategy

Monitors	5	1	4	3	1	4	3	2	4	3	4	3	1	4	A	145	
Monitors	3	1	3	3	0	4	4	4	3	3	4	2	3	1	B*	133	
Monitors	2	1	2	1	1	3	2	2	2	4	5	3	1	1	C*	108	
Monitors	1	1	4	1	1	1	4	4	5	4	4	1	2	1	D	105	
Monitors	5	3	5	3	3	4	3	3	3	3	4	4	2	3	E	201	
Monitors	2	2	4	3	3	3	4	4	3	3	4	2	1	2	F	147	
Monitors	4	2	4	2	1	4	4	4	2	5	5	2	1	1	G	147	
Monitors	3	2	4	2	2	2	3	3	4	3	5	2	1	2	H	150	
Monitors	5	1	5	1	1	5	4	4	3	5	5	2	1	2	I	138	
															Average Score	**141.6**	**Combined Average**
Average (Mean)	**3.3**	**1.6**	**3.9**	**2.1**	**1.4**	**3.3**	**3.4**	**3.3**	**3.2**	**3.7**	**4.4**	**2.3**	**1.4**	**1.9**	**Score Using Avg. Wt. And Avg. Score**	**142.3**	**142.0**
Nitrogen Blanket	5	2	2	2	3	2	3	4	3	3	3	3	2	2	A	135	
Nitrogen Blanket	4	2	4	2	2	3	4	2	3	4	4	3	2	2	B*	148	
Nitrogen Blanket	3	2	3	2	1	2	4	2	2	4	5	3	2	1	C*	129	
Nitrogen Blanket	3	2	3	3	2	3	3	3	2	2	4	3	2	2	D	128	
Nitrogen Blanket	5	3	5	3	3	4	3	4	4	3	4	4	2	3	E	208	
Nitrogen Blanket	2	2	2	2	2	2	4	3	4	3	4	1	1	1	F	120	
Nitrogen Blanket	3	2	2	2	2	2	3	4	1	5	5	2	2	2	G	129	
Nitrogen Blanket	3	3	4	3	3	4	4	4	4	3	5	3	1	2	H	183	
Nitrogen Blanket	4	3	3	2	2	3	3	3	2	5	5	3	3	2	I	141	
															Average Score	**146.8**	**Combined Average**
Average (Mean)	**3.6**	**2.3**	**3.1**	**2.3**	**2.2**	**2.8**	**3.4**	**3.2**	**2.8**	**3.6**	**4.3**	**2.8**	**1.9**	**1.9**	**Score Using Avg. Wt. And Avg. Score**	**145.7**	**146.2**
Nitrogen Blanket w/Oxygen Removal	5	3	3	3	4	3	2	3	3	3	3	3	3	2	A	152	
Nitrogen Blanket w/Oxygen Removal	4	3	4	2	1	3	3	2	2	4	4	3	2	2	B*	142	
Nitrogen Blanket w/Oxygen Removal	3	2	3	2	1	2	3	1	2	3	5	3	2	1	C*	120	
Nitrogen Blanket w/Oxygen Removal	3	3	3	3	3	2	2	2	2	2	4	3	1	2	D	122	
Nitrogen Blanket w/Oxygen Removal	5	3	5	3	3	4	3	4	2	3	4	3	2	2	E	192	
Nitrogen Blanket w/Oxygen Removal	2	2	2	2	2	2	4	3	4	3	4	2	1	2	F	127	
Nitrogen Blanket w/Oxygen Removal	3	3	2	3	3	2	2	3	2	4	5	3	2	2	G	142	
Nitrogen Blanket w/Oxygen Removal	3	4	4	3	3	4	2	3	3	3	5	4	2	2	H	183	
Nitrogen Blanket w/Oxygen Removal	4	3	2	2	3	2	3	2	3	5	5	3	3	3	I	143	
															Average Score	**147.0**	**Combined Average**
Average (Mean)	**3.6**	**2.9**	**3.1**	**2.6**	**2.6**	**2.7**	**2.7**	**2.6**	**2.6**	**3.3**	**4.3**	**3.0**	**2.0**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**146.0**	**146.5**

Table A-10. Average Scores for Each Strategy

Sorbents in Annulus	5	4	3	3	2	3	3	4	4	2	3	3	2	2	A	150	
Sorbents in Annulus	3	2	2	1	2	3	4	4	2	4	4	2	2	1	B*	127	
Sorbents in Annulus	2	3	3	3	1	2	3	4	2	3	3	2	3	3	C*	132	
Sorbents in Annulus	2	1	4	1	1	3	4	3	1	3	2	2	2	1	D	100	
Sorbents in Annulus	5	3	5	3	3	4	3	4	3	3	4	4	2	3	E	204	
Sorbents in Annulus	2	2	2	2	2	2	4	4	2	3	4	2	1	0	F	118	
Sorbents in Annulus	3	2	3	3	3	2	4	4	2	3	4	3	1	1	G	136	
Sorbents in Annulus	2	3	4	2	2	2	3	4	2	2	4	3	2	2	H	144	
Sorbents in Annulus	4	3	4	3	1	2	3	3	2	4	5	2	2	2	I	130	
															Average Score	**138.0**	**Combined Average**
Average (Mean)	**3.1**	**2.6**	**3.3**	**2.3**	**1.9**	**2.6**	**3.4**	**3.8**	**2.2**	**3.0**	**3.7**	**2.6**	**1.9**	**1.7**	**Score Using Avg. Wt. And Avg. Score**	**137.4**	**137.7**
Sorbents with Cathodic Protection	5	3	3	3	3	3	2	4	4	2	3	3	2	2	A	146	
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	3	3	4	4	2	2	2	B*	142	
Sorbents with Cathodic Protection	2	3	3	3	2	2	3	3	1	3	3	2	2	3	C*	128	
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	2	1	3	2	2	2	1	D	105	
Sorbents with Cathodic Protection	5	3	5	3	3	4	3	3	2	3	4	4	2	2	E	193	
Sorbents with Cathodic Protection	2	3	2	3	3	3	4	4	2	3	4	2	1	1	F	138	
Sorbents with Cathodic Protection	3	2	3	4	3	2	2	3	3	3	4	3	2	3	G	147	
Sorbents with Cathodic Protection	2	4	3	3	2	3	2	4	2	2	4	3	2	2	H	151	
Sorbents with Cathodic Protection	5	2	3	3	2	2	3	3	2	4	5	2	2	2	I	133	
															Average Score	**142.6**	**Combined Average**
Average (Mean)	**3.3**	**2.9**	**2.9**	**2.9**	**2.7**	**2.8**	**2.8**	**3.2**	**2.2**	**3.0**	**3.7**	**2.6**	**1.9**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**142.3**	**142.4**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	4	5	5	5	5	1	3	4	4	2	5	5	2	A	195	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3	2	2	2	2	2	1	3	2	2	4	3	2	2	B*	117	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	2	3	2	2	2	3	1	4	1	5	2	2	2	C*	121	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	5	1	5	5	3	1	2	3	1	4	4	1	5	D	161	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	3	5	3	3	4	3	3	2	4	4	4	2	2	E	191	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	3	3	3	2	3	3	2	3	3	4	2	1	2	F	135	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	4	3	4	4	3	1	2	2	1	5	4	1	3	G	152	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	5	2	5	5	5	1	2	4	2	5	5	4	4	H	213	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	5	5	5	4	5	3	4	5	2	5	3	2	4	I	181	
															Average Score	**162.9**	**Combined Average**
Average (Mean)	**3.2**	**3.7**	**3.2**	**3.8**	**3.6**	**3.6**	**1.9**	**2.4**	**3.2**	**2.2**	**4.2**	**3.6**	**2.2**	**2.9**	**Score Using Avg. Wt. And Avg. Score**	**163.4**	**163.2**

Table A-10. Average Scores for Each Strategy

Trench/Infiltration Barrier/Drying	5	3	4	4	5	4	2	2	4	4	2	4	4	2	A	175	
Trench/Infiltration Barrier/Drying	3	2	2	2	2	2	2	3	2	3	4	4	2	1	B*	123	
Trench/Infiltration Barrier/Drying	4	5	3	5	4	3	1	3	2	4	5	4	3	4	C*	188	
Trench/Infiltration Barrier/Drying	4	4	1	4	4	3	1	3	3	1	4	4	3	4	D	149	
Trench/Infiltration Barrier/Drying	4	3	5	3	3	4	3	4	4	4	4	4	2	4	E	210	
Trench/Infiltration Barrier/Drying	2	1	3	3	3	3	5	3	3	3	4	2	2	2	F	140	
Trench/Infiltration Barrier/Drying	2	4	3	4	4	3	2	3	2	1	5	3	1	3	G	153	
Trench/Infiltration Barrier/Drying	2	5	2	5	5	5	1	3	4	4	5	5	4	4	H	219	
Trench/Infiltration Barrier/Drying	4	5	5	5	4	5	3	4	5	5	2	5	2	4	I	190	
															Average Score	**171.8**	**Combined Average**
Average (Mean)	**3.3**	**3.6**	**3.1**	**3.9**	**3.8**	**3.6**	**2.2**	**3.1**	**3.2**	**3.2**	**3.9**	**3.9**	**2.6**	**3.1**	**Score Using Avg. Wt. And Avg. Score**	**171.8**	**171.8**
Vault & Tank Drying	5	3	3	3	4	3	2	3	3	3	4	3	3	3	A	160	
Vault & Tank Drying	3	4	4	3	4	3	3	2	2	3	3	4	3	2	B*	159	
Vault & Tank Drying	3	3	3	4	4	3	3	1	3	3	4	3	1	4	C*	158	
Vault & Tank Drying	3	3	3	3	3	2	3	3	4	2	4	4	3	2	D	139	
Vault & Tank Drying	4	3	4	3	4	3	3	4	3	3	4	3	1	3	E	186	
Vault & Tank Drying	1	2	2	2	2	2	3	3	3	3	4	2	1	3	F	120	
Vault & Tank Drying	3	4	3	4	3	3	3	2	2	4	5	3	2	3	G	163	
Vault & Tank Drying	2	4	4	5	4	5	2	3	4	4	4	5	3	3	H	208	
Vault & Tank Drying	5	5	3	4	4	5	4	4	4	3	5	4	3	4	I	187	
															Average Score	**164.5**	**Combined Average**
Average (Mean)	**3.2**	**3.4**	**3.2**	**3.4**	**3.6**	**3.2**	**2.9**	**2.8**	**3.1**	**3.1**	**4.1**	**3.4**	**2.2**	**3.0**	**Score Using Avg. Wt. And Avg. Score**	**165.5**	**165.0**
Vault Drying	5	2	2	2	3	2	3	4	3	3	4	3	3	3	A	146	
Vault Drying	4	3	4	3	3	3	3	3	2	3	4	4	2	2	B*	158	
Vault Drying	3	2	3	3	3	3	3	2	2	3	5	3	2	2	C*	143	
Vault Drying	3	2	4	3	2	3	3	3	4	2	4	4	3	2	D	142	
Vault Drying	4	3	4	3	3	3	3	3	3	3	4	3	1	2	E	175	
Vault Drying	2	2	2	2	2	2	4	3	4	3	4	1	1	3	F	126	
Vault Drying	3	3	3	3	2	3	4	3	2	4	5	2	2	2	G	147	
Vault Drying	2	4	4	4	3	4	3	3	4	3	5	4	3	2	H	192	
Vault Drying	5	4	4	4	4	5	4	4	4	5	5	4	3	4	I	192	
															Average Score	**158.0**	**Combined Average**
Average (Mean)	**3.4**	**2.8**	**3.3**	**3.0**	**2.8**	**3.1**	**3.3**	**3.1**	**3.1**	**3.2**	**4.4**	**3.1**	**2.2**	**2.4**	**Score Using Avg. Wt. And Avg. Score**	**158.7**	**158.3**

Table A-10. Average Scores for Each Strategy

Waste Removal	5	2	1	1	2	1	2	4	4	2	5	5	3	2	A	129	
Waste Removal	4	4	3	4	3	3	1	2	4	1	4	4	4	4	B*	167	
Waste Removal	4	5	5	5	5	4	1	4	3	1	4	5	5	4	C*	205	
Waste Removal	5	5	1	5	1	4	1	2	1	1	5	5	4	4	D	154	
Waste Removal	4	4	4	3	4	3	2	3	3	4	4	3	2	2	E	187	
Waste Removal	4	2	5	3	0	3	5	0	2	1	2	1	5	2	F	123	
Waste Removal	1	5	1	5	1	5	1	5	1	5	5	4	5	1	G	162	
Waste Removal	4	5	2	4	3	5	1	5	2	2	5	5	5	3	H	206	
Waste Removal	5	5	5	5	1	5	1	5	5	1	5	5	4	5	I	179	
															Average Score	**168.0**	**Combined Average**
Average (Mean)	**4.0**	**4.1**	**3.0**	**3.9**	**2.2**	**3.7**	**1.7**	**3.3**	**2.8**	**2.0**	**4.3**	**4.1**	**4.1**	**3.0**	**Score Using Avg. Wt. And Avg. Score**	**169.6**	**168.8**

Table A-11. Adjusted Average Scores for Each Strategy

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy			
Team Member																	
A	1	5	4	4	5	3	4	3	4	5	4	2	3	4			
B	Did not supply weightings																
C	Did not weight from 1-5																
D	2	3	5	5	4	5	3	3	2	1	4	3	2	5			
E	5	5	5	5	4	5	3	3	4	3	4	4	3	4			
F	4	5	4	4	4	4	3	3	3	4	4	4	2	3			
G	4	5	4	5	3	4	2	3	4	3	4	4	1	4			
H	5	5	4	4	5	5	3	2	4	2	5	4	3	4			
I	5	5	2	3	5	2	2	4	3	4	3	3	2	2			
Average Weighting Factor	**3.7**	**4.7**	**4.0**	**4.3**	**4.3**	**4.0**	**2.9**	**3.0**	**3.4**	**3.1**	**4.0**	**3.4**	**2.3**	**3.7**			
STRATEGY															**TEAM MEMBER**	**SCORE**	
Argon Blanket	5	3	2	2	3	2	3	3	3	3	4	3	2	2	A	141	
Argon Blanket	4	2	3	2	2	3	3	3	3	4	4	3	2	2	B*	144	
Argon Blanket	3	2	3	2	2	2	3	2	2	4	5	3	2	2	C*	134	
Argon Blanket	3	2	3	2	2	3	3	3	2	3	4	3	2	2	D	124	
Argon Blanket	5	3	4	3	3	3	2	3	3	3	4	3	2	2	E	180	
Argon Blanket	2	2	2	2	2	2	3	3	3	3	4	2	1	2	F	121	
Argon Blanket	3	3	1	3	3	2	2	3	2	5	5	2	2	2	G	137	
Argon Blanket	2	3	4	1	3	2	3	3	3	3	5	2	1	2	H	147	
Argon Blanket	4	3	2	2	2	2	2	2	3	5	5	2	2	2	I	129	
Note: *Average weighting factors from other team members were used															**Average Score**	**139.7**	**Combined Average**
Average Score	**3.4**	**2.6**	**2.7**	**2.1**	**2.4**	**2.3**	**2.7**	**2.8**	**2.7**	**3.7**	**4.4**	**2.6**	**1.8**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**139.0**	**139.3**
Argon Blanket w/Cathodic Protection	5	3	3	3	4	3	2	3	3	3	4	3	3	2	A	156	
Argon Blanket w/Cathodic Protection	4	3	3	3	2	3	3	3	3	4	4	3	2	2	B*	153	
Argon Blanket w/Cathodic Protection	3	2	3	2	2	2	3	2	2	3	5	3	2	2	C*	131	
Argon Blanket w/Cathodic Protection	3	3	3	3	3	3	2	3	2	3	4	3	2	3	D	138	
Argon Blanket w/Cathodic Protection	5	3	3	3	3	3	2	2	2	3	4	3	1	2	E	165	
Argon Blanket w/Cathodic Protection	2	2	2	3	3	2	3	3	2	3	4	2	2	2	F	128	
Argon Blanket w/Cathodic Protection	3	4	2	3	4	2	2	2	3	5	5	3	2	3	G	158	
Argon Blanket w/Cathodic Protection	2	4	3	2	3	2	3	2	3	3	5	2	1	2	H	150	
Argon Blanket w/Cathodic Protection	3	3	3	2	2	3	3	2	2	5	5	2	2	2	I	127	
															Average Score	**145.1**	**Combined Average**
Average (Mean)	**3.3**	**3.0**	**2.8**	**2.7**	**2.9**	**2.6**	**2.6**	**2.4**	**2.4**	**3.6**	**4.4**	**2.7**	**1.9**	**2.2**	**Score Using Avg. Wt. And Avg. Score**	**145.3**	**145.2**

Table A-11. Adjusted Average Scores for Each Strategy

Cathodic Protection	5	3	3	2	3	3	3	4	3	3	4	3	2	2	A	151	
Cathodic Protection	4	3	3	2	3	3	4	3	3	4	4	3	2	2	B*	156	
Cathodic Protection	3	2	3	2	2	3	4	3	3	4	5	3	2	2	C*	147	
Cathodic Protection	2	2	3	2	2	4	3	4	2	3	4	2	2	2	D	127	
Cathodic Protection	5	3	3	3	3	4	3	3	2	3	4	3	1	2	E	176	
Cathodic Protection	2	2	3	2	2	3	3	3	3	4	4	2	1	2	F	133	
Cathodic Protection	4	2	3	2	2	4	3	4	2	5	5	2	2	2	G	149	
Cathodic Protection	3	3	3	3	2	3	4	4	3	3	5	3	1	2	H	165	
Cathodic Protection	4	2	3	2	2	4	3	3	2	5	5	2	2	2	I	133	
															Average Score	**148.6**	**Combined Average**
Average (Mean)	**3.6**	**2.4**	**3.0**	**2.2**	**2.3**	**3.4**	**3.3**	**3.4**	**2.6**	**3.8**	**4.4**	**2.6**	**1.7**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**148.3**	**148.4**
Contamination Fixative/Drying	5	2	3	3	2	3	2	3	2	2	3	3	3	3	A	132	
Contamination Fixative/Drying	3	2	3	2	2	3	3	3	2	3	4	3	2	2	B*	134	
Contamination Fixative/Drying	3	4	3	3	3	3	2	2	2	2	2	2	2	3	C*	135	
Contamination Fixative/Drying	3	3	3	3	2	3	4	2	3	3	2	2	3	3	D	130	
Contamination Fixative/Drying	5	3	4	3	3	3	3	3	2	3	2	4	2	2	E	175	
Contamination Fixative/Drying	3	3	3	3	3	4	4	3	3	4	3	2	2	2	F	155	
Contamination Fixative/Drying	3	4	3	4	4	3	2	3	2	3	2	3	2	2	G	148	
Contamination Fixative/Drying	2	4	4	4	4	4	3	3	3	3	3	3	3	3	H	183	
Contamination Fixative/Drying	5	4	4	4	4	4	3	3	3	4	4	3	2	3	I	167	
															Average Score	**151.0**	**Combined Average**
Average (Mean)	**3.6**	**3.2**	**3.3**	**3.2**	**3.0**	**3.3**	**2.9**	**2.8**	**2.4**	**3.0**	**2.8**	**2.8**	**2.3**	**2.6**	**Score Using Avg. Wt. And Avg. Score**	**151.6**	**151.3**
Corrosion Inhibitors in Vault	5	3	3	3	3	3	4	4	3	2	4	3	2	2	A	154	
Corrosion Inhibitors in Vault	3	3	3	2	2	3	4	4	2	4	4	2	2	2	B*	144	
Corrosion Inhibitors in Vault	3	2	3	2	2	2	4	4	3	4	5	3	2	2	C*	146	
Corrosion Inhibitors in Vault	3	3	4	1	2	3	4	4	5	3	4	3	2	2	D	139	
Corrosion Inhibitors in Vault	5	3	4	3	3	4	4	3	2	3	4	3	2	2	E	187	
Corrosion Inhibitors in Vault	3	2	4	1	2	2	4	3	3	3	4	2	1	2	F	132	
Corrosion Inhibitors in Vault	3	2	3	3	3	2	4	4	3	2	4	2	1	2	G	137	
Corrosion Inhibitors in Vault	3	3	4	2	3	3	4	4	3	2	5	3	2	2	H	171	
Corrosion Inhibitors in Vault	5	3	4	3	3	4	4	4	5	4	5	2	2	2	I	164	
															Average Score	**152.7**	**Combined Average**
Average (Mean)	**3.7**	**2.7**	**3.6**	**2.2**	**2.6**	**2.9**	**4.0**	**3.8**	**3.2**	**3.0**	**4.3**	**2.6**	**1.8**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**153.3**	**153.0**

Table A-11. Adjusted Average Scores for Each Strategy

Current System	5	1	3	2	1	3	5	4	3	2	4	1	3	3	A	137	
Current System	4	2	3	1	1	3	4	2	4	3	4	2	1	2	B*	130	
Current System	3	1	3	1	1	3	5	4	3	4	5	2	3	2	C*	139	
Current System	3	1	4	3	1	4	5	4	5	3	4	3	3	2	D	149	
Current System	5	3	5	2	2	4	5	4	4	3	4	4	1	2	E	198	
Current System	3	2	3	2	2	3	4	3	4	4	4	1	1	3	F	142	
Current System	4	3	3	2	2	3	4	3	3	4	5	2	2	3	G	154	
Current System	3	2	5	2	2	2	5	4	5	3	5	2	1	2	H	166	
Current System	5	3	3	3	2	3	5	2	5	2	5	4	2	3	I	149	
															Average Score	**151.5**	**Combined Average**
Average (Mean)	**3.9**	**2.0**	**3.6**	**2.0**	**1.6**	**3.1**	**4.7**	**3.3**	**4.0**	**3.1**	**4.4**	**2.3**	**1.9**	**2.4**	**Score Using Avg. Wt. And Avg. Score**	**151.8**	**151.7**
Groundwater Barrier/Drying	4	3	3	3	4	3	3	4	4	4	3	3	3	3	A	171	
Groundwater Barrier/Drying	3	3	2	2	2	2	2	3	2	3	4	4	2	2	B*	131	
Groundwater Barrier/Drying	2	2	2	2	2	2	1	2	2	3	3	2	2	1	C*	102	
Groundwater Barrier/Drying	4	4	2	3	3	3	1	3	3	3	4	4	3	3	D	142	
Groundwater Barrier/Drying	4	3	4	3	3	3	2	2	2	3	4	4	2	2	E	172	
Groundwater Barrier/Drying	2	3	2	3	3	3	3	4	3	3	4	2	2	1	F	140	
Groundwater Barrier/Drying	3	2	3	2	2	3	2	3	2	4	5	2	2	3	G	137	
Groundwater Barrier/Drying	2	4	4	3	4	4	2	3	3	4	5	4	3	2	H	188	
Groundwater Barrier/Drying	4	4	4	3	4	4	2	4	4	4	5	3	3	3	I	169	
															Average Score	**150.3**	**Combined Average**
Average (Mean)	**3.1**	**3.1**	**2.9**	**2.7**	**3.0**	**3.0**	**2.0**	**3.1**	**2.8**	**3.4**	**4.1**	**3.1**	**2.4**	**2.2**	**Score Using Avg. Wt. And Avg. Score**	**150.4**	**150.3**
Infiltration Barrier/Drying	5	3	3	3	4	3	3	4	4	4	3	3	3	3	A	172	
Infiltration Barrier/Drying	3	3	2	2	2	3	2	3	3	3	4	4	2	2	B*	139	
Infiltration Barrier/Drying	1	2	3	2	2	3	3	3	3	3	3	2	2	2	C*	122	
Infiltration Barrier/Drying	4	2	2	3	3	3	2	3	4	3	4	4	3	3	D	141	
Infiltration Barrier/Drying	4	3	5	3	3	3	4	4	4	3	4	4	2	3	E	201	
Infiltration Barrier/Drying	1	2	2	2	3	3	4	4	3	3	4	2	2	2	F	133	
Infiltration Barrier/Drying	3	3	3	3	3	3	2	3	3	4	5	3	2	2	G	154	
Infiltration Barrier/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	H	196	
Infiltration Barrier/Drying	5	4	5	5	4	4	3	4	4	5	4	4	3	3	I	188	
															Average Score	**160.7**	**Combined Average**
Average (Mean)	**3.1**	**2.9**	**3.1**	**3.0**	**3.1**	**3.2**	**2.8**	**3.4**	**3.6**	**3.6**	**4.0**	**3.3**	**2.4**	**2.6**	**Score Using Avg. Wt. And Avg. Score**	**160.8**	**160.8**

Table A-11. Adjusted Average Scores for Each Strategy

Interceptor Trench/Drying	5	3	3	3	3	3	3	4	4	4	3	3	3	2	A	163	
Interceptor Trench/Drying	3	2	2	2	2	2	2	3	2	3	4	4	2	2	B*	126	
Interceptor Trench/Drying	2	2	2	2	2	2	2	2	2	3	3	2	2	2	C*	109	
Interceptor Trench/Drying	3	3	2	3	3	3	2	3	3	1	4	4	3	2	D	133	
Interceptor Trench/Drying	5	3	5	3	3	4	4	4	4	3	4	4	2	3	E	211	
Interceptor Trench/Drying	3	2	2	3	3	3	4	3	3	3	4	2	2	2	F	142	
Interceptor Trench/Drying	2	3	3	3	3	3	3	3	2	1	5	2	2	2	G	135	
Interceptor Trench/Drying	2	4	3	4	4	4	2	3	4	4	5	4	3	3	H	196	
Interceptor Trench/Drying	4	4	5	4	4	4	4	4	4	4	5	4	3	4	I	183	
															Average Score	**155.4**	**Combined Average**
Average (Mean)	**3.2**	**2.9**	**3.0**	**3.0**	**3.0**	**3.1**	**2.9**	**3.2**	**3.1**	**2.9**	**4.1**	**3.2**	**2.4**	**2.4**	**Score Using Avg. Wt. And Avg. Score**	**155.6**	**155.5**
Low Strength Grout	5	2	3	3	2	3	3	4	2	1	2	2	3	2	A	124	
Low Strength Grout	3	2	3	3	2	3	2	4	2	1	2	2	2	2	B*	121	
Low Strength Grout	4	4	4	4	2	3	3	5	3	1	1	3	4	4	C*	163	
Low Strength Grout	3	2	3	3	3	4	4	4	4	4	1	4	4	4	D	154	
Low Strength Grout	5	4	5	3	3	4	3	4	3	3	2	4	3	3	E	204	
Low Strength Grout	4	4	4	4	3	3	3	4	4	4	3	2	2	3	F	174	
Low Strength Grout	4	4	4	4	3	4	4	5	3	1	1	3	3	3	G	166	
Low Strength Grout	3	4	4	3	2	3	4	4	3	3	4	3	3	2	H	175	
Low Strength Grout	5	4	5	4	2	4	2	4	4	1	4	2	2	2	I	147	
															Average Score	**158.6**	**Combined Average**
Average (Mean)	**4.0**	**3.3**	**3.9**	**3.4**	**2.4**	**3.4**	**3.1**	**4.2**	**3.1**	**2.1**	**2.2**	**2.8**	**2.9**	**2.8**	**Score Using Avg. Wt. And Avg. Score**	**159.3**	**159.0**
Low Strength Grout/Drying	5	3	3	3	3	3	2	3	3	1	2	3	3	2	A	133	
Low Strength Grout/Drying	3	3	4	4	3	3	2	3	3	1	2	3	3	2	B*	144	
Low Strength Grout/Drying	4	5	4	5	3	3	2	3	3	2	1	3	2	4	C*	166	
Low Strength Grout/Drying	3	4	3	4	4	3	3	3	4	3	1	4	4	4	D	157	
Low Strength Grout/Drying	4	4	5	3	3	4	3	3	3	3	2	4	3	3	E	196	
Low Strength Grout/Drying	4	4	3	4	4	4	3	3	4	4	3	3	2	3	F	179	
Low Strength Grout/Drying	4	5	3	5	5	3	3	3	3	1	1	4	3	4	G	174	
Low Strength Grout/Drying	3	4	4	4	5	4	3	3	3	4	3	4	4	3	H	202	
Low Strength Grout/Drying	5	4	5	4	5	4	2	3	4	1	3	3	2	3	I	160	
															Average Score	**167.9**	**Combined Average**
Average (Mean)	**3.9**	**4.0**	**3.8**	**4.0**	**3.9**	**3.4**	**2.6**	**3.0**	**3.3**	**2.2**	**2.0**	**3.4**	**2.9**	**3.1**	**Score Using Avg. Wt. And Avg. Score**	**168.7**	**168.3**

Table A-11. Adjusted Average Scores for Each Strategy

Monitors	5	1	4	3	1	4	3	2	4	3	4	3	1	2	A	137	
Monitors	3	1	3	3	1	4	4	4	3	3	4	2	2	1	B*	135	
Monitors	2	1	3	1	1	3	3	2	2	4	5	3	1	1	C*	115	
Monitors	2	1	4	1	1	2	4	4	4	4	4	2	2	1	D	113	
Monitors	5	2	5	3	3	4	3	3	3	3	4	3	2	3	E	192	
Monitors	2	2	4	3	3	3	4	4	3	3	4	2	1	2	F	147	
Monitors	4	2	4	2	1	4	4	4	2	5	5	2	1	1	G	147	
Monitors	3	2	4	2	2	2	3	3	4	3	5	2	1	2	H	150	
Monitors	5	1	5	1	1	4	4	4	3	5	5	2	1	2	I	136	
															Average Score	**141.4**	**Combined Average**
Average (Mean)	**3.4**	**1.4**	**4.0**	**2.1**	**1.6**	**3.3**	**3.6**	**3.3**	**3.1**	**3.7**	**4.4**	**2.3**	**1.3**	**1.7**	**Score Using Avg. Wt. And Avg. Score**	**142.0**	**141.7**
Nitrogen Blanket	5	2	2	2	3	2	3	4	3	3	4	3	2	2	A	139	
Nitrogen Blanket	4	2	4	2	2	3	4	2	3	4	4	3	2	2	B*	148	
Nitrogen Blanket	3	2	3	2	2	2	4	2	2	4	5	3	2	1	C*	133	
Nitrogen Blanket	3	2	3	3	2	3	3	3	2	3	4	3	2	2	D	129	
Nitrogen Blanket	5	3	4	3	3	4	3	4	4	3	4	3	2	2	E	195	
Nitrogen Blanket	3	2	2	2	2	2	4	3	4	3	4	2	1	1	F	128	
Nitrogen Blanket	3	2	2	2	2	2	3	4	2	5	5	2	2	2	G	133	
Nitrogen Blanket	3	3	4	3	3	4	4	4	4	3	5	3	1	2	H	183	
Nitrogen Blanket	4	3	3	2	2	3	3	3	2	5	5	3	3	2	I	141	
															Average Score	**147.7**	**Combined Average**
Average (Mean)	**3.7**	**2.3**	**3.0**	**2.3**	**2.3**	**2.8**	**3.4**	**3.2**	**2.9**	**3.7**	**4.4**	**2.8**	**1.9**	**1.8**	**Score Using Avg. Wt. And Avg. Score**	**146.9**	**147.3**
Nitrogen Blanket w/Oxygen Removal	5	3	3	3	3	3	2	3	3	3	4	3	3	2	A	151	
Nitrogen Blanket w/Oxygen Removal	4	3	4	2	1	3	3	2	2	4	4	3	2	2	B*	142	
Nitrogen Blanket w/Oxygen Removal	3	2	3	2	1	2	3	2	2	3	5	3	2	2	C*	127	
Nitrogen Blanket w/Oxygen Removal	3	3	3	3	3	2	2	2	2	3	4	3	1	2	D	123	
Nitrogen Blanket w/Oxygen Removal	5	3	4	3	3	4	3	3	2	3	4	3	2	2	E	184	
Nitrogen Blanket w/Oxygen Removal	3	2	2	2	2	2	3	3	3	3	4	2	1	2	F	125	
Nitrogen Blanket w/Oxygen Removal	3	3	2	3	3	2	2	3	2	4	5	3	2	2	G	142	
Nitrogen Blanket w/Oxygen Removal	3	3	4	3	3	4	2	3	3	3	5	3	2	2	H	174	
Nitrogen Blanket w/Oxygen Removal	4	3	2	2	3	2	3	2	3	5	5	3	3	3	I	143	
															Average Score	**145.6**	**Combined Average**
Average (Mean)	**3.7**	**2.8**	**3.0**	**2.6**	**2.4**	**2.7**	**2.6**	**2.6**	**2.4**	**3.4**	**4.4**	**2.9**	**2.0**	**2.1**	**Score Using Avg. Wt. And Avg. Score**	**145.1**	**145.4**

Table A-11. Adjusted Average Scores for Each Strategy

Sorbents in Annulus	5	3	3	3	2	3	3	4	3	2	3	3	2	2	A	141	
Sorbents in Annulus	3	2	2	1	2	3	4	4	2	4	4	2	2	1	B*	127	
Sorbents in Annulus	2	3	3	3	1	2	3	4	2	3	3	2	2	2	C*	126	
Sorbents in Annulus	2	2	4	1	1	3	4	3	2	3	3	2	2	1	D	109	
Sorbents in Annulus	5	3	4	3	2	3	3	4	3	3	4	3	2	3	E	186	
Sorbents in Annulus	2	2	2	2	2	2	4	4	2	3	4	2	1	1	F	121	
Sorbents in Annulus	3	2	3	3	3	2	4	4	2	3	4	3	1	1	G	136	
Sorbents in Annulus	2	3	4	2	2	2	3	4	2	2	4	3	2	2	H	144	
Sorbents in Annulus	4	3	4	3	1	2	3	3	2	4	4	2	2	2	I	127	
															Average Score	**135.3**	**Combined Average**
Average (Mean)	**3.1**	**2.6**	**3.2**	**2.3**	**1.8**	**2.4**	**3.4**	**3.8**	**2.2**	**3.0**	**3.7**	**2.4**	**1.8**	**1.7**	**Score Using Avg. Wt. And Avg. Score**	**135.4**	**135.4**
Sorbents with Cathodic Protection	5	3	3	3	3	3	2	4	3	2	3	3	2	2	A	142	
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	3	3	4	4	2	2	2	B*	142	
Sorbents with Cathodic Protection	2	3	3	3	2	2	3	3	1	3	3	2	2	3	C*	128	
Sorbents with Cathodic Protection	3	3	2	2	3	3	3	3	1	3	3	2	2	1	D	112	
Sorbents with Cathodic Protection	5	3	3	3	3	3	3	3	2	3	4	3	2	2	E	174	
Sorbents with Cathodic Protection	2	3	2	3	3	3	3	4	2	3	4	2	2	1	F	137	
Sorbents with Cathodic Protection	3	2	3	3	3	2	2	3	3	3	4	3	2	3	G	142	
Sorbents with Cathodic Protection	2	4	3	3	2	3	2	4	2	2	4	3	2	2	H	151	
Sorbents with Cathodic Protection	5	2	3	3	2	2	3	3	2	4	4	2	2	2	I	130	
															Average Score	**139.8**	**Combined Average**
Average (Mean)	**3.3**	**2.9**	**2.7**	**2.8**	**2.7**	**2.7**	**2.7**	**3.3**	**2.1**	**3.0**	**3.7**	**2.4**	**2.0**	**2.0**	**Score Using Avg. Wt. And Avg. Score**	**140.0**	**139.9**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	4	5	5	5	5	1	3	4	4	4	5	4	2	A	200	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3	2	2	2	2	2	1	3	2	2	4	3	2	2	B*	117	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	2	3	2	2	2	3	2	4	1	5	2	2	2	C*	124	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	5	5	2	5	5	3	1	2	3	1	4	4	1	4	D	161	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	3	5	3	3	4	3	3	2	4	4	4	2	2	E	191	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	3	3	3	2	3	3	2	3	3	4	2	1	2	F	135	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	4	3	4	4	3	1	2	2	1	5	4	1	3	G	152	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	2	5	2	5	5	5	1	2	4	2	5	5	4	4	H	213	
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	4	5	5	5	4	5	3	4	4	2	5	3	2	4	I	178	
															Average Score	**163.5**	**Combined Average**
Average (Mean)	**3.2**	**3.7**	**3.3**	**3.8**	**3.6**	**3.6**	**1.9**	**2.6**	**3.1**	**2.2**	**4.4**	**3.6**	**2.1**	**2.8**	**Score Using Avg. Wt. And Avg. Score**	**164.1**	**163.8**

Table A-11. Adjusted Average Scores for Each Strategy

Trench/Infiltration Barrier/Drying	4	3	4	4	5	4	2	3	4	4	2	4	4	2	A	177	
Trench/Infiltration Barrier/Drying	3	2	2	3	3	3	2	3	2	3	4	4	2	2	B*	139	
Trench/Infiltration Barrier/Drying	4	5	3	5	4	3	1	3	2	4	5	4	3	4	C*	188	
Trench/Infiltration Barrier/Drying	4	4	2	4	4	3	1	3	3	1	4	4	3	4	D	154	
Trench/Infiltration Barrier/Drying	4	3	5	3	3	4	3	4	4	4	4	4	2	4	E	210	
Trench/Infiltration Barrier/Drying	2	2	3	3	3	3	3	3	3	3	4	3	2	2	F	143	
Trench/Infiltration Barrier/Drying	2	4	3	4	4	3	2	3	2	1	5	3	2	3	G	154	
Trench/Infiltration Barrier/Drying	2	5	2	5	5	5	1	3	4	4	5	5	4	4	H	219	
Trench/Infiltration Barrier/Drying	4	5	5	5	4	5	3	4	4	4	2	5	2	4	I	183	
															Average Score	**174.1**	**Combined Average**
Average (Mean)	**3.2**	**3.7**	**3.2**	**4.0**	**3.9**	**3.7**	**2.0**	**3.2**	**3.1**	**3.1**	**3.9**	**4.0**	**2.7**	**3.2**	**Score Using Avg. Wt. And Avg. Score**	**173.8**	**173.9**
Vault & Tank Drying	5	3	3	3	4	3	2	3	3	3	4	3	3	3	A	160	
Vault & Tank Drying	3	4	4	3	4	3	3	2	2	3	4	4	3	2	B*	163	
Vault & Tank Drying	3	3	3	4	4	3	3	2	3	3	4	3	1	4	C*	161	
Vault & Tank Drying	3	3	3	3	3	2	3	3	4	3	4	4	3	2	D	140	
Vault & Tank Drying	4	3	4	3	4	3	3	4	3	3	4	3	1	3	E	186	
Vault & Tank Drying	2	3	3	3	2	2	3	3	3	3	4	3	1	3	F	141	
Vault & Tank Drying	3	4	3	4	3	3	3	2	2	4	5	3	2	3	G	163	
Vault & Tank Drying	2	4	4	4	4	5	2	3	4	4	4	4	3	3	H	200	
Vault & Tank Drying	5	4	3	4	4	5	3	4	4	3	5	4	3	4	I	180	
															Average Score	**166.0**	**Combined Average**
Average (Mean)	**3.3**	**3.4**	**3.3**	**3.4**	**3.6**	**3.2**	**2.8**	**2.9**	**3.1**	**3.2**	**4.2**	**3.4**	**2.2**	**3.0**	**Score Using Avg. Wt. And Avg. Score**	**167.2**	**166.6**
Vault Drying	5	2	2	2	3	2	3	4	3	3	4	3	3	3	A	146	
Vault Drying	4	3	4	3	3	3	3	3	2	3	4	4	2	2	B*	158	
Vault Drying	3	2	3	3	3	3	3	3	2	3	5	3	2	2	C*	146	
Vault Drying	3	2	4	3	2	3	3	3	4	2	4	4	3	2	D	142	
Vault Drying	4	3	4	3	3	3	3	3	3	3	4	3	1	2	E	175	
Vault Drying	2	2	2	2	2	2	4	3	4	3	4	2	1	3	F	130	
Vault Drying	3	3	3	3	2	3	4	3	2	4	5	2	2	2	G	147	
Vault Drying	2	4	4	4	3	4	3	3	4	3	5	4	3	2	H	192	
Vault Drying	5	4	4	4	4	4	4	4	4	4	5	4	3	3	I	184	
															Average Score	**157.9**	**Combined Average**
Average (Mean)	**3.4**	**2.8**	**3.3**	**3.0**	**2.8**	**3.0**	**3.3**	**3.2**	**3.1**	**3.1**	**4.4**	**3.2**	**2.2**	**2.3**	**Score Using Avg. Wt. And Avg. Score**	**158.2**	**158.0**

Table A-11. Adjusted Average Scores for Each Strategy

Waste Removal	5	2	1	3	2	3	2	4	4	2	5	5	3	2	A	143	
Waste Removal	4	4	3	4	3	3	1	2	4	1	4	4	4	4	B*	167	
Waste Removal	4	5	5	5	4	4	1	4	3	1	4	5	5	4	C*	201	
Waste Removal	5	5	1	5	1	4	1	2	1	1	5	5	4	4	D	154	
Waste Removal	4	4	4	3	4	3	2	3	3	4	4	3	3	2	E	190	
Waste Removal	4	2	5	3	1	3	2	2	2	1	4	3	5	2	F	140	
Waste Removal	4	5	1	5	1	5	1	5	1	4	5	4	5	2	G	175	
Waste Removal	4	5	2	4	3	5	1	5	2	2	5	5	5	3	H	206	
Waste Removal	5	5	5	5	1	5	1	5	4	1	5	5	4	5	I	176	
															Average Score	**172.4**	**Combined Average**
Average (Mean)	**4.3**	**4.1**	**3.0**	**4.1**	**2.2**	**3.9**	**1.3**	**3.6**	**2.7**	**1.9**	**4.6**	**4.3**	**4.2**	**3.1**	**Score Using Avg. Wt. And Avg. Score**	**174.0**	**173.2**

Table A-12. Scores with Alternative Weighting Factors

EVALUATION CRITERIA---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy						
Average Weighting Factor--->	3.7	4.7	4.0	4.3	4.3	4.0	2.9	3.0	3.4	3.1	4.0	3.4	2.3	3.7						
Risk Weighting Factor-->	1	1	5	5	1	1	1	1	1	1	1	1	1	1						
No Weighting Factor-->	3	3	3	3	3	3	3	3	3	3	3	3	3	3						
Safety/Compliance Weighting Factor-->	5	5	1	1	5	5	1	1	1	1	1	5	1	1						
Certainty Weighting Factor-->	1	1	1	1	1	1	1	1	5	1	1	1	1	5						
Cost Weighting Factor-->	1	1	1	1	1	1	5	5	1	5	1	1	5	1						
UNSORTED															Score w/Average WF	Score w/Risk WF	Score w/No WF	Score w/Safety/ Compliance WF	Score w/Certainty WF	Score w/Cost WF
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	139	58	115	92	57	82
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	145	62	118	97	58	81
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	147	61	121	96	59	89
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	153	68	124	106	61	85
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	150	64	124	96	62	91
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	153	64	128	96	68	96
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	149	63	122	101	60	84
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	158	67	130	105	67	92
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	156	67	128	105	65	88
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	159	73	131	109	67	92
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	168	77	136	119	71	88
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	142	63	118	87	60	87
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	146	62	121	95	59	89
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	146	62	119	98	58	82
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	137	61	114	89	54	86
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	142	62	116	96	56	82
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	163	72	131	114	68	79
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	172	74	139	119	72	91
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	165	71	134	112	69	89
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	159	69	130	104	66	91
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	170	74	139	119	69	91

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH AVERAGE															Score w/Average WF					
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	**172**	**74**	**139**	**119**	**72**	**91**
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	**170**	**74**	**139**	**119**	**69**	**91**
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	**168**	**77**	**136**	**119**	**71**	**88**
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	**165**	**71**	**134**	**112**	**69**	**89**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	**163**	**72**	**131**	**114**	**68**	**79**
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	**159**	**73**	**131**	**109**	**67**	**92**
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	**159**	**69**	**130**	**104**	**66**	**91**
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	**158**	**67**	**130**	**105**	**67**	**92**
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	**156**	**67**	**128**	**105**	**65**	**88**
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	**153**	**64**	**128**	**96**	**68**	**96**
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	**153**	**68**	**124**	**106**	**61**	**85**
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	**150**	**64**	**124**	**96**	**62**	**91**
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	**149**	**63**	**122**	**101**	**60**	**84**
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	**147**	**61**	**121**	**96**	**59**	**89**
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	**146**	**62**	**119**	**98**	**58**	**82**
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	**146**	**62**	**121**	**95**	**59**	**89**
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	**145**	**62**	**118**	**97**	**58**	**81**
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	**142**	**63**	**118**	**87**	**60**	**87**
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	**142**	**62**	**116**	**96**	**56**	**82**
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	**139**	**58**	**115**	**92**	**57**	**82**
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	**137**	**61**	**114**	**89**	**54**	**86**

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH RISK																Score w/Risk WF				
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	**168**	**77**	**136**	**119**	**71**	**88**
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	**172**	**74**	**139**	**119**	**72**	**91**
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	**170**	**74**	**139**	**119**	**69**	**91**
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	**159**	**73**	**131**	**109**	**67**	**92**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	**163**	**72**	**131**	**114**	**68**	**79**
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	**165**	**71**	**134**	**112**	**69**	**89**
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	**159**	**69**	**130**	**104**	**66**	**91**
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	**153**	**68**	**124**	**106**	**61**	**85**
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	**158**	**67**	**130**	**105**	**67**	**92**
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	**156**	**67**	**128**	**105**	**65**	**88**
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	**153**	**64**	**128**	**96**	**68**	**96**
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	**150**	**64**	**124**	**96**	**62**	**91**
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	**142**	**63**	**118**	**87**	**60**	**87**
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	**149**	**63**	**122**	**101**	**60**	**84**
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	**146**	**62**	**119**	**98**	**58**	**82**
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	**145**	**62**	**118**	**97**	**58**	**81**
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	**146**	**62**	**121**	**95**	**59**	**89**
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	**142**	**62**	**116**	**96**	**56**	**82**
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	**147**	**61**	**121**	**96**	**59**	**89**
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	**137**	**61**	**114**	**89**	**54**	**86**
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	**139**	**58**	**115**	**92**	**57**	**82**

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH NO WEIGHTING																	Score w/No WF			
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	**172**	**74**	**139**	**119**	**72**	**91**
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	**170**	**74**	**139**	**119**	**69**	**91**
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	**168**	**77**	**136**	**119**	**71**	**88**
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	**165**	**71**	**134**	**112**	**69**	**89**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	**163**	**72**	**131**	**114**	**68**	**79**
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	**159**	**73**	**131**	**109**	**67**	**92**
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	**159**	**69**	**130**	**104**	**66**	**91**
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	**158**	**67**	**130**	**105**	**67**	**92**
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	**153**	**64**	**128**	**96**	**68**	**96**
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	**156**	**67**	**128**	**105**	**65**	**88**
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	**153**	**68**	**124**	**106**	**61**	**85**
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	**150**	**64**	**124**	**96**	**62**	**91**
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	**149**	**63**	**122**	**101**	**60**	**84**
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	**147**	**61**	**121**	**96**	**59**	**89**
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	**146**	**62**	**121**	**95**	**59**	**89**
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	**146**	**62**	**119**	**98**	**58**	**82**
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	**145**	**62**	**118**	**97**	**58**	**81**
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	**142**	**63**	**118**	**87**	**60**	**87**
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	**142**	**62**	**116**	**96**	**56**	**82**
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	**139**	**58**	**115**	**92**	**57**	**82**
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	**137**	**61**	**114**	**89**	**54**	**86**

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH SAFETY/COMPLIANCE																		Score w/Safety/ Compliance WF		
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	**168**	**77**	**136**	**119**	**71**	**88**
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	**172**	**74**	**139**	**119**	**72**	**91**
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	**170**	**74**	**139**	**119**	**69**	**91**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	**163**	**72**	**131**	**114**	**68**	**79**
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	**165**	**71**	**134**	**112**	**69**	**89**
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	**159**	**73**	**131**	**109**	**67**	**92**
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	**153**	**68**	**124**	**106**	**61**	**85**
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	**156**	**67**	**128**	**105**	**65**	**88**
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	**158**	**67**	**130**	**105**	**67**	**92**
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	**159**	**69**	**130**	**104**	**66**	**91**
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	**149**	**63**	**122**	**101**	**60**	**84**
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	**146**	**62**	**119**	**98**	**58**	**82**
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	**145**	**62**	**118**	**97**	**58**	**81**
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	**147**	**61**	**121**	**96**	**59**	**89**
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	**150**	**64**	**124**	**96**	**62**	**91**
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	**142**	**62**	**116**	**96**	**56**	**82**
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	**153**	**64**	**128**	**96**	**68**	**96**
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	**146**	**62**	**121**	**95**	**59**	**89**
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	**139**	**58**	**115**	**92**	**57**	**82**
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	**137**	**61**	**114**	**89**	**54**	**86**
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	**142**	**63**	**118**	**87**	**60**	**87**

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH CERTAINTY																			Score w/Certainty WF	
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	**172**	**74**	**139**	**119**	**72**	**91**
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	**168**	**77**	**136**	**119**	**71**	**88**
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	**170**	**74**	**139**	**119**	**69**	**91**
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	**165**	**71**	**134**	**112**	**69**	**89**
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	**153**	**64**	**128**	**96**	**68**	**96**
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	**163**	**72**	**131**	**114**	**68**	**79**
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	**158**	**67**	**130**	**105**	**67**	**92**
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	**159**	**73**	**131**	**109**	**67**	**92**
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	**159**	**69**	**130**	**104**	**66**	**91**
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	**156**	**67**	**128**	**105**	**65**	**88**
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	**150**	**64**	**124**	**96**	**62**	**91**
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	**153**	**68**	**124**	**106**	**61**	**85**
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	**149**	**63**	**122**	**101**	**60**	**84**
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	**142**	**63**	**118**	**87**	**60**	**87**
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	**147**	**61**	**121**	**96**	**59**	**89**
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	**146**	**62**	**121**	**95**	**59**	**89**
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	**146**	**62**	**119**	**98**	**58**	**82**
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	**145**	**62**	**118**	**97**	**58**	**81**
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	**139**	**58**	**115**	**92**	**57**	**82**
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	**142**	**62**	**116**	**96**	**56**	**82**
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	**137**	**61**	**114**	**89**	**54**	**86**

Table A-12. Scores with Alternative Weighting Factors

SORTED WITH COST																				Score w/Cost WF
Current System	3.8	2.1	3.4	2.0	1.8	3.2	4.7	3.4	3.9	3.2	4.3	2.3	1.9	2.6	153	64	128	96	68	96
Infiltration Barrier/Drying	3.0	2.8	3.1	2.9	3.1	3.1	2.9	3.4	3.4	3.4	3.9	3.3	2.4	2.6	158	67	130	105	67	92
Low Strength Grout	4.0	3.3	3.9	3.4	2.6	3.6	3.0	4.0	3.1	2.1	2.2	2.8	2.9	2.8	159	73	131	109	67	92
Vault Drying	3.4	2.8	3.3	3.0	2.8	3.1	3.3	3.1	3.1	3.2	4.4	3.1	2.2	2.4	159	69	130	104	66	91
Trench/Infiltration Barrier/Drying	3.3	3.6	3.1	3.9	3.8	3.6	2.2	3.1	3.2	3.2	3.9	3.9	2.6	3.1	172	74	139	119	72	91
Waste Removal	4.0	4.1	3.0	3.9	2.2	3.7	1.7	3.3	2.8	2.0	4.3	4.1	4.1	3.0	170	74	139	119	69	91
Corrosion Inhibitors in Vault	3.3	2.6	3.6	2.2	2.4	2.8	3.8	3.7	3.2	3.1	4.2	2.6	1.8	2.0	150	64	124	96	62	91
Cathodic Protection	3.6	2.4	3.0	2.2	2.3	3.2	3.2	3.4	2.6	3.7	4.4	2.4	1.8	2.1	147	61	121	96	59	89
Vault & Tank Drying	3.2	3.4	3.2	3.4	3.6	3.2	2.9	2.8	3.1	3.1	4.1	3.4	2.2	3.0	165	71	134	112	69	89
Nitrogen Blanket	3.6	2.3	3.1	2.3	2.2	2.8	3.4	3.2	2.8	3.6	4.3	2.8	1.9	1.9	146	62	121	95	59	89
Interceptor Trench/Drying	3.1	3.0	3.0	3.0	3.0	3.2	2.9	3.2	3.2	3.0	4.0	3.2	2.3	2.3	156	67	128	105	65	88
Low Strength Grout/Drying	3.8	4.0	3.8	4.0	3.8	3.6	2.6	2.9	3.3	2.2	2.1	3.3	3.0	3.1	168	77	136	119	71	88
Monitors	3.3	1.6	3.9	2.1	1.4	3.3	3.4	3.3	3.2	3.7	4.4	2.3	1.4	1.9	142	63	118	87	60	87
Sorbents in Annulus	3.1	2.6	3.3	2.3	1.9	2.6	3.4	3.8	2.2	3.0	3.7	2.6	1.9	1.7	137	61	114	89	54	86
Contamination Fixative/Drying	3.6	3.3	3.3	3.3	3.1	3.2	2.8	2.8	2.4	2.9	2.9	2.9	2.3	2.6	153	68	124	106	61	85
Groundwater Barrier/Drying	3.1	3.1	3.0	2.7	3.0	3.0	2.2	3.0	2.7	3.2	4.0	3.0	2.3	2.2	149	63	122	101	60	84
Sorbents with Cathodic Protection	3.3	2.9	2.9	2.9	2.7	2.8	2.8	3.2	2.2	3.0	3.7	2.6	1.9	2.0	142	62	116	96	56	82
Argon Blanket	3.4	2.7	2.8	2.1	2.3	2.2	2.7	2.9	2.7	3.7	4.3	2.7	1.8	2.0	139	58	115	92	57	82
Nitrogen Blanket w/Oxygen Removal	3.6	2.9	3.1	2.6	2.6	2.7	2.7	2.6	2.6	3.3	4.3	3.0	2.0	2.0	146	62	119	98	58	82
Argon Blanket w/Cathodic Protection	3.3	3.0	2.9	2.8	2.9	2.6	2.6	2.4	2.3	3.6	4.3	2.7	1.9	2.2	145	62	118	97	58	81
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	3.2	3.7	3.2	3.8	3.6	3.6	1.9	2.4	3.2	2.2	4.2	3.6	2.2	2.9	163	72	131	114	68	79

FINAL REPORT
WEST VALLEY HIGH-LEVEL WASTE TANK LAY-UP

June 29, 2001

Prepared for
Tanks Focus Area

Prepared by
Jacobs Engineering Group Inc. and
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Richland, Washington

CONTENTS

1.0 INTRODUCTION 1

2.0 EVALUATION CRITERIA FOR SELECTION OF PREFERRED OPTION 2

3.0 ALTERNATIVE LAY-UP STRATEGIES 4
- 3.1 CURRENT SYSTEM 4
- 3.2 CATHODIC PROTECTION FOR EXTERNAL TANK SURFACES 4
- 3.3 VAULT DRYING SYSTEM 5
- 3.4 VAULT AND TANK DRYING 5
- 3.5 NITROGEN BLANKET 5
- 3.6 NITROGEN BLANKET WITH OXYGEN REMOVAL 5
- 3.7 ARGON OR OTHER HIGH DENSITY INERT GAS INSTEAD OF NITROGEN 5
- 3.8 ARGON BLANKET WITH CATHODIC PROTECTION 6
- 3.9 INTERCEPTOR TRENCH/DRYING 6
- 3.10 TRENCH/INFILTRATION BARRIER/DRYING 6
- 3.11 INFILTRATION BARRIER/DRYING/ENHANCED PUMPING 6
- 3.12 GROUNDWATER BARRIER/DRYING 7
- 3.13 INFILTRATION BARRIER/DRYING 7
- 3.14 CORROSION INHIBITORS IN THE WATER OUTSIDE THE TANKS 7
- 3.15 SORBENTS IN ANNULUS 7
- 3.16 SORBENTS WITH CATHODIC PROTECTION 7
- 3.17 LOW-STRENGTH GROUT 7
- 3.18 LOW-STRENGTH GROUT/DRYING 8
- 3.19 CONTAMINATION FIXATIVE 8
- 3.20 MONITORS 8
- 3.21 WASTE REMOVAL 8

4.0 DECISION PLAN METHODOLOGY 10
- 4.1 TEAM SCORES 10
- 4.2 DEMONSTRATION OF METHODOLOGY 13
- 4.3 SENSITIVITY ANALYSIS 17

5.0 UNCERTAINTY OF STRATEGIES 19

6.0 WORKSHOP AT WEST VALLEY DEMONSTRATION PROJECT 21

7.0 CONCLUSIONS AND RECOMMENDATIONS 23

8.0 REFERENCES 24

FIGURE

1. Methodology for Identifying Preferred Lay-Up Approach 10

TABLES

1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up 9
2. Team Scoring Sheet 11
3. Team Member Rankings 14
4. Combined Rankings of Team Members 16
5. Weighting Factor Averages 18

1.0 INTRODUCTION

This report documents completion of Milestone A.4-1, "Issue Tank Lay-Up Strategies for WVDP Final Report," in Technical Task Plan RL30WT21A, "Post-Retrieval and Pre-Closure HLW Tank Lay-Up." This task was a collaborative effort among Pacific Northwest National Laboratory, Jacobs Engineering Group Inc., and West Valley Nuclear Services. The primary objective of the overall task was to develop and evaluate conceptual strategies for preclosure lay-up of the two large high-level waste storage tanks at the West Valley Demonstration Project.

Functions and requirements for tank lay-up were developed and previously documented in *Functions and Requirements for WVDP Lay-Up* (Henderson 2001a [Letter Report #1]). These functions and requirements served as the basis for criteria to evaluate potential lay-up options documented in *West Valley High-Level Waste Tank Lay-Up Strategies* (Henderson 2001b [Letter Report #2]). A methodology for ranking the alternative lay-up strategies was described in *Decision Plan for West Valley High-Level Waste Tank Lay-up* (Henderson 2001c [Letter Report #3]).

Several actions were identified for possible implementation to provide assurance of maintaining the West Valley Demonstration Project tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options. Alternative strategies for this lay-up period were then identified which are either individual actions or combinations of actions.

Criteria were identified for assessing the alternative strategies. The criteria represent requirements or desired features of any strategy selected. The lay-up strategy selected should provide the best balance among the evaluation criteria for placing the tanks in a safe, stable lay-up mode.

A methodology was developed for ranking the potential strategies. The methodology provides a consensus ranking even with wide variations in scores from individual team members as long as the number of team members is large enough. A minimum of 8 team members is recommended, and 10 to 12 members would be better. Because of the number and types of technical issues associated with the strategies, the evaluation team should consist of a broad spectrum of technical experts and decision makers.

The methodology is applicable to determining preferred lay-up approaches at other U.S. Department of Energy sites. Some of the alternative strategies identified for West Valley should also be considered for implementation at the other sites, and some would not be. Each site has unique characteristics that would require unique considerations for lay-up.

This final report contains a summary of all the previous reports and a summary of a workshop held at the West Valley Demonstration Project site to discuss the results of the sample scoring of alternative strategies (Letter Report #3).

2.0 EVALUATION CRITERIA FOR SELECTION OF PREFERRED OPTION

The following criteria were selected for evaluating alternative strategies for tank lay-up (Letter Report #1). The criteria represent requirements or desired features of any strategy selected. The methodology includes assigning weighting factors to the criteria to distinguish their relative importance. Two criteria were expanded into subcriteria for the sample scoring.

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period.

- **Prevent release of tank contents to the groundwater** – There shall be no release of radioactive or hazardous materials to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.

- **Ensure acceptable risk to workers and the public**

  - **Short-term risk:** The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable.

  - **Long-term risk:** The selected option should result in a reduced risk to workers and the public during the lay-up period.

- **Maintain integrity of the tanks** – The ability of the tanks to continue to contain the waste residual must be maintained. Corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up** – The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control costs**

  - Capital costs of new equipment or modifications to existing systems.
  - Routine operating costs during the lay-up period.

- **Utilize accepted methods and technologies** – The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation** – Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be generally avoided.

- **Preserve future options for decontamination and final closure** – The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude candidate final closure options, such as in-place stabilization or complete tank removal.

- **Gain acceptance for lay-up** – The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.
- **Reduce monitoring and surveillance** – Reductions in monitoring and surveillance, consistent with requirements, is desired.

3.0 ALTERNATIVE LAY-UP STRATEGIES

Several alternative actions were identified to provide for continued safe storage of the residual waste in the tanks prior to final closure (Letter Report #2). The lay-up strategy selected should provide the best balance among the evaluation criteria for placing the tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options. The following strategies were identified for consideration (Letter Report #2).

3.1 CURRENT SYSTEM

The historical methods of corrosion control have been to periodically remove water from the containment pan, control the pH and nitrite/nitrate ratio of the liquid inside the tanks, and maintain a nitrogen purge inside the vaults. The corrosion rate of the tank internals is believed to be controlled in the range of 0.013 to 0.025 mm/yr (0.5 to 1.0 mpy[1]) (Chang et al. 1999). However, pH and nitrite/nitrate limits have not been rigorously maintained since waste retrieval operations began, decreasing the level of the confidence of corrosion control.

Pumps are currently used to remove water from outside and inside the tank vaults. However, there will continue to be a concern that corrosion to the external surfaces of the tanks could eventually result in penetrations during the lay-up period. Corrosion of the external tank walls is primarily from the wet conditions inside the vaults. General corrosion rates determined from corrosion coupons are generally less than 0.075 mm/yr (3 mpy) and the highest measured rate is 0.188 mm/yr (7.4 mpy) (Chang et al. 1999). The external pitting corrosion rate has been estimated at up to 0.3 ± 0.075 mm/yr (12 ± 3 mpy) (Chang et al. 1998). If this rate has been experienced since the tanks were built, there may be little remaining corrosion allowance at locations prone to pitting.

The nitrogen inerting system has been in operation since August 1996. The oxygen concentration in the vault exhaust gas has been maintained at about 13.5% to 15.5% (oxygen concentration in air is 21%) even though the system was originally designed to maintain the oxygen concentration below 0.99% (WVNS-DC-065). Assuming an even distribution of nitrogen in the vaults, use of the system has resulted in an estimated decrease in the external corrosion rate of tank 8D-1 by about 33% (Chang et al. 1999). The nitrogen inerting system also reduces the concentration of other impurities in the gas surrounding the tanks, such as sulfur dioxide, that can also accelerate corrosion.

3.2 CATHODIC PROTECTION FOR EXTERNAL TANK SURFACES

Addition of cathodic protection to the tanks has been assessed. One alternative method for cathodic protection identified is to use the containment pan as the sacrificial anode.
The tank 8D-2 containment pan is known to have a hole in it, so use as a sacrificial anode would be reasonable because its original purpose is already compromised. There are several technical and engineering issues that must be resolved before this option could be selected. These include (1) galvanic corrosion on the bottom of the tank; (2) runaway voltage with the impressed current

[1]mpy = mils per year; a mil is 1/1000 of an inch.

system; (3) protection of welds; and (4) assurance that no electrical shorts are present (e.g., pan pump, dip tubes) (Chang et al. 1999).

3.3 VAULT DRYING SYSTEM

General textbook corrosion rates of carbon steel in water are generally 0.075 to 0.20 mm/yr (3 to 8 mpy) and pitting corrosion rates are generally 2.5 to 3.5 times the general corrosion rate. External tank corrosion could be virtually eliminated if the tank surfaces were kept dry. The criterion would be to maintain the relative humidity below 30% in the air surrounding the tanks (Chang et al. 1998). The drying system would include a dehumidifier and heater for air forced into the vaults. The exhaust air leaving the vaults would pass through high-efficiency particulate air filters.

3.4 VAULT AND TANK DRYING

An additional enhancement to also reduce corrosion inside the tanks is to install drying systems both inside the vaults and inside the tanks. Drying the inside of the tanks could result in contamination of the exhaust air by particles of dried solids in the tanks being suspended by the airflow through the tanks. However, once all the liquid inside the tanks was evaporated, only a very low-flow of heated, dehumidified air would be required to maintain low humidity inside the tanks. Keeping the tank internal surfaces the same temperature as the external surfaces would also prevent condensation of water on the tanks' external walls.

3.5 NITROGEN BLANKET

The current nitrogen inerting system has not been effective in maintaining the desired concentration of oxygen in the vault below 0.9% as specified in the design criteria (WVNS-DC-065). Sealing the vault as well as possible and then adding additional amounts of cold nitrogen to displace air from the vault should result in a more effective blanket and lower oxygen concentrations.

3.6 NITROGEN BLANKET WITH OXYGEN REMOVAL

Oxygen removal from the gas surrounding the tanks to a low level (the original design criterion for the nitrogen purge was less than 0.9% oxygen) may provide adequate protection without additional measures taken to keep the vaults dry. An efficient nitrogen blanket (recirculating system) would also be required for this option. Recirculated blanket gas could be passed through a device to remove oxygen. Such a system would be efficient only if air in-leakage is significantly reduced.

3.7 ARGON OR OTHER HIGH DENSITY INERT GAS INSTEAD OF NITROGEN

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults because argon is heavier than air. Proper use of an argon blanket should not require additional capability for oxygen removal. This option has been considered in the past, as early as 1997 (Meess and Chang 1997).

3.8 ARGON BLANKET WITH CATHODIC PROTECTION

This is an enhancement of using argon instead of nitrogen to improve the displacement of oxygen and other corrosion-inducing gases from the vaults in combination with cathodic protection for additional assurance of corrosion control.

3.9 INTERCEPTOR TRENCH/DRYING

One of the primary methods of preventing or significantly reducing corrosion on the outside of the tanks is to maintain very low humidity in the vaults. To do this, the ingress of water into the vaults must be prevented. The principal source of water into the vaults appears to be from percolation of rainwater and snowmelt through the soil layer above the vaults and groundwater flow in the soil/sand layer above the compacted clay layer. One method to significantly reduce this infiltration is to divert runoff and groundwater flow. This could be accomplished by installing an interceptor trench down to the compacted clay layer upgradient of the tanks. This trench would be filled with coarse gravel and perforated pipe would be installed at the bottom of the trench to collect and remove excess water. The trench would be connected to a culvert to carry water to an appropriate location downgradient from the tanks and vaults. This would be a totally passive system. Pumping of water from the vaults and the well between the vaults could be eliminated or significantly reduced.

3.10 TRENCH/INFILTRATION BARRIER/DRYING

To increase the effectiveness of a trench, a domed clay cap, roof, or some other cover barrier could be added above the vaults to divert rainwater and snowmelt to the trench rather than infiltrating through the soil to the vaults.

A principal source of water ingress into the tank vaults appears to be from infiltration from above the vaults. A cover to divert rainwater away from the area would be effective in preventing this water from entering the vaults. This barrier could be a clay cap, a membrane, a roof, or some other cover. Installation of a barrier above the vaults is complicated by the superstructure that was installed to support the mobilization pumps and penetrations into the soil above the tanks and vaults.

3.11 INFILTRATION BARRIER/DRYING/ENHANCED PUMPING

To ensure that water will not infiltrate into the vaults from groundwater around and below the vaults, the capability to pump water from the gravel bed below the vaults could be maintained or enhanced. Water is currently pumped from a well between the vaults, but the water table is not pumped to below the bottom of the vaults. The hydrology is not known well enough to determine the volume of water that would need to be pumped to maintain the water table below the level of the vaults. More frequent operation of the current system or additional wells and pumps may be needed. Elimination of surface water infiltration and possibly also a reduction in groundwater flow (as described in the preceding sections) may be necessary for this option to be effective.

If the combination of a trench, infiltration barrier and drying system was not effective, then additional pumping of water from inside and below the vaults could be instituted. The need for additional pumping is unlikely.

3.12 GROUNDWATER BARRIER/DRYING

A solid barrier to groundwater flow could be installed if more positive exclusion of groundwater from the vaults is needed. This barrier could be a solid grout wall, a frozen soil barrier, or a viscous liquid barrier.

A barrier around the vaults may be a more positive means to preclude water intrusion than would an interceptor trench. However this would be a much more costly approach and may not be necessary. Also, ponding (perched water) could accumulate behind the barrier.

3.13 INFILTRATION BARRIER/DRYING

A barrier above the tanks would be very effective in preventing water intrusion into the vaults. The combination of a barrier above the vaults and a drying system (no interceptor trench or barrier) may be adequate for keeping the vault humidity within an acceptable level. This is dependent on the amount of water that could infiltrate the vaults from groundwater flow alone, which appears to be quite small.

3.14 CORROSION INHIBITORS IN THE WATER OUTSIDE THE TANKS

Adding corrosion inhibitors to water in the containment pans may reduce the corrosion on the outer walls below the liquid level. The same corrosion inhibitors would not be effective for reducing corrosion in the high-humidity vapor space above the liquid level.

3.15 SORBENTS IN ANNULUS

An ion exchange and/or sorbent material could be added to the secondary containment pan and/or the vault to capture the radioactive species before they could migrate outside the vault. Additional information would be required to determine if a combination of materials could be selected which would be effective for all the species of concern.

3.16 SORBENTS WITH CATHODIC PROTECTION

This would be a relatively low-cost option of adding a cathodic protection system and also sorbents for added protection in the unlikely event of a leak. However, reliable corrosion control with cathodic protection alone is uncertain.

3.17 LOW-STRENGTH GROUT

The objective of this option is to provide a method for temporarily fixing the residual waste in the tank. Nearly all the residual liquid would have to be removed before the grout was added. A low-strength grout would be necessary so that it could be removed in the future if final closure requires additional decontamination of the tanks or complete removal of the tanks. Adequate mixing of the grout with the residual waste has not been demonstrated.

3.18 LOW-STRENGTH GROUT/DRYING

This would be the combination of adding a low-strength grout and a drying system for the tanks and vaults. The drying system would be very effective in reducing corrosion and the grout would stabilize the radionuclides and reduce or possibly prevent leakage even if a penetration in the tank wall developed.

3.19 CONTAMINATION FIXATIVE

Another option for temporary stabilization of the residual material in the tank would be to spray a coating to prevent any suspension of contamination. This option could be used in combination with the option to keep the inside of the tanks dry to prevent corrosion or to reduce contaminated solids suspension if the tank contents are allowed to dry during the lay-up period. In fact, the tank contents would first have to be dry before a fixative could be applied. The drying system would reduce corrosion and the fixative would stabilize the radionuclides and prevent dispersion into the off-gas system.

3.20 MONITORS

Radiation and/or contamination monitors in the tanks or vaults would indicate changes in conditions and possible leaks. There are several monitors on the market that could be installed to give early warning of a tank failure. A gamma monitor would need to be shielded from the background radiation inside the tank, or an alpha and/or beta monitor could be used.

Continuous corrosion monitors could also be installed in the tanks and vaults. These monitors would provide an indication of accelerated corrosion due to unexpected changes.

Depending on the composition of waste in the West Valley Demonstration Project carbon-steel tanks, the tanks may be susceptible to nitrate ion-induced stress corrosion cracking. Monitoring and maintaining adequate nitrite/nitrate ratio and hydroxide ion levels prevents this degradation. Sensors that could monitor all three species could reduce the costs of current baseline sampling and laboratory analysis methods and could minimize the addition of corrosion inhibitor solution. Savannah River Site personnel are currently evaluating a Raman spectroscopy-based method for in situ analysis of OH^-, NO_2^-, and NO_3^-.

3.21 WASTE REMOVAL

Very aggressive decontamination could be employed prior to temporary tank lay-up. Removal of all but a very small amount of residual contamination may preclude the need for any further action prior to final closure. This option might have a lower lay-up cost than other options that require continued operation of equipment (such as the nitrogen purge system) and surveillance. However, the criteria for what constitutes adequate decontamination are not established and any residual contamination could present a risk to the environment.

Table 1 is a summary of the lay-up strategies considered for the West Valley Demonstration Project tanks.

Table 1. Alternative Strategies for West Valley Demonstration Project Tank Lay-Up

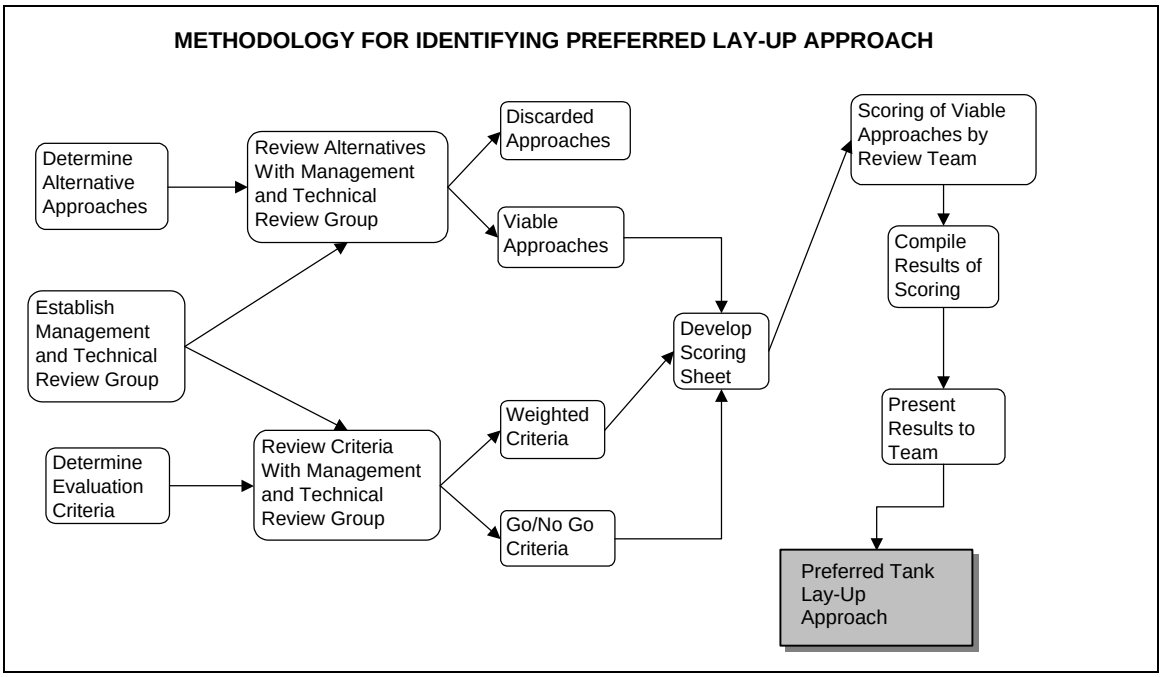
Strategy	Dry or Wet Option	Nitrogen Inerting	pH Control	Cathodic Protection	Vault Drying	Tank Drying	Nitrogen Blanket	Ar Inerting	Oxygen Removal	Interceptor Trench	Ground-water Barrier	Infiltration Barrier	Enhanced Pumping	Corrosion Inhibitors	Sorbents in Annulus	Low Strength Grout	Contamination Fixative	Corrosion Monitors	Radiation/ Contamination Monitors	Complete Waste Removal
Current System	Wet	X	X																	
Cathodic Protection	Wet	X	X	X																
Vault Drying	Dry		X		X															
Vault & Tank Drying	Dry				X	X														
Nitrogen Blanket	Wet		X				X													
Nitrogen Blanket w/Oxygen Removal	Wet		X				X		X											
Argon Blanket	Wet		X					X												
Argon Blanket w/Cathodic Protection	Wet		X	X				X												
Interceptor Trench/Drying	Dry		X		X					X										
Trench/Infiltration Barrier/Drying	Dry		X		X					X		X								
Trench/Infiltration Barrier/Drying/Enhanced Pumping	Dry		X		X					X		X	X							
Groundwater Barrier/Drying	Dry		X		X						X									
Infiltration Barrier/Drying	Dry		X		X							X								
Corrosion Inhibitors in Vault	Wet	X	X											X						
Sorbents in Annulus	Wet	X	X												X					
Sorbents with Cathodic Protection	Wet	X	X	X											X					
Low Strength Grout	Wet	X														X				
Low Strength Grout/Drying	Dry				X	X										X				
Contamination Fixative/Drying	Dry				X	X											X			
Monitors	Wet		X															X	X	
Waste Removal	Wet																			X

4.0 DECISION PLAN METHODOLOGY

A methodology for ranking the strategies was developed. The methodology consists of scoring each strategy with each of the selection criteria. The scoring matrix is shown as Table 2. Team members would supply weighting factors from 1 to 5 for each of the criteria, and scores from 1 to 5 for how well each strategy meets the criteria. A total score for each strategy is then calculated as a sum of the products of each score times the associated criterion weighting factor.

A flowchart of the methodology is shown in Figure 1.

Figure 1. Methodology for Identifying Preferred Lay-Up Approach



4.1 TEAM SCORES

The individual team rankings resulting from the scoring sheets can be depicted by ranking the total score from highest to lowest. A combined ranking of the strategies from the team member rankings can then be compiled. The combined ranking is based on assigning a score of 5 to each #1 ranking, a score of 4 to each #2 ranking, etc. down to a score of 1 for each #5 ranking. Many of the lowest-ranked strategies can be eliminated from further consideration, or the strategies can be reconfigured to combine elements into a strategy or strategies oriented at meeting the tank lay-up goals.

Table 2. Team Scoring Sheet (2 Sheets)

Evaluation Criteria------>	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy	
Weighting Factor (1-5) --->															
STRATEGY															**SCORE**
Maximum Score	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	
Current System															
Cathodic Protection															
Vault Drying															
Vault & Tank Drying															
Nitrogen Blanket															
Nitrogen Blanket w/Oxygen Removal															
Argon Blanket															
Argon Blanket w/Cathodic Protection															
Interceptor Trench/Drying															
Trench/Infiltration Barrier/Drying															
Trench/Infiltration Barrier/ Drying/Enhanced Pumping															
Groundwater Barrier/Drying															

Table 2. Team Scoring Sheet (2 Sheets)

Evaluation Criteria------>	**Compliance with Regulations and Permits**	**Prevent Release of Contents**	**Acceptable Risk (Short Term)**	**Acceptable Risk (Long Term)**	**Maintain Tank Integrity**	**Safe Operating Envelope**	**Capital Cost**	**Operating Cost**	**Proven Methods and Technologies**	**Minimize Secondary Waste**	**Preserve Closure Options**	**Regulatory and Stakeholder Acceptance**	**Reduced Monitoring and Surveillance**	**Certainty of Strategy**	
Weighting Factor (1-5) --->															
STRATEGY															**SCORE**
Maximum Score	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	***5***	
Infiltration Barrier/Drying															
Corrosion Inhibitors in Vault															
Sorbents in Annulus															
Sorbents with Cathodic Protection															
Low Strength Grout															
Low Strength Grout/Drying															
Contamination Fixative/Drying															
Monitors															
Waste Removal															

4.2 DEMONSTRATION OF METHODOLOGY

A team was selected with a broad range of experience to provide scores on the matrix that were used to demonstrate the methodology. These sample scores provided a starting point for demonstrating the methodology. The ranking of strategies resulting from these scores are reported only to demonstrate the methodology and are not intended as a recommendation of preferred strategies.

The scoring team was comprised of three personnel from the Richland Jacobs Engineering Group Inc. Office, three from the Denver Jacobs Office and three from Pacific Northwest National Laboratory. The disciplines represented were: (1) Chemist, (2) Chemical Engineer, (3) Civil Engineer, (4) Environmental Engineer, (5) Corrosion Engineer, (6) Hydrogeologist, (7) Mechanical Engineer, and (8) Regulatory Specialist (two).

The individual team rankings resulting from the scoring sheets are shown in Table 3. Team member B did not provide weighting factors, so the averages of the weighting factor scores from the other team members were used to determine scores for team member B. There are some interesting results from the individual scoring sheets. Note that team member A scored the grout options last, while team members F and G ranked them first. This may demonstrate a lack of understanding of this option by one or more of the team members. Scoring was completed on an individual basis and compiled for this report without a meeting to develop consensus for the weighting factors or scores. When the actual ranking of strategies is done, a meeting of all parties should be convened to discuss the scores and rankings and resolve such differences. The ranking from the raw scores and sensitivity analysis should merely serve as the starting point for the discussion.

The results shown in Table 3 indicate that the team members favored the strategy of using an interceptor trench, infiltration barrier, and vault drying. This may be a result of this strategy being one of the more extensive in terms of the number of actions taken to prevent water from entering the vaults. The addition of enhancement pumping to these three actions also scored high. The options of using grout to stabilize the tank contents also scored well. The waste removal option also scored in the top five.

A combined ranking of the strategies from the team member rankings is shown in Table 4. The combined ranking is based on assigning a score of 5 to each #1 ranking, a score of 4 to each #2 ranking, etc. down to a score of 1 for each #5 ranking. Table 4 shows that the strategy of installing an interceptor trench in combination with an infiltration barrier and vault drying is clearly preferred. There is very little difference in the scores for the strategies ranked second through fifth. There are a number of strategies that ranked low indicating that there was little confidence by any of the team members that the strategies as described would meet the tank lay-up goals. The bottom third of the strategies could be eliminated from further consideration or the strategies could be reconfigured to combine elements into a strategy or strategies oriented at meeting the tank lay-up goals.

Table 3. Team Member Rankings (2 Sheets)

A	B	C	D	E	F	G	H	I
Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Waste Removal	Waste Removal	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Interceptor Trench/Drying	Low Strength Grout/Drying	Low Strength Grout/Drying	Trench/Infiltration Barrier/Drying	Interceptor Trench/Drying
Trench/Infiltration Barrier/Drying	Vault Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout/Drying	Trench/Infiltration Barrier/Drying	Low Strength Grout	Low Strength Grout	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Contamination Fixative/Drying
Groundwater Barrier/Drying	Vault & Tank Drying	Low Strength Grout	Current System	Nitrogen Blanket	Contamination Fixative/Drying	Vault & Tank Drying	Vault & Tank Drying	Vault Drying
Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Corrosion Inhibitors in Vault	Low Strength Grout	Sorbents in Annulus	Monitors	Waste Removal	Waste Removal	Trench/Infiltration Barrier/Drying
Vault & Tank Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Cathodic Protection	Waste Removal	Low Strength Grout	Groundwater Barrier/Drying	Current System	Low Strength Grout/Drying	Infiltration Barrier/Drying
Interceptor Trench/Drying	Sorbents with Cathodic Protection	Current System	Trench/Infiltration Barrier/Drying	Infiltration Barrier/Drying	Interceptor Trench/Drying	Infiltration Barrier/Drying	Interceptor Trench/Drying	Vault & Tank Drying
Corrosion Inhibitors in Vault	Sorbents in Annulus	Low Strength Grout/Drying	Infiltration Barrier/Drying	Monitors	Trench/Infiltration Barrier/Drying	Trench/Infiltration Barrier/Drying	Infiltration Barrier/Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping
Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket w/Oxygen Removal	Vault & Tank Drying	Vault Drying	Current System	Sorbents with Cathodic Protection	Argon Blanket w/Cathodic Protection	Vault Drying	Waste Removal
Argon Blanket w/Cathodic Protection	Nitrogen Blanket	Sorbents in Annulus	Groundwater Barrier/Drying	Low Strength Grout/Drying	Argon Blanket w/Cathodic Protection	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Groundwater Barrier/Drying	Corrosion Inhibitors in Vault
Cathodic Protection	Monitors	Vault Drying	Vault & Tank Drying	Argon Blanket	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Contamination Fixative/Drying	Contamination Fixative/Drying	Groundwater Barrier/Drying
Sorbents in Annulus	Low Strength Grout/Drying	Nitrogen Blanket	Corrosion Inhibitors in Vault	Sorbents with Cathodic Protection	Current System	Cathodic Protection	Nitrogen Blanket w/Oxygen Removal	Low Strength Grout/Drying
Vault Drying	Low Strength Grout	Argon Blanket	Argon Blanket w/Cathodic Protection	Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket w/Oxygen Removal	Vault Drying	Nitrogen Blanket	Current System

Table 3. Team Member Rankings (2 Sheets)

A	B	C	D	E	F	G	H	I
Sorbents with Cathodic Protection	Interceptor Trench/Drying	Argon Blanket w/Cathodic Protection	Interceptor Trench/Drying	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Vault Drying	Sorbents with Cathodic Protection	Low Strength Grout	Low Strength Grout
Monitors	Infiltration Barrier/Drying	Sorbents with Cathodic Protection	Contamination Fixative/Drying	Corrosion Inhibitors in Vault	Waste Removal	Monitors	Corrosion Inhibitors in Vault	Nitrogen Blanket w/Oxygen Removal
Current System	Groundwater Barrier/Drying	Nitrogen Blanket w/Oxygen Removal	Nitrogen Blanket	Waste Removal	Argon Blanket	Nitrogen Blanket w/Oxygen Removal	Current System	Nitrogen Blanket
Argon Blanket	Current System	Infiltration Barrier/Drying	Cathodic Protection	Cathodic Protection	Vault & Tank Drying	Groundwater Barrier/Drying	Cathodic Protection	Monitors
Nitrogen Blanket	Corrosion Inhibitors in Vault	Trench/Infiltration Barrier/ Drying/Enhanced Pumping	Argon Blanket	Vault & Tank Drying	Nitrogen Blanket	Corrosion Inhibitors in Vault	Argon Blanket	Cathodic Protection
Contamination Fixative/Drying	Contamination Fixative/Drying	Contamination Fixative/Drying	Nitrogen Blanket w/Oxygen Removal	Groundwater Barrier/Drying	Infiltration Barrier/Drying	Sorbents in Annulus	Sorbents with Cathodic Protection	Sorbents with Cathodic Protection
Waste Removal	Cathodic Protection	Monitors	Sorbents with Cathodic Protection	Vault Drying	Sorbents in Annulus	Interceptor Trench/Drying	Monitors	Sorbents in Annulus
Low Strength Grout/Drying	Argon Blanket w/Cathodic Protection	Interceptor Trench/Drying	Monitors	Argon Blanket w/Cathodic Protection	Cathodic Protection	Argon Blanket	Argon Blanket w/Cathodic Protection	Argon Blanket
Low Strength Grout	Argon Blanket	Groundwater Barrier/Drying	Sorbents in Annulus	Contamination Fixative/Drying	Corrosion Inhibitors in Vault	Nitrogen Blanket	Sorbents in Annulus	Argon Blanket w/Cathodic Protection

Table 4. Combined Rankings of Team Members

Sorted by Rankings Score	Ranked #1	Ranked #2	Ranked #3	Ranked #4	Ranked #5	Rankings Score
Trench/Infiltration Barrier/Drying	1	3	2	0	0	23
Trench/Infiltration Barrier/Drying/ Enhanced Pumping	2	1	0	1	0	16
Low Strength Grout/Drying	2	1	0	0	1	15
Waste Removal	2	0	0	2	1	15
Low Strength Grout	0	2	1	1	1	14
Interceptor Trench/Drying	2	0	0	0	0	10
Vault & Tank Drying	0	0	3	0	1	10
Contamination Fixative/Drying	0	1	1	0	0	7
Vault Drying	0	1	1	0	0	7
Current System	0	0	1	0	1	4
Groundwater Barrier/Drying	0	0	1	0	1	4
Infiltration Barrier/Drying	0	0	0	1	1	3
Nitrogen Blanket	0	0	1	0	0	3
Corrosion Inhibitors in Vault	0	0	0	1	0	2
Monitors	0	0	0	1	0	2
Sorbents in Annulus	0	0	0	1	0	2
Cathodic Protection	0	0	0	0	1	1
Argon Blanket						0
Argon Blanket w/Cathodic Protection						0
Nitrogen Blanket w/Oxygen Removal						0
Sorbents with Cathodic Protection						0

The scores provided by the team for weighting factors for each criterion are shown in Table 5. Table 5 also shows the variation in scores (range) and a calculated average (mean) and median for each criterion. There was a very wide disparity in several of the weighting factors. The range for some was from 1 to 5. Again, this is something that should be discussed by team members to understand the basis for the differences. The criterion that scored highest was Prevent Release of Tank Contents. Other criteria that scored high were:

- Acceptable Long-Term Risk
- Maintain Tank Integrity
- Acceptable Short-Term Risk
- Safe Operating Envelope
- Preserve Closure Options.

4.3 SENSITIVITY ANALYSIS

As long as there are a relatively large number of people scoring the strategies (eight or more), average weighting factors and average scores can be used to determine a ranking order from the scoring sheets. High and low scores for weighting factors and each strategy should not be discarded, but should be discussed (Letter #3).

Table 5. Weighting Factor Averages

Evaluation Criteria---->	Compliance with Regulations and Permits	Prevent Release of Contents	Acceptable Risk (Short Term)	Acceptable Risk (Long Term)	Maintain Tank Integrity	Safe Operating Envelope	Capital Cost	Operating Cost	Proven Methods and Technologies	Minimize Secondary Waste	Preserve Closure Options	Regulatory and Stakeholder Acceptance	Reduced Monitoring and Surveillance	Certainty of Strategy
Team Member														
B	Did not supply weightings													
C	Did not weight from 1-5													
A	1	5	4	4	5	3	4	3	4	5	4	2	3	4
D	2	3	5	5	4	5	3	3	2	1	4	3	2	5
E	5	5	5	5	4	5	3	3	4	3	4	4	3	4
F	4	5	4	4	4	4	3	3	3	4	4	4	2	3
G	4	5	4	5	3	4	2	3	4	3	4	4	1	4
H	5	5	4	4	5	5	3	2	4	2	5	4	3	4
I	5	5	2	3	5	2	2	4	3	4	3	3	2	2
Mean (Average)	3.7	4.7	4.0	4.3	4.3	4.0	2.9	3.0	3.4	3.1	4.0	3.4	2.3	3.7
Median	4.0	5.0	4.0	4.0	4.0	4.0	3.0	3.0	4.0	3.0	4.0	4.0	2.0	4.0
Range	1-5	3-5	2-5	3-5	3-5	2-5	2-4	2-4	2-4	1-5	3-5	2-4	1-3	2-5

5.0 UNCERTAINTY OF STRATEGIES

After the alternative strategies and evaluation criteria were identified, it was apparent that information gaps made evaluation and ranking of the strategies difficult. The effectiveness and acceptability of several of the options are not fully developed. The principal information needs identified to reduce the uncertainties are listed below.

- A better estimate of the remaining corrosion allowance for the tanks.
- An estimate of the maximum rate of surface runoff from rain and/or snowmelt to establish the size of an interceptor trench in order to determine a cost estimate for that option. Are there existing storm sewers or other drainage systems?
- Data and analysis to establish if pumping from below the vaults alone would reduce groundwater infiltration into the vaults to a rate low enough for a drying system to be effective.
- Determination of whether maintaining a liquid inventory inside the tanks with continued chemistry adjustments is adequate to control internal corrosion.
- Determination of whether effective control of the oxygen concentration in the gas in the annuli alone can control external corrosion within an acceptable rate. If so, is an oxygen removal system needed or will a better inert gas system suffice?
- Determine if a system to maintain the vaults and all external surfaces of the tanks in a dry condition is necessary to ensure an acceptable corrosion rate. The primary concern is keeping the bottoms of the tanks dry.
- Determine if a tank wall penetration must be prevented during lay-up or if small penetrations that would not result in releases outside the tanks or vaults would be acceptable.
- Resolution of the technical and engineering issues related to cathodic protection.
- Determination of the acceptability of using argon rather than nitrogen due to the higher cost and safety concerns.
- Determination of whether the pumps in the catch pans need to be relocated to be at the lowest point.
- Determine if sorbent material(s) could capture all leaking radionuclides of concern.
- Estimates of the expected life of potential groundwater barrier systems.
- A more detailed assessment of adding and maintaining corrosion inhibitors in the water in the vault.
- Feasibility of decontamination prior to lay-up precluding the need for any further preparation for lay-up.

- Updates to existing preliminary cost estimates and new preliminary cost estimates for several options, including:

  - Installation of an interceptor trench or an underground barrier
  - Installation of an infiltration barrier
  - Addition of a roof above the vaults and tanks
  - Installation and operation of an oxygen removal system
  - Continuous corrosion monitoring of tanks' external surfaces.

6.0 WORKSHOP AT WEST VALLEY DEMONSTRATION PROJECT

A workshop was held at the West Valley site on June 19, 2001 to discuss the results of methodology demonstration. The meeting attendees included five West Valley Nuclear Services employees, a representative from the Tanks Focus Area, and a representative from Jacobs Engineering Group Inc. The methodology was described and feedback was received from the West Valley Nuclear Services personnel and the Tanks Focus Area customer. The meeting attendees agreed that the methodology was a valid tool for determining a preferred approach and that the methodology could be used to identify preferred options at other U.S. Department of Energy sites.

Some suggestions for improvements to the methodology were offered.

- The terminology of 'options' and 'strategies' was confusing to some of the participants. Use of the terms 'considerations' and 'concepts' was suggested.

- Much of the discussion was on the criteria selected for assessing potential concepts. The group decided that some of the criteria should be identified as go/no go criteria rather than being assigned a weighting factor. The suggested go/no go criteria included: (1) regulatory acceptance, (2) prevent release of tank contents to groundwater, (3) acceptable risk, (4) maintain tank integrity, (5) safe operating envelope, and (6) preserve future closure options. A particular concern for the West Valley site is that the current information is inadequate to judge whether or not several of the alternative approaches would meet all these go/no go criteria.

- A block diagram of the methodology was suggested to aid understanding for use at other sites.

- The meeting attendees reinforced the importance of having a well informed and diverse evaluation team.

- The pros and cons of each consideration and concept should be identified to aid the decision process.

- There were three categories of concepts identified: (1) individual actions, (2) combinations of actions, and (3) phased actions.

- One factor missing in the methodology is a time factor. Time is a consideration in how long it would take to implement a concept and also in phased implementation of the concepts that are combinations of several considerations.

- Monitors (and some other considerations) could be combined with just about any other consideration. Perhaps the considerations could be split into primary and secondary categories.

- The 'Waste Removal' strategy was not felt to be credible by West Valley Nuclear Services personnel.

- A ‘Consumer Report’ chart of the results was suggested.
- Some of the team members suggested assigning weighting factors by distribution of a total of 100 points to all the criteria, rather than assigning a factor of 1 to 5.
- Revisions to the ranking calculated from scores was debated. Some team members felt that the ranking should be modified by consensus from the team, but others felt that would take the objectivity out of the process. The group decided that discussion of the results was healthy and the methodology should be used as a tool to encourage information sharing and that modifications should be allowed as long as the cause for the original ranking is understood.
- A detailed discussion and common understanding of all the proposed concepts and criteria is needed before any scoring begins. This would also lead to identification of information needs to fairly assess all the candidate approaches. This may also identify technology development needs for potentially viable candidates that cannot be implemented until sometime in the future.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The methodology developed for ranking the potential strategies for lay-up of the West Valley Demonstration Project tanks can be used to provide a basis for a decision on the preferred path forward. The methodology will provide a consensus ranking even with wide variations in scores from individual team members as long as the number of team members is large enough. A minimum of 8 team members is recommended, and 10 to 12 members would be better. Because of the number and types of technical issues associated with the strategies, the evaluation team should be comprised of a broad spectrum of technical experts and decision makers.

The current uncertainties associated with several strategies will tend to result in more costly and complex strategies to be favored. Strategy-specific performance data could result in simpler strategies. Also, there may be other strategies and criteria identified during the process that will be ranked higher than most or all of the strategies identified in this report. In the absence of performance data for the strategies, there is a tendency to rank the strategies on a relative basis because the minimum but sufficient effort to meet the tank lay-up goals is unknown.

All the strategies and criteria should be presented to the team members to ensure a common understanding. The team should then determine if additional strategies should be scored and if the decision criteria should be modified. Any changes to the strategies or criteria should be done before the scoring starts. Orientation, scoring, and discussions should be in a facilitated session or sessions.

A difficulty in evaluating the lay-up strategies for the West Valley Demonstration Project tanks is that there is incomplete information on the cost and performance for several of the identified strategies. A recommended path forward would be to reevaluate the strategies identified in this report based on the example ranking and eliminate or reconfigure the strategies that were ranked at or near the bottom. Preconceptual engineering data should be developed for the remaining strategies to facilitate scoring and ranking using this methodology. The team members should be consulted to identify any additional information needs to support making informed decisions. The initial rankings will have to be made based on the available information.

Once each team member scores the alternatives, the scores can be combined and the team members can then be reconvened to discuss the results. Any wide variations among scores should be discussed to ensure there are no errors. This discussion will also help team members share their points of view and expertise or experience on the strategies. The discussion can then focus on the composite ranking to determine if there is consensus. The team members should be allowed to discuss if they feel the list should be modified based on the information shared. The team should develop a final, consensus-ranked list of the top five strategies. The team, West Valley Demonstration Project, and U.S. Department of Energy management should then decide whether to proceed with conceptual design of the top one or two strategies or specify the additional information needed to make a final decision.

The methodology is applicable to determining preferred lay-up approaches at other U.S. Department of Energy sites. Some of the alternative strategies identified for West Valley should also be considered for implementation at the other sites, and some would not be. Each site has unique characteristics that would require unique considerations for lay-up.

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HIGH-LEVEL WASTE TANK LAY-UP ASSESSMENT – YEAR-END PROGRESS REPORT

September 26, 2001

Prepared for
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CONTENTS

1.0 INTRODUCTION 1

2.0 BACKGROUND 1
- 2.1 TANK LAY-UP NEEDS AT SITES 2
- 2.2 HANFORD SITE 5
- 2.3 SAVANNAH RIVER SITE 5
- 2.4 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY 5
- 2.5 OAK RIDGE RESERVATION 6

3.0 PRELIMINARY NEEDS ASSESSMENT RESULTS 6
- 3.1 HANFORD SITE 6
- 3.2 SAVANNAH RIVER SITE 9
- 3.3 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY 9
- 3.4 OAK RIDGE RESERVATION 9

4.0 RECOMMENDATIONS 9

5.0 REFERENCES 10

6.0 BIBLIOGRAPHY 12

TABLES

1. Comparison of Site High-Level Waste Tank Programs 3
2. Site High-Level Waste Lay-Up Requirements and Considerations 7

LIST OF TERMS

DOE	U.S. Department of Energy
EIS	environmental impact statement
FY	fiscal year
HLW	high-level waste
INEEL	Idaho National Engineering and Environmental Laboratory
ORR	Oak Ridge Reservation
SRS	Savannah River Site
WVDP	West Valley Demonstration Project

1.0 INTRODUCTION

This report documents the preliminary needs assessment of high-level waste (HLW) tank lay-up requirements and considerations for the Hanford Site, Idaho National Engineering and Environmental Laboratory (INEEL), Savannah River Site (SRS), and Oak Ridge Reservation (ORR). This assessment includes the development of a high-level requirements and considerations list that evolved from work done for the West Valley Demonstration Project (WVDP) earlier in fiscal year (FY) 2001, and is based on individual site conditions and tank retrieval/tank closure schedules. Because schedules are continually subject to change, this assessment is considered preliminary and needs review and validation by the individual sites. The lay-up decision methodology developed for WVDP was based on standard systems engineering principles, and provided a structured framework for producing an effective, technically-defensible lay-up strategy.

On September 6, 2001, the results from the WVDP work were briefed to the Tank Focus Area Strategic Initiatives Review Board along with recommended follow-on work in FY 2002. Based on the verbal feedback during that meeting, there appear to be two potential paths for follow-on work. The first would be developing a tank lay-up informational database. This would include compiling a bibliography of documents from across the U.S. Department of Energy (DOE) complex concerning subjects of potential interest to lay-up, such as residual waste characterization and stabilization, tank integrity evaluation, surface and subsurface barrier installation and evaluation, high-performance cleanout methods and leak detection technologies, and techniques to reduce tank surveillance, monitoring, and maintenance. The second path would be the development of detailed lay-up requirements and considerations for one tank at one site. This would include developing cost estimates for continued operation of the tank under existing site requirements and the costs for lay-up of that one tank. This evaluation would provide a programmatic baseline for tank lay-up which could be of value to all sites. These two paths are not necessarily mutually exclusive. This task is currently awaiting the recommendations of the Review Board.

Background information is provided on each of the sites, including a comparison of the tank management programs. Finally, recommendations for follow-on work are provided.

2.0 BACKGROUND

HLW tanks were constructed and operated at a number of DOE sites to store waste that was mainly generated from the reprocessing of spent nuclear fuel. The initial step in remediating tank waste involves the retrieval and treatment of the tank waste for disposal. The second step involves dispositioning the tank facilities. Plans have been developed and are in various stages of implementation across the complex for the retrieval and treatment of the waste contained in the tanks and the tanks. Plans are less defined for how the tanks will be managed following retrieval and how they will be closed.

Each HLW tank in the DOE complex must transition from completion of its operational life to final closure, and depending on the uncertainty in the closure requirements or the uncertainty with closure decision making, the time this may take varies greatly. Technical, programmatic, and/or regulatory issues may make this tank transition management period last for years or even decades. Prudent tank closure planning accomplishes the following:

- Recognizes the potentially extended closure period
- Identifies objectives, requirements, and considerations
- Considers interim, pre-closure actions to place the tank and any residual contents into a safe, stable, and minimum maintenance condition without compromising final closure options.

The interim condition is referred to as tank lay-up. Tank lay-up recognizes that this period of time is different than normal tank operations, and this difference warrants evaluation of the requirements for configuring, operating, and maintaining the tanks during the transition from waste storage to closure. Tank lay-up is the bridge between the waste storage phase and closure phase in the life cycle of a tank.

The complexity and extent of tank lay-up actions will likely vary depending on the following:

- Lay-up period
- Tank's operating history and physical condition
- Current understanding of closure requirements
- Perceived risks of any residual waste.

One of the first actions in managing tank transition is the development of requirements and considerations for tank lay-up. Sites whose current schedules reflect relatively short transition periods may foresee few or no lay-up needs. Sites with relatively long transition periods may execute extensive lay-up plans, to minimize surveillance/monitoring costs and show progress toward closure.

2.1 TANK LAY-UP NEEDS AT SITES

Tank lay-up needs are a function of a number of different variables. The need for, and potential benefits from, tank lay-up depend on the number and physical condition of the tanks, the potential lay up period, the uncertainty in tank closure requirements, the risks associated with the waste heel, and the regulatory environment.

The intent of the lay-up period is to reevaluate the requirements and consider what is known about the tank, tank farm, and future tank closure criteria. The decision process developed for WVDP provides a means to weight the requirements and considerations based on individual site conditions and considerations.

Table 1 is a comparison of the tank programs at the various sites. WVDP is included for completeness. An evaluation of that site's tank lay-up requirements and considerations has been previously reported (Henderson, 2001a, b, c, and d).

The Hanford Site and SRS have 80% of the total HLW tanks to be closed, more than 95% of the HLW requiring retrieval and disposal, and all of the known and assumed leaking tanks. Because of the current uncertainties in these cleanup and closure programs, they may also have the greatest potential need for tank lay-up planning.

Table 1. Comparison of Site High-Level Waste Tank Programs (2 Sheets)

	WVDP	Hanford Site	SRS	INEEL	ORR
Number of tanks/areas to close	4/1 area	177/18 tank farms	51/2 tank farms	11[a]/1 tank farm	40/5 tank farms
Tank types	2	2	4	2	6
Tank sizes, 10^3 gal	15-750	55-1,160	750-1,300	318	1.5-170
Tank ages, years	35	15-58	20-50	37-50	3-58
Tank conditions	No leakers	67 confirmed and assumed leakers	11 leakers	No leakers	No leakers
Waste types	Alkaline	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	0.6	54	33	1.4	0.4
Waste radionuclides, 10^6 Ci	0.03	200	470	0.52	0.047
Retrieval schedule	Tank heels cleaned out in 2001 to Class C limits	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	90% of inactive tanks complete. Remainder as mission is completed
Closure schedule	Not yet finalized; closure expected to take up to 20 years	SSTs by 2024[b] and DSTs by 2032[b]	2022 for Type I, II, and IV; Type III by 2030	In six phases from 2005 to 2016	24 tanks without secondary containment by 2022; others as storage mission is completed
Tank maximum ages in years at closure	More than 50	More than 75	More than 75	More than 60	More than 70
Approved final closure requirements	No	No	Some top-level developed	Some top-level developed	No

Table 1. Comparison of Site High-Level Waste Tank Programs (2 Sheets)

	WVDP	Hanford Site	SRS	INEEL	ORR
Closure regulatory drivers	DOE/EIS-0226-D; NYSERDA 1980; WVDP Acts of 1980 & 1991	DOE/EIS-0189; DOE/EIS-0222F; Ecology et al. 1989; MOU 1996	DOE/EIS-0217; DOE/EIS-0303D; Site Treatment Plan; Supplemental EIS; Wastewater Closure Plan; WSRC-OS-94-42	DOE/EIS-0287D; DOE-ID 1991; Settlement Agreement	Accelerated Cleanup Plan; DOE/OR-1014; ORR Order
Site and tank specific considerations and uncertainties	Corrosion, in-tank hardware; water in vaults	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; seismic; no secondary containment	Waste not classified as high-level; in-tank chunks of gunite

[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 to extend dates.

DST = double-shell tank.
EIS = environmental impact statement.
FFCA = Federal Facility Compliance Agreement.
HLW = high-level waste.
INEEL = Idaho National Engineering and Environmental Laboratory.
MOU = memorandum of understanding.
ORR = Oak Ridge Reservation.
SRS = Savannah River Site.
SST = single-shell tank.
WVDP = West Valley Demonstration Project.

2.2 HANFORD SITE

Nearly two-thirds of all DOE HLW tanks and tank waste, and 85% of all confirmed and assumed leaking tanks are located at the Hanford Site. Many of the tanks are inactive and essentially empty. Waste retrieval projects are planned that would empty additional tanks over the next few years. An environmental impact statement (EIS) for retrieval and treatment of the tank waste has been issued, but tank closure requirements have not been finalized and closure decisions are not expected in the near term. Some of the older single-shell tanks, with single carbon steel liners, are nearly 60 years old. Waste retrieval and tank closure schedules are likely to be extended even further into the future because of the shortage of storage space in the newer, double-shell tanks, and because of recent delays in the tank waste disposal program. In addition, there are a myriad of regulatory, programmatic, and technical uncertainties and issues that will require resolution prior to tank closure. Agreement on future land use scenarios for tank farm closure evaluations are in progress, but work on a tank closure EIS has not yet begun.

The baseline strategy is to close the tanks and farms in place, but how much waste has to be removed and what actions need to be taken for past leaks and potential leaks during waste retrieval have not been established.

2.3 SAVANNAH RIVER SITE

More than two-thirds of the total curies to be retrieved and disposed in the DOE complex are contained in the HLW at the SRS. At least 10 of the tanks have leaked and/or have cracks in the tank liners. Two tanks have been interim closed, but a new EIS is required before any further tanks can be closed. Many of the older tanks will be nearly 70 years old before planned closure. Even the newest tanks are expected to be 60 years of age before closure. One tank was cleaned out 20 years ago, but is not yet closed. Several more tanks are expected to be cleaned out in the near future, but closure dates are uncertain. And, like at the Hanford Site, there are regulatory, programmatic, and technical issues surrounding final closure that will be addressed in the new EIS.

The baseline strategy is to close the tanks in place after stabilizing the tanks and any residual waste with grout.

2.4 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

Liquid HLW was removed from the INEEL tanks and calcined in 1998. Contaminated, sodium-bearing, liquid waste remains in the tanks at INEEL. The waste is in acidic form (little sludge) in 11 stainless steel tanks, awaiting a final disposal process. While the proposed path for disposal of the HLW is well defined, tank closure requirements and approvals are not yet finalized. Tank closure plans do address ‘operational or interim closure’ as a DOE/*Resource Conservation and Recovery Act of 1976* action on the path to final closure.

The baseline strategy is to close the tanks and farm in place after filling the tanks and ancillary piping with grout.

2.5 OAK RIDGE RESERVATION

The waste in the tanks at ORR, though physically, chemically, and radiologically similar to HLW at other sites, is not classified as HLW. Consolidation of all waste into the higher integrity tanks is well underway, and a Record of Decision is expected shortly that will allow interim closure of tanks by filling with a removable grout. All tanks without secondary containment are expected to be closed in the next 20 years and the remaining tanks within 30 years.

The baseline closure strategy is to clean out all tanks to meet waste acceptance criteria, then fill the tanks with grout.

3.0 PRELIMINARY NEEDS ASSESSMENT RESULTS

One of the initial products from FY 2001 work in support of WVDP was a list of the tank lay-up requirements and considerations. This list was evolved for each of the other tank sites, considering site-specific factors. The results are shown in Table 2.

There appear to be many Hanford Site and SRS HLW tanks that have potential lay-up periods in excess of 20 years, suggesting a higher potential need for lay-up planning at these two sites. Conversely, execution of the INEEL and ORR tank retrieval and closure programs appears more near-term and better defined, although tank lay-up considerations apply to these sites as well. One measure of the complexity of tank lay-up and closure is the number of significant issues that must be addressed. For this reason, potential site lay-up issues have been included in the table.

There is not a straight-forward regulatory path for tank lay-up. Lay-up actions may require regulatory approval, although regulatory requirements during lay-up are expected to be less restrictive than for normal operation. Examples of baseline documentation potentially impacted by lay-up considerations include operating specifications, technical safety requirements, safety analyses reports, and operating procedures. Depending on the regulatory framework, lay-up options may vary significantly between sites, and even between tanks at the same site. A site-specific and tank-specific evaluation process should be developed for the tanks as they reach the end of their operational life. Appropriate DOE orders, *Resource Conservation and Recovery Act of 1976* and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* regulations, and federal facility agreements should be evaluated against the known status of the tank, then lay-up (or closure) decisions made. This evaluation should include potential renegotiation, modification, or waiver of requirements in these documents based on the tank's proposed lay-up condition. The lay-up plan must also consider the individual tank(s) within the context of the closure plans for the tank's environment (e.g., tank farm and ancillary equipment, existing and projected waste leaks, soil and groundwater properties, site meteorology, seismology).

3.1 HANFORD SITE

While the path for near-term retrieving and processing tank wastes is relatively well defined, final closure of the tanks and tank sites is complicated by a myriad of challenging issues. This means that, over the next few years, an increasing number of very old, single-shell tanks will be cleaned out and will likely have to wait for a number of years before final closure. These tanks will be prime candidates for lay-up.

Table 2. Site High-Level Waste Lay-Up Requirements and Considerations (2 Sheets)

Requirements, Considerations, and Potential Issues		WVDP	Hanford Site	SRS	INEEL	ORR
Requirements	Ensure acceptable risks to workers and public	Establish safe operating envelope during lay-up. Maintain tank integrity. Prevent leaks to groundwater.	Minimize leaks to ground, air emissions. Maintain tank integrity. Minimize liquid ingress to tank.	Minimize leaks to soil, groundwater, air emissions. Maintain tank integrity. Minimize liquid ingress to tank.	Treat tank and vault exhausts as necessary.	Store old and currently generated waste in highest integrity tanks.
	Comply with regulations, permits, and agreements	Table 1 regulatory drivers, plus DOE letter with Class C limits on tank cleanout.	Table 1 regulatory drivers, plus authorization basis, closure EIS, incidental waste determination.	Table 1 regulatory drivers, plus new tank closure EIS, incidental waste determination, impact of NRDC lawsuit (DOE O 435.1), land use implementation.	Table 1 regulatory drivers.	Table 1 regulatory drivers.
	Preserve future tank closure options	Preserve future options for tank decontamination and closure.	Consider the potential for secondary waste retrieval, remediation of contaminated soils, and remediation of ancillary equipment.	No tank closures until approval of new EIS.	Tank closure criteria awaiting DOE/RCRA documentation.	Tank closures awaiting ROD and resolution of heel technical issues.
Considerations	Control life-cycle costs	Control capital and operating costs. Reduce tank surveillance and monitoring.	Reduce surveillance, monitoring, and maintenance requirements during lay-up period.	Reduce surveillance, monitoring, and maintenance requirements during lay-up period.	Utilize existing systems to greatest extent possible. Leave equipment in tanks when possible.	Close inactive tanks as soon as possible after waste acceptance criteria is satisfied.
	Gain stakeholder acceptance/ consensus	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.
	Minimize secondary wastes	Ensure secondary wastes can be readily disposed.	Use existing waste for retrieval. Dispose secondary wastes.	Ensure secondary wastes can be readily disposed.	Ensure secondary wastes can be readily disposed.	Ensure secondary wastes can be readily disposed.
	Use proven and accepted technologies	Include demonstrated construction methods.	Full-scale demonstration of retrieval technologies.	Modify techniques used to interim close two tanks.	Washball system to be used for cleanout.	Modify solids removal methods from other sites.

Table 2. Site High-Level Waste Lay-Up Requirements and Considerations (2 Sheets)

Requirements, Considerations, and Potential Issues		WVDP	Hanford Site	SRS	INEEL	ORR
Potential Issues	Specific to site	Ability to keep tank external surfaces dry. Ability to control oxygen (corrosion) in tanks. Effectiveness of groundwater barriers.	Dome loading, liner integrity analysis, leak detection; waste heel characterization/ inventory and classification; tank isolation, barriers; tank atmosphere control; retrieval performance; groundwater/vadose zone modeling, assessment; future land use.	Liner cracks; waste in annuli; waste in groundwater; ingress of groundwater into tanks.	Ability to demonstrate clean closure of tanks; in tank equipment; contaminated soil; source terms, groundwater modeling; future land use requirements.	Groundwater leaks into tanks; resin beads in the bottoms of some tanks.

DOE = U.S. Department of Energy.
EIS = environmental impact statement.
INEEL = Idaho National Engineering and Environmental Laboratory.
NRDC = National Resources Defense Council.
ORR = Oak Ridge Reservation.
RCRA = *Resource Conservation and Recovery Act of 1976*.
ROD = Record of Decision.
SRS = Savannah River Site.
WVDP = West Valley Demonstration Project.

3.2 SAVANNAH RIVER SITE

While the SRS has demonstrated interim closure on two tanks, future progress is clouded by the requirement for a new EIS before any further closure actions can be taken. These closure uncertainties, fueled by a relatively aggressive waste retrieval schedule, provide a good environment for considering lay-up.

3.3 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

Because of the relatively small amount of HLW remaining to be retrieved from a few nonleaking, stainless steel tanks, there is currently a diminished need for extensive lay-up planning at the site. However, because current closure plans are still not approved, INEEL could benefit from involvement in the lay-up planning process and from the results of a detailed evaluation of one tank at another site.

3.4 OAK RIDGE RESERVATION

More than half of the ORR tanks are already grouted, awaiting a Record of Decision that would allow them to be closed in-place without further action. Because of this and the fact that closure actions are not complicated by HLW considerations, the need for lay-up planning appears low. However, judicious and complete closure planning may require consideration of possible delays in the closure program, and ORR could benefit from involvement in the lay-up planning process.

4.0 RECOMMENDATIONS

The dialogue on tank lay-up needs to be expanded to the sites that are potentially most affected. This preliminary evaluation report is one vehicle for stimulating that dialogue and could be reviewed informally with the sites. This should include a review of the list of requirements and considerations for comprehensiveness. In parallel, this tank lay-up effort should be coordinated with the next Tank Closure Workshop, which may be scheduled sometime later in calendar year 2001. Interest and support at this workshop could greatly enhance the likelihood of involving subject matter experts at the key sites later on.

Selection of a path forward for this initiative will be made once the Tank Focus Area Strategic Initiative Review Board issues its recommendations. If it is decided to pursue a detailed lay-up evaluation for one tank, technical, programmatic, and regulatory issues should be developed as well. Candidates include tanks AX-104 and C-106 at the Hanford Site and tank 16 at the SRS. The success of this process will be highly dependent on the degree of interest and the commitment of subject matter experts at the selected site.

The tank lay-up evaluation process would include the following steps:

- Identify tank lay-up requirements and considerations
- Identify potential lay-up strategies
- Identify potential lay-up technologies
- Identify potential uncertainties and issues
- Configure lay-up alternatives for evaluation
- Evaluate lay-up alternatives using a weighted decision matrix.

This process will lead to a technically-defensible lay-up strategy for that one tank. The results of this evaluation can be applied generically by the other sites to tailor lay-up plans on an individual tank basis. Tank lay-up options resulting from this process would include the following:

- Continued operation of the tank in the same manner as before the waste was retrieved
- Wet lay-up of the tank with the addition of corrosion inhibitors
- Dry lay-up (drying the residual waste and tank atmosphere)
- Dry lay-up with the addition of a stabilizing material to the residual waste.

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POST-RETRIEVAL AND PRE-CLOSURE HIGH-LEVEL RADIOACTIVE LIQUID WASTE TANK LAY-UP STRATEGIES – PART II IMPLEMENTATION PLAN

May 15, 2001

Prepared for
Tanks Focus Area

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CONTENTS

1.0 INTRODUCTION 1

2.0 NEED FOR TANK LAY-UP STRATEGIES 1
- 2.1 TANKS FOCUS AREA WORKSHOP 2
- 2.2 HANFORD WORKSHOP 4

3.0 EVALUATION METHODOLOGY 4

4.0 EVALUATION CRITERIA 5

5.0 BACKGROUND 7

6.0 DOE TANK AND WASTE INFORMATION SUMMARY 7

7.0 SITE-SPECIFIC DESCRIPTIONS 9
- 7.1 HANFORD SITE 9
  - 7.1.1 Single-Shell Tanks 10
  - 7.1.2 Hanford Double-Shell Tanks 11
  - 7.1.3 Path to Closure for the Hanford Site 11
  - 7.1.4 Regulatory Drivers for the Hanford Site 12
  - 7.1.5 Milestones for the Hanford Site 13
  - 7.1.6 Post-Retrieval Tank Waste Characterization 13
- 7.2 SAVANNAH RIVER SITE 13
  - 7.2.1 Storage Tanks at the Savannah River Site 14
  - 7.2.2 Savannah River Site High-Level Waste Treatment and Tank Closure 17
  - 7.2.3 Path to Closure for the Savannah River Site 17
  - 7.2.4 Regulatory Drivers for the Savannah River Site 18
  - 7.2.5 Milestones for the Savannah River Site 19
- 7.3 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY 19
  - 7.3.1 Characteristics of Idaho National Engineering and Environmental Laboratory Tank Waste 20
  - 7.3.2 Storage Tanks and Calcine Bin Sets at the Idaho National Engineering and Environmental Laboratory 21
  - 7.3.3 Path to Closure for the Idaho National Engineering and Environmental Laboratory 23
  - 7.3.4 Regulatory Drivers for the Idaho National Engineering and Environmental Laboratory 23
  - 7.3.5 Milestones for the Idaho National Engineering and Environmental Laboratory 24
- 7.4 OAK RIDGE RESERVATION 24
  - 7.4.1 Legacy Waste 25
  - 7.4.2 Newly Generated Waste 25
  - 7.4.3 Tank Design 26
  - 7.4.4 Path to Closure for the Oak Ridge Reservation 28

7.4.5 Regulatory Drivers for the Oak Ridge Reservation 29
7.4.6 Milestones for the Oak Ridge Reservation 29

8.0 PROPOSED WORK PLAN 30
8.1 GENERIC HIGH-LEVEL WASTE TANK LAY-UP ALTERNATIVES EVALUATION METHODOLOGY 30
8.1.1 Target Problem 30
8.1.2 Work Element Descriptions 30

9.0 REFERENCES 33

FIGURES

1. Hanford Path to Closure 11
2. Savannah River Site Path to Closure 18
3. Idaho National Engineering and Environmental Laboratory Path to Closure 23
4. Oak Ridge Reservation Path to Closure 28

TABLES

1. Comparison of Tanks at Each Site 8
2. Hanford Site Milestones 13
3. Summary of Storage Tanks at the Savannah River Site 16
4. Savannah River Site Milestones 19
5. Summary of the Waste Storage Tanks at the Idaho National Engineering and Environmental Laboratory 21
6. Idaho National Engineering and Environmental Laboratory Milestones 24
7. Summary of Waste Storage Tanks at Oak Ridge National Laboratory 28
8. Oak Ridge Reservation Milestones 29

LIST OF TERMS

BVESTs	Bethel Valley Evaporator Service Tanks
DOE	U.S. Department of Energy
DST	double-shell tank
DWPF	Defense Waste Processing Facility
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
GAAT	Gunite and Associated Tanks
HLW	high-level waste
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
Jacobs	Jacobs Engineering Group Inc.
LLW	low-level waste
MVCITs	Melton Valley Capacity Increase Tanks
MVSTs	Melton Valley Storage Tanks
NRC	U.S. Nuclear Regulatory Commission
ORR	Oak Ridge Reservation
PNNL	Pacific Northwest National Laboratory
RCRA	*Resource Conservation and Recovery Act of 1976*
SCDHEC	South Carolina Department of Health and Environmental Control
SNF	spent nuclear fuel
SRS	Savannah River Site
SST	single-shell tank
TFA	Tanks Focus Area
TRU	transuranic
WVDP	West Valley Demonstration Project

1.0 INTRODUCTION

Jacobs Engineering Group Inc. (Jacobs) is developing and evaluating high-level waste (HLW) tank lay-up strategies in collaboration with the Pacific Northwest National Laboratory (PNNL) and West Valley Nuclear Services Company. This work is included in the U.S. Department of Energy (DOE) Tanks Focus Area (TFA) Technical Task Plan RL30WT21A, "Post-Retrieval and Pre-Closure HLW Tank Lay-Up."

Jacobs and PNNL are completing the approved portion of TTP RL30WT21A (Part I), Tank Lay-Up Strategies for the West Valley Demonstration Project (WVDP). Lay-up is the period between initial decontamination and decommissioning of the tanks and final closure. Alternative strategies have been identified and decision criteria have been developed to support selection of a preferred strategy for safe lay-up of the WVDP HLW tanks. The lay-up strategies will be evaluated with respect to the decision criteria to provide WVDP with a defensible decision process for selecting a tank lay-up strategy.

This Draft Work Plan for Part II, HLW Tank Lay-Up Strategies for the Entire DOE Complex, is an extension of the work completed to develop a WVDP Tank Lay-Up methodology.
The proposed next step is to extend the methodology to address lay-up needs for the other HLW tanks across the DOE complex. This Draft Work Plan includes a discussion of the HLW systems and issues at each site and the approach to identify and evaluate tank lay-up strategies. The proposed approach will provide a technically defensible methodology for evaluating tank lay-up strategies against a number of criteria, such as reducing monitoring and maintenance costs, meeting environmental regulations for tank closure, protecting worker health and safety, and addressing stakeholder concerns.

Completion of this proposed scope of work will benefit all the sites by developing a common, demonstrated methodology for the transition from active storage to closure of the tanks.

This Draft Work Plan will be used by the TFA Technical Integration Manager for Safety to make a determination on a path forward for Part II.

2.0 NEED FOR TANK LAY-UP STRATEGIES

As DOE sites complete retrieval of waste from tanks, it may not be possible to immediately move to final closure of the tank systems. This period of time may be decades for some tanks. Therefore lay-up, defined as placing tanks in a safe, stable, and minimum maintenance mode, needs to be considered on the path to closure. The operating and monitoring requirements during this transition phase will be different than during active waste storage.

All the sites have programs in place to monitor the condition of the tanks to prevent leaks to the environment and have long-range plans for closure of the tanks. However, the selection of preferred alternatives for interim lay-up of tanks has not been rigorously pursued. In addition to the tanks themselves, several of the sites have concerns with piping and other auxiliary equipment associated with the tanks.

2.1 TANKS FOCUS AREA WORKSHOP

The TFA held a Tank Integrity Workshop in Atlanta, Georgia, on October 31 and November 1, 2000, to focus on the following issue:

> "Our challenge is to ensure continued safe management and operation of the necessary tanks for whatever period of time these tanks are required in completing the weapons complex clean up."

The workshop participants felt that implementation of DOE Order 435.1 along with its guidance document (*Guidelines for Development of Structural Integrity Program for DOE High-Level Waste Storage Tanks*) is very important. The fact that the requirements are flexible and not prescriptive was also cited as important. The participants felt that most, if not all, the elements of a good tank integrity program had been considered and implemented somewhere in the DOE complex. The participants noted that communication, both internal and external to the sites, is very valuable and has improved in recent years. However, the participants felt that a change in culture at the sites that promotes the removal of barriers and encourages more openness about problems and lessons learned was equally important. The workshop participants felt that tools for analysis, inspection, and monitoring of the tanks and waste must continue to improve.

While it was recognized by the participants that many site-specific challenges exist, it was felt that consistency among the sites improves the tank structural integrity programs. Consistency allows the sites to learn from and build on each other's efforts, as well as contribute to a better working relationship with regulators and other stakeholder groups.

The participants viewed TFA funding for integrity assessment activities as a positive step. The enthusiastic direction and support provided by the Safety Technical Integration Manager was specifically mentioned. The sites welcome any assistance provided to assess their options for continued safe operation of tanks.

Even though the focus of this workshop was maintaining integrity for continued operation of tanks, many of the issues identified are also applicable during temporary lay-up. A detailed review and compilation of the options available for temporary lay-up at each site would promote additional sharing of information and options. There may be common solutions to lay-up at several sites that may not be identified without an integrated lay-up evaluation effort for all the sites.

The people involved with tank integrity activities should be valuable resources for the second phase of the tank lay-up task. These people provide a diverse and knowledgeable pool of personnel committed to tank integrity at each site.

Some issues were identified and potential solutions suggested by the participants. Those that are pertinent to tank lay-up are listed below. Many of these solutions will be assessed during the proposed Part II task.

Issue: Networking and communications between headquarters and sites, and across sites, is not adequate to support a collaborative, consistent, and cost-effective tank structural integrity program effort. Sites do not have an incentive to share information with other sites.

Proposed solutions:

- Request that the sites identify participants and parties interested in tank structural integrity activities at their site.
- Improve information flow on problems, lessons learned, accomplishments, and other subjects among the sites.
- Hold meetings or workshops to address specific topics/technical issues as needed.

Issue: Technology development required to implement the full scope of the tank structural integrity program may be hampered at some sites because of the unavailability of subject matter experts or lack of management commitment to invest in necessary technology development.

Proposed Solutions:

- Identify subject matter experts at each site.
- Compile a reference database that contains technical topics and contacts.
- Identify sources for compiling lessons learned from other industries.
- Conduct a "state of the complex" review of tank structural integrity program implementation.
- Implement a mechanism to establish and convene a complex-wide design review panel.
- Request the contractors to consider resource sharing (people) to ensure that the new tank structural integrity program implementation is a success.

Issue: Federal and state regulatory requirements are inconsistent and convoluted due to the ambiguity of DOE Order 435.1 and the different regulatory and oversight regimes for each site. DOE has not specified the guidance as the *only* mechanism to comply with the order. As a result, the resources and ongoing funding commitment by each site are not consistent for implementing the tank structural integrity program.

Proposed Solutions:

- Request DOE to authorize and direct the preparation of a tank structural integrity program panel strawman document that meets DOE Order 435.1 requirements.
- Establish a champion/point of contact at DOE-Headquarters.
- Gain Defense Nuclear Facilities Safety Board support of the champion and organization concept.

- Ensure that all sites endorse the new tank structural integrity program requirements.
- Ensure that management is fully aware and informed about compliance issues.

2.2 HANFORD WORKSHOP

CH2M HILL Hanford Group, Inc. held a workshop May 1-4, 2001 to initiate an effort to develop a technical basis for extending the lifetimes of Hanford's double-shell tanks (DSTs). Included in this workshop were numerous presentations by experts from across the DOE complex in tank waste chemistry, corrosion testing and monitoring, tank corrosion control, and tank inspection techniques.

One area of discussion during the workshop was the procedure used at Hanford to occasionally maintain a tank in an inactive state once the tank is put into service. An administrative requirement for the tank farms is to maintain positive ventilation of the tanks. This means that the inside of the primary tank is maintained at a few inches of water vacuum relative to the atmosphere. Before this can be done, a minimum volume heel of water must be pumped into the tank to prevent buckling of the flat tank bottom when the ventilation is turned on. The water is to be inhibited with 0.01 M caustic to prevent corrosion of the tank. Typically, this heel is not sampled to verify that the water remains inhibited.

Workshop participants cautioned that the caustic in a small volume of minimally inhibited liquid in a DST will be consumed rather quickly due to reaction with CO_2 absorbed from the air drawn through the tank head space by the ventilation system. As a result of these discussions, the workshop leader suggested that a procedure needs to be implemented for tank lay up that describes the requirements for inhibiting the tank heel water, adequately monitoring the chemistry of the heel, and adding more caustic as necessary to counteract the effects of hydroxide consumption by reaction with absorbed CO_2.

This discussion was directed primarily at maintaining a tank ready for receiving waste. However, a similar situation will exist once a tank is taken out of service but is not ready for final closure. Presumably, the tanks will require active ventilation for contamination control. Similarly, a minimal heel of waste would be rapidly depleted of inhibiting hydroxide unless the heel is monitored and additional inhibitor added as necessary, or unless some other action is taken to adequately stabilize and protect the tanks from degradation. Such a concern lends support to the need to develop a suitable plan for interim lay-up of these tanks to prevent inadvertent corrosion failure with loss of containment of the residual waste in the tanks. The decision methodology developed and demonstrated by this project will assist the site operator in selecting the proper lay up strategy(ies) for the tanks.

This is just one example of a site-specific issue that must be considered during the evaluation of lay-up options. This issue is applicable at all the sites where the waste is neutralized for corrosion control.

3.0 EVALUATION METHODOLOGY

The proposed methodology for assessing alternative strategies at all the sites will be the same as that for Part I, Tank Lay-Up Strategies for WVDP:

1. Evaluation Criteria for Alternative Tank Lay-Up Strategies

   Summary of the current conditions and the lay-up system functions and requirements for each site.

2. Alternative Tank Lay-up Strategies

   Summary of alternative lay-up strategies and any further development or information needed to support evaluation of the concepts against the decision criteria.

3. Decision Plan

   Summary of proposed decision criteria (performance objectives), scoring guidance (weighting factors), and sensitivity analysis methodology for selection of preferred strategies.

4. Demonstration of Methodology

   A demonstration of the tank lay-up evaluation methodology will be conducted using site and tank-specific information for one site. Following the demonstration, the methodology will be incorporated into an interactive program for evaluating and documenting the tank lay-up evaluations.

5. Tank Lay-up Strategies Final Report

   Final report to TFA documenting the formulation of decision criteria along with the scoring guidance prepared for each site to use in selecting approaches for tank lay-up.

4.0 EVALUATION CRITERIA

The criteria developed for selecting preferred options for the WVDP tanks will serve as the starting point for the criteria for the other sites. These criteria are based on the requirements during the temporary lay-up period.

The primary function of the tanks and auxiliary systems is to contain the waste and prevent releases to the environment. The primary objective for temporary tank lay-up is to maintain the tanks in a safe and stable configuration with minimum capital and operating costs until final closure is completed. Some of the decision criteria listed below are firm requirements (e.g., safety) while others are more value based. Weighting factors will be developed as part of the decision plan to provide a means for ranking alternative lay-up strategies. The weighting factors can be used as a way to vary the importance or influence of the different requirements. The decision criteria identified for temporary lay-up of the WVDP tanks are:

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period. Effluent releases must be maintained within permitted limits. This will require maintaining gaseous and liquid treatment capabilities for tank ventilation and potential treatment of liquids pumped from inside or around the vaults.

- **Prevent release of tank contents to the groundwater –** There shall be no release of any amount of the tank contents to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.

- **Ensure acceptable risk to workers and the public –** The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable. However, the selected option should result in a reduced risk to workers and the public during the lay-up period.

- **Maintain integrity of the tanks –** The ability of the tanks to continue to contain the waste residual must be maintained. Further corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up –** The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control construction and operating costs –** The cost of installing new equipment and the continued operating costs are considerations for selecting a preferred option. Construction and operating costs must be within projected budgets.

- **Utilize accepted methods and technologies –** The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation –** Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be avoided.

- **Preserve future options for decontamination and final closure –** The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude either of the currently identified final closure options of in-place stabilization and complete removal.

- **Gain acceptance for lay-up –** The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.

- **Reduce monitoring and surveillance –** Reductions in monitoring and surveillance, consistent with requirements, is desired.

These criteria will be modified as necessary based on unique conditions at each DOE HLW storage site.

5.0 BACKGROUND

DOE is responsible for 283 large, underground storage tanks that contain millions of gallons of radioactive waste. The tanks are located at the Hanford Site, Savannah River Site (SRS), WVDP, Idaho National Engineering and Environmental Laboratory (INEEL), and Oak Ridge Reservation (ORR).

As a result of processing spent nuclear fuel (SNF), DOE has generated over 100 million gal of liquid HLW complex-wide. Approximately 90 percent of this waste remains in storage in liquid form. DOE is proceeding with plans to treat the liquid HLW, converting it to solid forms that would not be readily dispersible into air or leachable into groundwater or surface water. The baseline technology is vitrification. Approximately 22,000 canisters (varying in volume from 0.6 to 1.2 m^3) will be produced if the total current inventory of HLW is vitrified.

The tanks were built from the 1940s through the 1980s and have capacities ranging from 50,000 to over 3,800,000 L (13,000 to over 1,000,000 gal). The waste in these tanks is classified as HLW, transuranic (TRU) waste, and/or mixed waste. Several of the tanks have exceeded or are approaching the end of their design life. Sixty-eight tanks are known or suspected to have leaked waste to the ground (67 at the Hanford Site and one at SRS).

As tanks age, the possibility of waste entering the environment increases. To minimize the risk of waste release and subsequent exposure to workers, the public, and the environment, and to adhere to cleanup agreements entered into by DOE, the waste must be retrieved and the tanks closed.

6.0 DOE TANK AND WASTE INFORMATION SUMMARY

The DOE currently stores about 340 million L (90 million gal) of waste containing more than 700 million curies of radioactivity. Table 1 provides a summary of the tanks and stored waste. The tank wastes differ both physically and chemically between sites, between tanks on a site, and in some cases, between phases of waste within a tank.

When generated, HLW is a highly radioactive, acidic liquid that generates heat and must be handled remotely behind heavy shielding in corrosion-resistant vessels, usually made of stainless steel. At the Hanford Site (Hanford), because stainless steel was in short supply, HLW was neutralized with caustic soda (sodium hydroxide), and sodium nitrite was then added for corrosion control so that the HLW could be stored safely in carbon-steel tanks. This practice continued at Hanford, the SRS, and the WVDP, even when stainless steel became more readily available.

Neutralization with caustic soda forms sodium nitrate (which remains in solution) and hydrated oxides of certain radionuclides and non-radioactive chemicals (which precipitate and collect as a sludge on the floor of the tank). The ^{137}Cs remains largely in solution. The supernatant liquid resulting from neutralization may also become concentrated by evaporation--either by self-boiling or in evaporators. If enough water is removed from the waste, sodium nitrate and sodium nitrite will crystallize from the solution. The crystals then will settle to the bottom of the tank liquid. If there are many crystals, a salt cake will form on top of the liquid.

Table 1. Comparison of Tanks at Each Site

	WVDP	Hanford	SRS	INEEL	ORR
Number of tanks	4	177	51 (2 closed in 1997)	11 (and 7 calcine vaults)	40 (6 new tanks added in 1998)
Volume of waste (million L)	2.3	205	130	4.9 (tanks) 3.8 (calcine)	1.5
Total curies (million curies)	0.03	198	534	2 (tanks) 50 (calcine)	0.2
Waste forms	High sodium liquid and sludge	Salt cake, sludge, viscous liquid	Alkaline waste and sludge	Acidic liquid and some solids in tanks; granular solids in bins	Sludges and liquid
Tank design	Single-shell	Single- and double-shell	Double-shell	Single-shell	Single- and double-shell
Types of Tanks	2	2	4	2 (Tanks and Bins)	6
Materials of Construction	Carbon steel (2), Stainless steel (2)	Carbon steel	Carbon steel	Stainless steel	Gunite (12), stainless steel (4) and carbon steel (18)
Leakage	None	67 tanks assumed (vol. leaked ~3.8 million L)	11 (only one into the soil)	None	None
Other problems	In-tank hardware, corrosion	In-tank hardware, potential leakage during waste retrieval	Some water leakage into tanks	In-tank cooling coils, corrosion	Large chunks of gunite in waste in some tanks; Groundwater leaked into some tanks
Principal Regulatory Drivers	WVDP Act, 1980 & 1991 Cooperative Agreements, EIS	FFCA (TPA), TWRS EIS	EIS, Closure Plan, FFCA, STP	ID Consent Order, Settlement Agreement, HLW EIS	FFCA, ORR Order, DOE Order 5820.2A, Accelerated Cleanup Plan
Closure requirements	All SSTs (149)	All	All	All	All tanks without secondary containment (24), others as storage missions are completed
Closure Milestones	Remove Tank Heels – 2001	Close SSTs – 2024 Close DSTs – 2032	Waste Removal – 2024	Cease Tank Use: Pillar/Panel – 2003 Monolithic - 2012	Complete Remedial Action – 2006

DOE-ID = DOE Idaho Operations Office.
DST = double-shell tank.
EIS = environmental impact statement.
HLW = high-level waste.
INEEL = Idaho National Engineering and Environmental Laboratory.
ORR = Oak Ridge Reservation.
SRS = Savannah River Site.
SST = single-shell tank.
WVDP = West Valley Demonstration Project.

The Hanford Site performed several different separations processes during plutonium production, and additional operations such as uranium, cesium, and strontium recovery. As a result, there are several different waste types at the Hanford Site. WVDP wastes were generated from commercial reprocessing of uranium and plutonium from SNF. ORR wastes are similar in composition to wastes at the Hanford Site and SRS because, during World War II, ORR developed and demonstrated many of the chemical separations processes used at those sites.

At INEEL, however, the waste has always been stored as an acidic liquid in stainless steel tanks. The majority of INEEL's waste has been calcined (converted to a dry, granular powder similar in consistency to dry laundry detergent), which is considered an interim storage waste form by the State of Idaho. Calcine waste requires further processing to convert it to a more durable, long-term waste form. In addition, INEEL has some tank-heel waste remaining that must be addressed.

Each site is at a different stage in remediation of its wastes and closure of tanks. All of the sites require technical assistance, scientific data, technology development, and baseline technology performance verification to improve efficiency, reduce costs, reduce risks, and enable the baseline tank waste remediation and closure activities to be implemented.

7.0 SITE-SPECIFIC DESCRIPTIONS

7.1 HANFORD SITE

The Hanford Site currently manages approximately 205 million L (54 million gal) of HLW in 177 under-ground carbon steel tanks (149 single-shell tanks [SSTs] and 28 DSTs. The waste consists of highly alkaline sludge, saltcake, slurry, and liquids.

The SSTs were constructed between 1944 and 1964 and received waste until 1980. The capacity of most SSTs is approximately 2 to 4 million L (500,000 to 1 million gal). The tanks are situated below grade and are covered with 2 to 3 m (6 to 10 ft) of earth. The 149 SSTs contain about 140 million L (36 million gal) of waste. Sixty-seven of the SSTs tanks have leaked or are assumed to have leaked. Approximately 2.3 million to 3.4 million L (600,000 to 900,000 gal) of waste has leaked or spilled into the nearby soil. Over the years, much of the liquid stored in SSTs has evaporated or been pumped to DSTs.

The Hanford Site tanks are cylindrical reinforced concrete structures with inner carbon-steel liners. The 149 SSTs have a single carbon-steel liner, and the 28 DSTs have two steel liners separated by a space called the annulus. The domes of the SSTs are made of concrete without a steel inner liner. The DSTs are completely enclosed by steel and reinforced by a concrete shell.

In the 200 East and 200 West Areas, the tanks were built in 18 groups called tank farms; 12 are SST farms and 6 are DST farms. The farms each contain from 2 to 16 tanks and hold different amounts of waste. The farms contain underground pipes so the waste can be pumped between tanks, between tank farms, from different facilities, and between the 200 East and 200 West Areas. The farms also house equipment used to route the waste, such as diversion boxes and valve pits.

7.1.1 Single-Shell Tanks

The 149 SSTs are located in 12 tank farms. The SSTs are constructed of carbon-steel that is ASTM A283 Grade C or ASTM A201 Grade C (AX tank farm), which lines the bottom and sides of a reinforced concrete shell. The bottoms of most tanks are slightly dished. The tanks are below grade with at least 1.83 m (6 ft) of soil cover that provides shielding, thereby minimizing radiation exposure to operating personnel. Inlet and overflow lines are located near the top of the liner. The volume capacity of each tank varies from 208,000 L to 3.8 million L (55,000 to 1 million gal). One hundred thirty-three of the SSTs are 22.86 m (75 ft) in diameter and 9.07 to 16.46 m (29.75 to 54 ft) high (at their highest points), with nominal capacities of 1.9 million to 3.8 million L (500,000 to 1 million gal). The larger tanks are numbered in the 100-series. Sixteen of the tanks are smaller units of a similar design, 6.1 m (20 ft) in diameter and 7.77 m (25.5 ft) high with capacities of 208,000 L (55,000 gal). The smaller tanks are numbered in the 200-series. Access to the tanks is provided by risers penetrating the domes of the tanks. Risers vary in diameter from 10 cm to 1.1 m (4 to 42 in.).

The carbon-steel liners used in the Hanford Site SSTs were not stress relieved after fabrication. The hot, alkaline radioactive waste mixture of liquid plus sludge has induced stress-corrosion cracking of the steel in some tanks.

Forced ventilation provides cooling for tanks containing materials that, through radioactive decay, generate heat that could exceed the established concrete temperature limits. Single-stage, high-efficiency particulate air filters allow atmospheric breathing for tanks that do not require cooling. Most of the waste in the SSTs is in the form of sludge, salt cake, and pumpable and nonpumpable liquids. Sludge consists of the solids (i.e., hydrous metal oxides) precipitated from the neutralization of acid waste before their transfer to the SSTs. Salt cake is made up of the various salts formed from the evaporation of water from the waste. Pumpable liquid exists as supernate and interstitial liquid in the tanks.

The SST waste is comprised primarily of sodium hydroxide; sodium salts of nitrate, nitrite, carbonate, aluminate, and phosphate; and hydrous oxides of aluminum, iron, and manganese. The radioactive components are fission product radionuclides such as strontium-90, cesium-137, and iodine-129 and of actinide elements such as uranium, neptunium, plutonium, thorium, and americium. The best-basis inventory (BBI 2001) contains a more complete description of tank contents.

The SSTs contain mostly inorganic waste, although relatively small amounts of plant solvents were added during fuel reprocessing. Water-soluble complexing agents and carboxylic acids were added in the B Plant waste fractionation process.

Waste management operations have created a complex intermingling of the tank waste. Nonradioactive chemicals have been added to the tanks to enhance storage capabilities, while varying amounts of waste and heat-producing radionuclides have been removed. Additionally, natural processes have caused settling, stratification, and segregation of waste components. Waste was also cascaded (i.e., allowed to gravity-flow from one tank to another) through a series of tanks; cooling and precipitation of radionuclides and solids occurred in each tank of the

cascade. As a result, it is difficult to estimate the character of the waste contained in the tanks through operation records.

Of the 149 SSTs, 126 have been interim stabilized (including all but 2 of the 67 assumed leakers). An interim stabilized tank contains less than 189,000 L (50,000 gal) of drainable interstitial liquid and less than 19,000 L (5,000 gal) of supernate liquid. If the tank was jet pumped to achieve interim stabilization, then the jet pump flow or saltwell screen inflow must also have been at or below 0.19 L/min (0.05 gal/min) before interim stabilization criteria are met.

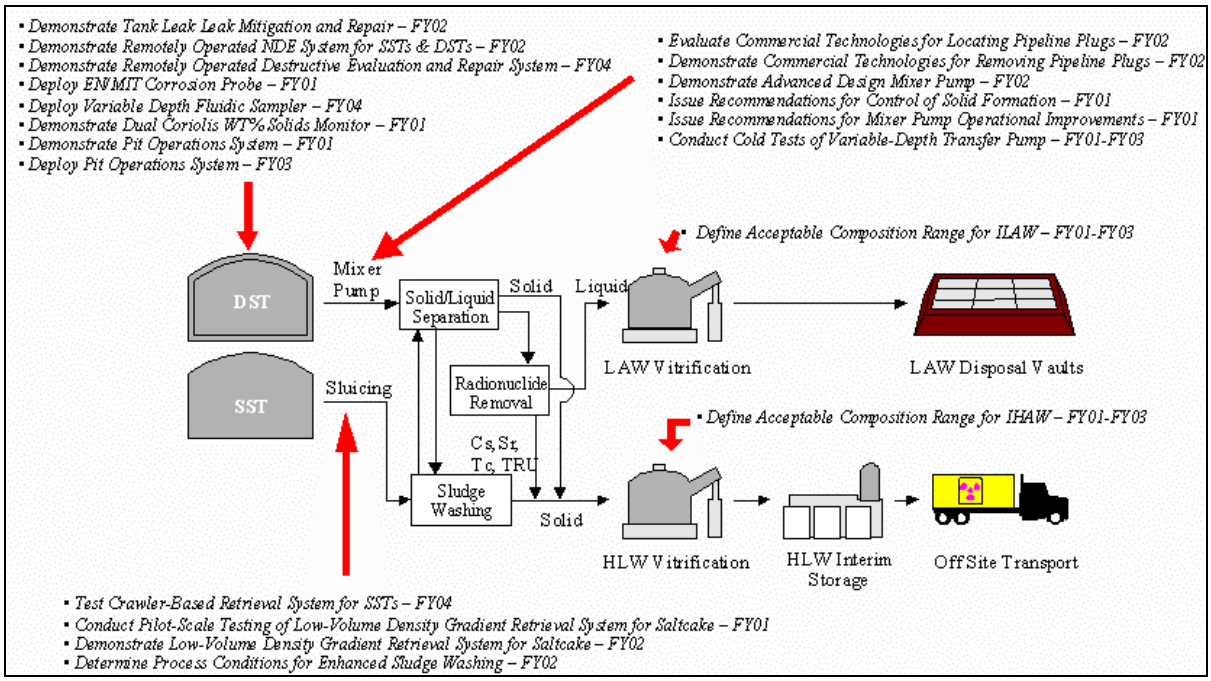
7.1.2 Hanford Double-Shell Tanks

There are 28 DSTs at the Hanford Site, each with a capacity of about 3.8-million L (1-million gal). The DSTs were constructed between 1970 and 1986. DSTs consist of two concentric structures; a steel primary tank used to contain radioactive waste materials; and an outer reinforced concrete confinement structure lined with steel. The space between the two walls is monitored for leaks. These tanks are also situated 2 to 3 m (6 to 10 ft) below ground level. DOE has used DSTs since 1970 and none of the DSTs at the Hanford Site have been known to leak. They are used to store a variety of liquid radioactive wastes including wastes from the SSTs interim stabilization program and from various Hanford Site processes. The wastes are stored in tanks based on composition, level of radioactivity, or origin. The 28 DSTs now contain about 80 million L (21 million gal) of waste (HNF-EP-0182-155).

7.1.3 Path to Closure for the Hanford Site

Figure 1 depicts the activities planned for tank waste remediation and closure at the Hanford Site (PNNL-13339). The current plan includes in-place stabilization of the SSTs and installation of a surface barrier.

Figure 1. Hanford Path to Closure



7.1.4 Regulatory Drivers for the Hanford Site

Regulatory drivers for remediating tank wastes at the Hanford Site include the following.

- **Hanford Federal Facility Agreement and Consent Order** (Ecology et al. 1989) (Tri-Party Agreement). This agreement between the U.S. Environmental Protection Agency (EPA) Region X, the DOE, and the Washington State Department of Ecology established the requirements for meeting federal and State *Resource Conservation and Recovery Act of 1976* (RCRA) regulations. The Hanford Federal Facility Agreement and Consent Order was originally signed in 1989, and has been amended numerous times. The fourth amendment committed DOE to retrieval of waste from the SSTs, vitrification of low-level waste (LLW), cessation of the grout program, and the *National Environmental Policy Act of 1969* coverage of actions. The most recent change implements a risk reduction strategy for SST waste retrieval, requires a demonstration of waste retrieval goals, and requires the establishment of an interface with the U.S. Nuclear Regulatory Commission (NRC) to reach agreement on allowable waste residuals in the tank and soil column. The Tri-Party Agreement serves as the site treatment plan required under the *Federal Facility Compliance Act of 1992*.

- **Environmental Impact Statement for the Tank Waste Remediation System** (DOE/EIS-0189). The environmental impact statement (EIS) provides information that has the potential to rebaseline tank waste remediation at the Hanford Site. The environmental consequences of a number of alternatives for treating tank waste, including in situ treatment, are evaluated. A record of decision (ROD) for the Tank Waste Remediation System EIS (62 FR 8693) stated that the phased approach was the best path forward for treating tank wastes.

- **Hanford Comprehensive Land-Use Plan EIS** (DOE/EIS-0222F). DOE has developed a land use plan for the Hanford Site that is included in the EIS for Hanford Site remedial actions. The Draft EIS was released in 1996, and the Final issued in 1999; the ROD was issued in 1999 (64 FR 61615). The plan and the ROD for the EIS identify land uses and accompanying restrictions for major site areas. The future land use assumed for the 200 Areas is industrial and/or commercial. This area will likely be held exclusively for disposal, containment, and management of waste, and other compatible uses. Access to the area and use of the groundwater is assumed to be restricted indefinitely.

- **DOE/Ecology Retrieval Performance Objectives Memorandum of Understanding** (MOU 1996). The memorandum of understanding specifies cost, risk, and safety as some of the key parameters that must be evaluated in comparing the interim retrieval goal to agreed-on performance objectives based on techniques developed and demonstrated in tank retrieval.

- **Defense Nuclear Facilities Safety Board Recommendation 93-5** (DOE/RL-00-01). The board issued recommendations to accelerate tank waste sampling at the Hanford Site to ensure adequate protection of public health and safety. Safety-related sampling and analyses were to be completed by July 1995. These deadlines have not been met.

7.1.5 Milestones for the Hanford Site

Selected Hanford Site milestones are presented in Table 2.

Table 2. Hanford Site Milestones

Milestone Title	Completion Date
Complete Phase I Processing (10% of waste by mass)	2018
Retrieve all single-shell tanks	2018
Close single-shell tanks	2024
Immobilize remaining tank waste	2028
Close all tanks	2032

7.1.6 Post-Retrieval Tank Waste Characterization

The Tri-Party Agreement defines allowable waste levels for SSTs after retrieval operations are completed. However, there are no agreed-upon standards for the specific data required to prove Tri-Party Agreement compliance. An agreed-upon standard, when established, will be reflected in the data quality objectives for post-retrieval tank waste characterization.

The post-retrieval tank waste characterization data quality objectives will identify the parameters that need to be measured to close the tanks. These parameters will undoubtedly include the final waste volume and the mass of the remaining contaminants of concern that contribute to long-term risk and regulatory compliance. Neither task is inconsequential in the technological challenges it poses. The SSTs are large (e.g., 100-series tanks are 22.9 m [75 ft] across) and contain a variety of in-tank equipment that tends to interfere with the extremely limited and remote access available for characterization efforts.

It is important to establish that any residual radioactive waste and contaminated soil remaining after retrieval is acceptable for near-surface disposal as LLW under DOE O 435.1. Characterization is the crucial first step and establishing the residual fraction of total activity remaining is the second. The past precedent of NRC action on the DSTs indicates that the planned 99% waste retrieval will be satisfactory.

The impact, if not resolved, would be that the residues would remain designated as HLW, which is not considered appropriate for near-surface disposal. Furthermore, the NRC has no regulatory structure in place for HLW disposed of anywhere but in a geological repository.

7.2 SAVANNAH RIVER SITE

The tank waste is HLW in three forms: sludge, salt, and liquid. The total activity of the 130 million L (34 million gal) of waste stored is estimated to be about 534 million curies. Almost all (>99%) of the activity of the waste comes from cesium-137 and strontium-90 and their decay products and from plutonium-238 and –239. Cesium-137 is soluble in the supernate, and strontium-90 is largely contained in the sludge. The soluble chemical constituents are

primarily sodium salts such as sodium nitrate (49 wt%), sodium nitrite (12 wt%), sodium hydroxide (13 wt%), sodium-aluminum tetrahydroxide (11 wt%), sodium sulfate (6 wt%), and sodium carbonate (5 wt%). The chemical composition of the insoluble sludges is primarily aluminum oxide (33 wt%), iron oxide (30 wt%), silicon oxide (6 wt%), sodium nitrate/nitrite salts (6 wt%), and zeolite (4 wt%) (HLW-TEC-950027).

Some 310 million L (82 million gal) of tank waste have been generated at SRS since the 1950s. Evaporation has reduced this volume by 60% to about 130 million L (34 million gal). Beginning in 1955 and 1957, tritium was separated and processed in the site's F and H Areas, respectively.

All of the tanks produce hydrogen as the water and trace organic compounds in the tank are broken down by action of the radioactivity. Tank 48 contains significant quantities of sodium tetraphenylborate, which was used in the in-tank precipitation process. This compound decomposes to produce benzene, which can volatilize and form a flammable vapor in the tank. To mitigate this problem, the tank has a primary and backup nitrogen inerting system that fills and mixes the vapor space with nitrogen, eliminating oxygen in the tank vapor space and, thus, preventing a fire or explosion.

Eleven of the SRS tanks (Type I, II and IV) have exhibited signs of leakage. Five of the Type I tanks are believed to have leaked (1F, 9-12H). All four Type II tanks are known to have leaked significant amounts to the secondary steel pan (13-16H). Tank 16 exhibits the most cracking with over 300 cracks detected. The largest of these cracks is approximately 15 cm (6 in.) long. In September 1960, a maximum of 2,650 L (700 gal) of waste rose above the top of the steel secondary containment pan of this tank for about 6 hours. Most of the 2,650 L (700 gal) was contained within the annular space by the concrete encasement, and was transferred to another tank. However, monitoring of the area indicates some radioactivity did escape through the thick-walled concrete encasement containment structures. Based on available information, a few tens of gallons of waste may have leaked into the soil. Two of the Type IV tanks (19F and 20F) have had minor water incursions. All of the cracks that have been detected are perpendicular to the welds with stress corrosion cracking being the likely failure mechanism. General and pitting corrosion damage do not appear to have caused significant damage.

Fairly recently, a long and unusually shaped crack was found in Tank 15. This crack was detected by visual means, and while it is not well characterized, estimates place it between 12 and 15 in. long. Prior to finding this crack in Tank 15, the longest measured crack was 6 in.

7.2.1 Storage Tanks at the Savannah River Site

The waste storage tanks were built from 1951 to 1981. They were built with three different sizes and four different designs, and are designated as Types I through IV (the labeling system does not denote the chronological order in which the tanks were built).

7.2.1.1 Type I Tanks. There are twelve 2.8-million-L- (750,000-gal-) capacity Type I tanks (Tanks 1 - 12) built between 1951 and 1954 at the H and F tank farm sites. The tanks were manufactured from A285 Grade B steel plate, which was welded together. No stress relieving was performed on these tanks. The primary tank rests in a steel pan that extends 1.5 m (5 ft) up the sidewall. The tanks are 22.5 m (75 ft) in diameter and approximately 7.5 m (25 ft) high.

The tanks and liners are encased in a concrete vault. There are twelve concrete columns within the primary tank to support the flat top. The columns are 0.6 m (2 ft) in diameter and encased in carbon steel plate. There are four 13-cm (5-in.) diameter risers providing access to the annulus area. There are 36 parallel cooling water coils suspended from the top of each tank.

Five Type I tanks (Tanks 1 and 9 - 12) have leaked detectable amounts of waste from the primary to the secondary containment, but there is no evidence that waste has leaked from the secondary containment. The tank tops are about 2.9 m (9.5 ft) below grade. Tanks 9 - 12 are located in the H Area Tank Farm and are in the water table.

7.2.1.2 Type II Tanks. There are four Type II tanks (Tanks 13 - 16) built during 1955 and 1956. All four are located in the H-Area Tank Farm. These 3.9-million-L- (1,030,000-gal-) capacity tanks were fabricated from A285, Grade B steel. No stress relieving was performed after welding. The tanks have a diameter of 25.5 m (85 ft) and a height of 8 m (27 ft). The primary tank sits in a steel pan that extends 1.5 m (5 ft) up the sidewalls. Each tank is encased in a concrete vault with a flat top that is supported by a single central column. A 0.7-m (2-½-ft) wide annulus area separates the primary tank from the vault wall around the outside diameter of the tank. There are 13-cm (5-in.) access risers into the annulus that allow 85 to 90 percent of the tank wall to be inspected. The tanks have 44 parallel cooling water coils suspended from the top of the tank.

All four Type II tanks are known to have leaked detectable amounts of waste from the primary to secondary containment. In Tank 16, waste overflowed the annulus pan (secondary containment) and migrated into the surrounding soil. Waste removal from the Tank 16 primary vessel was completed in 1980, but waste that leaked into the annulus has not been removed. These tanks are situated above the seasonal high water table.

7.2.1.3 Type III Tanks. The newest design, Type III, has a full-height secondary tank and forced water cooling. All of the Type III Tanks (Tanks 25 - 51) are situated above the water table. The 27 Type III tanks were constructed from 1967 to 1982. These tanks have a 2.8-million-L (1,300,000-million-gal-) capacity. The steel used to manufacture these tanks gradually evolved to include grades that were more resistant to stress corrosion cracking and had better fracture toughness properties. See Table 3 for a list of the materials used. All welds were stress-relieved. The Type III tanks are 25.5 m (85 ft) in diameter and 10 m (33 ft) high, and have provisions for better air circulation on the outside of the tank walls. Each tank is encased in a concrete vault with a flat top that is supported by a single central column. The vault is lined with a steel secondary containment liner. A 0.7 m (2 ½ ft) wide annulus area separates the primary tank from the secondary containment liner around the outside diameter of the tank. Eight-inch risers into the annulus area allow for access to 100 percent of the tank's circumference. A small airspace was provided between the central support column and the tank wall, and air slots were incorporated under the tank floor. Tanks 29 to 35 have removable cooling coil bundles suspended from the top of the tank.

Table 3. Summary of Storage Tanks at the Savannah River Site

Tank No.	Type	Construction Date	Steel Specification – Primary Tank	Stress Relieved	Suspected Leakers
1-8 F	I	1951–1953	A285 Grade B	No	1F
9-12 H	I	1951-1953	A285 Grade B	No	9-12H
13-16 H	II	1955-1958	A285 Grade B	No	13-16H
17-20 F	IV	1958	A285-54T Grade B	No	19-20F
21-24 H	IV	1962	A212-57T Grade B	No	
25-28 F	III	1975-1978	A516 Grade 70 (N)	Yes	
29-32 H	III	1967-1970	A516 Grade 70	Yes	
33-34 F	III	1969-1972	A516 Grade 70	Yes	
35-37 H	III	1974-1977	A516 Grade 70 (N)	Yes	
38-43 H	III	1976-1980	A537 Class I (N)	Yes	
44-47 F	III	1977-1980	A537 Class I (N)	Yes	
48-51 H	III	1978-1981	A537 Class I (N)	Yes	

These tanks contain the majority of the waste at SRS. Though none of these tanks is known to have leaked, there has been minor water leakage *into* two tanks. Most of the site's tank waste radioactivity and tank waste volume is contained in these 27 tanks.

The Type III tanks still receive small amounts of HLW from the site's limited production activities. Two types of waste are being sent: high-heat waste, which contains most of the radionuclides and must be aged in a high-heat waste tank before evaporation; and low-heat waste. After the waste is put in the Type III tanks, it separates into a bottom sludge layer and an upper layer of dissolved salts.

7.2.1.4 Type IV Tanks. The Type IV tanks were constructed from 1958 to 1962 and have a capacity of 1,300,000 gal. The tanks are 25.5 m (85 ft) in diameter and have 10-m (34-ft) high concrete sidewalls with a steel liner. The liners of the Type IV tanks were not stress relieved after welding. The tanks have a dome covering and do not contain cooling coils.

There were eight Type IV Tanks. Tanks 17 - 20 are located in the F-Area Tank Farm and Tanks 21 - 24 are located in H Area. Tanks 17 - 20 are slightly above the water table. Tanks 21 - 24 are above the groundwater table. However, they are in a perched water table caused by the original basemat under the tank area. Monitoring records suggest that a small amount of water has leaked *into* two of these tanks (Tanks 19 and 20), but there is no evidence that waste ever leaked out. Waste was removed from one Type IV tank because of a leak that developed in its carbon steel liner. Waste was removed from two other Type IV tanks (Tanks 17 and 20), and the tanks were grouted and closed in 1997.

7.2.2 Savannah River Site High-Level Waste Treatment and Tank Closure

The SRS HLW is being treated to separate the high-activity fraction (sludge) from the low activity fraction (liquid). The high-activity fraction is transferred to the Defense Waste Processing Facility (DWPF) for vitrification in borosilicate glass to immobilize the radioactive constituents for long-term storage. Final disposal of the vitrified waste will proceed after the transfer to a federal repository. The low-activity fraction is transferred to Z Area and mixed with grout to make saltstone, a concrete-like material disposed of in vaults. The environmental impacts of these processes and facilities were evaluated in the DWPF Supplemental EIS (DOE/EIS-0082S) and Waste Management EIS (DOE/EIS-0217).

After the bulk waste has been removed from the tanks for treatment and disposal, the tank systems would become part of the tank systems closure project. The primary concerns are how to deal with the waste that cannot be removed from the bottom of a tank (referred to as a heel) and tank stabilization methods. As outlined in the Closure Plan (DOE/EIS-0303D), DOE intends to close the tank systems to protect human health and the environment, and promote safety in and around these tank systems in accordance with South Carolina Regulation R.61-82, "Proper Closeout of Wastewater Treatment Facilities."

Upon completion of closure activities for geographical groups of tanks and waste handling systems, including evaporators, pumps, and transfer lines under this plan, portions of the HLW tank farms would transition from the tank closure project to the SRS Environmental Restoration program.

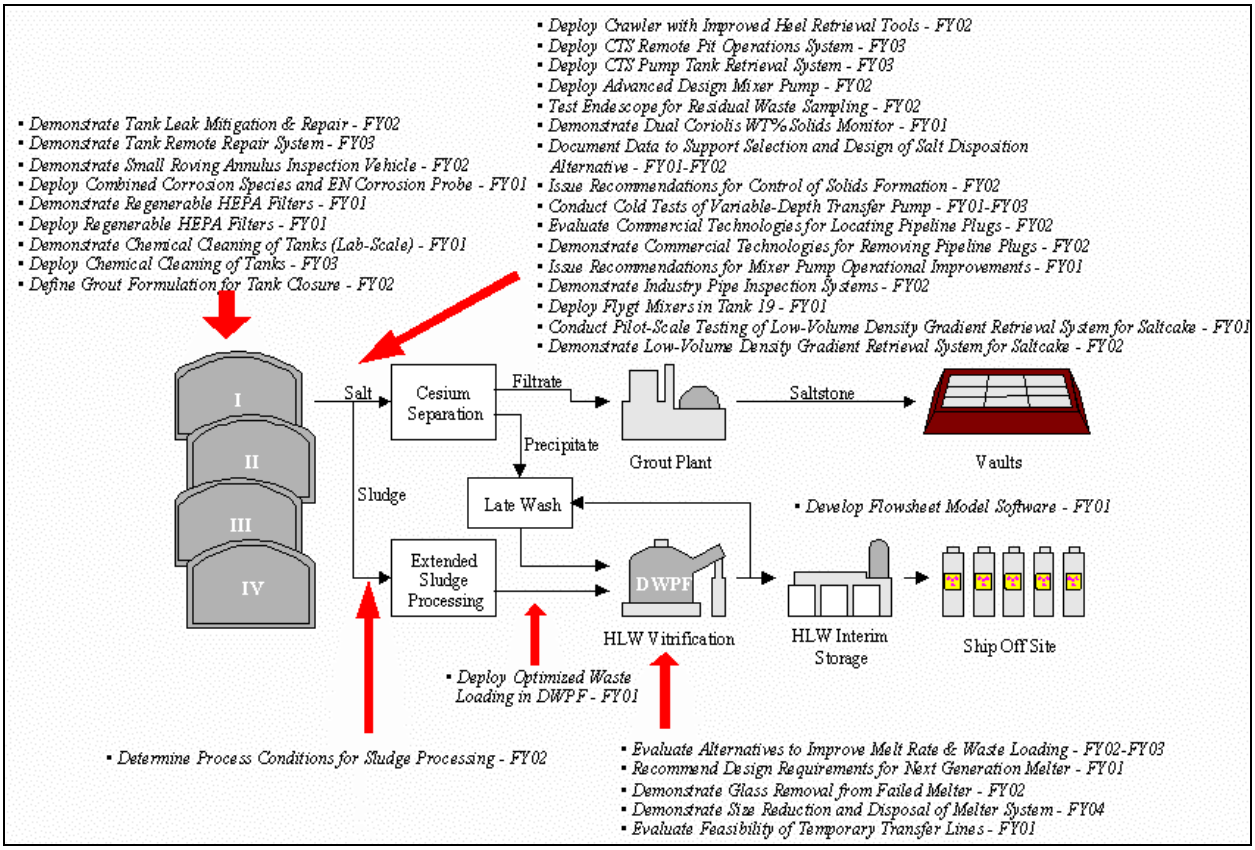
The proposed action is to remove the residual wastes from the tanks and to fill the tanks with a material to prevent future collapse and bind up residual waste, to lower human health risks, and to increase safety in and around the tanks. If required, an engineered cap consisting of clay, backfill (soil), and vegetation as the final layer to prevent erosion would be applied over the tanks. The selection of tank system closure method will be evaluated against the following *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* criteria described in 40 CFR 300.430(e)(9): (1) overall protection of human health and the environment; (2) compliance with applicable or relevant and appropriated requirements; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume through treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptable; and (9) community acceptance.

7.2.3 Path to Closure for the Savannah River Site

In accordance with the SRS Federal Facility Agreement between DOE, EPA, and the South Carolina Department of Health and Environmental Control (SCDHEC) (Docket No. 89-05-FF), DOE intends to remove the tanks from service as their storage missions are completed. DOE is obligated to close 24 tanks that do not meet EPA's secondary containment standards under RCRA by 2022. The 24 Type I, II, and IV tanks have been or will be removed from service before the 27 Type III tanks. Type III tanks will remain in service until there is no further need for them, which DOE currently anticipates to occur before the year 2030.

Figure 2 depicts the activities planned for tank waste remediation and closure at SRS (PNNL-13339).

Figure 2. Savannah River Site Path to Closure



7.2.4 Regulatory Drivers for the Savannah River Site

The regulatory drivers for remediating tank wastes at SRS are as follows:

- **Supplemental EIS** (DOE/EIS-0082S). DOE has prepared a supplementary EIS that addresses in-tank precipitation, saltstone processing and disposal, a late wash facility addition, and a number of other modifications to the DWPF. The ROD (60 FR 18589) was issued in April 1995 to complete startup testing and begin operation of the DWPF.

- **Draft EIS for HLW Tank Closure** (DOE/EIS-0303D). This supports a proposal to close 49 HLW tanks and associated waste handling equipment including evaporators, pumps, diversion boxes, and transfer lines, by cleaning and stabilizing the tanks and filling them with grout.

- **Industrial Wastewater Closure Plan for F and H Area HLW Tank Systems**. Approved by SCDHEC. Specifies the management of residuals as waste incidental to reprocessing.

- **Savannah River Federal Facility Consent Agreement**. This is an agreement between EPA Region IV, DOE, and the SCDHEC. This agreement establishes requirements for remediation of SRS. Tanks must meet structural integrity requirements or be removed from service.

- **Savannah River Waste Management EIS** (DOE/EIS-0217). This sitewide EIS provides the basis to select processes to manage wastes generated from ongoing operations and the operation of the Consolidated Incineration Facility. The ROD from this EIS (60 FR 55249) documents the decision to construct and operate the HLW evaporator and to transfer waste from the storage tanks to the DWPF.

- **Site Treatment Plan** (HLW-TEC-950027). The Federal Facility Compliance Act requires a site treatment plan for treating and disposing of mixed wastes. The SRS Site Treatment Plan identifies the DWPF as the preferred treatment option for treating liquid HLW.

7.2.5 Milestones for the Savannah River Site

Selected SRS milestones are shown in Table 4.

Table 4. Savannah River Site Milestones

Milestone Title	Completion Date
Startup salt waste processing	2010
Start shipping canisters to the federal repository	2015
Complete closure of 24 old-style tanks	2019
Waste removal complete from all tanks	2024
Sludge processing complete	2024
Salt processing complete	2024
Complete shipping canisters to the federal repository	2026

7.3 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

Eleven underground storage tanks were built for storage of radioactive waste at INEEL. One of the tanks (WM-190) is a spare to be used only if a problem should arise.

Since 1963, INEEL has been using a process called calcination to convert high-level liquid waste and sodium bearing waste into a granular solid, similar to dry sand. This conversion is accomplished by drawing the waste from the underground tanks, spraying it into a vessel heated with a mixture of kerosene and oxygen to about 500 degrees centigrade to evaporate the water and form metal oxides and fluoride salts. The waste exists in two basic compositions: aluminum calcine and zirconium calcine. Calcine is a safer waste form than liquid and substantially reduces the volume of waste (7 to 1) to be stored. The solid calcine waste is estimated to contain

50,000,000 curies of radioactivity. The radioactivity in calcine is primarily due to cesium-137 and strontium-90.

Prior to June 1997, the 11 underground stainless steel tanks contained approximately 6,400 m^3 (1.7 million gal) of acidic, radioactive liquid waste. This waste consisted of approximately 1,100 m^3 (300,000 gal) of high-level liquid waste and 5,300 m^3 (1.4 million gal) of sodium-bearing liquid waste. In 1997, Idaho Nuclear Technology and Engineering Center (INTEC) (formerly the Idaho Chemical Processing Plant) initiated a campaign to calcine all of the remaining high-level liquid waste by June 1998 to meet the Settlement Agreement with the State of Idaho. As of September 30, 2000, the total volume of waste in the 11 tanks had been reduced to 4.9 million L (1.3 million gal). This waste is primarily comprised of nitrates, sodium, aluminum, zirconium, and fluorides. The waste contains approximately 2,000,000 curies of radionuclides, with most of the radioactivity due to cesium-137 and strontium-90.

For INEEL, HLW projections are based on the recommended option from a new systems engineering approach to integrate all DOE Office of Environmental Management waste streams at the INEEL. The HLW projections include streams associated with the intermediate calcining of liquid waste, followed by separation of HLW and LLW fractions in the remaining liquid waste and redissolved calcine. No new HLW from reprocessing activities was produced after fiscal year 1992; SNF reprocessing facilities are being placed into cold standby pending decontamination and decommissioning. The current reference waste form at INEL is a glass. According to the October 17, 1995, Settlement Agreement, INEL is to calcine all of the liquid waste currently stored in the tanks by December 31, 2012. All of the HLW must be treated to be converted to the final waste form and be “road ready” by December 31, 2035. It is assumed that INEL will begin radioactive operations and thus produce canisters in 2020 and continue this operation through 2035.

7.3.1 Characteristics of Idaho National Engineering and Environmental Laboratory Tank Waste

Approximately 5.3 million L (1.4 million gal) of radioactive liquid waste containing 520,000 Ci of radioactivity are stored as acidic solutions in INTEC 11 tanks. The tank waste consists of sodium-bearing waste generated from activities incidental to reprocessing, such as facility decontamination.

In general, the tank waste at INTEC is different from the waste at the other DOE tank sites. The INTEC waste is extremely acidic, with a pH of less than 1 and is characterized by large concentrations of nitrates and dissolved metals such as aluminum, potassium, and sodium with small concentrations of sulfates, chlorides, and heavy metals such as chromium and nickel (WHC-EP-0566). The liquid waste has a density of 1.1 to 1.3 g/cm^3 (WHC-EP-0566).

The waste is composed predominantly of nitric acid and sodium nitrate. Small amounts of fission products and TRU elements are also in the waste. Some of the major constituents of waste by molarity (nominal) are nitrate, 4.5; sodium, 1.5; acid, 1.3; aluminum, 0.57, and potassium, 0.17. The basic (high pH) waste in the other site’s tanks caused many radioactive and nonradioactive metals to segregate into a complex chemical and physical mixture of liquids, slurries, and sludges.

In contrast, the metals and other dissolved material in INTEC's acidic tank waste remain in solution. Other than a few inches of accumulated solids on the bottom of the tanks, the liquid is clear to the bottom of the tanks. This simplifies waste characterization and retrieval compared to other DOE tank sites.

INTEC's tank waste has been divided into two categories: high-level liquid waste and sodium-bearing waste. All of the high-level liquid waste resulting from the dissolution and processing of SNF has been calcined and is stored in bin sets. Only sodium-bearing waste remains in storage in the tank farm.

7.3.2 Storage Tanks and Calcine Bin Sets at the Idaho National Engineering and Environmental Laboratory

The tanks are 15 m (50 ft) in diameter and 6.3 to 6.9 m (21 to 23 ft) in height resulting in a capacity around 300,000 gal. The tanks are capped with a dome top. All of these tanks were fabricated from Type 304L or 347 stainless steel plate ranging in thickness from 0.8 to 0.5 cm (5/16 to 3/16 in.). The tanks were not stress-relieved after welding. The tanks contain cooling coils that are elevated off the tank bottom by a support plate. Each tank is encased in a concrete vault, which is covered with about 3 m (10 ft) of soil. Table 5 summarizes the tanks at the INEEL and the three designs of the concrete vaults are described below.

Table 5. Summary of the Waste Storage Tanks at the Idaho National Engineering and Environmental Laboratory

Tanks Number	Const.	Vault Type	Volume of Liquid in Tank (Gallons as of 9/30/00)
180 181	1951 to 1952	Octagonal	267,000 271,000
182 183 184 185 186	1955 to 1957	Pillar and Panel	7,300 13,000 262,600 43,100 273,200
187 188 189 190 (Spare)	1958 to 1964	Cast-in-Place Square	86,800 13,600 22,600 500

<u>Octagonal Concrete Vault Tanks (Tanks WM-180 and -181)</u>

These two tanks are encased in an octagonal, cast-in-place (monolithic) concrete vault. Tank WM-180 is equipped with cooling coils, but Tank WM-181 is not. The tanks were built between 1951 and 1952.

Pillar and Panel Vault Tanks (Tanks WM-182 to WM-186)

These five tanks are housed in octagonal vaults that were built with precast concrete pillar and panel components. The tanks were constructed from 1955 to 1957, and all have cooling coils except Tanks WM-184 and WM-186.

Cast-in-Place Square Vault Tanks (Tanks WM-187 to WM-190)

These four tanks are housed in two rectangular, cast-in-place concrete vaults. Each vault contains two tanks. The tanks were built between 1958 and 1964, and all have cooling coils.

In addition to the underground storage tanks, the site also stores waste in seven Calcine Solids Storage Facilities. These facilities were designed to store waste in a granular solid form that is easier to contain and retrieve. The facilities consist of stainless-steel bins encased in concrete vaults. Bin set 1 was constructed from Type 405 stainless steel and the remainder from Type 304 or 304L stainless steel. There are five different configurations to these facilities. The facilities contain a combined 4,386 m^3 or about 1,000,000 gal of granular waste called calcine. The Calcine Solids Storage Facilities were designed to have a 500-year life.

The amount of waste is not spread evenly among the 11 tanks. Some tanks are close to capacity while others are not. One of the tanks is empty and has been declared a spare tank. The tanks are similar in design, constructed of stainless steel, and contained in underground concrete vaults. Each tank has four to five access risers. Steam jets are used to transport waste from tanks into the process system.

Eight of the 11 tanks can be cooled using cooling coils located along the tank floors and walls. These cooled tanks were used to contain the wastes and fission products (e.g., cesium-137 and strontium-90) from the thermally hottest first- and second-cycle extraction processes. Chemical raffinate from later extraction cycles and LLW evaporator concentrates were stored in the uncooled tanks. The wastes are stored in the tanks until ready for calcination. To date, none of these tanks has leaked waste to the surrounding environment.

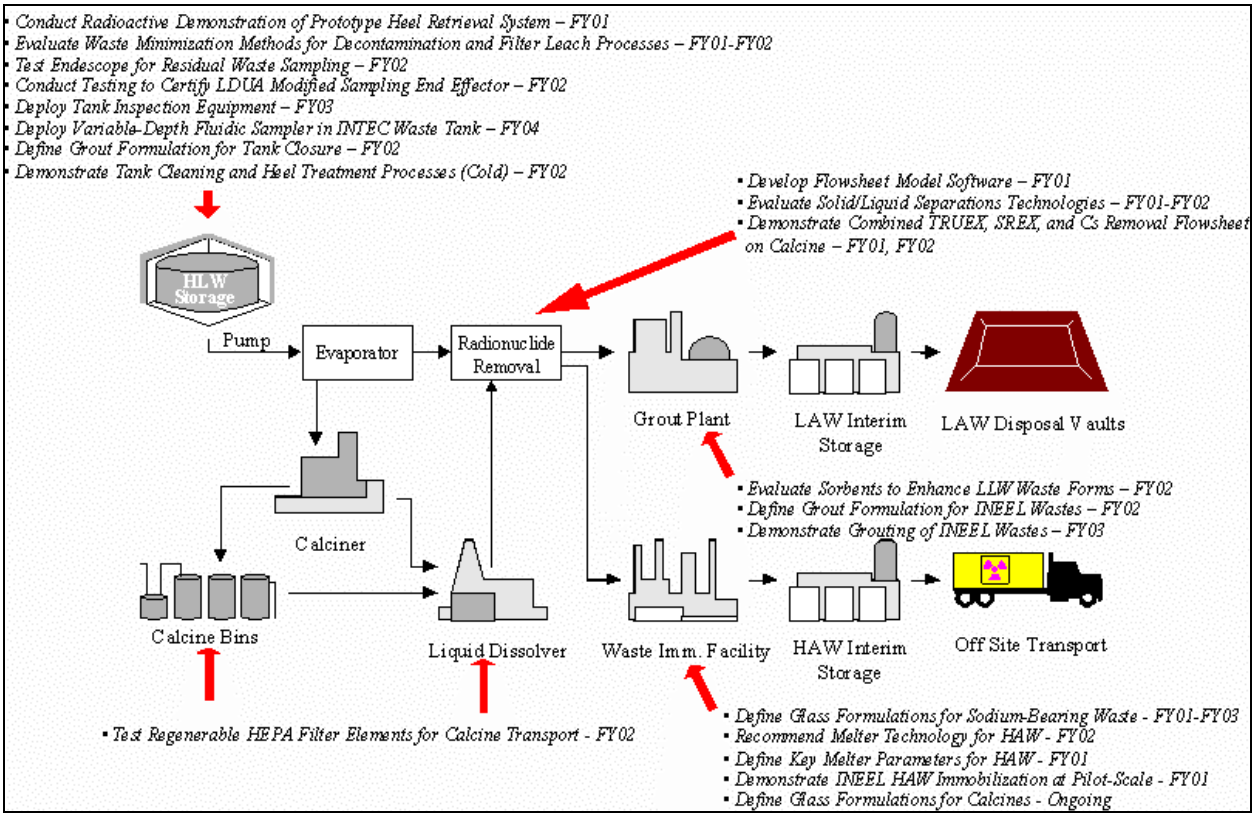
Approximately 3.8 million L (1 million gal) of calcine containing 24 million curies of radioactivity are stored in seven stainless-steel bin sets enclosed in concrete vaults with walls up to 1.2 m (4 ft) thick. Thus, the calcine contains about 98% of the waste radioactivity at INTEC. The bin sets have a network of monitoring systems that include temperature, pressure, and radiation monitors (WHC-EP-0566). Five of the seven storage facilities are full, the sixth is being filled, and the seventh is empty.

The bins have a life expectancy of 400 to 500 years. Radiation doses of 1,000 rem/hr have been measured in the annulus space of these bins. Calcined waste is not an acceptable form for permanent disposal because of concerns that the dry waste could be easily dispersed. Therefore, the calcined waste will be converted to an acceptable final form before disposal in a geologic repository.

7.3.3 Path to Closure for the Idaho National Engineering and Environmental Laboratory

Figure 3 depicts the activities planned for tank waste remediation and closure at INEEL (PNNL-13339).

Figure 3. Idaho National Engineering and Environmental Laboratory Path to Closure



7.3.4 Regulatory Drivers for the Idaho National Engineering and Environmental Laboratory

Idaho's major cleanup issues for INTEC are driven by two regulations: the Notice of Noncompliance Consent Order and the Idaho Settlement Agreement. Also, the Accelerating Cleanup plan plays a significant role.

- **Accelerating Cleanup: Paths to Closure** (DOE/EM-0362). The plan provides a project-by-project projection of the technical scope, cost, and schedule required to complete all 46 projects at INEEL's remaining cleanup sites.

- **Notice of Noncompliance Consent Order** (Cory 1998). The Consent Order, developed by the state, requires DOE Idaho Operations Office to cease use of the five pillar and panel vault tanks by 2009 and to cease use of the remaining six tanks by 2015. An August 1998 modification to the Consent Order accelerated these dates to 2003 and 2012, respectively.

- **Idaho Settlement Agreement**. The Settlement Agreement (formally known as the Settlement Agreement between the Governor of Idaho [Philip E. Batt], DOE, and the Navy [Kelly 1999]) required all high-level liquid waste to be calcined by June 1998, with the remaining sodium-bearing waste calcined by 2012. By 2009, a ROD must be issued that establishes a date for completion of the calcine treatment. (Other treatment alternatives for sodium-bearing waste may be employed to meet the intent of this agreement, in accordance with the HLW EIS that is currently being finalized [DOE/EIS-0287D]). By 2035, DOE must remove all spent fuel from the site and have all HLW road-ready for shipment and disposal at a repository.

To meet these last agreements, the following assumptions have been made. The bulk of the liquid tank waste will be retrieved and calcined, leaving liquid heels in the tanks that will be treated as part of tank closure. Calcine will then be retrieved from the bins and dissolved. After dissolution, the resulting liquid will be separated into high- and low-activity fractions. High-activity waste, containing the cesium-137, strontium-90, and TRU elements, will be vitrified for disposal. Low-activity waste, containing the radioactive chemicals, will be grouted and disposed of properly. Currently, no agreements or plans have been finalized to close INTEC's tanks or calcine bins.

7.3.5 Milestones for the Idaho National Engineering and Environmental Laboratory

Selected milestones in the remediation of INEEL's radioactive waste are shown in Table 6.

Table 6. Idaho National Engineering and Environmental Laboratory Milestones

Milestone Title	Completion Date
Commence negotiating a plan and schedule for calcined waste treatment	1999
Commence calcination of sodium-bearing radioactive liquid waste	2001
Cease use of waste tanks in pillar and panel vaults	2003
Issue ROD for treatment of sodium-bearing waste	2009
Complete treatment of sodium-bearing waste	2012
Cease use of waste tanks contained in monolithic vaults	2012
Complete treatment of all high level radioactive waste. Ready for offsite shipment to a repository.	2035

ROD = Record of Decision.

7.4 OAK RIDGE RESERVATION

Waste in ORR's tanks is classified as either low-level or TRU mixed waste. Although typically less radioactive, the contents of some ORR tanks have many of the characteristics of the high-level tank waste at the other DOE sites, such as the Hanford Site and SRS. Chemically, the

waste is principally sodium nitrate, as is the HLW generated from weapons production activities. However, because the U.S. definition of HLW is based on the waste's origin (waste from processing SNF is classified as HLW regardless of its radioactivity), the site's waste is not classified as HLW. Nonetheless, the most concentrated of the TRU waste sludge in ORR tanks contains as much radioactivity as some of HLW at other DOE facilities. The waste was created from several sources, including reactor water cleanup, radiochemical process development and processing areas, facility decontamination, and laboratory operations.

The waste in the ORR tanks is mixed LLW or TRU waste. The waste is classified as mixed because it contains both radionuclides (e.g., cesium, strontium, plutonium, uranium, technetium, and ruthenium) and hazardous materials (e.g., lead, chromium, mercury, and some organic compounds). The waste is low- level or TRU (depending on its concentrations of long-lived alpha emitters) because it results from the variety of research and development activities described above.

The ORNL has 95 underground storage tanks with capacities ranging from 40 to 170,000 gal. Of these, 40 tanks hold the bulk of the site's past and current liquid waste. These 40 tanks contain legacy waste (stored in 21 inactive tanks) and active waste (stored in 17 active tanks). The remaining 55 tanks are small tanks used to store waste temporarily before it is pumped elsewhere.

There has been extensive transfer and mixing of wastes among the various groups of tanks at ORR. Therefore, the current tank waste situation is described in two dimensions: time of generation (legacy and newly generated) and current storage location (gunite tanks, Old Hydrofracture Tanks, Bethel Valley Evaporator Service Tanks [BVESTs], Melton Valley Storage Tanks [MVSTs]).

7.4.1 Legacy Waste

Legacy waste, waste created from historical processing activities, is stored in the 16 Gunite and Associated Tanks (GAATs) and the five Old Hydrofracture Facility Tanks. The site has approximately 1.2 million L (328,000 gal) of legacy waste containing about 93,000 curies of radioactivity (mostly cesium-137 and strontium-90). About 67% (835,000 L) of this legacy waste is liquid LLW. The remaining 405,000 L (107,000 gal) are sludge that contains the bulk of the TRU radionuclides. This legacy waste is typically 10 to 100 times less radioactive than tank waste at other DOE sites.

Originally, legacy wastes were acidic. Sodium carbonate, sodium hydroxide, or lime were used to neutralize the waste so it would not rapidly corrode the carbon steel and concrete tank containers. Neutralization caused the heavy metals and TRU isotopes to precipitate, forming layers of sludge in the bottom of many tanks. This sludge now contains most TRU elements and more than 80% of the fission products. The later addition of calcium carbonate combined with waste evaporation enhanced the precipitation and sludge formation.

7.4.2 Newly Generated Waste

Newly generated waste results from decontamination activities and ongoing research and development efforts. Annual generation is about 1.5 million L (400,000 gal) of liquid waste.

Through evaporation and other processes, this is concentrated to about 56,000 L (15,000 gal) of waste containing approximately 13,000 Ci of radioactivity.

Over 99% of the radioactivity (primarily cesium-137 and strontium-90) in this waste is from a single facility called the Radiochemical Engineering Development Center. This facility recovers a variety of radioisotopes for beneficial uses in medical, industrial, and research applications.

The newly generated waste is stored in thirteen 189,000-L (50,000-gal) stainless-steel tanks: eight MVSTs, five BVESTs, and six 378,000-L (100,000-gal) stainless steel tanks Melton Valley Capacity Increase Tanks (MVCITs). The MVSTs are also being used to consolidate inactive tank waste for future treatment and disposal.

The typical waste composition is a 4 to 5 molar sodium nitrate solution with large concentrations of soluble compounds such as potassium nitrate and sodium chloride. Examples of insoluble compounds found in the sludge include aluminum hydroxide, calcium phosphate, and bentonite. The major radioactive contaminants of concern in the supernatants are strontium-90, cesium-137, technetium-99, and ruthenium-106.

7.4.3 Tank Design

Tanks at the ORR are GAATs, Old Hydrofracture Tanks, MVSTs, BVESTs. These tanks - built in the 1940s and the 1950s with a design life of 20 to 30 years - are located in five tank farms. Because the 13 active storage tanks in Melton Valley and Bethel Valley are nearly full, six new 379,000-L (100,000-gal) tanks were built. These tanks came on line in December 1998 and are called the MVCITs.

7.4.3.1 Gunite and Associated Tanks. Twelve underground gunite tanks were built between 1943 and 1951 to collect, neutralize, and store radioactive and other hazardous chemical wastes routinely produced by facility operations. Gunite is a mixture of cement, sand, and water sprayed through a nozzle over a steel reinforced framework. These tanks have since been removed from service because of their age and changes in onsite liquid waste system needs. These 12 tanks and four nearby stainless-steel tanks are known as the GAATs. The largest gunite tank measures 18 m (50 ft) in diameter and 5.4 m (18 ft) in height.

Four gunite and four stainless-steel tanks are in the North Tank Farm. Six gunite tanks are in the South Tank Farm. Two separate gunite tanks also exist: Tank W-11 (a small tank 2.4 m [8 ft] in diameter with ~5,500 L [1,500 gal] capacity) and Tank TH-4 (a larger tank with a 6-m [20-ft] diameter and a ~67,700-L [17,900-gal] capacity) are located in Bethel Valley, but outside the North and South Tank Farms. None of the 16 tanks are known to have leaked waste; however, groundwater has leaked into the tanks.

From 1981 to 1983, most of the sludge was removed from the GAATs using hydraulic sluicing and was transferred to the MVSTs. Less than a foot of sludge remained in each tank, though a few were reported to contain several feet of sludge. Removal of the remaining sludge was completed from 1998-2000.

7.4.3.2 Old Hydrofracture Facility Tanks. Hydrofracturing was used at ORR from 1963 to 1984 for the subsurface disposal of radioactive waste. The Old Hydrofracture Facility was used

from 1963 to 1980. The hydrofracture process involved mixing intermediate-level (about 0.25 curies per liter) radioactive waste with a blend of cement and other additives to form a grout. The grout was then injected underground into a shale layer at depths of 240 to 330 m (800 to 1,100 ft). Within the fractures in the shale, the grout hardened into thin, horizontal sheets several hundred meters wide. In 1980, a new hydrofracture facility was operating and continued to operate until 1983. Hydrofracture disposal of waste ceased in 1984 and is no longer considered an acceptable disposal option in the U.S.

The Old Hydrofractuer Facility tanks are made of carbon steel. These five tanks vary in size from ~49,000 to 94,000 L (13,000 to 25,000 gal). In 1997, these tanks contained a total of 162,000 L (42,900 gal) of liquids and 37,000 L (9,800 gal) of sludge from previous hydrofracture operations. In 1998, the bulk of the waste was removed with the Borehole Miner and transferred to the MVSTs.

7.4.3.3 Melton Valley Storage Tanks. The eight 190,000 L (50,000-gal) stainless-steel MVSTs contain 1.2 million L (310,000 gal) of waste and 126,500 curies of radioactivity. The MVSTs are cigar shaped, measuring 3.6 m (12 ft) from floor to roof and 18.7 m (61.5 ft) from end to end. The tanks are contained in stainless-steel vaults equipped with sumps and liquid level detectors. Each tank has a capacity to hold 189,000 L (50,000 gal). These tanks contain waste from current site activities as well as waste transferred from the GAATs.

The major radioactive contaminants of concern in the supernate are strontium-90, cesium-137, technetium-99, and ruthenium-106. While the composition of the supernate varies, a typical chemical composition is a 4 to 5 molar sodium nitrate solution with large concentrations of soluble compounds such as potassium nitrate and sodium chloride. The sludge, which contains TRU elements, makes up 35% of the waste volume and 80% of the radioactivity in the MVSTs. Chemically, the sludge contains insoluble compounds, such as aluminum hydroxide, calcium phosphate, and bentonite. The volume and composition of the waste in the MVSTs is changing as waste from current site activities and other tanks is transferred to these tanks for storage and final treatment.

7.4.3.4 Bethel Valley Evaporator Service Tanks. Five 189,000-L (50,000-gal) stainless-steel tanks were built in 1979 to hold waste before it was transferred into the Bethel Valley Evaporator. The cylindrical tanks, called the BVESTs, are approximately 3.6 m (12 ft) high and 18.7 m (61.5 ft) long. The tanks are filled with numerous pipes and other obstructions. Over the years, chemical reactions in the tanks have caused solids to precipitate. In addition to waste destined for the evaporator, the tanks contain “evaporator bottoms.” Evaporator bottoms are the residual wastes from the evaporator or, the solids that do not evaporate. For years, the bottoms were pumped back into the tanks after each evaporator campaign and formed a layer of sludge. In 1998 and 1999, the sludge was removed from three BVESTs using the Fluidic Pulse Jet Mixer.

7.4.3.5 Melton Valley Capacity Increase Tanks. Similar in design, though larger than the MVSTs, the MVCITs are approximately 4.8 m (16 ft) in diameter and 19.5 m (65 ft) long, with a useable capacity of 340,000 L (90,000 gal) (an additional 380,000 L is reserved for headspace). Each of the six cylindrical, horizontal tanks are contained in a lined tank vault. The new MVCITs are used to store/transfer liquid LLW to and from the existing MVST facility and the

LLW Evaporator in Bethel Valley. One tank is a spare. The new facility went on line in December 1998.

Table 7 provides a summary of the ORR tanks.

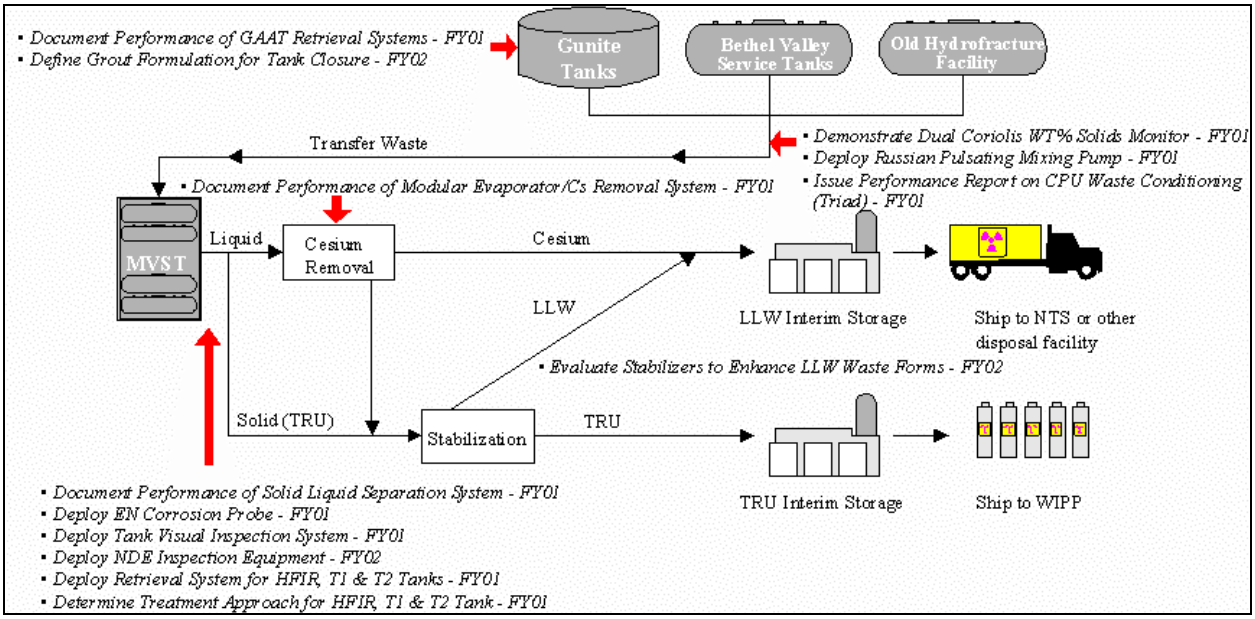
Table 7. Summary of Waste Storage Tanks at Oak Ridge National Laboratory

Description	Location	Construction & Number of Tanks	Volume (gal)	Status
Gunite & Associated Tanks	Bethel Valley	Gunite 12 Corrosion Resistant Steel 4	170,000 1,500	Inactive
Old Hydrofracture Facility Tanks	Melton Valley	Carbon Steel 5	13,000 – 25,000	Inactive
Melton Valley Storage Tanks	Melton Valley	Corrosion Resistant Steel 8	50,000	Active
Melton Valley Capacity Increase Tanks	Melton Valley	Corrosion Resistant Steel 6	90,000	Active
Bethel Valley Evaporator Service Tanks	Bethel Valley	Corrosion Resistant Steel 5	50,000	Active

7.4.4 Path to Closure for the Oak Ridge Reservation

Figure 4 depicts the activities planned for tank waste remediation and closure at ORR (PNNL-13339).

Figure 4. Oak Ridge Reservation Path to Closure



7.4.5 Regulatory Drivers for the Oak Ridge Reservation

The regulatory drivers for remediating ORR tank wastes are as follows:

- **Federal Facility Agreement for ORR** (DOE/OR-1014). This is an interagency agreement between EPA, DOE, and the Tennessee Department of Environment and Conservation. This agreement establishes requirements under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* for the management of tanks. Per this agreement, DOE must remove from service all tanks that operate without secondary containment. Tanks with secondary containment may continue to operate.

- **Tennessee Department of Environment and Conservation Commissioner's Order for ORR Site Treatment Plan**. This requires that RCRA land disposal restricted waste must be treated for disposal per the agreed upon schedule.

- **DOE Order 5820.2A** requiring treatment of TRU waste for disposal at the Waste Isolation Pilot Plant

- **Comprehensive Environmental Response, Compensation, and Liability Act of 1980**

7.4.6 Milestones for the Oak Ridge Reservation

Selected ORR milestones are shown in Table 8.

Table 8. Oak Ridge Reservation Milestones

Milestone Title	Completion Date
Complete Bethel Valley Remedial Action	2006
Complete White Oak Creek Remedial Action	2006
Complete legacy TRU waste treatment	2005
Complete legacy mixed and LLW treatment	2006
Complete Bethel Valley Remedial Action	2006

LLW = low-level waste.
TRU = transuranic.

8.0 PROPOSED WORK PLAN

8.1 GENERIC HIGH-LEVEL WASTE TANK LAY-UP ALTERNATIVES EVALUATION METHODOLOGY

8.1.1 Target Problem

Retrieval of HLW from underground storage tanks is underway throughout the DOE complex as a first step in the process of remediating the human health and environmental threat posed by the tank waste. The final step in this remediation process will be the closure of the tanks and tank farms. While there is a good deal of support for retrieval and treatment of the waste, there is some reluctance to establish final closure criteria for the tanks and move forward with tank closure, due in part to the finality of closure and the uncertainty associated with future impacts. As a result, each site will be faced with managing HLW storage tanks that are not quite empty for varying lengths of time after retrieval is complete until the tanks can be closed.

8.1.2 Work Element Descriptions

This task involves developing a methodology to support evaluation and selection of tank lay-up strategies for HLW tanks throughout the DOE complex. This methodology will focus on strategies for managing HLW tanks for the period of time between waste retrieval and tank closure. The methodology will be developed to allow consideration of tank-specific and site-specific issues.

Completion of this proposed scope of work will benefit all the sites by developing a common, demonstrated methodology for the transition from active storage to closure of the tanks.

8.1.2.1 Develop Functions and Requirements for Generic HLW Tank Lay-Up

Technical Description of Work:

Functions and requirements will be developed at a level of detail sufficient to support evaluations of the conceptual tank lay-up strategies developed for each site. The identification of functions and requirements will result in evaluation criteria to support the primary objective of placing the tanks in a safe, stable, and minimum maintenance mode that does not compromise final closure options.

Milestone:

Issue Generic HLW Tank Lay-Up Functions and Requirements

Description: Letter report to TFA summarizing tank lay-up system functions and requirements for the various DOE sites identifying the objectives of laying up the tanks, current tank conditions, and the tank lay-up system requirements.

8.1.2.2 Develop Representative Lay-Up Strategies for Generic HLW Tanks

Technical Description of Work:

A list of representative tank lay-up strategies will be developed. The development of these strategies will include solicitation from the sites along with a search of outside sources to identify any new concepts that should be considered. These scenarios will be developed to a level of detail sufficient to support an evaluation using the criteria developed from the functions and requirements. It is anticipated that the tank lay-up strategies developed for WVDP will be used as a starting point for this activity.

One of the challenges expected in performing this task is laying out the methodology for moving tanks from the retrieval mode and into the tank lay-up mode. Jacobs is currently conducting a residual waste assessment of tank C-106 at Hanford, which was subjected to waste retrieval activities. The objective of the residual waste assessment is to evaluate options for the disposition of tank C-106 to support a decision on whether there is a need to retrieve additional waste or if the tank can be operationally closed (tank lay-up) pending final closure actions. Experience gained in evaluating regulatory, programmatic, and technical issues associated with lay-up of tank C-106 will be valuable in performing this task. Some of the difficulties in moving forward with tank lay-up strategies are the complexity of the closure criteria (which have not been fully defined) and less than ideal performance of waste retrieval systems. Waste retrieval systems typically leave some residual solids and liquid wastes behind that need to be considered in any tank lay-up strategy.

Milestone:

Issue Representative Generic HLW Tank Lay-Up Scenarios

Description: Letter report to TFA listing representative lay-up scenarios that have been reviewed and commented on by participants from other DOE sites and other appropriate sources

8.1.2.3 Develop Generic HLW Tank Lay-Up Decision Plan

Technical Description of Work:

Performance objectives and specific criteria will be developed to provide a means for evaluating tank lay-up strategies. The overall objective of the decision process will be to provide a technically defensible methodology for evaluating tank lay-up strategies. The decision criteria developed for WVDP under Part I will be used as a starting point for this task and expanded to cover the other sites. Examples of performance objectives or attributes that could be used include: minimize monitoring and maintenance cost, meet environmental regulations for operations, meet environmental regulations for tank closure, ensure nuclear safety, protect worker health and safety, and address stakeholder concerns. Specific criteria will then be developed for each of the performance objectives to the extent necessary to fully evaluate the objectives.

Scoring guidance will be developed for each criteria to support a quantitative comparison of the strategies. If determined to be necessary, a methodology will also be provided that will allow the

decision makers to assign weighting factors to each of the decision criteria. Weighting factors will allow the decision makers the ability to identify the relative importance of the criteria to the decision.

A methodology for conducting a sensitivity analysis will be developed to validate that small changes would not significantly alter the final ranking of the strategies. The sensitivity analysis will be conducted after the ranking has been completed. The decision criteria along with scoring guidance will be documented for use by the sites in evaluating and selecting an approach for tank lay-up.

Milestone:

Issue Generic HLW Tank Lay-Up Decision Plan

Description: Letter report to TFA summarizing proposed decision criteria, scoring guidance, and sensitivity analysis methodology to be used for generic tank lay-up evaluations throughout the DOE complex

8.1.2.4 Evaluate Technical Concerns for Generic HLW Tanks

Technical Description of Work:

In parallel with development of representative lay-up strategies, technical areas of concern will be identified, prioritized, and addressed by subject matter experts. The technical concerns identified for WVDP will be used as a starting point and will be expanded to cover technical concerns for the other sites. These technical concern areas will be reviewed and prioritized with site representatives and the TFA Technical Integration Manager for Safety relative to their impact on the identified lay-up strategies. Subject matter experts will evaluate a select number of the higher priority technical concerns to the extent necessary to factor the concerns into the decision criteria process. It is envisioned that subject matter experts will be tasked with developing white papers to address the specific technical areas of concern. These white papers will then be incorporated into the description of tank lay-up scenarios.

The primary areas of technical concern that have been identified include tank integrity and corrosion issues. Additional areas of technical concern include, but are not limited to, identification and evaluation of stabilization materials, tank monitoring requirements, retrieval/closure criteria, and regulatory analysis.

Milestones:

No milestones associated with this work element. Output from this work element will be included in the description of tank lay-up scenarios and in the final report for the project.

8.1.2.5 Perform Demonstration of Generic HLW Tank Lay-Up Evaluation Methodology

Technical Description of Work:

A demonstration of the tank lay-up evaluation methodology will be conducted using site and tank-specific information for one tank. The purpose of the demonstration will be to apply the methodology to a specific tank in order to evaluate the methodology as a "value-added" tool to support individual site evaluation and selection of strategies for tank lay-up. Following the demonstration, the methodology will be incorporated into an interactive program for evaluating and documenting the tank lay-up evaluations. It is envisioned that this program will facilitate the application of the tank lay-up methodology by reducing the end user's need to rely on the written reports for definition and guidance for applying the methodology.

Milestones:

Demonstrate Generic HLW Tank Lay-Up Alternatives Evaluation Methodology

Description: Letter report to TFA summarizing the application of the evaluation methodology to a selected tank at one site

Issue Final Report For Generic HLW Tank Lay-Up Alternatives Evaluation Methodology

Description: Final report to TFA describing and documenting the evaluation methodology developed under this task to aid individual sites in evaluating and selecting strategies for tank lay-up

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REVIEW OF TANK LAY-UP STATUS AT U.S. DEPARTMENT OF ENERGY RADIOACTIVE WASTE TANK SITES

Draft

March 5, 2002

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CONTENTS

1.0 PURPOSE AND BACKGROUND 1

2.0 SITE PROGRESS TOWARD TANK LAY-UP 3
- 2.1 OAK RIDGE RESERVATION 3
- 2.2 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY 4
- 2.3 SAVANNAH RIVER SITE 6
- 2.4 HANFORD SITE 7

3.0 CONCLUSIONS AND RECOMMENDATIONS 8

4.0 REFERENCES 9

5.0 BIBLIOGRAPHY 10

APPENDICES

A CONTACTS LIST FOR TANK LAYUP ..... A-i

B SITE TANK LAY-UP QUESTIONNAIRE ..... B-i

LIST OF TERMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DOE	U.S. Department of Energy
FY	fiscal year
HLW	high-level waste
HSEE	heel sampling end effector
SST	single-shell tank
INEEL	Idaho National Engineering and Environmental Laboratory
LDUA	light-duty utility arm
ORR	Oak Ridge Reservation
RCRA	*Resource Conservation and Recovery Act of 1976*
ROD	Record of Decision
SRS	Savannah River Site
WIR	waste incidental to reprocessing

1.0 PURPOSE AND BACKGROUND

During fiscal year (FY) 2001 as part of a Tanks Focus Area strategic initiative, tank lay-up options were developed and evaluated for the two high-level waste (HLW) storage tanks at the West Valley Demonstration Project (Henderson 2001a, b, c, d, e). As a follow-on task, a list of key contacts throughout the U.S. Department of Energy (DOE) complex was developed (included as Appendix A). Visits were then made to discuss the concept and applicability of tank lay-up. This report documents the results of individual discussions with tank closure staff at the four DOE Sites concerning tank closure status and plans as well as lay-up options and activities.

To provide some focus and structure to the Site discussions, a tank lay-up information package and questionnaire was developed and provided before each Site visit (Appendix B). Tank lay-up discussions were held with management and technical staff from Hanford Site and Idaho National Engineering and Environmental Laboratory (INEEL) in December 2001 and with Hanford Site and Savannah River Site (SRS) and Oak Ridge Reservation (ORR) management and technical staff in January 2002. Discussion topics included current closure schedules, plans, progress, and issues that need to be addressed before closure.

Tank lay-up follows the completion of a tank storage mission and is a temporary, transitional state of the tank on the path to final closure. Tank lay-up can be defined as placing a tank and its residual contents into a safe, stable, and minimum-maintenance condition pending, and without precluding, final closure options. The need for and potential benefits from tank lay-up depend on the following:

- Number and physical condition of tanks
- Expected lay-up period
- Uncertainty in closure requirements
- Perceived risks associated with waste heels
- Regulatory environment.

Tank lay-up may occur in phases as (1) funding is available; (2) final closure requirements become known; and (3) identified issues are resolved by new technologies, better information, and/or stakeholder acceptance.

Tank closure program decisions are driven by many Site-specific and tank-specific variables. The better the Site has knowledge and control of these variables, the faster and easier the closure plans will be developed and approved. Tank lay-up options will vary among Sites and perhaps even between tanks at the same Site. Site-specific variables include the following:

- **Site Physical Conditions** – Soil chemistry, geology, hydrology, seismology, meteorology; vulnerability to hostile actions; proximity to cities and to publicly accessible water sources

- **Tank and Tank Farm Conditions** – Tank ages, designs (single- or double-lined, size, materials of construction, in-tank equipment); composition and extent of surface and subsurface contamination from tank and other sources; classification, composition, configuration, and perceived risk of residual tank waste

- **Federal Facility Agreements and Regulatory Requirements** – *Resource Conservation and Recovery Act of 1976* (RCRA) versus *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)

- **Relationship with and Involvement of Stakeholders** – Tribes, locals, downwinders, advisory boards

- **Closure Schedules** – Cost versus available funding profiles

- **State of Closure Technologies** – Availability, adaptability, performance, cost-benefit, maturity, acceptability, applicability

- **Complexity and Resolution of Issues –** Future land use designation; results (and acceptance of results) of contaminant release/transport modeling; post-closure requirements; disposal options, including allowances for heel dilution with fill materials.

As part of the closure planning process, baseline documentation will be reviewed for requirements that can be renegotiated, modified, waived, relaxed, or eliminated along the final closure path. Documentation that could be impacted by lay-up planning includes operating specifications, technical safety requirements, safety analysis reports, and procedures.

Tank lay-up activities (e.g., reducing tank chemical and radiochemical inventories, stabilizing residual waste heels, isolating tanks, stabilizing tanks) are expected to reduce the perceived risks associated with the tanks. Likewise, subsequent hazard/accident analyses on a tank-by-tank basis could result in the following:

- Lowering the hazard classification for certain facilities, which could impact conduct of operations, hazardous waste management, emergency preparedness, and training

- Reduction in the number of safety-class, safety-significant, and defense-in-depth structures, systems, and components, which could reduce the number of required engineered and administrative controls

- Reduction in the number of technical safety requirements (e.g., safety limits, limiting control settings, limiting conditions for operation)

- Reduction in monitoring or surveillance frequencies (e.g., liquid/solids levels, waste temperatures, vapor space pressures, leak detection probing, corrosion prevention)

- Reduction in tank reporting requirements

- Reduction of maintenance on the tanks and supporting and interfacing systems (e.g., vapor space filtration, liquid level devices, temperature probes, light-duty utility arm [LDUA], core sampling system)

- Reduction in the interface requirements associated with non-tank facilities and systems

- Reduction in configuration management requirements, procedure maintenance, number and depth of assessments, required personnel training, hazardous materials and radiation protection requirements, and other requirements to be determined on a Site and tank basis.

The baseline closure strategy for three of the Sites (ORR, INEEL, SRS) is to clean out the tanks to meet closure criteria, then fill the tanks and ancillary equipment with grout. The Hanford Site is currently developing its baseline closure strategy as part of a planned tank closure demonstration. At all Sites, final closure of the tanks would occur as part of final closure of the associated tank farms or sites. Closure of the highest-risk tanks at all four Sites is planned for completion during the next 20 years; closure of the remaining tanks will occur as storage missions are complete.

2.0 SITE PROGRESS TOWARD TANK LAY-UP

Each Site has shown progress on the path to final closure of tanks. The following sections summarize progress for each Site.

2.1 OAK RIDGE RESERVATION

All but 3 of 40 inactive tanks have been closed under the ORR Federal Facility Agreement (DOE/OR-1014), 25 tanks in FY 2001 alone. Because closures were governed by a CERCLA process, work proceeded under remediation plans rather than closure plans for the tanks. Waste characterization plans were developed that preceded and supported the remediation plans. Several remedial action reports have been issued (DOE/OR/01-1955&D1; DOE/OR/01-1953&D2; DOE/OR/01-1953&D2/A2). Because work is proceeding under an interim Record of Decision (ROD), these remedial action reports actually define interim disposal actions that could become final once the ROD becomes final.

Regulator agreement early in the process was crucial. The regulators agreed to a closure program based on accepted (10^{-6} incidental lifetime cancer risk) criteria 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.

The Providence Group was the key ORR closure subcontractor. Using a variety of existing technologies, the bulk sludge (as well as 95% of the radioactivity) was removed from the tanks to the extent practical, and consolidated in the Melton Valley Storage Tanks. Some of the key technologies integrated into the closure program included the following:

- The Houdini, with rotating end effector
- Pulse air and Flygt mixers
- Russian pulsating mixer pumps
- High-pressure, multiple-site grout injection system
- Installation of new access risers in the tank domes.

The tanks and associated piping were then filled with a flowable, self-leveling grout. Subcontractors developed the grout recipes, eventually settling on one called "Harrison mix 80" (SPG-OR051-A001; SPG-OR003-A001). While no attempt was made to intimately mix grout with residual heels, credit was allowed for full grout dilution of the transuranic residual waste heels. Foster-Wheeler is building a treatment plant for the sludges, allowing for eventual disposal at the Waste Isolation Pilot Plant. Some of the tanks were closed without further sludge retrieval.

It was determined that the Authorization Basis for the inactive ORR tanks was not consistent throughout the farms, and revamped the system to ensure all tanks were handled the same. A 15-minute video depicting the successes of the closure program, including in-tank views of some of the robotics used to retrieve the wastes was also developed.

Closure of the remaining three inactive tanks, which contain resin beads (and are in groundwater), was covered by a ROD that has been withdrawn because of the funding uncertainties associated with the current DOE-Environmental Management scope and budget review. If these resin tanks are not funded for closure, they will probably not be lay-up candidates because they are already in a low-risk, low-maintenance condition.

By strict definition closure of the ORR tanks is not final because the tank areas themselves have not yet been closed; this may occur much later under a separate ROD. The tanks are within the Oak Ridge National Laboratory, which is approved in perpetuity for government/industrial use.

The ORR staff are eager to share lessons learned, both successes and failures, and would support continued dialogue among the Sites on tank lay-up. Closure of the Melton Valley Storage Tanks may benefit from this continued dialogue.

2.2 IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

INEEL is pursuing an aggressive program to complete RCRA closure of all 11 stainless steel HLW storage tanks by FY 2016. Clean closure of these tanks requires an extensive retrieval and decontamination program. A RCRA closure plan was submitted to the state of Idaho in December 2000 and comments were received in March 2001. A revised closure plan was submitted in May 2001 and the state still objected to the approach for evaluating groundwater risk. A new plan was submitted to the state in November 2001; state response to this latest plan is expected in February 2002.

A Tier 1 closure plan was also prepared in accordance with the requirements of *Radioactive Waste Management* (DOE O 435.1) for approval by DOE. This plan was submitted for DOE-Headquarters review in January 2002; approval is anticipated in March 2002.

The liquid tank waste is stored in acid form with very few solids. None of the tanks have failed, and leakage during waste retrieval and tank decontamination operations is not a big concern. INEEL expects to fill the first two tanks with grout by the end of FY 2004, and an accelerated plan to increase that number to five tanks is being considered. Closure plans are being finalized to meet the RCRA requirement to have an approved closure plan within 90 days of 'ceasing use,' and to fill tanks with grout within one year after cleaning. There would still be CERLA actions required to close the entire tank farm.

Calcination of all high-level liquid waste at INEEL was completed in 1998. The liquid waste remaining in the INEEL tanks is process equipment waste from evaporator operation and sodium-bearing decontamination solutions. This remaining liquid waste is known as sodium-bearing waste. Current plans are to treat this waste by a method other than calcination. The plan is to reclassify this waste as waste incidental to reprocessing (WIR) according to DOE O 435.1 to expand the treatment and disposal options.

The tank clean up and closure activities are considered as 'off-normal operations, so unreviewed safety question evaluations are required. Also, an addendum to the safety analysis report is being prepared to modify the Authorization Basis.

INEEL intends to reuse several components for tank cleaning and grouting, such as the wash ball and directional nozzle cleaning system and the grout delivery system. 'Interface adapters' to isolate the tanks before grouting have also been developed. These are inserts to put in transfer piping with a blind flange and connections on either side of the flange to remove or add materials to the tank being closed while isolating it from the rest of the tank farm system. Ancillary equipment and systems will be grouted in a similar manner.

INEEL is also developing a new method for sampling the solids in the residual waste heels in the tanks. This sampler is deployed using the LDUA. The heel sampling end effector (HSEE) provides the ability to access off-riser locations over a large area of the tank bottom to obtain representative heel samples up to 800 mL (0.2 gal) in volume. The HSEE contains a light source, a camera with a viewing range of 0 to 15 m (0 to 50 ft), and a radiation detector with a range of 0-1000 rad/h. The HSEE is constructed of stainless steel, weighs about 30.5 kg (67 lbs), and has a remotely detachable sample chamber.

The wash ball is the primary remediation technology selected for tank cleaning. The wash ball nozzles operate at relatively low pressure (0.69 MPa [100 psi]) and a relatively high flow rate [0.0047 m^3/sec (75 gal/min)]. In the tank, the nozzle maximum stand-off distance is approximately10.7 m (35 ft). The wash ball is supplemented by a directional nozzle system. Similar to the 'sluicing nozzle' used at Hanford, the manually-controlled directional nozzle will be used to direct streams of water to the tank walls, cooling coils, or floor to dislodge accumulations of tenacious solids, and to sweep solids to the steam jet intake.

INEEL has demonstrated a method of pouring grout onto a tank floor in such a manner to permit retrieval of additional slurry from the tank using a variable depth steam jet. Sequential pouring of the grout pushes liquid toward the jet intake, allowing removal of additional liquid from the large-diameter tanks.

INEEL has demonstrated successful deployment of the LDUA for sampling and inspection. The LDUA could be a very effective tool to assist with cleaning of the tanks if a portion of the walls, floor, or other internal structures turn out to be more difficult to clean. Another option is a simpler articulated mast like the maintenance arm used at Hanford or the Wiedeman arm used at the West Valley Demonstration Project. These devices can easily fit through the 31 cm (12 in.) diameter risers at INEEL and can be used to deploy a high-pressure lance for more aggressive cleaning.

INEEL would be very important participants in future dialogue on tank lay-up.

2.3 SAVANNAH RIVER SITE

Closure of the 24 SRS HLW storage tanks that do not meet secondary containment requirements is planned to be completed by FY 2022. The remaining 27 tanks will be closed when the storage mission is complete in FY 2028. The associated tank farms will be closed at a later time.

The SRS tank closure evaluation was worked on for six years, and issued a Tier I closure plan to DOE-Headquarters for approval, which is expected during the second quarter of FY 2002. An independent review of the closure plan has been completed and comments are being resolved. In establishing the performance objectives for HLW tank system closure, DOE has assumed that the residual waste material remaining in the tank at closure will not be managed as HLW. In accordance with DOE O 435.1, DOE will demonstrate that the residual waste is WIR. SRS also estimated the HLW holdup in the piping and ancillary systems as 20% of the total inventory.

SRS regulatory points of compliance are seeplines about 0.6 km (1 mi) from the tank farm areas. Development of a three-dimensional model of the groundwater-vadose zone is being considered because it could provide more flexibility in planning than does the current one-dimensional model. Good regulatory support has been received from NUS Corporation, Sandia National Laboratories, and the Savannah River Technical Center.

The SRS tank closure environmental impact statement proposes the tank farm areas be considered for industrial land use in the future. This means the Site would remain under the ownership of the federal government (National Environmental Research Park), prohibiting residential uses and limiting recreational opportunities.

Tanks 17 and 20 have already been closed under CERCLA and the South Carolina Department of Health and Environmental Control industrial wastewater permits regulating their operation. Legal issues raised subsequent to the closure of these two tanks are being resolved. Bulk waste was removed from each tank down to less than 113,550 L (30,000 gal), then four 200 horsepower, 2,000-hour life mixer pumps were installed at a cost of $4 million per pump. Oxalic acid was used to help clean out the tanks, and each was left with the equivalent of 3,785 L (1,000 gal) of the original heel, the maximum allowable under their performance assessment. Finally, the tanks were filled with three distinct types of grout: a reducing grout to stabilize the heel, a low-strength grout to fill the majority of the tank, and a high-strength grout cap to inhibit human intrusion. Two buried solvent extraction storage tanks have also been CERCLA closed at the Site.

Tanks 18 and 19 are scheduled for closure by FY 2004; preparation of Tier II closure plans is already underway. Closure planning will include a WIR determination for each tank. The SRS will not be able to transfer some of the tank closure technologies used by other Sites (e.g., the Houdini system and the LDUA) because of the cost of maintaining these systems for their larger and differently configured tanks or because they require too much supporting superstructure over the tanks. The following technologies have been deployed in Tanks 18 and 19: Flygt mixers, Bibo transfer pump, Pitbull pump, Khrone density meter, hydrolance, and Goulds transfer pump.

During FY 2002 they expect to install a newly developed corrosion probe in Tank 43, procure and test an annulus inspection crawler, conduct laboratory scale demonstrations of leak mitigation technologies, complete hot testing of Khlopin acid for tank sludge removal, and evaluate an industrial pipeline unplugging system.

A phased lay-up is being considered for Tank 11, reviewing and changing the tank Authorization Basis to allow the tank to be maintained in a safer condition and cheaper. This includes placing a rain barrier/collection system over the tank. Like other Sites, caustic, nitrites, and nitrates to residual heels are added to inhibit tank corrosion.

A video considered important to public relations was produced to help develop understanding and support for the Site closure program. The video contained interviews with many prominent politicians and leaders and was widely available for local, state, and DOE-Headquarters meetings.

SRS representatives were receptive to the idea of a web-based tank lay-up/closure reference library but undecided about the value of a workshop.

2.4 HANFORD SITE

The Hanford Site contains 177 HLW underground storage tanks located in 18 tank farms on two separate areas. There are 149 of the older (up to 60 years old) single-shell tanks (SSTs), each consisting of a reinforced-concrete vault with a single carbon steel liner, that are currently planned to be emptied by FY 2027 and then closed. Sixty-seven of these tanks are known or assumed to have leaked to the soil. The 28 newer tanks each have two carbon steel liners, none are known to have leaked, and all are to be emptied and closed by FY 2032. A Tier 1 general tank closure plan is scheduled for issuance in FY 2008. Planning is currently underway on an accelerated tank closure demonstration project that would operationally close four or five of the SSTs by FY 2004.

The primary focus of the tank remediation program over the past decade has been on waste characterization and retrieval due to the need to remove the waste from the failing SST as soon as possible and to provide feed to a planned vitrification facility. Liquid-based waste retrieval systems currently under consideration include salt cake dissolution for tanks containing salt cake, a crawler system for tanks containing sludge, and fluidic mixing systems for tanks that contain both salt cake and sludge. This has also led to development and field testing of leak detection systems (e.g., electrical resistance tomography, high-resolution resistivity, and cross borehole radar) and leak mitigation strategies, as well as extensive three-dimensional modeling of the transport of tank waste through the Hanford vadose zone and groundwater.

Closure of the Hanford tanks will occur under DOE O 435.1 and the Washington State “Hazardous Waste Management Act” and its implementing “Dangerous Waste Regulations” (WAC-173-303). The current closure strategy assumes waste retrieval will be sufficient that the residual heel can be determined WIR. This strategy also assumes the residual heels and other tank farm sources will be considered non-HLW by the U.S. Nuclear Regulatory Commission.

Closure of the Hanford tanks and the surrounding soil is greatly complicated by the large number of failed tanks as well as an estimated 3.8 million L (1 million gal) of tank wastes that are now in

the surrounding vadose zone and groundwater. Eight of the 12 SST farms have been placed into the RCRA Corrective Action Program, and evaluation of the closure options for some of these tanks has concluded that clean closure would result in a substantial commitment of resources for minor reductions in long-term impacts. The planned land use for the areas containing the closed tank farms is industrial-exclusive for at least 50 years. During the 1980s extensive design, fabrication, and demonstration of a full-scale, no-maintenance, 10,000-year final barrier for placement over the tank farms was conducted. Likewise, a prototype 'rock slinger' was procured and tested to allow basalt rocks to be placed into tanks as fill material; and field-testing of subsurface barriers (e.g., grout) was conducted. More recently, Hanford has been investigating an 'Apatite-based' compound for potential use as a subsurface chemical barrier.

Hanford may derive the most benefit from continuing intersite dialogue on tank lay-up, especially during the early phases of detailed planning for tank operational closure.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The following are conclusions and recommendations derived from the information received and developed during this task.

- There is a wealth of knowledge, experience, and lessons-learned on tank lay-up and closure. Each Site will be reviewing and revising their Authorization Bases as part of closure planning. Hanford has the most to gain from what has been tried at other Sites. A lessons-learned workshop or videoconference, initially focusing on the changes in Authorization Bases associated with tank lay-up activities, should be considered.

- Various stakeholders have expressed an interest in developing meaningful information on the cost per 'closure unit' (e.g., curie, gallon) of tank closure activities at the Sites. Such cost data would be highly sensitive to each Site's initial conditions and the programmatic, technical, and regulatory frameworks for tank closure. Consideration should be given to adding this as a topic of discussion for a lessons-learned workshop or videoconference.

- The Site tank closure programs are at varying levels of maturity and may derive some benefit from continued dialogue on the tank lay-up concept. As currently planned, the Hanford tank closure demonstration should provide detailed lay-up requirements and costs, in a complex regulatory environment, for both small and large DOE HLW tanks. Consideration should be given to how Tanks Focus Area could provide meaningful support to the Hanford demonstration that would also benefit the other Sites.

- All Sites would contribute to and benefit from a tank lay-up/closure reference library. In the near term, assembling references may be complicated by comprehensive security review of documents at some of the Sites. Developing a user-friendly, comprehensive, readily accessible (perhaps web-based) reference library on tank lay-up/closure should be pursued.

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APPENDIX A

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APPENDIX B

SITE TANK LAY-UP QUESTIONNAIRE

The contents of this appendix have been previously distributed as JEG-01-031, *Tank Lay-Up Information Package and List of Questions for U.S. Department of Energy Waste Sites*.

B1.0 INTRODUCTION

This document provides background information and a list of questions to be addressed during an information-gathering visit by Jacobs Engineering Group Inc. (Jacobs) personnel. Jacobs has been funded by the Tanks Focus Area to complete a task "Pre-closure Interim Tank Maintenance." The overall objective of this task is to develop a central information center of site conditions, site requirements, alternative technical and other approaches, closure plans and activities, regulatory drivers and methodologies for decision-making to assist site decision-makers in the evaluation of alternative waste tank lay-up configurations. Lay-up is the term used for the period between initial decontamination and decommissioning of the tanks and final closure. Successful lay-up will place the tanks in a safe, stable, and minimum-maintenance mode until final closure.

B2.0 BACKGROUND

Subsequent to the end of tank retrieval activities but prior to final closure, U.S. Department of Energy (DOE) waste tank storage sites face challenges to appropriately maintaining aging tanks that still contain residual waste. These tanks must be kept in a stable configuration pending development and implementation of the final closure methods during a period that may exceed 10 years. Both in- and ex-tank concerns will impact the approaches selected. The alternative approaches available for achieving a stable interim configuration have not been evaluated for all tanks at all sites. Criteria for selection of preferred alternatives may vary from site to site. Special equipment to monitor and maintain the tanks may also need to be developed. Interim measures may include reducing corrosion, monitoring integrity, and maintaining structural stability. Lay-up strategies should be measured against criteria such as reducing monitoring and maintenance costs, meeting environmental regulations for tank closure, protecting worker and public health and safety, and addressing stakeholder concerns.

Current tank integrity efforts appear to be focusing on the (short-term) period when tanks are still active (for example, at the Hanford Site the emphasis is primarily on double-shell tanks and resolution of known safety issues). A Tank Integrity Workshop in November 2000 focused on the "period of time these tanks are required in completing the weapons complex cleanup." It is not clear that this period of concern includes the post-retrieval timeframe when the tanks may be considered inactive. Many of the tools and technologies being developed and used during a tank's active phase may also be applicable during its inactive phase (e.g., those for structural integrity and corrosion), but additional technologies may also be required to safely and responsibly manage the tank until it is closed, such as the following:

- More refined in-tank or ex-tank leak detection instrumentation and residual waste and vapor space characterization techniques (that possibly do not require physical sampling)
- Remote or automated monitoring of in-tank conditions
- Detailed, comprehensive, permanent visual records (and analysis) of the tank interior at specified frequencies
- Temporary interim barriers over or around the tanks until final barriers are in place.

During fiscal year 2001 Jacobs examined how a decision methodology developed for the West Valley Demonstration Project is applicable to the other DOE waste tank sites and determined what additional requirements and approaches will need to be considered. Additionally, a crosswalk of the lay- up requirements developed for West Valley was prepared against those identified for other sites. Table B1 is a comparison of the DOE tank sites. Table B2 summarizes the initial evaluation of tank lay-up requirements and considerations for each site.

B3.0 FISCAL YEAR 2002 PLANS

The task will continue in fiscal year 2002 with identification of characteristics unique to the individual sites and tanks (e.g., topography, meteorology, tank history, regulatory commitments, stakeholder concerns). Technical concerns to be considered during the evaluation include, but are not limited to the following:

- Prevention of internal tank corrosion (e.g., inhibitors, nitrogen inerting)
- Prevention of external tank corrosion (e.g., dehumidification, cathodic protection, inhibitors)
- Capability to monitor tank containment integrity (e.g., electrochemical noise, Raman spectroscopy, Corrosometer™, radiation detectors)
- Maintenance of structural integrity (maintenance or fill material)
- Development of treatment methods of air-borne contamination (filter disposal)
- Development of surface-fixation methods and material (coatings)
- Development of heel stabilization materials.

Jacobs will finalize a list of considerations or attributes applicable to the safe lay-up of waste tanks. The list of attributes shall address, at a minimum, regulatory, operational, technical, design, cost, and stakeholder concerns; safety concerns; and site-specific concerns and shall be organized or binned in a logical order. Each consideration shall be developed in sufficient detail to permit evaluation of intent and applicability to lay-up alternatives. The sites will provide comments and the list shall be finalized. Information needs will include the following:

- Tank type
- Tank condition
- Process history
- Heel condition
- Location
- Meteorological conditions
- Services
- Monitored variables
- Hazards
- Estimated duration of lay-up.

Table B1. Comparison of Site Waste Tank Programs (2 Sheets)

	WVDP	Hanford Site	SRS	INEEL	ORR
Number of tanks/areas to close	4/1 area	177/18 tank farms	51/2 tank farms	11[a]/1 tank farm	40/5 tank farms
Tank types	2	2	4	2 tank sizes	6
Tank sizes, 10^3 gal	15-750	55-1,160	750-1,300	300-318, 30	1.5-170
Tank ages, years	35	15-58	20-50	37-50	3-58
Tank conditions	No leakers	67 confirmed and assumed leakers	11 leakers	No leakers	No leakers
Waste types	Alkaline	Viscous, alkaline liquid, sludge, salt cake	Viscous, alkaline liquid, sludge, salt cake	Acidic, liquid sodium waste, sludges	Liquids, sludges
Waste volumes, 10^6 gal	0.6	54	33	1.4	0.4
Waste radionuclides, 10^6 Ci	0.03	200	470	0.52	0.047
Retrieval schedule	Tank heels cleaned out in 2001 to Class C limits	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	90% of inactive tanks complete. Remainder as mission is completed
Closure schedule	Not yet finalized; closure expected to take up to 20 years	SSTs by 2024[b] and DSTs by 2032[b]	2022 for Type I, II, and IV; Type III by 2030	In six phases from 2002 to 2016	24 tanks without secondary containment by 2022; others as storage mission is completed
Tank maximum ages in years at closure	More than 50	More than 75	More than 75	More than 60	More than 70
Final closure requirements approved	No	No	Some top-level developed	Some top-level developed	No

Table B1. Comparison of Site Waste Tank Programs (2 Sheets)

	WVDP	Hanford Site	SRS	INEEL	ORR
Closure regulatory drivers	DOE/EIS-0226-D; NYSERDA 1980; WVDP Acts of 1980 & 1991	DOE/EIS-0189; DOE/EIS-0222F; Ecology et al. 1989; MOU 1996	DOE/EIS-0217; DOE/EIS-0303D; Site Treatment Plan; Supplemental EIS; Wastewater Closure Plan; WSRC-OS-94-42	DOE/EIS-0287D; DOE-ID 1992; Settlement Agreement; CERCLA; DOE O 435.1	Accelerated Cleanup Plan; DOE/OR-1014; CERCLA
Site and tank specific considerations and uncertainties	Corrosion, in-tank hardware; water in vaults	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; seismic	Waste not classified as high-level; in-tank chunks of gunite

[a] Plus four 30,000 gal stainless tanks in the tank farm facility.
[b] Currently reevaluating to extend dates.

DST = double-shell tank.
EIS = environmental impact statement.
FFCA = Federal Facility Compliance Agreement.
HLW = high-level waste.
INEEL = Idaho National Engineering and Environmental Laboratory.
MOU = memorandum of understanding.
ORR = Oak Ridge Reservation.
SRS = Savannah River Site.
SST = single-shell tank.
WVDP = West Valley Demonstration Project.

Table B2. Site Waste Tank Lay-Up Requirements and Considerations (2 Sheets)

Requirements, Considerations, and Potential Issues		WVDP	Hanford Site	SRS	INEEL	ORR
Requirements	Ensure acceptable risks to workers and public	Establish safe operating envelope during lay-up. Maintain tank integrity. Prevent leaks to groundwater.	Minimize leaks to ground, air emissions. Maintain tank integrity. Minimize liquid ingress to tank.	Minimize leaks to soil and groundwater, air emissions. Maintain tank integrity. Minimize liquid ingress to tank.	Filter tank and vault exhausts as necessary; remote operation.	Store old and currently generated waste in highest integrity tanks.
	Comply with regulations, permits, and agreements	Table 1 regulatory drivers, plus DOE letter with Class C limits on tank cleanout.	Table 1 regulatory drivers, plus authorization basis, closure EIS, incidental waste determination.	Table 1 regulatory drivers, plus new tank closure EIS, incidental waste determination, impact of NRDC lawsuit (DOE O 435.1), land use implementation.	Table 1 regulatory drivers.	Table 1 regulatory drivers.
	Preserve future tank closure options	Preserve future options for tank decontamination and closure.	Consider the potential for secondary waste retrieval, remediation of contaminated soils, and remediation of ancillary equipment.	No tank closures until approval of new EIS.	Tank closure criteria awaiting DOE/RCRA documentation; HLW EIS.	Tank closures awaiting ROD and resolution of heel technical issues.
Considerations	Control life-cycle costs	Control capital and operating costs. Reduce tank surveillance and monitoring.	Reduce surveillance, monitoring, and maintenance requirements during lay-up period.	Reduce surveillance, monitoring, and maintenance requirements during lay-up period.	Utilize existing systems to greatest extent possible. Leave equipment in tanks when possible.	Close inactive tanks as soon as possible after waste acceptance criteria is satisfied.
	Gain stakeholder acceptance/ consensus	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.	Involve key decision makers and stakeholders in planning/approval process.
	Minimize secondary wastes	Ensure secondary wastes can be readily disposed.	Use existing waste for retrieval. Dispose secondary wastes.	Ensure secondary wastes can be readily disposed.	Ensure secondary wastes can be readily disposed.	Ensure secondary wastes can be readily disposed.
	Use proven and accepted technologies	Include demonstrated construction methods.	Full-scale demonstration of retrieval technologies.	Modify techniques used to interim close two tanks.	Washball system to be used for cleanout; steam jets.	Modify solids removal methods from other sites.

Table B2. Site Waste Tank Lay-Up Requirements and Considerations (2 Sheets)

Requirements, Considerations, and Potential Issues		WVDP	Hanford Site	SRS	INEEL	ORR
Potential Issues	Specific to site	Ability to keep tank external surfaces dry. Ability to control oxygen (corrosion) in tanks. Effectiveness of groundwater barriers.	Dome loading, liner integrity analysis, leak detection; waste heel characterization/ inventory and classification; tank isolation, barriers; tank atmosphere control; retrieval performance; groundwater/vadose zone modeling, assessment; future land use.	Liner cracks; waste in annuli; waste in groundwater; ingress of groundwater into tanks.	Ability to demonstrate clean closure of tanks; in tank equipment; contaminated soil; source terms, groundwater modeling; future land use requirements; final treatment system.	Groundwater leaks into tanks; resin beads in the bottoms of some tanks.

DOE = U.S. Department of Energy.
EIS = environmental impact statement.
HLW = high-level waste.
INEEL = Idaho National Engineering and Environmental Laboratory.
NRDC = National Resources Defense Council.
ORR = Oak Ridge Reservation.
RCRA = Resource Conservation and Recovery Act.
ROD = Record of Decision.
SRS = Savannah River Site.
WVDP = West Valley Demonstration Project.

A list of candidate technologies and representative lay-up scenarios shall be prepared. To the extent possible, the strawman lists shall include scenarios solicited from the sites as well as from other appropriate sources (e.g., industry, literature searches, technology evaluations). The goal is to be able to thoroughly characterize each scenario by virtue of identified attributes. Each major site will be visited to confirm the requirements and discuss the strawman scenarios. The selected scenarios (and associated attribute lists) will provide the basis for application of the prioritization methodology to identify preferred interim tank waste storage configurations. The decision methodology tool demonstrated in fiscal year 2001 will be updated to provide easier use.

Currently-funded activities include the following.

- Review and revise the preliminary lists of tank lay-up requirements and alternatives developed in fiscal year 2001.
- Meet with end users and stakeholders at each site to gather information on needs and potential strategies.
- From identified site-specific needs, develop potential tank lay-up strategies for each site.
- Identify data gaps and uncertainties that can be used to drive additional technical evaluations and/or data collection to support ranking of candidate lay-up options for each site.
- Prepare a letter report documenting the above activities.

Proposed future activities include the following.

- Information will be collected to close as many information gaps as possible.
- A workshop will be held with key individuals from the waste tank sites to share information and to collectively use the prioritization method to determine preferred options for each site.
- An information center containing technical, regulatory, and site-specific information will be established to provide a resource for future tank lay-up planning and decisionmaking. This information center will be maintained and technical and decision support will be provided.

The questions to be used during site visits are provided in the Attachment to this document. The answers to these questions will serve as the basis for establishing the programmatic, regulatory, and technology development status and plans applicable to waste tank lay-up.

ATTACHMENT
QUESTIONS FOR SITE VISITS

ATTACHMENT
QUESTIONS FOR SITE VISITS

CLOSURE CRITERIA

What are your criteria for closure?

What regulations or agreements apply?

What other drivers do you have for lay-up and closure?

Is the attached list of lay-up criteria developed for the West Valley Demonstration Project applicable at your site?

What other site-specific criteria are there?

SCHEDULE

What is your schedule for

- Ceasing operational use?
- Decontamination?
- Final closure?

Do you envision a lengthy lay-up period between last operational use and final closure?

What issues might delay the closure schedule?

PLANS

What techniques do you intend to use for

- Cleaning?
- Lay-up?
- Closure?
- Monitoring and surveillance?

Can you envision cost savings and/or risk reduction during the lay-up period?

WASTE CHARACTERIZATION

What characterization of the residual waste has been done/is planned?

Are estimates of the composition of the residual waste after retrieval available?

Have any risk analyses been done for the residual waste?

TECHNOLOGY DEVELOPMENT

What relevant technology development activities are you conducting, sponsoring or aware of applicable to tank lay-up and closure?

TANK CHARACTERISTICS

What unique characteristics of your tanks influence lay-up and closure? Some considerations follow:

- What is the tank's leak history?
- What is the tank's operational history?
- How clean does it have to be, including removal of in-tank equipment and/or debris?
- What is the physical condition of the tank (e.g., dome, liner, shell)?
- What tank isolation activities are required?

WASTE STABILIZATION

Is additional removal of waste planned?

Is interim stabilization of the residual waste planned prior to final closure? If so, how?

SITE CHARACTERISTICS

What unique characteristics of your site influence lay-up and closure? Some considerations follow:

- What is the soil chemistry and conditions?
- What are the climatic conditions, especially rainfall?
- What is the proximity to aquifers, rivers, lakes, cities, etc.?
- What are the stakeholder issues, especially the public?
- What are the planned long-term land uses?
- What are the potentials for earthquakes and floods?
- What is the hydrology and geology of the area under and around the waste?

WEST VALLEY DEMONSTRATION PROJECT LAY-UP CRITERIA

The following criteria were developed to assess alternative approaches for interim lay-up of the West Valley Demonstration Project tanks. The primary objective for temporary tank lay-up is to maintain the tanks in a safe and stable configuration with minimum capital and operating costs until final closure is completed. Some of the decision criteria listed below are firm requirements (e.g., safety) while others are more value based. Do these also apply to your site, and are there other criteria or considerations at your site? Have you developed your own list of criteria, considerations, or requirements?

- **Comply with regulations and permit requirements** – All regulations and permit requirements must be complied with during the lay-up period.

- **Prevent release of tank contents to the groundwater** – There shall be no release of radioactive or hazardous materials to the groundwater. This is a consideration during any preparatory activities and during the lay-up period.

- **Ensure acceptable risk to workers and the public**

  – **Short-term risk:** The risks associated with the installation of any new equipment required for the selected option must be as low as reasonably achievable.

  – **Long-term risk:** The selected option should result in a reduced risk to workers and the public during the lay-up period.

- **Maintain integrity of the tanks** – The ability of the tanks to continue to contain the waste residual must be maintained. Corrosion of the tanks must be controlled, and the structural integrity of the tanks must be ensured.

- **Establish a safe operating envelope during temporary lay-up** – The operational requirements during the lay-up period must continue to be within safe limits, but reduced monitoring and surveillance should be considered in evaluating options.

- **Control costs**

  – Capital costs of new equipment or modifications to existing systems.
  – Routine operating costs during the lay-up period.

- **Utilize accepted methods and technologies** – The preferred option should be based on proven construction methods and demonstrated technologies.

- **Avoid production of secondary wastes during construction and operation** – Options that may produce secondary wastes, especially radioactive wastes that will require further treatment and disposal, should be generally avoided.

- **Preserve future options for decontamination and final closure** – The selected lay-up option must maintain the ability to sample the waste, perform additional waste removal, and complete additional decontamination of the tanks if necessary. Also, the lay-up option selected must not preclude candidate final closure options, such as in-place stabilization or complete tank removal.

- **Gain acceptance for lay-up** – The selected option must be acceptable to stakeholders. Any changes to permits or other requirements must be acceptable to regulatory agencies.

- **Reduce monitoring and surveillance** – Reductions in monitoring and surveillance, consistent with requirements, is desired.