APPENDIX 1
Charge Summary

Issue	Suggested Activities	Expected Output/ Work Product	Notes
Charge 1 Modeling for Life-Cycle Analysis	This task entails reviewing the modeling approaches for determining tank waste remediation life-cycle costs at both SRS and Hanford. This includes evaluating assumptions in system plans for completing tank waste missions at Hanford and SRS, as well as the rigor of the models for identifying activities and costs through the end of each site's program.	Recommendation(s)	At Hanford, LAW vitrification capital and operating costs are potentially substantially greater than competing technologies. A second LAW vitrification plant is currently part of the baseline in order to treat the balance of the low activity waste volume. The estimated additional capital cost is >$1B. At SRS, minimizing life-cycle costs is dependent upon successfully implementing pretreatment capabilities and ensuring its low-activity waste treatment facility can be operated in such a manner as to match the HLW vitrification campaign.
Charge 2 Assess Candidate Low-Activity Waste Forms	At Hanford, the WTP is being designed, constructed and commissioned to treat, via vitrification, all of the high-level tank waste and up to 50 percent of the low-activity tank waste. The Subcommittee shall evaluate candidate waste forms including a vitrified glass waste form, a mineralized FBSR form, and grout as to their suitability for completing the Hanford tank waste mission. This assessment will use the results of the TEG review related to 1) waste loading in low-activity vitrified glass, 2) Tc-99 and I-129 capture in glass, and 3) whether tank waste samples for FBSR testing are sufficiently bounding to make mission critical decisions regarding waste form performance.	Recommendation(s)	Two separate waste forms are proposed for low-activity wastes – a grouted "saltstone" waste form at SRS, and a vitrified borosilicate glass waste form at Hanford. There may be advantages to utilization of alternative waste forms, particularly at Hanford, to address Tc-99 and I-129 capture and contribute to lower life-cycle costs due to the chemical complexity of the waste.
Charge 3 Assess at-tank or in-tank candidate technologies	This includes use of technologies currently being considered to perform some at or in-tank pretreatment activities, such as rotary	Recommendation(s)	

Issue	Suggested Activities	Expected Output/ Work Product	Notes
for augmenting planned waste pretreatment capabilities.	micro-filtration for solids separation and use of small-column ion exchangers for removal of Cesium.		
Charge 4 Evaluate various Melter Technologies.	Over the last 15 to 20 years, the EM program has considered various melter technologies and operational strategies to increase the efficiency of tank waste vitrification processes. This task will entail review of the different approaches and technologies that would be considered as second-generation (at Hanford), or third/fourth generation (at SRS) replacement melters, (e.g. cold crucible melters and advanced joule heated melters). The Subcommittee will consider the merits of different glass formulations, both borosilicate and other glass types, e.g., iron phosphate, as they apply to the advanced melter technologies above.	Recommendation(s)	
Charge 5 Evaluate the reliability of waste delivery plans	A key component of the tank waste programs at Hanford and SRS are the ability to reliably provide feed materials to existing and planned waste treatment facilities. At SRS this has been demonstrated, but further reduction of life-cycle costs will require enhancements to current waste retrieval and delivery processes. For Hanford this will require an evaluation of proposed plans to finalize waste acceptance criteria (WAC) for treatment facilities, optimally sequence tank waste delivery to meet the WAC, and identify specific vulnerabilities to achieving	Recommendation(s)	

Issue	Suggested Activities	Expected Output/ Work Product	Notes
	waste delivery. The Hanford baseline waste feed delivery approach to date consists of two major phases of operation – single-shell tank (SST) waste retrieval into the double-shell tank (DST) system for waste staging prior to treatment, and mixing and delivery of DST waste to the treatment facilities. The Subcommittee will consider the SST retrieval and waste staging options to enable timely, reliable feed delivery.		
Charge 6 Identify other tank waste vulnerabilities at SRS and Hanford	During the course of performing the tasks above, the Subcommittee should identify other vulnerabilities not specifically encompassed by those tasks and propose any recommendations to mitigate those vulnerabilities.	Recommendation(s)	
Charge 7 Vision 2020, Early start-up of One (1) LAW Melter	Recognizing that the Construction Project Review Management Subcommittee notes substantial improvements in WTP and Tank Farms coordination, the Management Committee strongly endorses the proposed phased commissioning approach and opportunities presented by accelerated low-activity waste operations. This task, recommended by the CRPM and accepted by the Assistant Secretary, is to conduct a rapid, thorough review of the WTP and Tank Farms integration programs to determine the optimal method for achieving cost and schedule savings available through these integration efforts. This review would include	Recommendation(s)	The review should include impact on pretreatment strategy, sampling facility support, operational readiness, labor issues, and complexity of nuclear conduct of operations within a construction site environment. The review should be in concert with on-going EM-TWS review and should be completed no later than June 22, 2011 as presented to EMAB full committee.

Issue	Suggested Activities	Expected Output/ Work Product	Notes
	evaluation of the Tank Farms' ability to support options for sequential initiation of radioactive waste processing and transition to full operations at WTP, specifically considering necessary Tank Farm improvements, benefits and risks to WTP project completion, and benefits and risks to the overall tank waste processing mission.		
Charge 8 EM-TWS Life Cycle Cost Analysis	This task entails reviewing and assessing the EM HLW retrieval strategies that could impact overall budget and life cycle costing. This assessment shall include life cycle cost review for programmatic / technical strategy, environmental liability, human health risk, waste disposition, and compliance to regulatory agreements.	Recommendation(s)	The TWS will provide its subject matter expert opinion relative to the task to the EMAB committee by June 22, 2011. This opinion shall be in DRAFT form to the EMAB for EMAB review and issue to the DOE CFO and the DOE EM Assistant Secretary.

APPENDIX 2
Membership of the EM-TWS

Members	E-Mail Address
Dennis Ferrigno, Co-Chair	Dennis.ferrigno@cafllco.com
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Shirley Olinger, Associate Principal Deputy for Corporate Operations, EM-2.1	Shirley.olinger@hq.doe.gov

Appendix 3
Meeting Schedules/Agendas

Environmental Management Advisory Board
Tank Waste Subcommittee Meeting Agenda
Augusta Marriott Hotel and Suites • Moody and Hamilton Rooms
Two Tenth Street, Augusta, Georgia 30901
December 13-15, 2010

DECEMBER 13, 2010 – MOODY ROOM (CLOSED SESSION)

Introduction 1:00 p.m.
Larry Papay, TWS Co-Chair

Administrative and Legal Matters 1:30 p.m.
Larry Papay, TWS Co-Chair
Terri Lamb, DFO

General discussion on TWS charges for 2011 2:00 p.m.
Mark Frei
Barry Naft
Herb Sutter

Lifecycle Costs (LCC) 2:30 p.m.
Mark Frei and Rod Strand
OMB Requirements
DOE 413.3 Requirements
Standardization models used at DOE/DoD/Others
Budget Process for Capital Projects and how LCC is used in Appropriations/Critical Decision Process

Welcome 3:30 p.m.
Inés Triay, Assistant Secretary for Environmental Management (via telephone 706-823-6554)

Resume Lifecycle Costs discussion 4:00 p.m.
Mark Frei
Rod Strand

HLW Journey to Excellence/near-term objectives 5:00 p.m.
Shirley Olinger, Associate Principal Deputy for Corporate Operations, EM-2.1 (via telephone 706-823-6554)

Roundtable Discussion (15 min.) 5:30 p.m.

Adjourn 6:30 p.m.

DECEMBER 14, 2010 – MOODY ROOM (CLOSED SESSION)

Welcome and Overview 8:00 a.m.
Dennis Ferrigno and Larry Papay, Co-Chairs, EMAB Tank Waste Subcommittee

Welcome and Introduction 8:15 a.m.
Terry Spears, Assistant Manager for Waste Disposition, DOE-SR

SRS Liquid Waste Mission 8:25 a.m.
Terry Spears, AMWDP, DOE-SR
Tank Waste Operations Overview and System Planning
Doug Bumgardner, SRR

Roundtable Discussion (15 min.) 9:00 a.m.
Brent Gifford, SRR Interim Salt Processing: ARP and MCU

Salt Waste Processing Facility Project 9:15 a.m.
Tony Polk, Acting Federal Project Director
Roundtable Discussion (15 min.)

Deployment of Accelerating Technologies 10:15 a.m.
Karthik Subramanian, SRR
Sludge Processing: DWPF bubblers, Evaluation of CCIM
Supplemental Salt Processing: SCIX, NGS, ELAWD
Roundtable Discussion (15 min.)

Fluidized Bed Steam Reforming for SRS Tank 48 11:15 a.m.
Karthik Subramanian, SRR
Roundtable Discussion (15 min.)

Non-Glass Waste Forms for Potential 12:00 p.m.
Hanford Low-Activity Waste Disposition
Carol Jantzen, SRNL

OPEN SESSION – HAMILTON ROOM

SR Site-Specific Advisory Board Issues and Concerns 1:00 p.m.
Manuel Bettencourt, Outgoing Chair
Roundtable Discussion (15 min.)

South Carolina Department of Health and Env. Control 1:45 p.m.
Shelly Wilson, SCDHEC
Roundtable Discussion (15 min.)

RETURN TO THE MOODY ROOM FOR CLOSED SESSION

Small Column Ion Exchange (SCIX) 2:30 p.m.
Richard Edwards, SRR

Technical Support Team Presentation 3:30 p.m.
on Understanding of Issues
Barry Naft and Herb Sutter

Work Session 4:30 p.m.
Dennis Ferrigno and Larry Papay, TWS Co-Chairs

Adjourn 6:00 p.m.

DECEMBER 15, 2010

Closeout/Next Steps 8:00 a.m.
Larry Papay/Dennis Ferrigno, TWS Co-Chairs

Transportation to Site for Tours 9:00 a.m.
Sheron Smith/SRS Transportation Department

Obtain SRS badges at SRS Visitor Control 9:45 a.m.

Welcome and Waste Operations Overview
Terry Spears, SRS

Transport to H-Area 10:00 a.m.

Tour of H-Area HLW Tank Farms 10:15 a.m.
Tom Gutmann, Waste Disposition Operations

Transport to S-Area 10:45 a.m.

Tour the Defense Waste Processing Facility 11:00 a.m.
Phil Giles, Waste Disposition Operations

Drive-by of the Salt Waste Processing Facility Site 12:00 p.m.
Tony Polk/Dave Bender, SWPF Project

Depart SRS to return to Augusta Marriott 12:15 p.m.
Sheron Smith/SRS Transportation Dept.

Return to Hotel/Adjourn 1:00 p.m.

EM-TWS Agenda
Marriott Courtyard Hotel
480 Columbia Point Drive
Richland, WA 99352
January 24 – 27, 2011

Monday, January 24

3:00 – 5:00 PM Review "Where we are" with emphasis on LCCA
5:00 - 6:00 PM Dale Knutson meeting with Dennis and Larry

Tuesday, January 25

8:00 AM – 1:00 PM Working Session (working lunch at 12:00 PM)
Overviews:
Jonathan "JD" Dowell
Tom Fletcher
Dale Knutson

As time allows, focus on the following:
Status of the WTP Construction Project (SPI, CPI, Quality, PJM technical issues)
Status of the Integrated Commissioning Strategy
Present program policy / procedure for compliance with Appropriations Strategy for the In-Tank / Out-of-Tank Capital Projects
How does the Tank Farm and WTP work the integration of startup and operational readiness?
How do you envision Lifecycle Cost Analysis and representation of savings to the budget process for each of the assigned programs?

Presentations by Federal Directors and Contractors
- Include, as appropriate, Small-Column Ion Exchange Program, Rotary Bed Microfiltration, Precipitation, Grinding
- Lifecycle Cost Analysis - Assumptions, Methodology, Application in System Planning, Results
- Assessment of Low-Activity Waste Forms
- At-Tank/In-Tank Technologies
- Design basis heat/mass balance and process description including ARF/LiHT and waste streams for integrated At-Tank/In-Tank process (Tank waste staging → Feed to Glass Forming)
- Corresponding design basis heat/mass balance including waste streams for WTP PT process (Tank waste staging → Feed to Glass Forming)
- Describe the LiHT process and your plans to use it to precipitate Al from feeds to the WTP.
- Pros/cons of alternate technologies that were considered but not selected
- Scale-up: What's been done and what remains to be done
- Melter Technology
- What technologies are being considered?
- What parameters are being used to evaluate the different technologies?

- What are the evaluation results?
- How would you implement new technologies in time, space, retrofit within a radioactive facility, issues with interface, etc.?
- What is the cost basis that is being used to compare new technologies against?
- How are you doing the costs of new replacement technology (detailed design and engineering costs, operating costs, or ROM)?
- Waste Delivery Plans
- Waste Disposition Pathways
- Waste Acceptance Criteria
- Risks for Waste Disposition
- Orphan Waste Potential
- System Plans 4, 5, and 6
- Secondary Treatment Strategy
- Tc-99 Issues and how WTP In-Tank / Out-of Tank-Technologies address this waste treatment concern

2:00 – 5:00 PM Public Session
Site-Specific Advisory Board
Washington State Department of Ecology
State of Oregon
Other interested members of the public

Wednesday, January 26

7:15 – 11:00 AM Tank Farm Tour (meet at the Federal Building with ID)
11:00 – 3:00 PM Wrap-Up Action Items / Path Forward (working lunch at 12 pm)
3:00 – 7:30 PM Finishing presentations from WRPS

Conclude any working session business from Tuesday

Chapter Captain Reports / drafts for review

Introduction – Papay / Naft
Modeling Lifecycle Costs – Strand / Frei
Assessment of LAW Waste Forms – Brown / Naft
Initial Assessment of Augmentation Prospects for In-Tank / Out-of-Tank Candidate Technologies – Leviton / Sutter
Evaluation of Melter Technologies – Lahoda / Sutter
Evaluation of the Reliability of Waste Delivery Plans – Brown / Naft
Identification of Other Tank Waste Vulnerabilities – Strand / Sutter
Findings / Conclusions – Ferrigno / Frei

Thursday, January 27

8:00 AM Dennis, Kevin, Alan, and Herb meet at Chris Burrows' office with WRPS and ORP personnel

Environmental Management Tank Waste Subcommittee Meeting *Phoenix, AZ* *February 28 – March 3, 2011*		
Agenda Item	Lead/Presenter	Time
February 28, 2011		
Reflections on the EMAB meeting and new task review	Larry Papay	12:00 – 1:00 PM
In-Tank / Out-of-Tank findings and conclusions	Alan Leviton	1:00 – 3:00 PM
LCC findings and conclusions	Rod Strand	3:00 – 4:00 PM
Evaluate the reliability of waste delivery plans findings and conclusions	Kevin Brown	4:00 – 5:00 PM
Summary of action items	Dennis Ferrigno Elaine Merchant	5:00 – 5:30 PM

Environmental Management Tank Waste Subcommittee Meeting *Phoenix, AZ* *February 28 – March 3, 2011*		
Agenda Item	Lead/Presenter	Time
March 1, 2011		
Assess candidate low-activity waste forms findings and conclusions	Kevin Brown	12:00 –1:00 PM
Melter Technology findings and conclusions	Ed Lahoda	1:00 – 2:00 PM
LCC findings and conclusions (cont'd.)	Rod Strand	2:00 – 3:00 PM
Charge 1B - EM-TWS Life Cycle Cost Analysis	Dennis Ferrigno (telephone call with Paul Dabbar)	3:00 – 4:00 PM
Summary of action items	Dennis Ferrigno Elaine Merchant	4:00 – 5:00 PM

Environmental Management Tank Waste Subcommittee Meeting *Phoenix, AZ* *February 28 – March 2, 2011*		
Agenda Item	Lead/Presenter	Time
March 2, 2011		
Brainstorming Working Session to Identify other tank waste vulnerabilities at SRS and Hanford	Dennis Ferrigno	8:00 - 11:30 AM
LCC vulnerabilities	Rod Strand	8:00 – 9:00 AM
In-Tank / Out-of-Tank Vulnerabilities	Alan Leviton	9:00 - 10:00 AM
Candidate waste forms / reliability of Waste Delivery Plan	Kevin Brown	10:00 - 11:00 AM
Melter technologies	Ed Lahoda	11:00 - 11:30 AM
Charge 7, Vision 2020, early startup of one LAW melter	Larry Papay	11:30 AM - 12:30 PM

Environmental Management Tank Waste Subcommittee Meeting *Aiken, SC* *March 21-23, 2011*		
Agenda Item	Lead/Presenter	Time
March 20, 2011		
Preparatory Mtg	Dennis Ferrigno Larry Papay Kristen Ellis	4:30 – 8:00 PM
March 21, 2011 (Meeting at SRNL Room 2138) **(Conference call-in number 803-725-1403, access code: 5262724)**		
RMF SRNL Site Visit	Dennis Ferrigno Alan Leviton Herb Sutter	8:30 AM – 12:00 M
Discussion with Terry Spears on LCC	Dennis Ferrigno Larry Papay	12:00 – 1:00 PM
LCC Review	Rod Strand Dennis Ferrigno Bob Hanfling	1:00 – 5:00 PM
Meet at SRNL	Ferrigno, Papay, Sutter, Naft, Leviton	
March 22, 2011 (Meeting at SRNL Room 2138) **(Conference call-in number 803-725-1403, access code: 5262724)**		
In-Tank/At-Tank	Alan Leviton	8:00 AM - 12:00 M
Waste Delivery Plans	Kevin Brown	1:00 – 4:00 PM
March 23, 2011 (Meeting at Houndslake; call-in number 202-287-6515)		
Where We Are / Next Steps	Dennis Ferrigno Larry Papay	8:00 - 11:30 AM

Environmental Management Tank Waste Subcommittee Meeting Nashville, TN April 5-6, 2011		
Agenda Item	**Lead/Presenter**	**Time**
April 5, 2011		
Opening Remarks / Where We Are / Schedule Review	Dennis Ferrigno Larry Papay	8:00 – 8:30 am
Chapter Captain status reports:		
1A: Modeling for LCCA- Section Review	Rod Strand	9:00 - 10:00 am
Break		**10:00 - 10:15 am**
1B: EM-TWS Lifecycle Cost Analysis; status and review of material to date	Paul Dabbar	10:15 - 11:15 am
2: Low-Activity Waste Forms- Section Review	Kevin Brown	11:15 am - 12:15 pm
Lunch		**12:15 - 1:00 pm**
2: Low-Activity Waste Forms- Section Review Continued	Kevin Brown	1:00 - 2:00 pm
3: In-Tank/At-Tank Technologies- Section Review	Alan Leviton	2:00 – 4:00 pm
4: Melter Technologies- Section Review	Ed Lahoda	4:00 - 5:00 pm
April 6, 2011		
5: Reliability of Waste Delivery Plans- Section Review	Kevin Brown	8:15 - 10:15 am
Break		**10:00 - 10:15 am**
6: Tank Waste Vulnerabilities at SRS and Hanford- Section Review	Dennis Ferrigno	10:30 – 12:00 pm
Lunch		**12:15 - 1:00 pm**
7: Vision 2020, Early Startup of One LAW Melter- Section Review	David Kosson	1:00 pm -2:00 pm
Chapter Status Wrap-up & Actions / Next Section Review Meeting	Dennis Ferrigno	2:00 pm - 2:30 pm
NAS Presentation- Waste Form Results		2:30 - 3:30 pm

Environmental Management Advisory Board
Tank Waste Subcommittee
May 2-4, 2011
Red Lion Hotel
N. 1101 Columbia Center Blvd.
Kennewick, WA 99336

Agenda Item	Lead/Presenter	TIME
Monday – May 2, 2011		
Meeting Introductions and Agenda Overview	ORP	8:00am – 8:30am
2020 Vision One System Overview	WRPS – Chris Burrows	8:30am – 9:30am
LOI #1: Mission, Objectives, Benefits and Issues for the 2020 Vision	WRPS – Martin Wheeler BNI – Ken Wells	9:30am – 10:00am
LOI #2: 2020 Vision for sequential start up of WTP with LAW as the first facility to undergo hot commissioning	WRPS – Martin Wheeler	10:00am – 10:30am
BREAK		10:30am – 10:45am
LOI #3: LAW waste feed	WRPS – Scott Saunders	10:45am – 11:15am
LOI #4: LAW waste feed preparation and delivery	WRPS – Doug Larsen	11:15am – 11:45am
LUNCH		11:45am – 1:00pm
LOI #5: LAW effluent management	WRPS – Kim Smith	1:00pm – 1:30pm
LOI #6: Sampling and Analysis	WRPS – TBD	1:30pm – 2:00pm
LOI #7: Operations and Management	BNI – Ken Wells	2:00pm – 2:30pm
LOI #8: Permitting	WRPS – Steve Killoy	2:30pm – 3:00pm
BREAK		3:00pm – 3:15pm
LOI #9: Safety	WRPS – TBD	3:15pm – 3:45pm
LOI #10: Project uncertainties, vulnerabilities and risks	WRPS – Martin Wheeler BNI – Ken Wells	3:45pm – 4:15pm
Action Item Review and Daily Close-Out	ORP	4:15pm – 4:45pm
Subcommittee discussions	TWSC only	4:45pm- 6:00 pm

Tuesday – May 3, 2011		
Data Call # 3: BNI summary description of Forecast Update 4 for WTP cost and schedule	BNI – TBD	8:00am – 9:00am
Data Call #4: Tank Farm Vulnerability Assessment – 2020 Vision Section	WRPS – Chris Burrows	9:00am – 9:30am
Data Call #5: Documentation of additional actions and resource commitment necessary to meet accelerated WTP facility commissioning, dates relative to FU4	BNI – TBD	9:30am – 10:15am
BREAK		10:15am – 10:30am
Data Call #9: List, description, and schedule and cost of all ETF upgrades (previously indicated to be ca. 30) needed, and which ones are absolutely needed to support early LAW	WRPS – Kim Smith	10:30am – 11:15am
Data Call #10: Number, size, location and schedule and cost for new blending/mixing tanks to enable proper sampling of feed to WTP	WRPS – Scott Saunders	11:15am – 11:45am

Data Call #11: Supernate Feed – Resins and Secondary Waste	WRPS – Paul Rutland	11:45am – 12:15pm
LUNCH		12:15pm – 1:30pm
Additional Presentations – As Requested by EMAB	TBD	1:30pm – 4:00pm
Action Item Review and Daily Close-Out	ORP	4:00pm – 4:30pm
Subcommittee discussions	TWSC only	4:30pm- 6:00 pm
Subcommittee Working Dinner: Anthony's Restaurant	TWSC only	7:00pm

Wednesday – May 4, 2011	
Data call items 4, 5, 7: a) review of the applicable regulatory requirements; b) compliance status of current projects; c) anticipated compliance problems or issues on the horizon; d) how project alternatives being reviewed would impact compliance; e) what authorizations or permits would be needed for such alternatives, and f) impacts from a range of waste retrieval scenarios (no retrieval to 99.9% retrieval)	8:30 a.m. – 10:30 a.m.
Break	10:30 a.m. – 10:45 a.m.
Data calls items 1, 2, 3, 6: 1989 Hanford EIS, 1996 Tank Waste Remediation System EIS, and the draft Tank Closure and Waste Management EIS relative to analysis of tank waste retrieval alternatives with emphasis on impacts (relative to the current baseline) to: life-cycle cost, technical strategy/baseline and issues (including impacts to tank farm operations, supplemental treatment, WTP, and waste disposition), safety, health and environmental risk, regulatory compliance, and other identified issues/vulnerabilities Presentations will track with Data Call requests 1-7.	10:45 a.m. – 12:00 p.m.
Lunch	12:00 p.m. – 1:00 p.m.
Data Call items 8,9,10: Any additional documented technology development studies/ evaluations of waste retrieval alternatives (relative to the current baseline) – including historical evaluations that pre-date the 1989 and 1996 Hanford EIS	1:00 p.m. – 3:45 p.m.
Break	3:45 p.m. – 4:00 p.m.
Data call item 11: Most current summary of integrated LCC for ORP mission which combines Tank Farm management of waste retrieval with WTP EPCC and mission life operations.	4:00 p.m. – 5:00 p.m.
Adjourn	5:00 p.m.

Thursday – May 5, 2011	
TWS Charge 1B Team: Discussion on information received from May 4 session; discussion of information received from current data call; identification of supplemental data call requirements	8:00 a.m. – 10:00 a.m.
Break	10:00 a.m. – 10:15 a.m.
TWS Charge 1B Team: Continuation of discussions; identification of path forward and schedule and action items	10:15 a.m. – 12:00 p.m.
Adjourn	12:00 p.m.

Environmental Management Advisory Board Tank Waste Subcommittee May 23-24, 2011 Vanderbilt University 400 24th Ave. South, Nashville, TN 37212 Building: Featheringill Hall/Jacobs Hall room 110		
Agenda Item	**Lead/Presenter**	**TIME**
Monday – May 23, 2011		
Meeting Introductions and Agenda Overview	Dennis Ferrigno	11:00 am – 11:30 am
Chapter Status Reports/Final Edits		
Charge 7: 2020 Vision Appendix	David Kosson	11:30 am – 12:30 pm
LUNCH		12:30 pm – 1:00 pm
Charge 1: LCCA Modeling Appendix & Summary write-up	Rod Strand	1:00 pm – 2:30 pm
Charge 2: LAW Waste Forms Appendix & Summary write-up	Kevin Brown	2:30 pm – 4:00 pm
BREAK		4:00 pm – 4:15 pm
Charge 3: In-Tank/At-Tank Appendix & Summary write-up	Alan Leviton	4:15 pm – 5:45 pm
Tuesday – May 24, 2011		
Opening	Dennis Ferrigno	8:00 am – 8:30 am
Charge 4: Melter Technologies Appendix & Summary write-up	Ed Lahoda	8:30 am – 9:30 am
Charge 5: Waste Delivery Plans Appendix	Kevin Brown	9:30 am – 11:00 am
Charge 6: Vulnerabilities Appendix & Summary write-up	Dennis Ferrigno	11:00 am – 12:30 pm
LUNCH		12:30 pm – 1:30 pm
Further discussions	Dennis Ferrigno	1:30 pm – 3:00 pm
BREAK		3:00 pm – 3:15 pm
Closeout and Next Steps	Dennis Ferrigno	3:15 pm – 4:00 pm
Adjourn		4:00 pm

APPENDIX 4
Data Call Summary

Data Call for Charge 1A –Lifecycle Cost Analysis

The EMAB Tank Waste Subcommittee has been tasked to access the systems approach being used for lifecycle cost analysis and what procedures are being followed. This approach is for the High-Level Waste Program as it relates to alternate technologies and approaches for Tank Waste at SRS and Hanford.

The EM organization has tasked the EM-TWS with the following request / work plan:

This task entails reviewing the modeling approaches for determining tank waste remediation lifecycle costs at both SRS and Hanford. This includes evaluating assumptions in system plans for completing tank waste missions at Hanford and SRS, as well as the rigor of the models for identifying activities and costs through the end of each site's program.

1. Life cycle cost analysis performed in support of the System Plan (including all assumptions, uncertainties, criteria, etc.) – i.e., detailed documentation, including risk management, which supports the latest Rev (SRS Rev 15 and 16's page 5 statement re: optimization of program life-cycle cost, Hanford Rev 5 and Draft Rev 6).

2. The identification/description and validation of the modeling tools used to support item 1.

3. Cost analysis including information on modeling that supports SRS's comments (T. Spears') comment during briefing: The 'life cycle cost' difference comparing the following 2 scenarios is $100M lower for scenario a. below:

    a. ARP/MCU operations (then shutdown) followed by SWPF and SCIX operations in parallel

    b. ARP/MCU continued operations in parallel with SWPF, with no SCIX deployed or operated

4. Cost analysis information and LCC modeling including the list of limiting factors and the risk profile for each to support SRS SWPF cost information

5. Cost analysis information and LLC modeling to support SCIX cost information

6. SRS's cost information and decision analysis that supports their proposal to proceed with SCIX and the other waste disposition enhancements briefed to the TWS

7. OMB Exhibit 300 (FY 2011 and FY 2012 budget versions) for SWPF, and the corresponding DOE Project Data Sheets

8. DOE and Site/Program policy and procedure documentation that covers life-cycle cost estimates/analyses, and the consideration of management reserve/contingency, and their use in project management and program decision-making (like the System Plan)

Data Call Information for Charge 1B

1. All documentation within the Hanford site-wide EIS promulgated circa 1989, which relates to the assessment of alternatives for disposition of tank farm wastes.
2. Correspondence with the USEPA and/or their designees, which relates to the acceptance of these alternatives.
3. Correspondence with Tri-Party Agreement stakeholders, which relates to the acceptance of these alternatives.
4. All documentation within the latest DOE draft of the revised Hanford site-wide EIS, which relates to the assessment of alternatives for disposition of tank farm wastes.
5. Listing of the pertinent references in 1. through 4. above which supports this documentation.
6. Studies performed by DOE to conceptualize and/or evaluate the cost-benefit of alternatives for disposition of Hanford tank farm wastes for inclusion in the circa 1989 site-wide EIS (including any alternatives evaluated but not included in the EIS).
7. Any documented revisions to those cited in 5. above that were performed for the revised site-wide EIS.
8. Design and/or cost and schedule analysis for the grout vaults constructed at the Hanford 200 area.
9. Any technology development studies performed at Hanford regarding cementation (i.e., Cast Stone) of Hanford tank waste or similar studies commissioned to be performed elsewhere (with particular emphasis on composition limitations that determine resultant solidified waste volumes and the basis for same).
10. Any studies referenced in 9. Above that may have been revised with regard to the Supplemental Treatment Waste Form down select for WTP.
11. Most current summary integrated baseline Life Cycle Cost for ORP mission which combines Tank Farm management of waste retrieval with WTP EPCC and mission life operations.

Note: It is recognized that some of this data call re-visits work performed at Hanford which in some cases occurred more than twenty years ago and that the current ORP and contractor staff may not be cognizant of such data sources. Given that in part it is not possible to ask for related references unless we are aware they exist, it is suggested that ORP identifies a small group of “old timers” who have long experience at Hanford from within the local contractor community and that ORP and TWS have a sort teleconference with them to identify other pertinent reference documents.

Data Call for SRS Meetings, March 2011

1. How is new resin bed established (set) in IX columns? Backwashing? Downwashing? Some other method?
2. The operations strategy states: “The SCIX process will be operated 24 hours per day, seven days per week, with an expected 25 percent downtime for system maintenance, resin replacement, Tank 41 heel transfers, and salt batch receipts and preparation.” What is the basis for assuming 25 percent downtime? Has OR modeling been done?
3. Several documents say the following (or equivalent): “The SCIX program will provide additional salt processing capability in Tank 41 to increase salt processing capacity by 2.5 Million (MM) gal/year. Assuming continuous SCIX operation at 75 percent attainment requires a nominal processing rate of 10 gpm.” However, at 75 percent on-stream, rate only needs to be 6.5 gpm to reach 2.5 MM gallons per year. Why is the stated value 10 gpm?
4. Are DSS receipt tank batches tested before transfer to Saltstone?
5. How large is the DSS receipt tank? Will the entire contents of the DSS receipt tank be transferred to Saltstone or is DSS transferred in batches based on some Saltstone requirement?
6. The following statement was in the Engineering Execution Plan: “Due to constraints with the design of the RMF feed pump in relation to Tank 41 and the SCIX process, initial integrated system testing and simulate operation will be performed at an on-site test facility (not Tank 41).” Please describe these constraints.
7. Engineering Execution Plan Common Plant Equipment, Paragraph 3.3.4.1, describes chemical addition as follows: This scope provides required cold chemicals (MST, caustic, nitric acid) to the system. Please describe the expected use of nitric acid including purpose, quantity, and frequency of use.
8. The RMF Conceptual Design document (M-CDP-H-00044) states: “The Riser H Splash Liner is a stainless steel sleeve which integrates with the linings of the Riser H Extension cylinder and cover to form a continuous barrier to corrosive liquids which may be present in the riser. The splash liner is specifically provided to protect the carbon steel in Riser H of Waste Tank 41F from nitric acid which is periodically used to clean the RMF filter elements.” Were other concerns regarding use of nitric acid for an in-tank process considered? How were they resolved?
9. Engineering Execution Plan Paragraph 3.4.2.6, Sodium Aluminosilicate (NAS) formation studies states: “Develop a feed specification that prevents NAS formation in the columns.” Please elaborate on this including the potential causes and potential operating problems.
10. The Ion Exchange Column Conceptual Design document (M-CDP-H-00045) states: “The INEX Component will be equipped with two sluice lines to allow sluicing of full-batch or half-batch volumes depending on disposal capacity. Prior to sluicing spent resin, the resin must be conditioned with caustic and Inhibited Water (IW) to avoid possible precipitation of aluminum hydroxide.” Please provide a more detailed description of this potential precipitation problem.
11. Engineering Execution Plan Paragraph 6.7.1 Ion Exchange Columns states: Existing drawings obtained through Oak Ridge National Laboratory (ORNL) from TTI Engineering show a well developed ion exchange component design. This design was performed in 2005. This design will be evaluated against the SRR TR&C requirements. These drawings as well

as a list of required changes will constitute the conceptual design and will form the input to an equipment specification for a design-build procurement." Has this design been used in any operating facilities or is this the first application of this design? If it has been used before please describe the application(s) and what problems, if any, have been encountered? Please provide drawings of the ion exchange columns and related P&ID's for the ion exchange operation.

12. Paragraph 6.7.4.2 Resin Preparation states: "Existing drawings obtained through ORNL from TTI Engineering show a well developed resin preparation component design. This design was performed in 2005. This design will be evaluated against the latest SRR requirements and these drawings as well as a list of required changes will constitute the concept design. These drawings, plus required changes, will form the input to an equipment specification for a design-build procurement." Has this design been used in any operating facilities or is this the first application of this design? If it has been used before please describe the application and what problems, if any, have been encountered?
13. What is the status of regulatory issues including environmental impact statement, wastewater treatment, air quality, and WAC for spent resin?
14. The RMF Conceptual Design document (M-CDP-H-00044) states: "Modeling and gamma monitoring will be performed to determine the actual CST resin replacement frequency. For the purposes of this document, the baseline assumption is the CST resin will be replaced once every two weeks, based on operating 24 hours a day, seven days per week." What is the basis for the estimate of once every two weeks resin replacement?
15. Please provide a drawing (or sketch) illustrating the RMF installation, which we understand to comprise four parallel 25 disk units. If one of the four parallel units requires repair, can its disk assembly be removed alone, or must the other three disk assemblies also be removed to gain access?

Additional SRS Data Call to Address EM-TWS Charge 2 (Assess low activity waste forms) and Charge 5 (Evaluate reliability of waste delivery plans)

It will be necessary to increase in the production of qualified sludge and salt waste feed for future SRS operations to accommodate increased DWPF throughput and the SWPF (to complete treatment of tank wastes by 2024). Because this is in the planning and construction phases (for SWPF), the necessary increases have not yet been demonstrated with the current infrastructure.

- The EM-TWS would like to see the bases, plans, and cost projections for increasing the production and qualification of sludge and salt batches in the SRS Tank Farm for treatment in the DWPF for the remaining SRS macrobatches. This description should include any new infrastructure as well as the use of the necessary modeling and simulation tools (WCS, Sludge Batch Toolkit, SpaceMan, PCCS, etc.) for said increases. For example, the modeling to support the washing / preparation of sludge batches for DWPF (using the Sludge Batch Toolkit) was recognized in the 2009 External Technical Review as a single expert-driven process where the expert is required to supply the necessary logic to the washing study. A similar level of expertise is needed to use other modeling and simulation systems including Spaceman. These processes were found to be expert-driven and highly labor-intensive without the possible software connections among the various tools to reduce possible transcription errors. Experts are relied upon to review the data and calculations to assure errors are not made in transcription. The process has been demonstrated to work for the first seven macrobatches (for primarily sludge-only operations); however, coupled accelerated operations may increase the possibility for inconsistencies and errors in the modeling to support sludge and salt batch preparation.

- In a related matter, the EM-TWS would also like to see the technical and regulatory documents describing the bases for qualifying the sludge and salt batches for coupled operations and their combination and treatment in DWPF. From the meeting at SRS in March 2011, changes in the sampling and qualification of sludge batches, sampling and qualification of salt batches, and sampling within the CPC were briefly mentioned and discussed. The current method for demonstrating that qualified sludge and salt feeds when treated in DWPF will result in acceptable glass product should also be provided. This should also include descriptions of how uncertainties are managed, variability and other laboratory studies for tank and simulated wastes, pour stream sampling and evaluation, prediction of the number of cans produced, and other relevant information. The basis documents describing the relationship of this information to necessary waste acceptance and compliance activities should also be provided.

- The EM-TWS would also like to see the technical basis reports for SME acceptability sampling and any recent changes in waste acceptance constraints (e.g., TiO_2, sulfate, REDOX, etc.) for DWPF treatment. For example, the TiO_2 limit in glass has been increased from 1 to 2 percent by weight in glass. The WSRC-TR-2003-00396, Rev. 0 report (entitled *Evaluation of the TiO2 Limit for DWPF Glass*) is available on the OSTI bridge, but the WSRC-RP-2003-00523 report (entitled *Analysis and Justification for Increasing the TiO2 Loading in Glass*) was not. Please provide the WSRC-RP-2003-00523 report as well as any revisions. On the sampling side, if the Acceptability determination is still made on a subset of four of six SME analyses (where the four are selected based on oxide sum), then the technical justification of the basis for selection (i.e., four of six) and the analysis of the possible resulting bias on the acceptability results is requested. Mention was also made by an SRS representative that the MFT sample may no longer be taken and analyzed; the basis for this exclusion should be provided. While it is understood that many of these actions can be justified based on information learned over many sludge-only batches, the technical bases to justify that the original sampling and analysis basis (especially for acceptability determination and confirmation) does not need to be reinstituted for coupled operations is needed.

Additional ORP Data Call to Address EM-TWS Charge 2 (Assess low activity waste forms) and Charge 5 (Evaluate reliability of waste delivery plans)

We would like the following additional information from ORP to better understand the various options and potential issues related to waste feed characterization, retrieval, preparation, and delivery for subsequent treatment in the WTP and ultimate disposal:

- A current or very recent electronic snapshot (or equivalent to be agreed upon by the EM-TWS) is requested of the in-tank estimates (for each SST and DST) for those elements, radionuclides, compounds, etc. that are important from waste compliance and environmental liability perspectives. Any RCRA metals should be included. The bases for these estimates include total, by phase (e.g., supernate, interstitial fluid (if different from supernate), salt, sludge), by species (gibbsite vs. boehmite vs. other) if available or assumed. An indication of the bases used to generate the estimates is also needed and may include core, auger, and grab sample information, when available, process knowledge as well as waste type templates. These estimates would provide a better indication of the variation of components of potential concern currently in the SSTs and DSTs that impact feed delivery and ultimately treatment (that impacts waste form decisions). For example, these estimates may be obtained from the best-basis inventories available in TWINS for the tanks in question or may already be documented elsewhere. The preferred delivery method is an electronic format such as Excel spreadsheets, JMP files, etc. unless the requested information already exists in report format. An example of the requested information appears to be the basic information used to define the composition clusters in the report entitled *Feed Variability and Bulk Vitrification Glass Performance Assessment* (PNNL-14985, Rev. 0). An example of the clusters generated in the aforementioned report on a waste oxide basis is provided in Figure 1.

- An electronic compilation (or equivalent to be agreed upon by the EM-TWS) is requested of each individual LAW/HLW waste feed batch composition (including total, by phase, and by species as indicated above) that would be treated from System Plans 4, 5 and 6 (when available) for the various scenarios that have been run. The components reported should be similar to those in the above request (e.g., elements, radionuclides, compounds, etc. important from waste compliance and environmental liability perspectives and including the RCRA metals). We hope the System Plan 6 information would include compositions from scenarios representing the Enhanced Tank Waste Strategy, Supplemental Treatment Project, and Vision 2020. The source tanks and, if possible, any pretreatment processes applied to obtain the feed batches would be helpful. This information would provide a better idea of the variation from feed batch to feed batch as well as how sensitive the feed batch compositions are to the various scenarios considered over the most recent System Plan revisions. The preferred delivery is again an electronic format such as Excel spreadsheets, JMP files, etc. unless this information already exists in report format. For example, these compositions may be obtained from the HTWOS model runs supporting development of the most recent ORP System Plans.

The second area of additional information being requested pertains to a question and resulting discussion during the January EM-TWS meeting in Richland, WA. Because of the apparent disagreement between DOE and the Washington State Department of Ecology on the performance basis for treated LAW waste forms (glass or other), the question was raised as to what exactly DOE has agreed to in terms of the treated LAW waste forms and their disposal. In light of the resulting discussion, the EM-TWS is requesting the following information:

- The performance basis for the treated LAW waste form should be described with relevant citations to regulations, the TPA and other agreements. The current Hanford TPA has major milestone M6200 that states:

- “Complete pretreatment processing and vitrification of Hanford High Level (HLW) and Low activity (LAW) Tank Wastes.”

Although earlier versions indicated that the LAW would be treated using grout or glass. DOE is currently investigating treatment methods that do not involve vitrification, which has caused confusion and apparently some degree of consternation. For example, the performance benchmark for treated HLW (currently a borosilicate glass) at both SRS and Hanford was defined to be the Environmental Assessment (EA) glass. If recollection serves, a driver for the selection of the EA glass as a performance benchmark was uncertainty related to the final disposal site. This is not necessarily the case for treated LAW at Hanford as the disposal site is likely the IDF. If a glass or set of glasses has been selected as a performance benchmark for treated Hanford LAW, then please provide the report(s) describing the characteristics of the benchmark glass(es) as well as the technical basis for its selection, and the testing regimes that will be used to either test Hanford LAW waste forms and/or to parameterize the models that used to predict performance (as well as the models themselves) over the relevant (often very long) periods of performance. Because is regulated under RCRA, any issues related to not using the best demonstrated available technology (i.e., vitrification) should be addressed as part of this data call.

Data Call for In-Tank/At-Tank Technologies

The EMAB Tank Waste Subcommittee has been tasked to evaluate the different In-Tank/At-Tank technologies that have been studied for treating Tank Waste at SRS and Hanford. We are looking for review papers, reports, feasibility studies, etc. that you might have that look at a range of technologies and critically evaluate their pluses and minuses for application at your site.

The EM organization has tasked the EM-TWS with the following request / work plan:

This includes the use of technologies currently being considered to perform some at or in-tank pretreatment activities, such as rotary micro-filtration for solids separation and use of small-column ion exchangers for removal of cesium.

Items we are requesting include:

1. Available In-Tank/At-Tank technologies that you are aware of including, but not limited to, chemical treatment, filtration, ion exchange, and mixing
2. Block diagrams illustrating connectivity between various combinations of In-Tank/At-Tank technologies required to treat tank waste
3. State of development of each technology (TRL ratings)
4. Technology development effort for moving each technology to TRL 6
5. Deployment strategies associated with each technology (e.g., some indication of scope of civil, electrical, instrumentation and process control, HVAC, etc.)
6. Tank waste treatment rates
7. Estimated life cycle cost/benefit for implementing each technology
8. Respective pro’s and con’s of each technology

9. Drawings of a typical tank farm tank expected to be used for the In-Tank/At-Tank operations.
10. Information on the physical size and features of the rotary microfilters that have been used for experiments so far; and the size and physical features of the rotary microfilters that will be used for full-scale operations.
11. Information on the physical size and features of the ion exchange columns that have been used for experiments so far; and the size and physical features of the ion exchange columns that will be used for full-scale operations.

The technologies we are including in our review as of now are:

- Chemical treatment: MST
- Filtration: rotary microfiltration
- Small Column Ion exchange: crystalline silicotitanate (CST) and spherical resorcinol formaldehyde (sRF)
- Mixing: submersible mixing pumps

If there are any additional technologies that we should be considering, please identify them.

Data Call for Reliability of Waste Feed Delivery

- The EMAB Tank Waste Subcommittee (EM-TWS) has been tasked to evaluate the reliability of the waste feed delivery plans at both Hanford and SRS. The ability to reliably provide qualified feed to existing and planned waste treatment facilities is a key element of the tank waste programs at these sites even though the details differ for the sites. At SRS reliable feed delivery has been demonstrated, but further life-cycle cost reduction (e.g., related to increased melter throughput due to bubblers) would require enhanced waste retrieval, separations, qualification, and delivery processes.

- Because the WTP at Hanford is not yet operational, proposed plans and preliminary (or final) waste acceptance criteria (WAC) for treatment facilities and how they will be satisfied must be evaluated, tank waste feed sequencing must be optimized to the extent practical while meeting the WAC and other constraints, and any vulnerabilities to achieving adequate waste delivery must be identified. There are a number of regulatory and other constraints on Hanford tank waste processing that must also be evaluated for their potential impact on waste delivery. For example, the Hanford baseline waste feed delivery approach considers two major operational phases: single-shell tank (SST) waste retrieval and transfer to double-shell tanks (DST) for waste staging prior to treatment, and mixing and delivery of DST waste to the treatment facilities. Among other factors, the EM-TWS will consider the SST retrieval and waste staging options to enable timely, reliable feed delivery.

- Because the tank farm and WTP have different contractors, the interface between the tank farm and WTP is critical and thus an examination of the interface documents, underlying assumptions, and future plans is needed. Other issues to be evaluated include:

- Compliance with mission objectives (e.g., what is being or will be done to assure that waste retrieval and pretreatment keep pace with treatment operations and managing the corresponding risks),
- Adequate processing flexibility to efficiently manage variability in the feed delivered both within and between qualified batches and to potentially compensate for vulnerabilities in feed delivery, and
- Water management strategies including improved retrieval and pretreatment strategies to reduce the water to be evaporated and new evaporator technology to manage the water.

A key component of the tank waste programs at Hanford and SRS is the ability to reliably provide feed materials to existing and planned waste treatment facilities. At SRS this has been demonstrated, but further reduction of life-cycle costs will require enhancements to current waste retrieval and delivery processes. For Hanford this will require an evaluation of proposed plans to finalize waste acceptance criteria (WAC) for treatment facilities, optimally sequence tank waste delivery to meet the WAC, and identify specific vulnerabilities to achieving waste delivery. The Hanford baseline waste feed delivery approach to date consists of two major phases of operation – single-shell tank (SST) waste retrieval into the double-shell tank (DST) system for waste staging prior to treatment, and mixing and delivery of DST waste to the treatment facilities. The Subcommittee will consider the SST retrieval and waste staging options to enable timely, reliable feed delivery

Preliminary Assumptions: This will be an evaluation of the SRS plan for remaining feed delivery, assumptions, WAC, and cost information, especially in the areas that can improve life-cycle costs. For Hanford, the most recent waste delivery plans, assumptions, preliminary (or final) WAC, and cost information must be evaluated for not only improvements but also vulnerabilities.

In general, we will need the information to evaluate the topics listed above. This information should include current waste feed delivery plans (e.g., system plans) and important supporting documentation including that describing the major constraints on such plans and assumptions made to develop the plans. The reports describing the feed qualification processes at the two sites will also be needed. The reports describing final WAC for SRS treatment facilities and proposed WAC for the WTP and feed systems will be needed. The corresponding cost information will also be required so that impacts on life-cycle costs can be evaluated.

Data Call for Alternative LAW Forms

The EMAB Tank Waste Subcommittee (EM-TWS) has been tasked to evaluate alternative Low Activity Waste (LAW) forms that have been studied for treating the low activity fraction of the Tank Waste at SRS and Hanford. Please inform us if the list of alternative waste forms below excludes any that are potentially viable. We are looking for review papers, reports, feasibility studies, etc. that you might have that look at a range of alternative waste forms and critically evaluate their pluses and minuses for application at your site. It would also be very helpful to have background information on the current regulatory framework (because it sets requirements for the waste form), how the framework has evolved, and any changes that will be pursued in the future. The current understanding of said requirements by State and other regulators would be of interest. Additional potential sources of information are enumerated below.

At Hanford, the WTP is being designed, constructed and commissioned to treat, via vitrification, all of the high-level tank waste and up to 50 percent of the low-activity tank waste. The Subcommittee shall evaluate candidate waste forms including a vitrified glass waste form, a mineralized FBSR form, and grout as to their suitability for completing the Hanford tank waste mission. This assessment will use the results of the TEG review related to 1) waste loading in low-activity vitrified glass, 2) Tc-99 and I-129 capture in glass, and 3) whether tank waste samples for FBSR testing are sufficiently bounding to make mission critical decisions regarding waste form performance.

Preliminary Assumptions: This is primarily a discussion of the alternative (including non-borosilicate glass) waste forms that could be used to replace the second LAW facility at Hanford; however, any synergy related to SRS LAW should be evaluated; e.g., iron phosphate glass should be considered distinct from a silicate/borosilicate glass waste form. The alternative LAW forms to be considered should have sufficient experimental evidence and manufacturing information (including an adequate basis for cost analysis) to provide a basis for comparison to the other types.

Bases for Comparison of Alternatives: There are a set of important dimensions (that are not necessarily independent) on which to make the comparison of alternative LAW forms:

- Acceptability of waste form (e.g., ability to capture and retain Tc-99 and I-129 for regulated period) in the existing regulatory framework (also should we examine alternative regulatory frameworks—acceptable waste form versus “as good as glass”?) and need for additional treatment (e.g., encapsulation of granular waste form)
- Long-term chemical durability and stability
- Radiation resistance
- Mechanical integrity / strength (varies by disposal site)
- Testing protocols (including any perceived gaps in testing methods)
- Technical maturity including the alternative waste form production technology (where we may use TRA/TRL as a metric where TRL 6 is target)
- Waste loading / tolerance for expected variability in waste feed (also impacts on production due to processing considerations)
- Potential to produce additional secondary or potentially orphan waste streams (that must then be treated), e.g., processing temperature increasing losses of volatiles radionuclides of concern
- Location of treatment (e.g., at- or near-tank versus PT) including enclosure-related issues (e.g., “hardened” facility versus not)
- Lifecycle cost (assumptions and other dimensions impact costs)

Potential Alternative LAW Forms:
- Cementitious forms (e.g., Cast Stone, Hydroceramics)
- FBSR waste forms (e.g., Carbonate, Alkali aluminosilicate (NAS) mineral form, Sodalite)
- Other Vitrified forms (e.g., Bulk Vitrification, Iron Phosphate)

- Ceramic and glass ceramic forms (e.g., HIP)
- Geopolymers and co-polymers

Potential Information Sources:
- Documentation supporting development of the portions of the EIS and PAs related to 2nd LAW and secondary wastes including cost information and especially the assessment of the ability of the waste to immobilize constituents of concern. Planned revisions to the EIS would be of use.
- The history of the waste forms selected for Hanford LAW with emphasis on past evaluations will be of particular interest. For example, FBSR was previously evaluated; however, bulk vitrification was selected (possibly because of the large amount of fines produced by FBSR). Have the issues with FBSR (e.g., excessive fines) been resolved? A grouted waste form (in vaults) was also attempted (including construction of a grout plant), but there were problems with the formulation and ultimately not pursued.
- NAS report on Alternative Waste Forms when available
- Expected LAW Compositions (LAW fraction of feed to PT and LAW resulting from PT) per batch especially for constituents of concerns (Tc-99, I-129, etc.) and discussion of uncertainty in these estimates—in other words, providing only the best-basis inventory estimates will not suffice for this evaluation
- Plans for ETF upgrades needed to treat secondary wastes and the waste forms currently considered for secondary wastes and the TRA for the secondary waste forms

Data Call for Melter Technologies

We have been tasked to evaluate the different technologies that are available to stabilize nuclear waste. Our prime focus is high level nuclear waste (INL, Hanford and SRS) and low activity nuclear waste (Hanford and INL). We are looking for review papers, reports, feasibility studies, etc. that you might have that look at a range of technologies and critically evaluate their pluses and minuses for application at your site.

The EM organization has tasked the EM-TWS with the following request / work plan:

Over the last 15 to 20 years, the EM program has considered various melter technologies and operational strategies to increase the efficiency of tank waste vitrification processes. This task will entail review of the different approaches and technologies that would be considered as second-generation (at Hanford), or third/fourth generation (at SRS) replacement melters, (e.g. cold crucible melters and advanced joule heated melters). The Subcommittee will consider the merits of different glass formulations, both borosilicate and other glass types, e.g., iron phosphate, as they apply to the advanced melter technologies above.

Items we wish to obtain your input on:

1. Available waste solidification technologies that you are aware of for your site
2. Respective pro's and con's of each technology
3. State of development of each technology (TRL ratings)
4. Technology development effort for moving each technology to TRL 6

5. Estimated life cycle cost/benefit for implementing each technology

The technologies we are including in our review as of now are:

- Cold crucible melting Induction heating (glasses)
- Joule heated melter (glasses)
- Steam reforming (mineral/ceramic forms)
- Plasma torch continuous melter
- In-can melter
- Rotary plasma arc melter

If there are any additional technologies that we should be considering, please identify.

APPENDIX 5
Liquid Tank Waste Processing Program
Modeling for Life-Cycle Cost (LCC) Analysis
Issues and Recommendations

5.1 Foreword

This document was generated by the Environmental Management Advisory Board (EMAB) Environmental Management Tank Waste Subcommittee (EM-TWS) to assess DOE EM life-cycle cost analysis processes, procedures, and systems used by the liquid tank waste programs at the Hanford Site (Hanford) and Savannah River Site (SRS) to estimate, budget, manage, appropriate funds, and close out the tank waste operations at each site. Portions of this document will be used, as needed, to support the final findings and recommendations of the EM-TWS to the EMAB.

5.2 Introduction

The management and disposition of tank waste is the single largest Life-Cycle Cost (LCC) element within the EM budget and poses a significant environmental, safety and health threat to the public. It accounts for nearly 36 percent of the total EM cleanup LCC and is therefore the major contributor to EM's cleanup legacy. EM's LCC from FY 2011 forward ranges from $182 billion to $237 billion. EM estimates cleanup will be completed between 2050 and 2062. With so much of the program cost and schedule still forecasted to be completed, there are continual opportunities to make meaningful engineered value-added technology and operational improvements that could reduce the LCC and potentially accelerate the reduction of overall liability and risk of the cleanup.

DOE-EM has charged the EM-TWS with the following as it relates to LCC Analysis:

> …This task entails reviewing the modeling approaches for determining tank waste remediation LCCs at both SRS and Hanford. This includes evaluating assumptions in system plans for completing tank waste missions at Hanford and SRS, as well as the rigor of the models for identifying activities and costs through the end of each site's programs…

The EM-TWS has been tasked by EMAB to gather data related to six issues related to departmental projects and mission (Appendix 1). EM-TWS visited the Savannah River Site (SRS) and the Hanford Site (Hanford) (See Appendix 3 for schedule and agenda) where presentations by Tank Waste Program DOE Operations Office and contractor representatives provided status of individual projects and the overall site liquid tank waste programs. EM-TWS also requested several documents (See Appendix 4 for data calls from each site to perform this work).

5.3 Modeling for LCC Analysis

5.3.1 Requirements

This task entails reviewing the modeling approaches for determining tank waste remediation LCCs at both SRS and Hanford. This includes evaluating assumptions in system plans for completing tank waste missions at Hanford and SRS, as well as the rigor of the models for identifying activities and costs through the end of each site's program.

5.3.2 Background – Existing LCC Guidance, Processes, and Modeling

5.3.2.1 Guidance and Requirements

The DOE guidance for appropriation of capital-funded projects comes primarily from the Office of Management and Budget's (OMB's) Capital Programming Guide, which was initially released in 1997 (the 2006 current version 2.0 is to help clarify and provide examples for capital asset planning and management). The Guide is intended to assist Federal departments, agencies, and administrations (herein collectively referred to as agencies) effectively plan, procure and use these assets to achieve the maximum return on investment. The guidance integrates the various Administration and statutory asset management initiatives, including:

- *Government Performance and Results Act* (Public Law No. 103–62) [1],
- The Clinger-Cohen Act (Divisions D and E of Public Law No. 104-106, the *Federal Acquisition Reform Act and the Information Technology Management Reform Act of 1996*, as amended; popularly known as the Clinger-Cohen Act) [2],
- Federal Acquisition Streamlining Act of 1994 (Public Law No. 103–355) [3],
- Executive Order 13327 of February 4, 2004, *Federal Real Property Asset Management* [4], and
- OMB Circular A-11, Part 7, *Planning, Budgeting, Acquisition, and Management of Capital Assets*, OMB June 2008 [5].

Additional guidance has been issued within DOE to establish an integrated capital programming process to ensure that capital assets successfully contribute to the achievement of agency strategic goals and objectives. DOE O 413.3B (*Program and Project Management for the Acquisition of Capital Assets*, revised November 2010) [6] and its accompanying guides provide requirements and guidance to ensure sound project management for capital asset management and are applicable to capital asset acquisition projects having a Total Project Cost (TPC) ≥ $50M, along with Project Assessment and Reporting System (PARS) reporting requirements that apply to all projects with a TPC ≥ $10M. In addition to the OMB guidance, DOE O 413.3B provides for a more rigorous cost estimating development and independent review process, integration of safety into design and construction, enhancement to DOE's structured project management policies, organizes projects by five critical decisions with clear prerequisites (or gateways to the subsequent Critical Decision (CD) phase) related to each CD, enhanced roles and responsibilities for all entities, and a contractor requirements document similar to other key

DOE Orders. This Order provides for the opportunity, if followed, for consistency and uniformity across capital programs. DOE O 413.3B allows for a tailoring process within these requirements to accommodate the unique nature and requirements of each capital project. In EM's parlance, capital projects range from large design/construction projects that are budgeted for via line-item funding (like Hanford's WTP or SRS's SWPF), to small projects that are budgeted for via operating-expense funding that involve work in the field (like retrieval of subsurface-stored waste, installation of a groundwater treatment system, D&D of an excess facility, or design/construction of a new processing line/system.

According to OMB guidance, the cost of a capital asset is its full LCC (Figure A5.1.2.1) [7], which is defined to include all direct and indirect costs for planning, procurement (purchase price and all other costs incurred to bring it to a form and location suitable for its intended use), operations and maintenance (including service contracts), and disposal (OMB Circular No. A–11, Part 7, *Supplement: Capital Program Guide*). These costs are reflected in Exhibit 300s that each Federal agency must submit in December as part of the proposed President's budget request to Congress; an Exhibit 300 is required for each proposed or ongoing capital asset project that the agency seeks to have funded. [In DOE's parlance for nuclear facilities, LCC begins with planning (before CD-0, *Approve Mission Need*) and ends with final decontamination and decommissioning (with all equipment and waste dispositioned) once operations (authorized via CD-4) are completed.]

OMB also requires an Executive Review Committee (ERC), acting for or with the Agency Head, to be responsible for reviewing the agency's entire capital asset portfolio on a periodic basis and making decisions on the proper composition of agency assets needed to achieve strategic goals and objectives within the budget limits. This committee should be composed of the senior operations executives and the chief information, financial, budget and procurement officers.

> In addition to review by the ERC, each project requires an Integrated Project Team (IPT) composed of a qualified program manager and necessary personnel from the user community, budget, accounting, procurement, value management, and other functions to be formed, as appropriate, to: "…establish a baseline inventory of existing capital assets; (2) analyze and recommend alternative solutions; 3) manage the acquisition, if approved; and (4) manage the asset once in use…"

Whether the capital project is a line item-funded (i.e., a standalone project with a (construction) project data sheet submitted as part of the Federal Agency's budget request to Congress) or operating expense-funded project, the process and procedure are to instill discipline and rigor to effectively select and deploy technologies and operational resources to complete mission requirements.

DOE O 413.3B provides additional guidance on IPTs for each project or program managed under the Order to ensure that each Federal Project Director has the resources and support needed to effectively manage to its scope, cost, and schedule baseline.

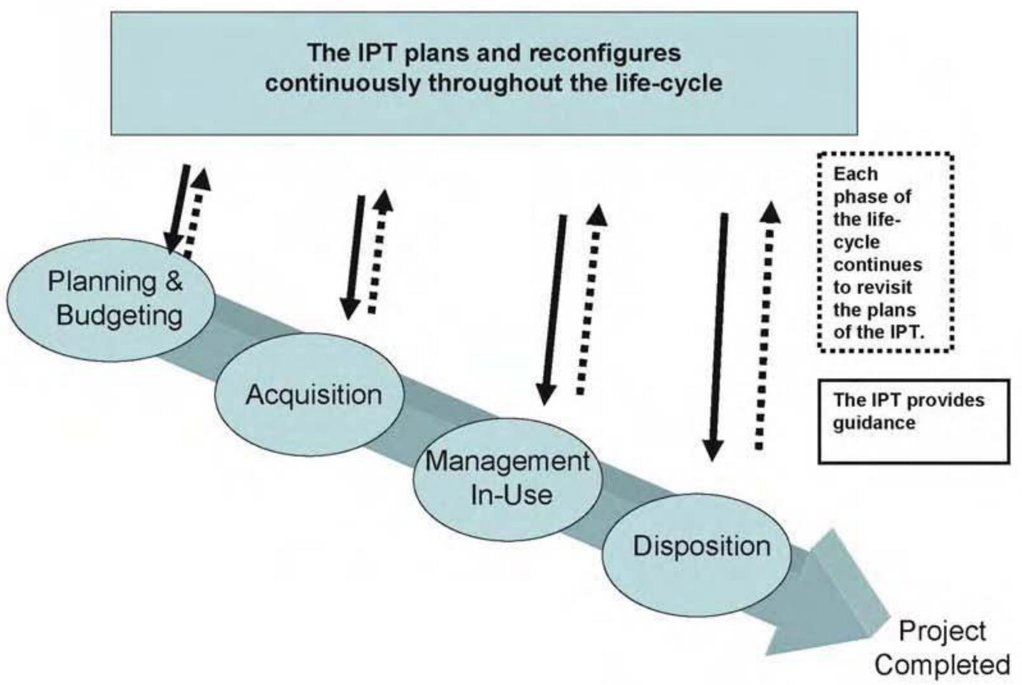
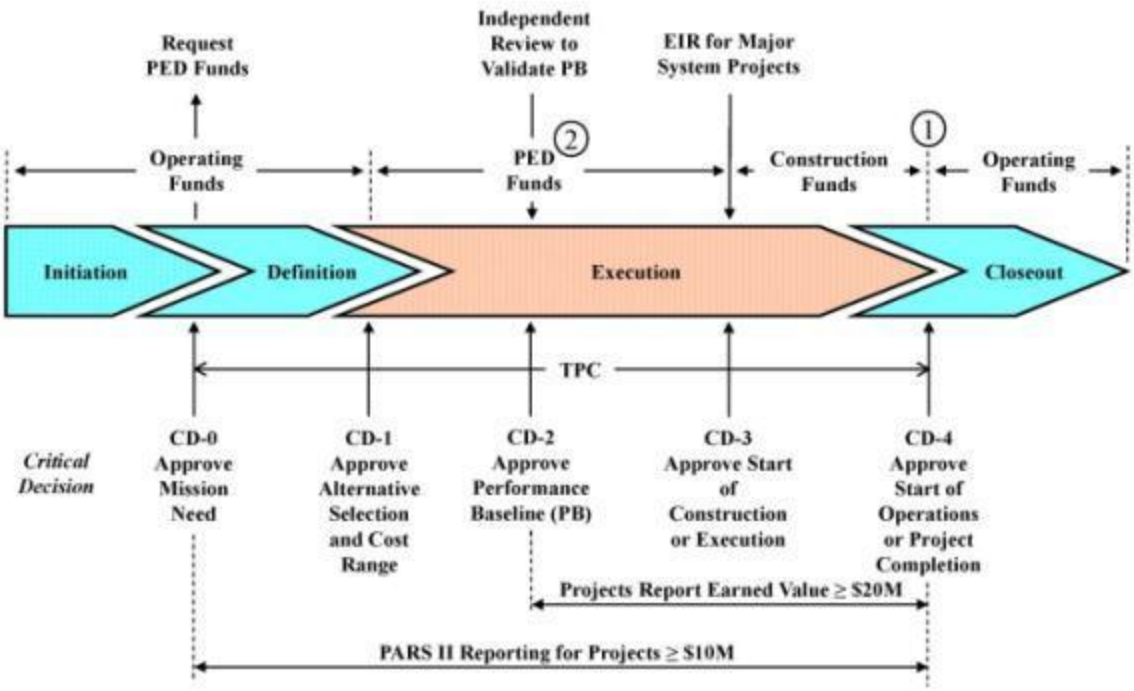


Figure A5.1.2.1. The Capital Planning Life Cycle

DOE's Office of Engineering and Construction Management (OECM) provides overall guidance on the critical decision (CD) process that is to be used for aligning funding decisions with the engineering process for acquiring capital assets. Figure A5.1.2.2 [6] shows the CD processes, reviews required, and reporting requirements through a standardized process that can provide uniform cost elements across the Department. This process also mandates various levels of independent cost estimates or reviews to verify the forecast cost of the project. While CD-0 includes a rough order of magnitude (ROM) cost range based on a preconceptual engineering formulation with LCC assumptions, the primary focus of a project going through the CD steps is on "total project cost," which excludes costs before mission need (upfront planning costs, for example) and after facility or project operations are started up or initiated (commissioned) – meaning that LCC per se is not managed via the DOE O 413.3B process. It should be noted that the Order does define LCC as "The sum total of all direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the planning, design, development, procurement, production, operations, and maintenance, support, recapitalization, and final disposition of real property over its anticipated life span for every aspect of the program, regardless of funding source." The Project Execution Plan required for all CD-2 (Approved Performance Baseline) and beyond projects must contain LCC information including drivers, key applicable assumptions, and other relevant factors. Additionally, the project data sheet for Congressional line-item projects requires estimates of cost and schedule for the life-cycle of the project, but this only includes operations and maintenance of the facility. The Project Accounting and Reporting System (PARS)-II allows field elements to input through a central database current costs against an approved baseline to allow Field and Headquarters elements to view the most current and accurate project performance data.



NOTES:
1. Operating Funds may be used prior to CD-4 for transition, startup, and training costs.
2. PED funds can be used after CD-3 for design.

Figure A5.1.2.2. DOE O 413.3B Critical Decision Process for Projects

DOE O 413.3B requires these prerequisites for each CD, as follows:

CD-0	• Pre-conceptual planning • Mission validation independent review • Mission Need Statement • Independent Cost Review • Safety-in-Design (DOE-STD-1189)
CD-1	• Acquisition Strategy • Project Execution Plan (Federal Project Director, Risk Management Plan, and Integrated Project Team) • Independent Cost Estimate or Independent Cost Review if TPC > $100M • One-for-one replacement compliance • Conceptual Design (including Code of Record requirements) • Preliminary Hazard Analysis Report (for nuclear facilities less than Hazard Category 3) • Integrated Safety Management Plan • Quality Assurance (QA) Program • National Environmental Protection Act strategy • Project Data Sheet • Safety Design Strategy (DOE-STD-1189) • Independent Project Review (IPR) by Program Office • Conceptual Safety Design and Validation Reports (for Hazard Category 1, 2, and 3 nuclear facilities)

CD-2

- Updated Acquisition Strategy (TPC and funding profile – DOE G 413.3-13)
- Performance Baseline (TPC, CD-4 date, and Key Performance Parameters)
- Updated Project Execution Plan (funding profiles; long-lead procurements)
- Project Management Plan
- Preliminary Design (including Code of Record) (facility complexity drives design maturity expectation)
- External Independent Review (EIR) of Performance Baseline
- Independent Cost Estimate for TPC > $100M
- Project Definition Rating Index Analysis for TPC > $100M
- OECM EIR if TPC > $100M or Program IPR if TPC < $100M
- Earned Value Management System (compliant)
- Technology Readiness Assessment/Technology Maturation Plan
- Hazard Analysis Report
- Updated QA Program
- Preliminary Security Vulnerability Assessment
- Final Environmental Impact Statement or Environmental Assessment with Finding of No Significant Impact
- Updated Project Data Sheet
- Technical Independent Project Review
- Updated Safety Design Strategy
- Preliminary Safety Design and Validation Reports

CD-3

- Final Design (including Code of Record)
- Earned Value Management System (certified)
- External Independent Review for Construction Readiness
- Independent Cost Estimate for TPC > $100M
- OECM EIR if TPC > $100M or Program IPR if TPC < $100M
- Technology Readiness Assessment
- Hazard Analysis Report
- Safety and Health Plan
- Updated QA Program
- Final Security Vulnerability Assessment
- Updated Project Data Sheet
- Updated Safety Design Strategy
- Preliminary Documented Safety Analysis and Safety Evaluation Report

CD-4

- Validation of Key Performance Parameters and Project Completion Criteria
- Transition to Operations Plan
- Final Hazard Analysis Report
- Operational Readiness Review or Readiness Assessment
- Documented Safety Analysis and Safety Evaluation Report
- Code of Record

Regarding the project cost, funding and budget cycle:

- To request preliminary engineering and design (PED) (as shown in Figure A5.1.2.2), funds in the Congressional budget (e.g., FY 2012), a project needs to receive approval for CD-1 by December of the previous budget year (e.g., for a FY 2011 approval, submittal would be required by December 2010).

- Starting with CD-2, a line item in the DOE budget must include a (construction) project data sheet, which includes:
  - Significant Changes,
  - Design, Construction and D&D Schedule,
  - Baseline and Validation Status,
  - Project Description, Justification, and Scope,
  - Financial Schedule,

- Details of Project Cost Estimate,
- Schedule of Project Costs (see Financial Schedule),
- Related O&M Funding Requirements,
- Required D&D Information, and
- Acquisition Approach.

- If conceptual design is to exceed $3M, then the Secretary must request funds from Congress.

- Conceptual design must be completed before requesting funds for a construction project.

- If the total estimated cost (TEC) for design is > $600K, funding must be authorized by Congress.

- A project cannot continue obligating funds (e.g., construction cannot start) if current TEC is > 25 percent of TEC in the project data sheet submitted to Congress, unless the Secretary notifies Congress via formal letter with an updated PDS.

- Projects with a TPC < $50M should request all project funding in same FY appropriation.

- Funding profile changes after CD-2 that negatively impacts the project requires acquisition executive endorsement.

- Risks are to be analyzed using a range of 70 percent-90 percent confidence level (80 percent used as basis for CD-2 baseline and DOE-funded contingency).

PARS-II allows field elements to input through a central database current costs against an approved baseline allowing field and Headquarters elements to view the most current and accurate project performance data. Monthly reporting into PARS begins from CD-0 through CD-4 (with earned value management system reporting starting at CD-2). Assessments are performed monthly by the Federal Project Director, Program Manager, and OECM, and project reviews are held quarterly with the acquisition executive.

Two types of independent cost reviews are performed during certain critical decision steps:

1. ICR (Independent Cost Review)—an evaluation of the cost estimate for quality and accuracy – with an emphasis on cost and technical risks, approach, and assumptions, and
2. ICE (Independent Cost Estimate)—an evaluation to determine accuracy and reasonableness using the project's baseline database.

At CD-0, an ICR is performed to validate the Rough Order of Magnitude (ROM) cost range basis and reasonableness of range; at CD-1, an ICR or ICE is performed to validate the basis of preliminary cost range, to ensure reasonableness and executability, with a full accounting of LCC to support alternative selection and budget; and at CD-2, an ICE is performed to validate the performance baseline cost parameters of Total Estimate to Complete, Total Project Cost, and the associated funding profiles.

5.3.2.2 Processes for Modeling Costs and Planning

Recent reviews completed by EM's Tank Waste System IPT and by outside organizations show the need to have a tool available to analyze alternatives to the EM baseline [8]. This tool should have the capability to make changes to the tank waste system process flow sheet (new steps, production rates) in addition to cost and schedule adjustments, and it should be capable of analyzing the impacts and synergies between multiple strategies. As a result of this IPT's effort, a limited life-cycle model has been developed. The next steps are for site-specific process characteristics from current system plans to be loaded into the model and validation runs to be completed. This work should be continued [8] as the Department will continue to be challenged to look for means to improve tank waste system performance and minimize LCCs. In particular, multiple attributes of the tank waste systems should be evaluated together to determine if additional transformational changes can be made to the tank waste systems at Hanford and Savannah River.

The EM Tank Waste System IPT also recognized a need for development of sampling systems for large tank characterization technologies and of tank modeling capabilities [8]. Also recognized was technology development that includes improved model development and data integration from both sites [8].

However, the use of computer modeling to replace large pilot- and full-scale testing with simulants carries large technical risk [9]. These technical risks could be reduced if Computation Flow Dynamics (CFD) models or other models of relatively complex behaviors could be calibrated using data from tests with actual wastes. The models would then be used to predict the fluid system's behavior under other conditions. Engineering tests under those conditions would determine the degree to which the computer-generated predictions were met. This approach could be used for a number of different phenomena including heat transfer, fluid flow in tanks and porous media, explosive atmosphere testing, chemisorption phenomena on resins and other solid media, and precipitate formation in heat exchangers and on pipes, pumps, and vessels. An essential component of bridging the gaps among waste simulants, computer models, and the behavior of actual waste will be R&D aimed at discovering potential, unexpected interactions or other phenomena inherent in the actual wastes that could lead to a process upset or failure. This is an example of discovery-oriented R&D that may help ensure that the conceptual model, which is manifested by the computer model, is correct [9].

Two other examples to reduce LCCs are included below. Work on waste forms such as sintered or minimally bonded sludges at SRS or Hanford may rely heavily on computer modeling of waste and repository characteristics to show that they could meet their disposal requirements [9]. Ensuring that the high-level waste in the form of calcine currently stored at Idaho National Laboratory can be disposed without further treatment or an addition of a binder would provide a strong cost driver for this R&D.

Increased waste loading develops options to increase the amount of radioactive tank waste that can be incorporated into the currently deployed borosilicate glass waste form. An increase of the waste-to-glass ratio has a dramatic impact on the timeframe established to process radioactive tank waste inventories at Hanford and SRS; an improvement of a few percent would decrease the radioactive tank waste processing life-cycle by a year (or more) and provide substantial cost savings. Improved glass formulations included in this effort also allow a higher waste loading to reduce the number of waste packages and improve throughput. This effort also develops supplemental treatment operations for radioactive tank wastes that are not appropriate for vitrification [10, 11, 12].

In a recent GAO report [13], it was pointed out that EM lacks an overall strategy for managing its computer models. At both SRS and Hanford, modeling generates data for forecast of schedules, costs, technical specifications for waste processing and handling and numerous other critical and intensive activities. The TWS has reviewed the process for populating certain of these models as well as how the model outputs are used as input to other tank waste activities.

5.3.3. Observations and Findings

5.3.3.1. DOE O 413.3B

As stated above, while the initial CD-0 (Approve Mission Need) includes a ROM cost range with LCC assumptions, the primary focus of a project going through the CD steps is on “total project cost,” which excludes costs before mission need (upfront planning costs, for example) and after facility or project operations are started up or initiated (commissioned) – meaning, LCC is not used as part of the project management and decision-making process as mandated by OMB requirements, as identified in GAO’s 12-step cost estimating process, and as required in the DOE O 413.3B [6] process.

GAO has issued a 12-step cost estimating process to guide Federal agencies’ review and approval of projects. Key steps in this process include (steps 6 through 10) the preparation and documentation of the LCC estimate and (step 11) a briefing to management on the estimate, including the documented LCC and a comparison of the LCC estimate to the budget [15]. This process, when applied to projects with capital line item funding and program operating expense dollars, is of great value to defining LCC, and could include trade-off analyses to determine the most cost-effective alternative to a mission need.

As a general observation gained from historical reviews of each site, the EM-TWS has concerns over the uniformity of the approaches used at each site to achieve program authorizations and capitalization budget requests. With annual operating budgets used to achieve progress on tank waste technology projects where significant expenditures (i.e., more than $100 M) are required, particularly in the small-column ion exchange (SCIX) project, the lack of rigor and compliance to Federal requirements and guidelines in the area of LCC may lead to non-optimal decisions regarding waste processing alternatives.

It appears that there is inconsistency between Operations Office and contractor submittals in the approach to secure appropriated funding for the capital/operating funds for the tank waste programs. Some projects (e.g., the proposed in-tank SCIX separations project at SRS) are to be funded within the operating budgets of the site and are not being treated as line-item capital asset acquisitions (i.e., not formally completing project data sheets; not compliant with OMB Exhibit 300; and seem to not be planning to utilize the CD process steps per DOE O 413.3B). (Note that

Exhibit 300 does not call for or emphasize net present value (NPV)). In addition, the Exhibit 300 section on risk (Part 2 Section B, Risk Management) does not allow for enough space for identifying how investment risks are reflected in the LCC estimate and investment schedule.

The buildup of operational costs, as well as operational savings, appears to be based on historical "level of effort" based on site staffing and schedule reductions. While SRS (contractor and DOE-SRS) has exhibited an extensive process for deriving a bottoms-up estimate, fitting staffing, operational experience and provisions for fine-tuning operations of the soon-to-be-inserted technologies, nuclear conduct of operations protocol and the specific resource requirements for power, infrastructure, manpower, and ALARA assessments—all carry substantive risk and impact the optimistic schedules. Since operations and maintenance costs are such a dominant component of LCC, a more detailed and rigorous methodology seems to be warranted.

It appears that the rigor for LCC analysis—as defined by OMB and DOE O 413.3B and recommended by GAO—is not being used in its entirety in the project decision-making process. LCC currently being utilized or reviewed seems to include costs beyond facility shutdown (i.e., deactivation, decontamination, decommissioning (including removed equipment and waste disposition), and post-decommissioning reclamation) and disposition of facilities to return the site to the original condition. Waste disposition is not included in the LCC; i.e., the LCC analysis does not seem to include disposition of the wastes. **It is the EM-TWS observation that the decision making process of alternative choices (CD-0, CD-1) should include capital, operating, decommissioning, and waste disposition costs modeled at the appropriate cost of money and escalation with a net present value over the lifecycle period.**

5.3.3.2. Risk

OMB and DOE O 413.3B [6] require a risk management plan for capital investments which includes probabilities, impacts, mitigation strategy, and a process for management throughout the life cycle. The Hanford Tank Operations Contractor (TOC) risk analysis model [14] used to perform the TOC near-term baseline and out-year planning estimated risk analysis consists of two Excel workbooks—one with risk information, and the other with risk analysis. For the TOC, this tool is used to derive estimates for resources and commodities and to quantify residual risks. The analysis provides for management reserve and contingency for TOC operations.

A risk strategy that includes the determination of critical technology elements (CTEs) and Technology Readiness Levels (TRLs) has been extensively used for evaluating technologies to be deployed at both sites for proposed new tank waste processing projects [16]. This process also provides for the development of a Technology Maturation Plan (TMP). The TMP, in addition to describing the required technology development activities, also provides for a brief discussion of the life-cycle benefit of the technology. This process is well documented with its utilization described in DOE O 413.3. It has been used by NASA, DOD, and FDA to determine risks associated with technologies and products.

It appears that EM programs at Hanford and SRS, as well as the site direction itself, are not uniformly following LCC protocols in a consistent and disciplined manner. The communication between sites appears to be good; however, the end product in how and what tools deployed for the appropriation of funds as well as representation of LCC savings and justifications may need additional review for consistency as to net present value. Additionally the integration of analysis between the WTP and the Tank Farm Operation appears to require additional uniformity and discipline to establish similar methodology and consistency of analysis.

5.3.3.3. LCC Uncertainty

DOE reports from the first *Baseline Environmental Management Report* in 1995 through the *Top-to-Bottom Report* in 2002, explicitly or implicitly, recognize four major sources of uncertainty impacting life-cycle costs: legal/political environment; technology in terms of both the current technology's reliability and the potential for a shift in the technological paradigm in the future; project funding; and estimating the net-present value of costs and benefits decades or more years in the future [17].

Managing uncertainty and risk as well as the sensitivity of the parameters affecting risk are key to our liabilities management process that, with the duration between full operations and closure being quite lengthy, can be minimally attended to during the baseline preparation and validation. A number of risk and uncertainty factors have been identified by the EM-TWS that greatly affect the LCC:

- Technology R&D has many uncertainties and unknowns that are inherent to the process; it appears there is no technology strategy that addresses alternative plans in the event of failure. Thus, technology development has uncertainty that is introduced to the LCC and does not appear to be factored in the LCC in a manner that reflects operational contingency and backup planning.

- The estimates for the structures, components, and controls (SC&Cs) appear to be underestimated. The SC&Cs are one of a kind (in some cases, a first-of-a-kind application) and are generally more complicated than currently presented.

- Radioactive waste treatment inevitably involves auxiliary systems (e.g., offgas systems and treatment systems for secondary waste streams) that could turn out to be far more complicated and costly than first thought. It appears that the secondary treatment costs for operations are modeled in a simplistic methodology without detailed operations backup.

- The estimates at this point involve vendor estimates that are sometimes underestimated when it comes to applying the technology to a new situation and nuclear quality standards. **The EM-TWS makes a point that this should be cautioned and observed even at the CD-0 and CD-1 stages of project review.**

- Most estimates are based on technology maturation plans that are success-oriented, where each test is expected to produce the desired result. This is unrealistic in that the process of maturation requires an evaluation of assumptions and conditions that can lead to trying something else. This greatly affects LCC. It appears that this method of approach needs a greater element of realism.

- Some LCC estimates and associated risks as included in risk management plans are optimistic. The cost realism is realized mostly in design and construction portion of the LCC, while technology immaturity lacks sufficient operational experience in the present system plans. Other operational optimism can greatly underestimate LCC. For example, schedule impacts for transfers from single shell tanks to double shell tanks is projected at more than 3 times what has been achieved to date. Long-term tank farm viability and subsequent interruptions to overall schedules have been optimistically estimated. Operations, decommissioning, and waste disposition LCC costs should be considered when evaluating each of the alternatives in the processing and disposition of wastes. This overly optimistic approach to LCC continues to erode confidence in the program. As a result, DOE, Congress, and the public cannot be assured that DOE's present strategy appropriately balances risk reduction with cost.

- The LCC effect of facility processing rate can be significant, overwhelming all other parameters since operating costs tend to dominate capital costs and are most sensitive to operational efficiency. WTP pretreatment contains many first-of-a-kind applications for process technologies (e.g., filtration, ion exchange, pulse-jet mixers, chemical leaching), has uncertainty in the waste feed characteristics, waste form acceptance, and involves high solids content processing. If one believes commercial industry experience for first-of-a-kind chemical processing and experience at other DOE nuclear process facilities, the odds are not great that the facility could reach nameplate capacity. That translates to extending the treatment mission with substantial increases in LCC.

- The final facility for each technology will greatly affect D&D costs, which affects LCC. In most cases, the estimate can only be a ROM because the final facility characteristics including supporting equipment and processes are unknown.

- The uncertainty of the physical and chemical properties of the wastes, waste form acceptance after treatment, their disposal characteristics, and regulatory compliance directly affect LCC.

- GAO recognized technology uncertainty and introduced the TRA (TRL) Program and the associated requirements for TRL 6 for CD-2. DOE O 413.3B only requires a TRA be performed for CD-2. EM has held to the TRL/TMP Guide for CD-1 and CD-2 recommendations.

- DOE is preparing an Environmental Impact Statement at the Hanford Site that evaluates a number of potential strategies for permanently closing the tanks after the waste has been retrieved. According to DOE, this study will include an analysis of (1) the costs and risks posed by waste left in tanks under a number of different closure configurations; (2) the contamination associated with other waste sites at Hanford; and (3) risks under various treatment, disposal, and closure scenarios to workers, the public, and the environment. This study is not intended to assess the tanks' present condition or their ability to continue safely storing waste until retrieval. A single failure of the tanks over the current schedule will greatly increase LCC. This study, when completed, will greatly affect LCCs and, ultimately, mission success.

5.3.3.4. Modeling and Planning

DOE's Federal Energy Management Program (FEMP) sponsors a system for Building Life Cycle Costs (BLCC5) that is maintained by the U.S. National Institute of Standards and Technology (NIST) to build LCC for capital projects [18]. BLCC5 provides comprehensive economic analysis of proposed capital investments. Up to 99 different alternatives can be evaluated to determine which provides the lowest life cycle cost. This program is updated annually on October 1 to incorporate the most recent changes in discount rates and DOE/EIA energy price escalation rates. NIST also provides guidance on LCC methodology in their guide to reporting and computing LCC of environmental management programs [18, 19, 20]. **The EM-TWS suggests that DOE review this model for cost estimating and evaluate its application for the Tank Waste alternatives analysis. This system is being successfully used for Los Alamos for capital projects.**

During discussions with SRS and Hanford personnel, the impacts of year-to-year funding and technology alternatives on LCC planning were a consistent theme. EM-TWS understands the positive impacts and benefits of, in essence, "multi-year appropriations" on past EM projects such as Fernald and Rocky Flats. In fact, the reliability of stable funding was a key success factor for these closure sites (note that while these closure projects did not, strictly speaking, have multi-year appropriations, the fact remains that funding was stable from year to year, and this funding within the closure sites appropriations account was effectively "fenced off" for the exclusive use of each closure site, resulting in the same outcome as receiving multi-year appropriations). With this funding strategy, execution could be optimized and costs reduced by as much as 20 percent due to reduction of numerous replanning and reprogramming activities and actions. These programs also used proven technologies (i.e., low-risk) over marginally proven technologies (higher risk), resulting in schedule acceleration and subsequent cost savings. *De facto* funding forces the use of lowest and simplest technology with the lowest negative impact on mission success.

Discussions were held on efforts being made to develop an overall model of WTP and Tank Farm process reliability, availability, and maintainability. Without such a tool, scenario development, bottlenecks, and quantification of uncertainties in the development of LCC is not possible. It is recognized by the sites that such a tool would also help in maintaining and modifying the system plans and allow for linkage of cost and schedule to such parameters as retrieval, waste processing, and disposal to an overall LCC.

The Hanford Tank Waste Operations Simulator (HTWOS) flowsheet model has been developed by the Tank Farm Contractor [21]. The HTWOS is a dynamic event simulation model, governed by prescribed initial conditions, boundary conditions, and operating logic that is used to simulate the full duration of the U.S. Department of Energy, Office of River Protection (ORP) mission. The HTWOS model uses simple chemistry assumptions to provide a gross estimate of the solid/liquid equilibrium of the wastes and does not necessarily provide an accurate estimate of the waste chemistry. Use of the HTWOS-predicted waste compositions should be with due consideration of the uncertainty behind the estimate. The necessary information and tools are not available to improve the chemistry predictions made by the HTWOS model. Limited ability to analyze the chemistry associated with tank wastes via a model or tool limits the formulation of how the pre-treatment or processing capability will affect LCC [8]. An integrated tool was found to be lacking for SRS Liquid Tank Waste planning and scenario development [22]. Similarly, an integrated planning tool was recommended for Hanford [23].

Although EM uses general departmental quality assurance policies and standards that apply to computer models and relies on contractors to implement specific procedures that reflect these policies and standards, these policies and standards do not specifically provide guidance on ensuring the quality of the computer models used in cleanup decisions. NQA-1 provides requirements for addressing safety system software for nuclear facilities. However, NQA-1 and DOE O 414.1C, *Quality Assurance,* do not clearly address the use of computer software not considered as safety software, such as those used by computer models that support DOE's cleanup decisions.

In contrast, other Federal agencies and DOE offices have taken steps to improve consistency and reduce duplication as part of a comprehensive, coordinated strategy to manage the use of computer models [13]. For example, EPA organized a Center for Regulatory Environmental Modeling in 2000 as part of a centralized effort to bring consistency to model development, evaluation, and usage across the agency. The Center brings together senior managers, modelers, and scientists from across the agency to address modeling issues. Among its tasks are to help the agency (1) establish and implement criteria so that model-based decisions satisfy regulatory requirements; (2) implement best management practices to use models consistently and appropriately; (3) facilitate information exchange among model developers and users so models can be continuously improved; and (4) prepare for the next generation of environmental models.

Within DOE, the Office of Nuclear Energy recently established an initiative—the Nuclear Energy Modeling and Simulation Energy Innovation Hub—that provides a centralized forum for nuclear energy modelers [13]. According to the director of the Office of Nuclear Energy's Office of Advanced Modeling and Simulation, the hub will provide a more centrally coordinated effort to bring together modeling and simulation expertise to address issues associated with the next generation of nuclear reactors. Similar comprehensive, coordinated efforts are lacking within EM and, as a result, EM may be losing opportunities to improve the quality of its models, reduce duplication, keep abreast of emerging computer modeling and cleanup technologies, and share lessons learned across the EM complex.

Because the decisions EM makes must protect human health and the environment for thousands of years into the future, it is critical that the models on which EM bases its decisions are of the highest possible quality. In addition, because these cleanup efforts will take decades and cost billions of dollars, it is also important that models used for planning, scheduling, and budgeting purposes provide the most accurate data possible for EM and Congress to make informed decisions on cleanup activities.

5.3.4. Major Vulnerabilities

Mission success is driven by a number of complex processes, a number of which have uncertainty and risk associated with them. LCCs are affected by all phases of the system plans and all aspects of the EM-TWS chapters being evaluated. While risks for each of these plans have been registered at each site in risk management plans [14] and an attempt to quantify the risks to the overall system plan made, uncertainty in technology, lack of true operational experience, and incorporating these uncertainties into realistic LCCs is a daunting process. Also important is the lack of understanding of which subsystems or processes; i.e., which LCC parameters, when changed due to new performance data, provide the most change in LCC. This high-level modeling capability, which provides an understanding of sensitivity of the factors affecting LCC, is lacking.

The basis for deriving major programmatic vulnerabilities for LCC comes primarily from reviewing the documented processes and interviews of responsible personnel. Since no single tool has been mandated for collecting data and providing estimates across SRS and Hanford, the vulnerabilities stem from a standardized process for modeling; i.e., configuration and control of data collections, key values in models, input to the model processes, parameterization of the models, and the criticality of personnel to the modeling process. Key personnel input data to the waste form recipe and the formula for glass to models, a process that has taken years to understand and perfect.

At SRS, SWPF coming online as currently planned and scheduled is also a major vulnerability to mission success. While risks have been identified in the risk registers for SRS as well as potential offsets to the risk, there exists little evidence that the risk elements of this key element of mission success have the highest priority for risk reduction.

At Hanford, mission vulnerabilities are: a) successful operations and turnover of the WTP with an optimistic commissioning schedule and resource loading; b) successful and timely waste characterization to formulate recipe for glass; c) waste treatment / pretreatment and parallel waste form acceptance in the time period for treatment technology to be built and integrated with tank farm operations to ensure the desired feed parameters; and d) the integration of WTP commissioning with operations.

In both cases, the EM-TWS evaluation is that recovery of schedule with interim steps or new process strategies could diffuse the base mission of making glass and waste disposition while retiring tanks. EM-TWS recommends that the following be considered:

- The efforts for the SRS In-Tank Treatment as well as Tank 48 organic system workaround are applauded; however, in the event SWPF does not meet the current schedule, the LCC impact of delay in SWPF is much more significant than interim process savings. The EM-TWS recommends that DOE establish regulatory workarounds that could account for delay, provide resources totally focused on current operation and delivering SWPF to the new schedule, and refrain from the spending of new capital dollars. The risk for one year of additional delay in SWPF dwarfs the potential upside savings of supplemental system savings.

- The efforts for the ORP Vision 2020 with early deployment of At-Tank processing presents significant challenges and vulnerabilities as it relates to construction of new systems in an operating nuclear conduct of operations area. Additionally, the strategy for trying to accelerate production for the LAW glass making is applauded. The significant vulnerability is the potential impact on completing WTP construction on time. The scenarios of spills, NOVs, or operational incidents and the potential of a site stop-work are significantly increased when considering this accelerated path. Delay of WTP and the cost of construction overages could outweigh the savings of implementing a three-year At-Tank strategy for early 2016 start of LAW.

5.3.5. Recommendations

1. EM-TWS recommends a standardized and consistent methodology, such as the software tool BLCC5, which is funded by DOE and maintained by NIST, for analysis of life cycle cost expressed in net present value for evaluation and decision making. In addition, the GAO 12-step cost estimating process could be applied to all capital projects for tank waste processing — both line item-funded and operating expense-funded.

2. EM-TWS recommends that SRS and Hanford (both within the Contractors and within DOE) use the standardized approach applying DOE O 413.3B to project planning/management and decision-making for alternatives analysis, including having a documented LCC, for all tank waste processing projects.

3. EM-TWS recommends the development and adoption of a consistent probabilistic methodology for uncertainty characterization that includes sensitivity analysis and a validation process for schedule and cost. Inclusive in the methodology is a validation process that uses industry-based experts to provide cost realism and an evaluation of the uncertainty and sensitivity process. This will allow management to assess overall system uncertainty in alternatives analysis. In addition, as the yearly programmatic baseline is reviewed, the risk register and the uncertainty analysis need to be updated.

4. EM-TWS recommends that DOE seek (with OMB support) multi-year appropriations from Congress (abandoning year-to-year funding) for mission-critical projects.

5. The successful installation and operation of SWPF and WTP, including efficiency and continuity of operations, has significant life cycle cost and schedule impact. The added programs such as supplemental treatment and in-tank treatment could distract the resources and top-level managers from delivering baseline performance and increased productivity of operations. EM-TWS recommends that DOE keep diligent focus on the schedule and cost delivery in accordance with baseline mission requirements as it contemplates added system focus in the potential implementation of new technologies.

6. EM-TWS recommends that DOE-EM develop guidance that defines the accuracy and role of computer models, using a tiered approach, in the public policy process, discusses appropriate ways of dealing with uncertainty, establishes criteria for peer review, and addresses quality assurance procedures for computer modeling. Specifically, 1) QA requirements that would include model effectiveness, limitations, performance, criteria, application to planning in cleanup alternatives, and inclusion of risk/uncertainty in the model, 2) assessment of the model's compliance with the QA requirements, and 3) an overall strategy to promote

consistency, configuration control of data input to modeling processes, at site and between site reduction of duplication of modeling efforts, and inclusion of the findings in a lessons learned program across EM.

7. EM-TWS recommends the implementation and deployment of a general planning model suited for uncertainty and scenario-based analysis [23, 7, 2], and feasibility/optimization of retrieval, blending, and processing. This would include the capability to propagate uncertainties through the planning process, and characterization of important uncertainties [22].

8. EM-TWS recommends that the cost for waste disposition be included in life-cycle cost alternatives analysis for CD-1 selection and documentation. This is in addition to inclusion of capital, operating, decommissioning, and risk uncertainty analysis.

9. EM-TWS recommends that DOE EM consider conducting a detailed sensitivity analysis for both SRS and Hanford based on full LCC modeling on both a current-year dollars basis and an NPV basis to allow development of a business case for decision making purposes.

5.1.6. References

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APPENDIX 6
Assessment of Low-Activity Waste (LAW) Forms

6.1 Introduction

The U.S. DOE Environmental Management Advisory Board (EMAB) Tank Waste Subcommittee (EM-TWS) has been charged with evaluating alternative low-activity waste (LAW) forms that have potential for treating the low-activity fractions of the high-level tank wastes at the Savannah River Site (SRS) and Hanford Site. Because of the advanced stage of LAW treatment at SRS and the construction of the Salt Waste Processing Facility (SWPF), the EM-TWS review focused on Hanford LAW treatment; however, any potential relevance to SRS LAW treatment is considered.

High-level tank wastes (Figure 6-1) at both SRS and the Hanford Site will be separated into high-activity and low-activity fractions for treatment and ultimate disposal; treatment of the tank wastes at the West Valley Demonstration Project (WVDP) using vitrification was completed in 2002, as indicated in Figure 6-2. The high-level waste (HLW) fraction at SRS and Hanford will be treated using vitrification into borosilicate glass for on-site storage until a national geologic repository is ready for disposal[1]. The low-activity waste (LAW) fraction at SRS has been treated using a cementitious waste form (denoted Saltstone) and disposed of onsite since 1990 (Figure 6-2). Whereas the Hanford HLW Vitrification Facility was designed to treat the entire high-activity fraction of the Hanford tank wastes, the Hanford LAW Immobilization Facility (ILAW), which is over 60 percent constructed, was designed to treat less than 50 percent of the expected LAW feed. This first LAW facility will use vitrification to immobilize the LAW in a borosilicate glass waste form expected for onsite disposal at the Hanford Integrated Disposal Facility (IDF).

Figure 6-1. Examples of Various Tank Wastes at the Savannah River Site (SRS)

[1] At the Savannah River Site, the high-activity, insoluble sludge portion of the tank waste has been treated using vitrification in the Defense Waste Processing Facility (DWPF) since 1996, as indicated in Figure 6-2. Processing of the high-activity salt portion of the tank waste began in 2007 with the Deliquification, Dissolution, and Adjustment

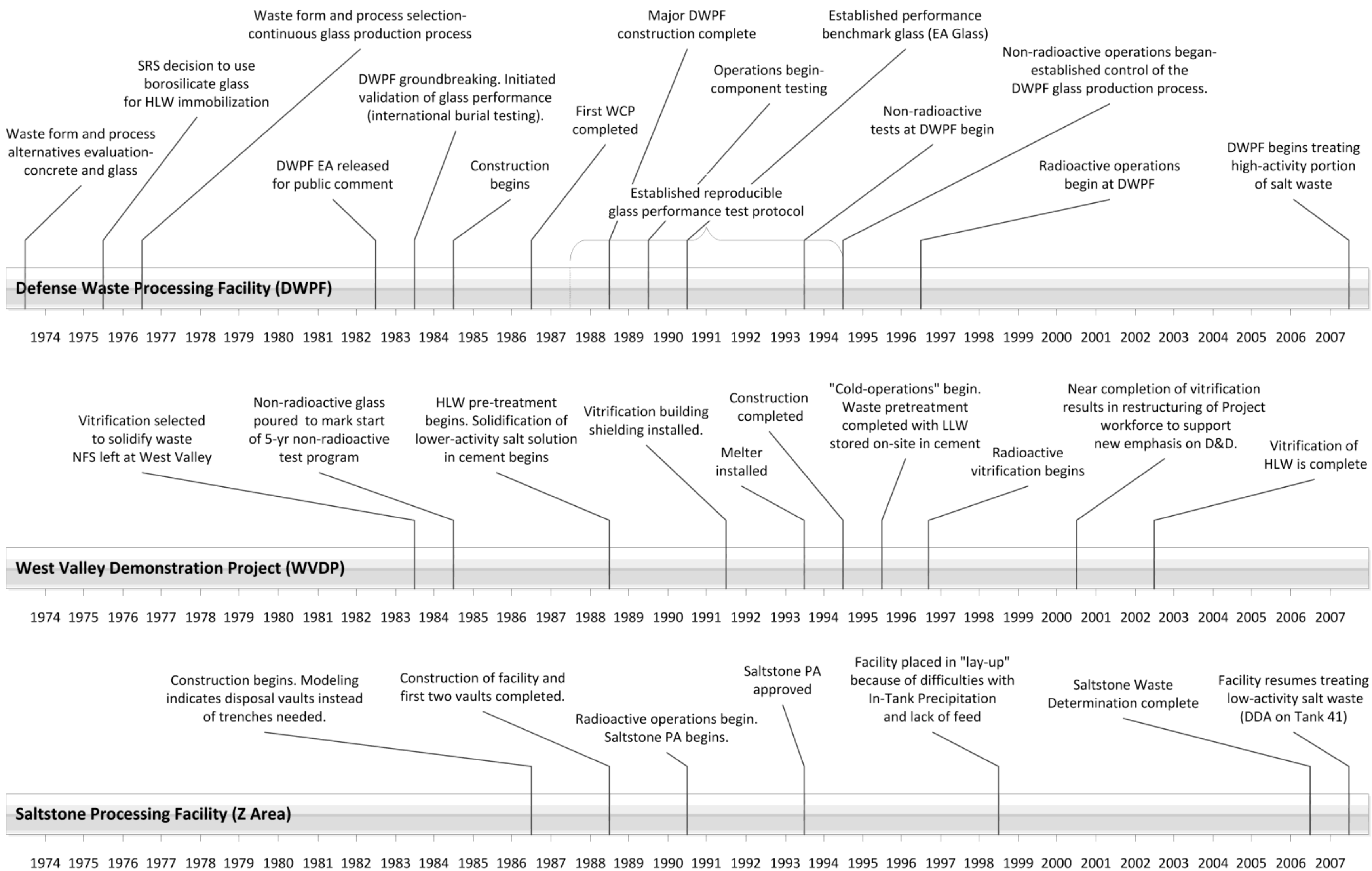

Figure 6-2. Selected Key Dates for Three DOE Treatment Projects

The Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement or TPA) mandates that all Hanford tank wastes be treated (currently using vitrification) by 2047 (including retrieval from all single-shell tanks and their closure by 2040 and 2043, respectively) [1]. Meeting the treatment completion date (including deciding how the remaining LAW will be treated especially if not by vitrification) presents significant programmatic, budgetary, and technical challenges. The high initial capital and operating costs of a second ILAW facility (especially if it is like that currently under construction) has resulted in the consideration of strategies to accelerate the treatment schedule and supplemental treatment alternatives to vitrification [2] [3]. A summary of the results of one such evaluation is provided in Table 6-1; this and other evaluations resulted in further evaluations of ILAW, bulk vitrification, grouting, and FBSR for possible alternatives to treat the remaining Hanford LAW.

Table 6-1. Example of the Evaluation of Hanford LAW Treatment Options [2]

Option	Brief Description	Secondary Waste	Years to Process	Primary Concerns
Bulk Vitrification	LAW passes through CsIX (CST) to remove Cesium (Cs). Technetium (Tc) removal assumed. Waste stream processed via bulk vitrification using clay or soil as glass formers in a disposal canister. CST (with Cs-137) could go to HLW vitrification facility. Eluted Tc returned to DST.	No	38	Compliance & Safety Operability Programmatic
Active Metal Reduction	LAW passes through CsIX (CST) to remove Cs. Tc removal assumed. Waste processed in two steps: 1) reacting with Aluminum (Al) metal forming sodium aluminate (with destruction of nitrate, nitrite, and hydroxide species) and 2) reacting the sodium aluminate with phosphoric acid to create a phosphate-based ceramic waste form. The liquid stream would be disposed of in phosphate-based cement. CST (with Cs-137) could go to HLW vitrification facility. Eluted Tc returned to DST.	No	20	Compliance & Safety Operability Technical Programmatic
Steam Reforming	LAW passes through CsIX (CST) to remove Cs. Tc removal assumed. Waste processed in a high-temperature fluidized bed destroying nitrates and incorporating radioisotopes together with sodium, sulfate, chorine, and fluorine in a granular, mineralized waste form that could be containerized or grouted. CST (with Cs-137) could go to HLW vitrification facility. Eluted Tc returned to DST.	No	--	Compliance & Safety Operability Programmatic
Clean Salt (2 Options)	The 2 options differ in whether CsIX is included. In both options, LAW is reacted with nitric acid converting sodium salts to sodium nitrate with the reacted solution is evaporated and cooled to crystallize out the sodium nitrate. For the first option, the crystals are washed to remove radionuclides and other species. For both options, the crystals are filtered and immobilized in grout and the depleted stream is sent to the DST.	Yes	34	Compliance & Safety Operability Technical Programmatic
Clean Salt with Sulfate Removal (2 Options)	The first option excludes CsIX but includes a washing step and the other option includes CsIX but no washing. These options similar to the Clean Salt options described above with the following differences: 1) filtrate liquid is processed to remove sulfate before return to the DST 2) sulfate treated via grout, and 3) sodium nitrate crystals immobilized by macroencapsulation.	Yes	22	Compliance & Safety Operability Technical Programmatic

Option	Brief Description	Secondary Waste	Years to Process	Primary Concerns
Containerized Grout	LAW passes through CsIX (CST) to remove Cs. Tc removal assumed. Waste mixed with grout formers to form a solid grout product placed into disposal containers. No secondary products are sent to WTP. CST (with Cs-137) could go to HLW vitrification facility. Eluted Tc returned to DST.	No	20	Compliance & Safety Project Utility Programmatic
Sulfate Removal	LAW passes through CsIX (CST) to remove Cs. The resulting waste is reacted with nitric acid to change the stream from alkaline to acidic and then strontium nitrate is added to precipitate sulfate. The sulfate species filtered from the liquid for immobilization in grout. Sulfate-depleted waste stream (containing Tc and other soluble species) returned to the DST for disposal via WTP.	Yes	29	Programmatic

CsIX – Cesium Ion Exchange DST – Double-Shell Tank
CST – Crystalline Silicotitanate HLW – High-level Waste

Figure illustrates a number of timelines that may be pertinent to evaluating the path forward for the WTP and Hanford LAW disposition. After construction of the SRS Defense Waste Processing Facility (DWPF) was completed in 1988, it took six years to begin nonradioactive operations and another two years before commencement of radioactive operations on actual HLW sludge. Seven years elapsed before a reproducible glass performance protocol was developed and accepted by the stakeholder and regulators (which was completed approximately two decades after borosilicate glass was first selected as the SRS HLW form). On the other hand, two years were needed for both WVDP and SRS Saltstone to go from construction-complete status to radioactive operations. WTP construction and commissioning will likely be more complicated than any of the facilities represented in Figure (which, among other things, has prompted consideration of sequential commissioning of facilities). There is also a need to get the required permits for disposal of treated LAW in the IDF. The bottom line is that the necessary actions may require considerable time, effort, and funding that may make developing an acceptable alternative LAW treatment technology and corresponding waste form problematic. Currently, various scenarios are being evaluated for completing and accelerating the Hanford treatment schedule, including:

- *Baseline* – assumes all pre-treatment is completed in the Pretreatment (PT) Facility and that a 2nd LAW vitrification facility (ILAW) will be constructed to treat the remainder of the LAW feed.

- *Supplemental Treatment* – assumes that 2nd LAW treatment facility is selected from ILAW, Bulk Vitrification, Grouting, or Fluidized Bed Steam Reforming (FBSR) and is predicated on successful deployment of pre-treatment technologies (in-tank Rotary Microfiltration (RMF) / Small-Column Ion Exchange (SCIX) or at-tank filtration / ion exchange).

- *Enhanced Tank Waste Strategy* – assumes that vitrification would not be used to treat *any* Hanford LAW—instead three FBSR units would be used. This strategy is also predicated on successful deployment of in-tank pre-treatment technologies (RMF / SCIX).

- *Vision 2020* – assumes a path to achieve earliest possible hot operations of WTP facilities (e.g., sequential facility completions, Operational Readiness Reviews, etc. starting with LAW / Balance of Facilities (BOF) / Laboratory (LAB)). This strategy provides an opportunity to produce LAW glass early (2016) and continue until the Pretreatment Facility is commissioned. Pre-treatment technologies (in- or at-tank filtration / ion exchange), new transfer lines to direct feed LAW and lines from LAW to ETF, a single LAW melter operating, and offgas recycle to the double-shell tanks (DSTs) are needed.

Figure 6-3 illustrates key schedule dates and milestones described in the current TPA Action Plan [1] that relate to alternative LAW forms for the various strategies listed above. If a treatment technology other than vitrification (e.g., grouting or steam reforming) is selected as either the primary or secondary option for the remaining LAW[2], then a Supplemental Treatment Technologies Report must be submitted by October 31, 2014 [1]. The treatment technology for the remaining LAW feed must be selected by April 20, 2015 with any dispute between DOE and the Washington State Department of Ecology (Ecology) managed per Article VIII of the TPA [1].

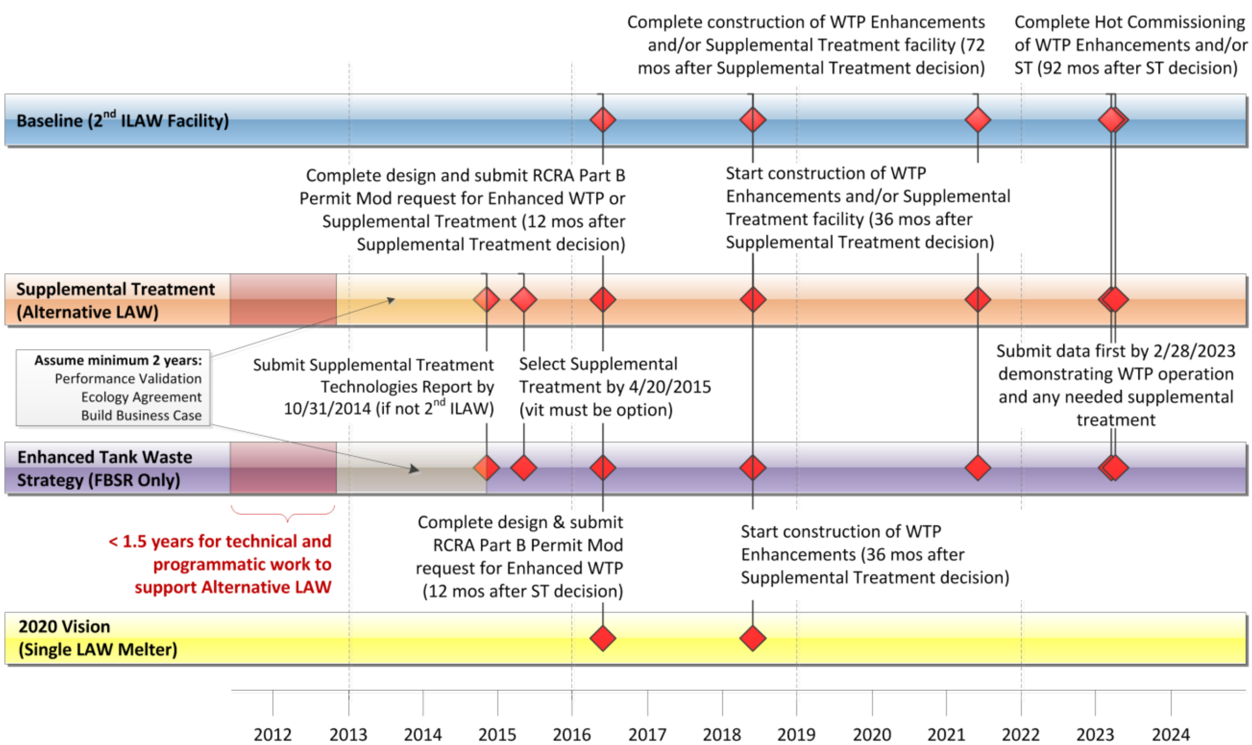

Figure 6-3. Key Dates and Milestones related to Alternative LAW Forms [1]

To better frame potential difficulties with selecting an alternative waste form for Hanford LAW, it was assumed by the EM-TWS that it would require a minimum two years to ensure performance validation, to reach an accord with Ecology, and to build the appropriate business

[2] A primary and secondary option will be selected for treating the remaining Hanford LAW. One of these options must be a 2nd ILAW facility (that would use vitrification to immobilize LAW).

case for the alternative treatment technology[3]. Under this assumption, there would be less than 1½ years to complete the technical, design, and programmatic work needed to propose an alternative waste form to treat the remaining Hanford LAW[4]. The information in Figure highlights the amount of time some of these actions have taken in the past for similar DOE treatment projects. However, treated Hanford LAW is just one type of waste to be disposed of in the IDF. The types of wastes intended to be disposed in the Hanford IDF include [4]:

- Immobilized Low-Activity Waste (ILAW) – Hanford tank waste that has undergone separation and bulk radionuclide removal and treated using vitrification in the Waste Treatment and Immobilization Plant (WTP) into a borosilicate glass waste form. Presently, *vitrification* is the only approved treatment process for Hanford LAW.

- Low-level waste (LLW) – Waste generated at Hanford or off-site that contains man-made radionuclides but not classified as high-level waste, spent nuclear fuel, transuranic waste (TRU), or certain byproduct materials.

- Mixed low-level waste (MLLW) – LLW that also contains materials regulated under the Resource Conservation and Recovery Act (RCRA) or the applicable dangerous waste management laws of the State of Washington. Failed and decommissioned WTP melters, that may contain glass, are considered MLLW.

The wastes to be treated at the Hanford Site, including those at the IDF, are governed by three laws [4]:

- The Atomic Energy Act (AEA) covering radioactive wastes [5],

- The Comprehensive Environmental Recovery and Liability Act (CERCLA), also known as Superfund, covering those wastes generated from remedial activities at facilities [6], and

- The Resource Conservation and Recovery Act (RCRA) covering wastes that contain hazardous materials in treatment, storage, or disposal (TSD) facilities [7]. The U.S. Environmental Protection Agency (EPA) granted authority over mixed wasted (including those that will be placed in the IDF) to the State of Washington.

The TPA was initially signed by DOE, EPA, and Ecology in 1989 to coordinate CERCLA remedial action provisions and RCRA TSD regulations and corrective action provisions at the Hanford Site [1]. The TPA, which has been updated many times including most recently in May 2011, is legally binding and consists of:

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[3] Information provided in the presentation by D. Swanberg to the EM-TWS on January 25, 2011, entitled “FBSR Waste Form Qualification and Testing” indicated approximately two years of testing would be performed on the FBSR waste form to support its consideration for Hanford LAW supplemental treatment.

[4] To reinforce the issues related to timing, DOE indicated to the EM-TWS that the downselect for the treatment technology for the remaining LAW material will be made by the end of FY2011, which is before the results from the waste from qualification tests will be available per Swanberg (Footnote 3).

- The Agreement describing the roles, responsibilities, and authority of the three signatories in the remedial, compliance, and permitting processes and setting up the enforcement and dispute resolution processes.

- The Action Plan describing the implementation of the Agreement, including milestones.

The TPA also outlined the process for changing, removing, or adding milestones, the conditions under which penalties may be issued, and the requirements for public involvement relating to Hanford cleanup actions. Major changes to the TPA require approval of all three agencies and are only made after a public participation process is followed.

As noted above, the LAW treatment facility currently under construction at WTP (Figure 6-4) was designed to vitrify less than 50 percent of expected LAW feed. The processes to treat the remaining LAW feed (denoted Supplemental Treatment) are described in Milestone M-062-40 (TPA Action Plan Appendix D [1]). This milestone indicates that 100 percent of both the separated high-level and low-activity waste streams would be vitrified; however, if a treatment technology is proposed other than vitrification, then a one-time Hanford Tank Waste Supplemental Treatment Technologies Report would be required no later than October 31, 2014, with a one-time selection made no later than April 30, 2015, as indicated in Figure 6-3 [1].

Figure 6-4. The Hanford LAW Facility under Construction in November 2010

Considerable effort has been expended historically to refine the alternatives being considered for Supplemental Treatment. Alternative treatment processes and waste forms have been considered for Hanford LAW; the following processes and corresponding waste forms have selected for detailed evaluation for treating the remaining LAW material:

- 2nd LAW Vitrification (denoted ILAW) producing a borosilicate glass waste form of the type produced in the LAW vitrification facility current under construction at WTP
- Bulk Vitrification (BV) producing a sodium silicate glass waste form
- Cast Stone producing a cementitious or grouted waste form
- Fluidized Bed Steam Reforming (FBSR) producing an aluminosilicate mineral waste form

The EM-TWS review will focus on these alternatives; however, other alternatives are also described based on their likely technical maturation for the specific case of treatment of specific Hanford LAW streams.

Glass has been seen as more effective than other waste forms such as grout at immobilizing the hazardous metals and as very effective at destroying the organic listed waste constituents. However, treatment processes other than vitrification (e.g., grouting for SRS LAW) have been effective at treating hazardous and radioactive constituents in wastes. Since Hanford LAW is listed waste, the treatment technology and resultant waste form must satisfy universal treatment standards (UTS) for underlying hazardous constituents prior to land disposal [8]. For example, EPA determined that vitrification was UTS Best Demonstrated Available Technology (BDAT) for high-level tank wastes (including mixed wastes) at DOE sites [9]. Thus DOE would have to request a Determination of Equivalent Treatment (DET) for an alternative treatment technology to be compliant [8].

Initially, the preferred treatment for Hanford LAW was grouting [10] and a grout facility was constructed at the Hanford Site. The renegotiation of the TPA in 1993 deflected the treatment path from grouting to vitrification due to concerns of disposal volume and performance. By 1997, the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) did not even consider grouting as a viable option for evaluation [11] although it had been in use at SRS for LAW treatment since 1990. The preferred treatment path for both HLW and LAW at Hanford would be vitrification, with retrievable on-site storage for treated LAW. Since that time, Ecology has maintained that Hanford LAW must be vitrified or that the waste form produced from any supplemental treatment technology satisfy the requirements for the glass produced from WTP. DOE has replied with its position on how it would comply with Ecology's requirements for waste forms produced from supplemental treatment [12].

6.2 Charge

At Hanford, the WTP is being designed, constructed and commissioned to treat, via vitrification, all of the high level tank waste and up to 50% of the low-activity tank waste. The Subcommittee shall evaluate candidate waste forms including a vitrified glass waste form, a mineralized FBSR form, and grout as to their suitability for completing the Hanford tank waste mission. This assessment will use the results of the TEG review related to 1) waste loading in low-activity vitrified glass, 2) Tc-99 and I-129 capture in glass, and 3) whether tank waste samples for FBSR *testing are sufficiently bounding to make mission critical decisions regarding waste form performance*[5].

6.3 Findings and Conclusions

The findings and conclusions enumerated were derived from a review of the presentations and technical reports provided by DOE personnel during face-to-face meeting and resulting from data calls. The impacts related to the various scenarios for accelerating Hanford tank waste treatment are also considered.

6.3.1. Previous experience indicates there may be insufficient time to develop an acceptable alternative LAW treatment process and waste form

The information for previous major DOE tank waste treatment projects (Figure 6-2) indicates that years have been required to develop treatment technologies and waste forms and to construct and commission these types of facilities for treating HLW and LAW. Based on the milestones in the TPA, DOE must submit a technology report during 2014 if a treatment process other than vitrification is an option for treating the remainder of the Hanford LAW. A decision concerning an alternative treatment for Hanford LAW must be made in 2015 [1]. Furthermore, DOE must make a decision long before these milestones to have sufficient design and development time. DOE is currently targeting the end of FY2011 to downselect alternative treatment technologies for Hanford LAW treatment. Alternative treatment technologies (e.g., fluidized steam bed reforming or FBSR) have been researched; however, as noted by the EM Technical Expert Group (TEG), these alternative treatment technologies and corresponding waste forms have not been developed to an adequate level allowing for a conclusive evaluation of performance or cost-benefit analysis relative to vitrification / glass [13]. For example, there are technical, qualification, and regulatory issues with FBSR that will be unresolved by the end of FY2011. There appears to be little time in the schedule and little available funding to develop the information to support the critical decision of an alternative waste form.

6.3.2. There appears to be inadequate flexibility in waste treatment processes and strategies

There has often been a tendency to attempt global approaches (including treatment processes and corresponding waste forms) where possible even if targeted solutions may be available. Global approaches may allow DOE to reduce certain programmatic and budgetary risks; however, there are technical and operational tradeoffs that often may result in inadequate processing flexibility. These decisions also appear to have impacted choices of treatment technologies and waste forms; e.g., selecting vitrification of Hanford LAW despite the high initial capital and operating costs of such projects and the potential availability of other viable technologies. There appears to have been some improvements in the selection process with the recent pursuit of advanced glass

[5] No EM-TEG results were provided [13] concerning: "*whether tank waste samples for FBSR testing are sufficiently bounding to make mission critical decisions regarding waste form performance*"; however, this point factors into observations, vulnerabilities, and recommendations made by both the EM-TEG and EM-TWS concerning FBSR and the critical need to manage uncertainties. The EM-TEG focus on the use of real waste was on the potential to reduce uncertainties for pretreatment processes at both SRS and Hanford [13].

formulations, in-tank and at-tank pretreatment technologies, and alternative treatment technologies and waste forms.

6.3.3. Vitrification appears to be seen by Ecology as the only acceptable technology for Hanford LAW treatment

The preferred treatment path for both HLW and LAW at Hanford has been defined by Ecology as vitrification, with retrievable on-site storage for treated LAW. Ecology has maintained for some time that Hanford LAW must be vitrified, or that the waste form produced from any supplemental treatment technology (that is not vitrification) must satisfy the requirements for the glass produced from WTP. Predicting the performance of any waste form for the period of compliance (often millennia) is highly uncertain for any waste form. The selection of a best available technology (which is usual and customary under RCRA) instead of using a performance criterion such as being protective of human health and the environment may restrict treatment and disposal options for Hanford LAW. Reasonable alternatives can be considered to treat the Hanford LAW in such a way that meets or exceeds appropriate requirements for land disposal *under relevant uncertainties*. These alternatives may be specific to the characteristics of the wastes (i.e., limited to the waste in a subset of Hanford tanks).

6.3.4. Modeling that captures relevant controlling processes and conditions must be used to determine the relative performance of an alternative LAW form to that of glass requiring careful management of uncertainties

There is no single standard test or suite of standard tests that alone can determine the performance of a waste form for a given disposal facility over a period of performance that is very long when compared to available experimental data. Standard tests such as ASTM C1285 (also known as the Product Consistency Test or PCT), the single-pass flowthrough (SPFT) test, and the Vapor Hydration Test (VHT) can provide valuable information concerning the behavior of some waste forms (e.g., for parameterizing models), but do not determine the performance of a given waste form over the many years—often, millennia—required of the waste form. These tests were developed specifically for glass waste forms and have limited applicability to non-glass waste forms. The U.S. Environmental Protection Agency (EPA) is developing additional test methodologies that are intended to relate to calibrating performance assessments for a wider range of waste forms, but these tests do not necessarily capture long-term degradation mechanisms. The use of field tests and natural analogues may build confidence in a waste form for a given application; however, modeling must be performed to predict the performance of a waste form for the required centuries or millennia. Available standard tests can be used to parameterize the performance models; however, there are large uncertainties in both the parameters and the models themselves that must be adequately addressed to compare the performance of waste forms over long periods of time that might make such comparisons problematic.

6.3.5. The difficulty in capturing volatile contaminants of concern (e.g., Tc-99) in LAW glass should be taken into account when considering alternative treatment processes and waste forms for Hanford LAW

The EM-TEG noted the "surprisingly large gap and large uncertainties" in understanding the fate of Tc-99 given the amount of research conducted (albeit largely with simulants like rhenium) and the relative maturity of the treatment processes [13]. The apparent inability to incorporate Tc-99 and other volatile, long-lived radionuclides in waste forms created at high temperatures (e.g., borosilicate glass melted at 1150 °C in ILAW or sodium silicate glass melted at 1300-1350 °C in a bulk vitrification facility) would impact Hanford LAW melter off-gas and recycle streams. The accumulation of these volatile radionuclides and other constituents (e.g., glass formers) may impact the process equipment and the ability to efficiently produce subsequent product batches. The lack of capturing Tc-99 and other volatile radionuclides in the LAW form may also have an impact on the Effluent Treatment Facility (ETF) because there are currently only two outlets for Hanford tank wastes—treated glass and the ETF. This may require additional treatment for the ETF streams as significant quantities of Tc-99 or other radionuclides would violate the ETF Waste Acceptance Criteria (WAC) [14]. Off-site disposal, alternative treatment technologies that would immobilize volatile and mobile contaminants of concern, and techniques for better incorporating these contaminants in the current LAW glass are under evaluation.

6.4 Background/Overview

6.4.1 Detailed Regulatory Framework for Hanford LAW Treatment and Disposal

The performance basis for treated Hanford LAW has been derived from two separate sources. The first source includes the requirements for the management (including treatment, storage and disposal) of hazardous waste constituents under the Solid Waste Disposal Act (SWDA) of 1965 [15]. The SWDA was amended to become the Resource Conservation and Recovery Act (RCRA) of 1976 [7] and further strengthened with the Hazardous and Solid Waste Amendments of 1984 (HSWA) [16]. The corresponding Washington State law regulating solid and hazardous wastes is Chapter 70.105 of the Revised Code of Washington, *Hazardous waste management* [17].

The second source for the Hanford LAW form performance is the requirements for the near surface disposal of radioactive wastes that are contained in DOE 435.1[6] for the self-regulation of radioactive waste management pursuant to the Atomic Energy Act of 1954 (as amended) [5]. Among other things, DOE 435.1 provides the requirements for managing high-level waste including LAW as low-level waste after said waste has been determined to be waste incidental to reprocessing (WIR). The pertinent safety requirements are comparable to the performance objectives set out in 10 CFR Part 61, *Licensing Requirements for Land Disposal of Radioactive Waste* [18].

[6] DOE 435.1, *Radioactive Waste Management*, https://www.directives.doe.gov/directives/current-directives/435.1-BOrder-c1/view that consists of the Order, a Manual that lists the requirements, the Technical Basis for the requirements, and an Implementation Guide.

Land disposal of Hanford LAW requires treatment with the resulting waste form satisfying the Land Disposal Restrictions [19]. Since Hanford LAW is listed and characteristic waste, the treatment technology and resultant waste form must satisfy UTS for underlying hazardous constituents prior to land disposal [8]. For example, EPA determined that vitrification was UTS BDAT for HLW (including mixed wastes) at DOE sites [9]. A Determination of Equivalent Treatment (DET) must be approved for an alternative treatment technology to be compliant for HLW [8].

If the LAW treatment facility is determined to be a new point of generation under RCRA, then there is no BDAT for Hanford LAW and the LAW would be subject to UTS for its underlying hazardous constituents [19]. DOE elected to file a site-specific treatability variance [20] to establish vitrification as the UTS for vitrified Hanford LAW. Approval of a treatability variance [20] and/or determination of equivalent treatment [21] may be necessary to fully comply with the LDR standards although this is typically necessary only if DOE elects to use a technology other than vitrification (i.e., the BDAT). There is currently no regulatory pathway for treatment of LAW by a technology other than vitrification; compliance with the LDR standards would require approval of a treatability variance [20] and/or determination of equivalent treatment [21] for any alternative technology (e.g., grouting or steam reforming). As mandated in the TPA, if a treatment technology is proposed other than vitrification, then a one-time Hanford Tank Waste Supplemental Treatment Technologies Report would be required no later than October 31, 2014 with a one-time selection made no later than April 30, 2015 [1].

From a NEPA perspective, the preferred treatment alternatives for Hanford HLW and LAW were initially (1987) vitrification and grouting, respectively [10]. For example, SRS LAW waste has been grouted since 1990. The renegotiation of the TPA in 1993 began a fundamental change from grouting Hanford LAW to vitrifying it due to concerns regarding disposal volume and adequate performance. By 1997 the *Hanford Tank Waste Remediation System* (TWRS) EIS did not evaluate grouting as a viable option [11]. However, the grouting alternative was evaluated (along with bulk vitrification and steam reforming) in the 2009 Draft *Tank Closure and Waste Management* (TC&WM) EIS for the Hanford Site [22][7]. The treatment path described in the TPA for both HLW and LAW at Hanford would be vitrification, with retrievable on-site storage for treated LAW. Any alternative path forward for treatment must be consistent with the bounds provided in the Final Hanford TC&WM EIS and Record of Decision.

The LAW fraction of the tank waste may be managed as low-level waste after completion of the Waste Determination (WD) process upon which it has been declared Waste Incidental to Reprocessing (WIR). The NRC conditionally approved the designation of LAW and "incidental waste" making it provisionally not subject to NRC licensing as long as the following criteria would be satisfied [23]:

1. "...wastes have been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical…." It was noted that that "if actual radionuclide inventories, either in the tanks or following separation, are

[7] Plans are to finalize the Draft Hanford Tank Closure and Waste Management EIS by the end of CY2011 and possibly issue a Record of Decision by June 2012.

significantly higher than or different in character from those projected, compliance with this criterion will require re-evaluation by NRC."

2. "...wastes will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C [low-level waste] as set out in 10 CFR Part 61…" The letter further stated that "if the radionuclide inventories in the LAW are significantly higher than those projected in the Technical Basis report, or if the waste form type or total volume are [*sic*] altered, reevaluation of conformance with this criterion will be necessary."

3. "...wastes are to be managed, pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C are satisfied."

A series of performance assessments (PAs) would be required to satisfy the NRC criteria as the information on which the provisional approval was based was not sufficient to make an absolute determination. The additional PAs would be used to confirm the original analysis and resolve outstanding issues. Substantive changes to the technical basis would require DOE re-evaluation with NRC consultation, including [23]:

- Tank waste characterization indicates that the radionuclide inventory is higher than or different in character from that used to develop the Technical Basis report and the Interim PA. This change in the inventory estimate would affect the resolution of all three criteria.

- The LAW fraction of the Hanford tank waste would not be vitrified, or the final volume of the waste form is significantly different from that projected in the Technical Basis report. The waste form is a determining factor in waste classification (Criterion 2) and would also impact the PA (Criterion 3).

- The selection of the final LAW disposal site, or changes to site characterization parameters would affect the resolution of Criterion 3.

A PA was performed in 2001 to evaluate the projected performance of vitrified LAW disposed of in trenches in the Hanford Site 200 East Area[8] [24]. A one-dimensional analysis was used based on a single LAW glass composition (considered to be bounding) and indicated that the predicted performance would be acceptable in immobilizing both hazardous and radioactive constituents. In 2003, a supplemental risk assessment was conducted using three LAW feeds (Envelopes A, B, and C) to evaluate alternative LAW forms (i.e., cast stone, bulk vitrification glass, and the steam reforming product) [3].

At the request of Ecology, both hazardous and radioactive constituents were evaluated versus drinking water standards in the 2001 PA and 2003 risk assessment analyses. The primary constituents of concern (COCs) from both analyses were Tc-99 and I-129. The performance of the glass and mineral waste forms were modeled using kinetic rate laws for dissolution and

[8] This analysis was performed before the Hanford Integrated Disposal Facility (IDF) was under development. The requirements for disposal in the IDF are provided in RPP-8402 [25].

alteration parameterized using accelerated test results. The grout form was modeled via a diffusion mechanism using diffusivities derived from standard tests. Results indicated that groundwater concentrations of COCs for the 10,000-yr assessment period in a 100-m downgradient well would be lower than Federal drinking water standards for the glass and mineral waste forms. Based on the assumptions used in the model, the results for the grout waste form were close to or might exceed standards.

However, certain things should be recognized about the previous analyses. The methodology for conducting PAs (including how uncertainties are managed) has changed since the 2001 PA and 2003 risk assessment were conducted. Furthermore, results are driven by the assumptions made in the models. For example, the assumptions made for the grout waste form source release impact the predicted release values by several orders of magnitude, which could impacts the conclusions of the analyses. Finally, additional information has been obtained about the proposed alternative Hanford LAW forms that might impact the predicted performance. For example, as much as 10-20 percent of carbon (coal) fines must be incorporated into the FBSR product with an unknown impact on the ability of the proposed mineralized waste form to satisfy product requirements (Table 6-2)[9]. Furthermore, Ecology indicated a concern with applying the same assumptions concerning contaminant partitioning and its effects on waste form performance to both bulk vitrification and steam reforming considering the lower technical maturity of the steam reforming process [22].

In 2003, Ecology and DOE-ORP participated in the Cleanup, Constraints, and Challenges (C3T) process during which alternative supplemental treatment technologies were discussed. As a result of these discussions, Ecology indicated that the waste form from any supplemental treatment technology must meet the same qualifications as the glass produced from the WTP, including the ILAW. The specification for ILAW product is outlined in the WTP Statement of Work Section C, Specification 2 and includes requirements as enumerated in Table 6-2 [26].

Table 6-2. Specification 2 from the WTP Statement of Work Section C [26]

Package description Waste loading Size and configuration Mass Void space Chemical composition documentation Radiological composition documentation (including qualification and production) Radionuclide concentration limitations Surface dose rate limitations Surface contamination limitations	Labeling, closure and sealing External temperature Free liquids Pyrophoricity or explosivity Explosive or toxic gases Waste form testing (including PCT and VHT) Compressive strength Dangerous waste limitations Compression testing Container material degradation Manifesting

Ecology emphasized that any "waste form resulting from any supplemental treatment must be proven to perform 'as good [*sic*] as glass'" and that supplemental treatment would only be considered for a "small increment of the LAW feed material" [27]. The use of "as good as glass" as Ecology's measuring stick for a successful supplemental treatment technology was reaffirmed

[9] Certain factors involving coal fines can lead to the creation of hazardous conditions, including fires and explosions.

in the 2009 Draft TC&WM Hanford EIS [22]. To wit, Ecology maintained that all waste forms produced from supplemental technology would be expected to [27]:

(1) perform over the specified time period as well as, or better than, WTP vitrified waste;
(2) be equally protective of the environment as WTP glass;
(3) meet LDR requirements for hazardous waste constituents; and
(4) meet or exceed all appropriate performance requirements for glass, including those in the WTP contract, relevant ILAW Interface Control Documents, and ILAW PA.

Furthermore, Ecology required that supplemental waste forms produced from Hanford tank wastes be equal to, or better than, WTP glass in a number of areas [27] that generally replicated those in the WTP Statement of Work (Table 6-2).

Based on the supplemental treatment technology and waste form selected, some of the above limitations or testing regimes would not be applicable (e.g., crystalline phase identification or VHT for cementitious waste forms). DOE replied with its position on why it is pursuing alternative supplemental treatment technologies and how it would comply with Ecology's requirements for waste forms produced from supplemental treatment [12]. A look at the various treatment technologies and resulting waste forms will help frame the evaluation further.

6.4.2 Waste treatment technologies and waste forms

The selection of an appropriate waste treatment technology and corresponding waste form is a critical step in the overall waste management strategy at a site. A number of factors should be considered when selecting a treatment technology and waste form for a given stream, such as cost, technical maturation of the technology, compatibility of the form with the waste stream, disposal environment, durability of the waste form, waste form disposition, and the creation of secondary / potentially orphan wastes. For mixed wastes like Hanford LAW, one or more waste forms often can satisfy the necessary requirements; the classes of waste forms that have been evaluated in the past include [28] [29]:

- Grout and cementitious forms
- Glass (typically single-phase)
- Polymers and geopolymers
- Crystalline ceramics (including mineralized FBSR waste form)
- Vitreous (or glass) ceramics
- Metals
- Hydroceramics
- Ceramicretes

These classes of waste forms all have potential benefits; however, some may not be cost-effective, technically mature, or compatible with waste streams that must be treated. Much has been written about the various waste forms that might be used to treat Hanford LAW; the various waste forms will be briefly described here.

6.4.2.1 Grout and cementitious forms

Grouting has been the treatment technology of choice for many routine DOE mixed waste stabilization actions [28] and is the treatment technology used to stabilize LAW at the Savannah River (Figure 6-5) and West Valley Sites. Furthermore, grouting has been commonly used to solidify and stabilize low-level radioactive wastes. Grouting is a mature treatment technology for many waste types including the stabilization of RCRA metals to meet EPA requirements. However, cements are often limited to the treatment of wastes with relatively low concentrations of radionuclides because of radiolysis issues [29]. The radionuclides stabilized in grout are also often limited to relatively immobile and shorter-lived radionuclides.

The properties of concrete have been well characterized and experience with cements and concrete is extensive in both the construction and waste management fields. Despite this experience, formulations must take into account waste compositions and other characteristics to achieve satisfactory physical and chemical properties and leach resistance.

Cementitious waste forms are inorganic materials produced from adding water, Portland cement (hydraulic calcium silicates), aggregates, and other additives to the waste material at ambient conditions and letting the mixture set. As the mixture hardens, the cement undergoes hydration to form colloids that agglomerate into gels and precipitates; the gels then dry and crystallize [28]. The cement acts to bind the materials together as it undergoes hydration. Other materials with different encapsulation properties such as lime, slags, pozzolans, and fly ash can also be added to the mixture. Under appropriate conditions, inorganic waste constituents can be microencapsulated into the gels that form during hydration and eventually become part of the crystal structure of the cement.

Figure 6-5. Existing Savannah River LAW Disposal Units

6.4.2.2 Vitreous waste forms (glass)

Decades of research and application have made glass the waste form of choice for immobilizing high-level wastes (HLW)[10]. Vitrification at both the Savannah River and West Valley sites (Figure 6-6) has been used to produce borosilicate waste forms that have been stored on-site for

[10] EPA identified vitrification as the BDAT for DOE high-level tank wastes [9].

ultimate disposal in a national geologic repository. Vitrified waste forms are generally considered to be more stable and leach-resistant than other waste forms [28]. Vitrification is a mature technology that requires high-temperature processing in specialized and often expensive equipment requiring careful control of the melt reduction-oxidation (REDOX) state.

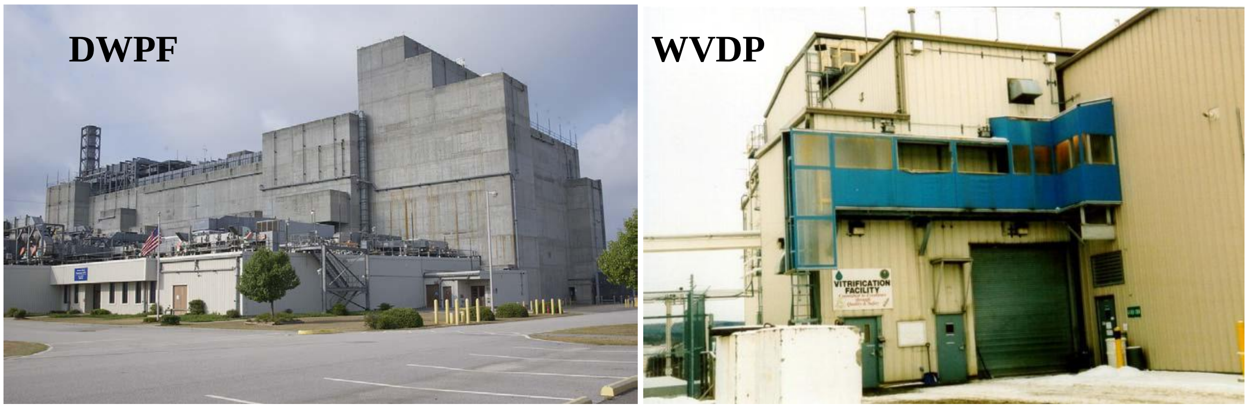

Figure 6-6. DOE High-Level Waste (HLW) Vitrification Facilities

Because of the expense involved, vitrification has historically been limited to HLW treatment because the resulting waste forms have low leach rates and are mechanically and thermally stable (important when highly radioactive constituents must be treated). Many waste constituents dissolve and organics are destroyed at normal melt temperatures (1100-1500 °C) making high waste loading and volume reduction possible; however, sulfates and some RCRA metals do not readily dissolve in the melt making the efficient production of a single-phase glass with high waste loading problematic depending on the waste composition.

Borosilicate glass produced from Joule-heated, ceramic-lined melters is the most commonly used waste form for treating high-level tank wastes [29]. Phosphate, aluminosilicate, and various other glass formulations have been studied for the purpose of immobilizing specific waste types [28] [29]. Each formulation has strengths and weaknesses depending on the characteristics of the waste to be treated and/or the melter technology used and may be appropriate for tank wastes that are difficult to treat with other methods. Typically wastes are pretreated (e.g., calcination) and combined with glass formers (e.g., frit or individual glass forming chemicals) and additives to control REDOX (e.g., acids or sucrose) and melted at high temperatures and finally cooled in a container to form a solid[11] for disposal. The properties of waste glasses have been characterized over decades of effort and the important properties (e.g., leach resistance, waste solubility) can be modified by changing the glass formulation and/or the processing conditions (e.g., melt temperature, melt mixing).

Even though glass has been shown to be a reasonably robust waste form, the effectiveness and efficiency of the vitrification process and the quality of the resulting waste glass depend on the compatibility of the waste characteristics (especially composition) and the glass formulation as well as the melt conditions [28]. The critical processing parameters involved (i.e., waste loading,

[11] Glass is often considered amorphous; however, there is research that would suggest that glass may actually be a quasi-crystalline material with ordering between that of an amorphous material and a crystalline material [30].

melt temperature, residence time, REDOX) and the resulting properties of the waste glass (e.g., crystallinity, melt viscosity, durability) are interdependent. Higher temperatures can often be used to increase the solubility of waste constituents in melts resulting in higher waste loadings and homogeneity [28]; however, increased melt temperatures increases refractory corrosion potential and volatilization of contaminants of concern (e.g., mercury, Tc-99, Cs-137, halides) that must then be captured in the offgas system for treatment as secondary wastes. Vitrification is effective at destroying organic compounds; however, organic compounds must be accounted for in controlling the melt REDOX to prevent precipitation of less soluble, problematic species and/or plating out of metals or other conductive compounds in resistance-heated melters. Wastes that are to be vitrified must be well characterized and the treatment process should be thoroughly tested to ensure compatibility of the waste with vitrification.

6.4.2.3 Polymers and geopolymers

Waste constituents can be encapsulated in organic polymers or inorganic geopolymers (Figure 6-7). Wastes can either be dispersed as a powder (microencapsulation) or coated (macroencapsulation) at low temperatures. Common (organic) polymers include bitumen, polyethylene, resins, and polyesters. Geopolymers are ceramic-like, inorganic polymers that are made when aluminosilicates crosslink with alkali metal ions [29]. The cost of using organic polymers to treat wastes tends to be between that of grouting and vitrification and appears to provide a high degree of contaminant retention until the polymer itself degrades [28]. Geopolymers appear to be adequate binders and may be more acceptable than cement waste forms for some applications.

Figure 6-7. Examples of polymer waste monolith (left) [34] and Duralith Geopolymer made with Hanford Secondary Waste (right)

Macroencapsulation using polymers to envelope debris is complaint with EPA's requirements for treating debris waste and has been declared BDAT for radioactive lead solids [31] [28], and is thus a mature technology for these applications. Microencapsulation is a process by which fine waste particles are mixed with the polymer and this process is considered an alternative treatment standard for hazardous waste [32] as long as the waste form would pass the Toxicity

Characteristic leaching Procedure (TCLP) limit [33]. Geopolymers are being evaluated for treating radioactive and hazardous wastes including mixed wastes and as sealants, caps, barriers, and other structures needed for remedial actions at contaminated sites [29].

There are two general types of polymers: thermoplastic and thermosetting. Because of the varied nature of the polymers used for encapsulation, the processes may vary also. Thermosetting polymers require reactions between a liquid monomer and the curing agent–some waste constituents may react with the monomer and curing agent interfering with solidification; thus, thermosetting polymers are best suited to macroencapsulation [33]. Thermoplastic polymers are typically heated above their melting points and mixed with powdered wastes; the resulting molten mixture is then either extruded into pellets or poured into a container for solidification and disposal. Geopolymers are typically fabricated by mixing an aluminosilicate or Class F fly ash with a highly concentrated caustic solution and an alkali silicate solution; these waste forms may be made at ambient temperatures but are often cured to produce a more homogeneous underlying structure [29].

Microencapsulated (polymeric) waste forms are less likely to retain their dimensional stability than cement forms often requiring secondary containers [28]. Biological and radiolytic processes can degrade organic materials including polymers (where polyethylene appears to have reasonable radiation stability); high radiation levels in polymer waste forms produce radiolytic gases that may impact disposal. Because waste constituents are not chemically bound to the matrix in encapsulation forms, these technologies may have limited applicability[12].

6.4.2.4 Hydroceramics

A “hydroceramic” waste form (Figure 6-8) is a concrete-like, monolithic solid of tectosilicates made by mixing inorganic waste, vermiculite, water, and Na_2S with pozzolanic materials (e.g., thermally-treated clays) activated using alkali under hydrothermal conditions [29]. Hydroceramics are primarily composed of crystalline silicates and possess a similar mineralogy to the “zeolitized” rock indigenous to the Yucca Mountain region [35]. The silicates formed in hydroceramics have cancrinite and sodalite structures (Figure 6-8) that can accommodate a variety of molecules including sodium carbonate, sodium nitrate, and sodium hydroxide.

Hydroceramics are not a mature technology but do have potential application to various important DOE waste streams. The primary effort related to this waste form has been to tailor it to potentially treat sodium-bearing waste (SBW) at the Idaho National Laboratory (INL) [36]. Hydroceramic waste forms have also been developed and tested for HLW calcined wastes at INL [37] and Hanford LAW [38]. The need to cure hydroceramics at relative high temperature and to denitrate the waste before curing would likely limit the applicability of this treatment technology, especially treatment of SRS and INL LAW [29].

[12] The lack of chemical binding of waste constituents may also impact testing results including TCLP if the sample is ground before leach testing [28].

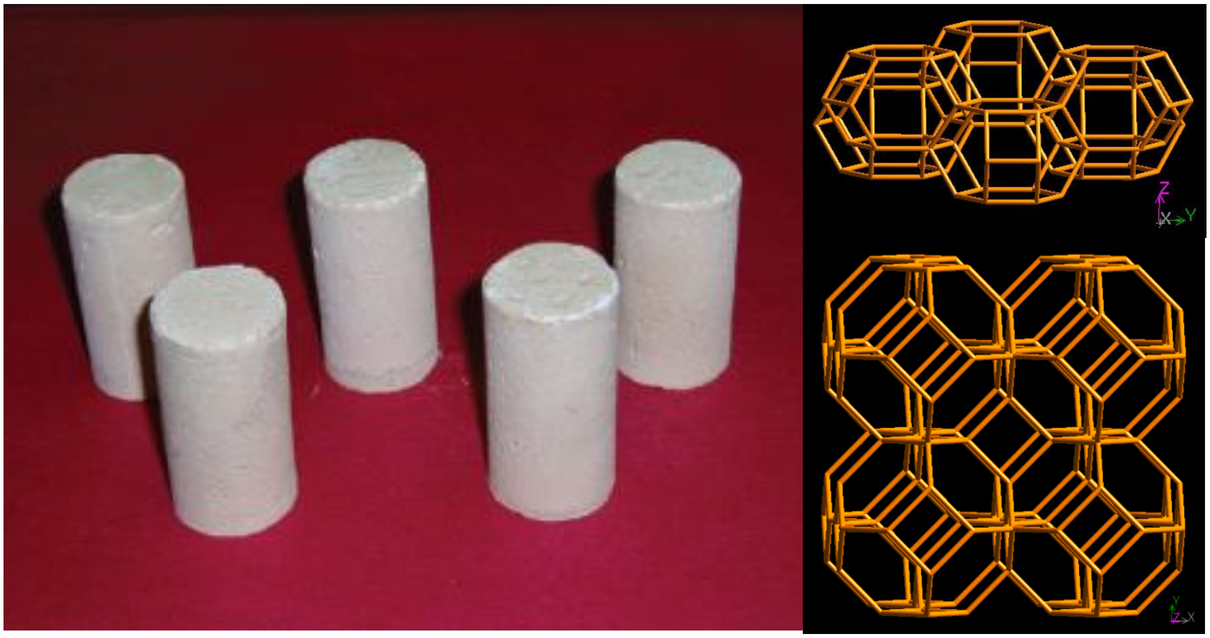

Figure 6-8. Cylindrical Hydroceramic monoliths [38] and Framework Structures for Cancrinite (upper right) and Sodalite (lower right) [39]

6.4.2.5 Crystalline ceramics (including mineralized waste forms)

Crystalline ceramics (often denoted ceramics) are inorganic, non-metallic solids composed of assemblages of crystalline phases. These materials are typically produced by firing clays or hot-pressing similar inorganic materials at high temperatures [28]. Ceramic waste forms have been considered for HLW treatment [40] [41], Hanford LAW treatment [42], and to immobilize long-lived actinides such as plutonium [43]. Despite the interest in ceramic waste forms over the years and the relative maturity of the processes involved, there has been little actual use of these waste forms.

An example of ceramic waste form considered for HLW treatment is SYNROC (SYNthetic ROCk), which is a traditional hot-pressed monolithic ceramic form consisting of three titanate phases (i.e., zirconolite, hollandite, and perovskite) produced around 1200 °C. Another example is the mineral waste form produced from fluidized bed steam reforming (FBSR) (Figure 6-9) that is being evaluated for Hanford LAW treatment [42]. Waste constituents are trapped in the molecular structure of the crystals (e.g., as zeolites trap metal ions for use as catalysts in the chemical industry) [28]. Because constituents of concern must be accommodated within the molecular “cage” of the minerals, care must be taken to assure that the ceramic form and waste constituents are compatible.

Ceramic waste forms tend to be highly resistant to leaching except in solutions with high silica chemical activities [28]. Some of these materials may be prone to radiation damage associated with actinides that undergo alpha decay; however, typically radiation and biological processes do not deleteriously impact the host ceramic matrix. For ceramics produced at high temperatures, the operational issues are similar to those for other high-temperature treatment processes such as vitrification. When the waste form is produced by pressing, the issues related to the limits on heat transfer and mass transfer become important as well as the time to reach thermal equilibrium. These processes coupled with the need to understand binder burnout and sintering are important to assure the quality of the product (i.e., cracking). If properly formulated, ceramics have been shown to be very durable—even more so than comparable glasses. Furthermore, because ceramics are composed of crystalline phases that resemble naturally occurring minerals, the stability and long-term leaching behavior of ceramics can often be reasonably estimated from natural analogues [28].

Figure 6-9. Studsvik Processing Facility in Erwin, TN employing FBSR for LLW

6.4.2.6 Vitreous (or glass) ceramic materials

Vitreous ceramics or glass-ceramic materials (GCMs) (Figure 6-10) contain both crystalline phases and vitreous material (glass). These waste forms are often produced at high temperatures from plasma-heated systems, melt crystallization, multiple heat treatments, or encapsulation of ceramics in glass [28] [29]. Depending on the intended application, the major component may be crystalline with a vitreous phase acting as a bonding agent, or the major component may be vitreous containing dispersed crystalline particles [44]. Glass-ceramic waste forms have been proposed for HLW treatment that can offer a useful compromise between glass and ceramic materials for waste disposal: GCMs can be easier and cheaper to fabricate than traditional ceramic forms while offering the potential for reduced leaching potential than glass as long as the most soluble phases retain the contaminant of concern. Additionally, glass-ceramic waste forms may provide additional advantages over glasses including increased waste loading and density that would result in reduced disposal volumes [29].

Glass-ceramics can immobilize constituents (e.g., sulfates, chlorides, molybdates, and refractory materials) that have low solubilities in typical glass melts. If formulated properly, the long-lived radionuclides (e.g., actinides) can be incorporated into the more durable crystalline phases while short-lived radionuclides (including many fission products) can be accommodated in the less durable vitreous phase [29] [44]. Relatively low leach rates have been observed for some GCMs, and results indicate that the leach rates for ceramics, glasses, and glass-ceramics are of the same order of magnitude [44]. However, the mixture of vitreous and ceramic phases may make the assurance of product quality and durability more difficult than for a single-phase waste form.

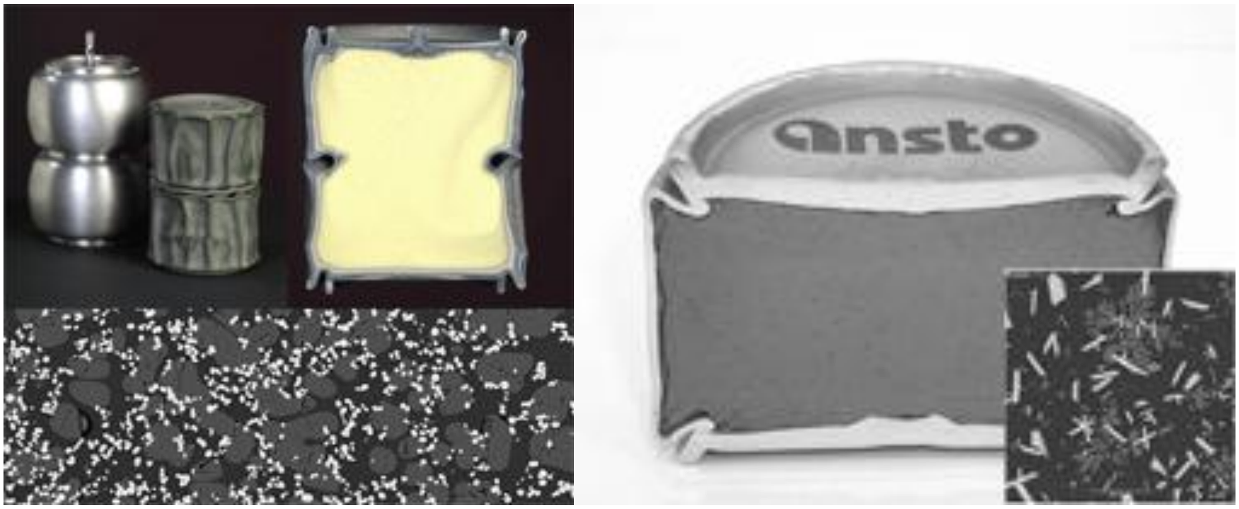

Figure 6-10. synrocANSTO Glass-Ceramic Waste Forms proposed for INL Calcined Wastes (left) and Impure Actinides (right)[13]

6.4.2.7 Metals and metallic waste forms

Metals, metallic waste forms, and/or allow systems (Figure 6-11) have been studied as potential waste forms for technetium [45], sealed radioactive sources [46], and nuclear fuel wastes including undissolved solids, cladding hulls, and transition metal fission products [47]. Like crystalline ceramics, metallic waste forms can be composed of single phases or assemblages of multiple phases; the waste form can also be either granular or monolithic [29]. Metallic waste forms have been produced from sintering or casting. Each of these techniques may present difficulties in finding metals or alloys and treatment processes that effectively wet and encapsulate the dispersed constituents to be treated [29].

Various metals and alloys have been considered to treat wastes. Lead and lead-based alloys have been used in Russia to encapsulate sealed radioactive sources to ensure safe and secure storage and to enable subsequent retrieval, transportation and disposal [46]. At DOE, a Zr-Cu-Fe alloy has been evaluated as a waste form to incorporate nuclear fuel wastes (i.e., undissolved solids, cladding hulls, and transition metal fission products) in a multiphase alloy using a melt process at a relatively low temperature [47]. An alloy of stainless steel and zirconium is being evaluated for immobilizing technetium [45], which might have further application to Hanford secondary wastes and technetium separated from LAW and/or the feed to Hanford Effluent Treatment Facility (ETF). The basic processes used to create metallic waste forms are relatively mature; however, the difficulty often relates to finding or tailoring a known metallic waste form or alloy system to the waste components that must be treated.

[13] http://www.synrocansto.com/Wasteforms/WF/GlassCeramics.html

Developmental-scale metallic waste forms for Tc-99 immobilization have been created in resistance and induction-heated furnaces (under an inert atmosphere) by first placing zirconium in the bottom of a crucible and then adding pieces of stainless steel on top. As the stainless steel melts, it wets the Zr metal, inducing it to melt at a much lower temperature (approximately 1600 °C) than the melting temperature of Zr metal (1855 °C). No measureable technetium was lost to volatilization during the melting process, and the resulting metallic waste forms appeared to be very durable [45].

Figure 6-11. Metal Waste Form Production Furnace being readied for Installation [48] and a Zirconium-based Metallic Waste Form (right) [47]

6.4.2.8 Ceramicretes

Ceramicretes are chemically bonded phosphate ceramics (Figure 6-12) that have been evaluated for use in various waste management activities including[14]

- Stabilization of contaminated solids, sludges and liquids
- Chemical immobilization and physical encapsulation of hazardous metals, low-level radioactive waste, fission products, and transuranics
- Macroencapsulation of contaminated debris, metal and nonmetal equipment

The ceramics are formed by acid-base reactions between an acid phosphate (of potassium, ammonium, or aluminum) and a metal oxide (of magnesium, calcium, or zinc) [49]. In practice, a powder mixture of oxides and additives such as retardants and fillers are stirred into a phosphate solution; considerable amounts of mineral and other inorganic waste can be added to these ceramics (up to 60 percent waste). If inorganic waste is added during formation, the waste constituents will also be converted into phosphates (that have a much lower solubility than their

[14] http://www.anl.gov/techtransfer/Available_Technologies/Material_Science/Ceramicrete/index.html

oxides or salts) and encapsulated in a dense phosphate matrix. This dual mechanism of chemical immobilization and physical encapsulation may be very effective at immobilizing contaminants of concern [49]. These ceramics can chemically stabilize hazardous contaminants as well as fission products and can encapsulate radioactive elements and large-scale contaminated equipment.

Figuer 6-12. Chemically Bonded Phosphate Ceramics Proposed for INL and Hanford Wastes [50]

The technology for producing ceramicretes has been patented[15] and licensed to treat low-level and mixed wastes [51] and is relatively mature for these wastes. Ceramicretes have also been used to macroencapsulate and containerize uranium [50]. DOE has evaluated this technology for microencapsulating and macroencapsulating hazardous and radioactive wastes including Hanford LAW and secondary wastes and INL sodium-bearing waste [29].

6.4.3 Potential Alternative Hanford LAW Treatment Technologies and Waste Forms

Considerable effort has been expended to develop technologies and corresponding waste forms for treating radioactive and mixed wastes. For example, the idea of immobilizing radioactive waste in either vitreous or crystalline materials is almost 60 years old [29]. The result of these efforts is a diverse set of treatment technologies and corresponding waste forms that range from full-scale DOE applications on real wastes to those that have only been studied at laboratory or pilot scales. Examples of treatment technologies and waste forms that have been used at DOE to treat tank and other wastes include:

- Grouting LAW at SRS for disposal in vaults (Figure 6-5) and low-level waste at WVDP
- Vitrifying HLW at SRS and WVDP (Figure 6-6) for on-site storage until a national geologic repository is ready for final disposal
- Macroencapsulation of radioactive lead solids using polymers (Figure 6-7)

[15] http://www.anl.gov/techtransfer/Available_Technologies/Material_Science/Ceramicrete/Ceramicrete_Patents.html

Vitrification has been selected by Ecology as the treatment technology for both HLW and LAW at Hanford [1] [22]. Other technologies have been used to treat LAW (i.e., grouting at SRS) or may show promise for treating Hanford LAW (e.g., FBSR) [29], and there are technical and programmatic reasons for pursuing alternative technologies and waste forms. However, based on current TPA milestones [1] (Figure 6-3), despite the attractive characteristics of alternative treatment technologies and waste forms being researched, selecting a treatment technology (other than vitrification) for the remaining Hanford LAW under the current time constraints represented in the TPA represents a high degree of risk. Furthermore, the EM-TWS evaluation indicated that no alternatives other than those evaluated for the remaining Hanford LAW (i.e., vitrification, steam reforming, or grouting) should be considered as viable under the times constraints imposed by the TPA.

6.4.3.1 Potential application of grouting and cementitious waste forms for Hanford LAW treatment

Grouting is a mature technology that has been used to treat SRS LAW and low-level wastes at the WVDP for over three decades (Figure 6-2). Grouting was originally planned for Hanford LAW treatment, but this technology was terminated in the 1990s due to concerns with the adequacy of the resulting cementitious waste form to inhibit leaching of contaminants of concern and the costs related to making the waste forms retrievable [11]. Others studies have echoed concerns about the potential performance of the grouted LAW form relative to glass and other potential waste forms [3]. However, many of the assumptions used in these studies are excessively “conservative” for likely Hanford IDF disposal conditions and may overestimate source release predictions for grouted forms by several orders of magnitude.

The selection of vitrification by Ecology as the preferred treatment technology for Hanford LAW under RCRA has, in part, engendered the requirement that the waste form from any alternative LAW treatment process be “as good as glass.” Because of the porous nature of and the assumptions typically applied to cementitious waste forms in performance assessments [52], these forms will generally be predicted to be less durable than their glass counterparts. Such a difference is not unreasonable given that vitreous waste forms immobilize contaminants in the glass matrix; whereas, cementitious forms do not. However, the large uncertainties in parameters and models must be considered for glass, cementitious, or other proposed waste forms to make meaningful and objective comparisons of predicted performance [53]. These changes in how uncertainties are addressed and the assumptions made pertaining to cementitious and other potential waste forms have been incorporated into more recent DOE performance assessments [54] [55].

Predictions of performance are needed because no standard tests are available that can determine the performance of a material with high confidence over the often long periods of performance (e.g., centuries or millennia) necessary to satisfy regulations. There is a further lack of waste form-specific performance requirements [29] for the disposal of treated LAW; there is instead a preferred treatment technology (vitrification) and corresponding waste form (glass) defined by Ecology under RCRA. Thus, there is some degree of flexibility in how the performance of an alternative waste form could be assessed relative to that of a benchmark glass. Typically, comparisons have been made using performance assessment methods that rely on parameterized source release and fate and transport models to predict the performance of the various waste forms under consideration [3]. However, the methods supporting the assessments used historically to evaluate candidate waste forms have changed significantly, and the assumptions used for cementitious waste forms have been shown to be often overly conservative. This new information should be incorporated into any assessment of cementitious or other waste forms relative to glass to support alternative treatment technology evaluation for Hanford LAW.

However, even though the effectiveness of cementitious waste forms may have been under predicted historically, the porous nature of these forms and the fact that the waste constituents are not bound within the matrix (like for glass) would likely make any objective comparison of performance to a comparable, well-made glass less than favorable (but not unnecessarily unsafe). Furthermore, the typical advantage of using grout (i.e., relatively much lower costs of production) was obviated by the retrievability requirement for Hanford LAW forms in the IDF. Furthermore, the short time horizon available for selecting an alternative treatment method (Figure 6-3) makes developing the necessary technical support for grouting and the necessary accord with Ecology likely highly problematic.

One possible path forward that could include grouting of Hanford LAW wastes would involve first finding a reasonable subset of Hanford LAW for which grouting would be an acceptable alternative to Ecology for on-site disposal[16]. One example of such a waste would be saltcake with low activity and small concentrations of long-lived and potentially mobile radionuclides that had been previously processed to capture fission products; whereby the fission product capture might be considered a treatment process since it removed a large quantity of highly radioactive material. This path forward is not unlike that taken by Savannah River with the with the Deliquification, Dissolution, and Adjustment (DDA) process on the Tank 41 waste (as described in more detail in Appendix 9 of this report). There are concerns that the effort needed to develop the necessary technical information, albeit tenable, may not be amenable to the selection of grouting as an alternative treatment technology by 2015.

A related path forward would be to select and treat a subset of Hanford LAW for disposal off-site. Even if such an approach cannot be applied to tank waste directly, there may be secondary wastes that would be produced in the WTP that may be reasonable candidates for solidification in grout or other waste form for off-site disposal. Potential off-site locations would be the low-level waste disposal facility being constructed in Texas (Waste Control Specialists) or the Waste Isolation Pilot Plant (WIPP) in New Mexico where the appropriate location would be dictated by the results of a formal waste incidental to reprocessing (WIR) determination per DOE O 435.1. However, the permitting and regulatory issues related to these disposal sites are complex and likely very time-consuming relative to the need to select an alternative treatment technology by 2015. Any path forward is predicated on working closely with Ecology (and, in the case of the WIPP facility, the New Mexico Environment Department).

[16] Some pretreatment may be necessary to prepare the feed for grouting; however, care should be taken to not generate any orphan waste streams.

6.4.3.2 Potential application of fluidized bed steam reforming (FBSR) and a mineralized waste form for Hanford LAW treatment

Fluidized bed steam reforming (FBSR) has been evaluated for treating SRS Tank 48H waste[17] [56] and the sodium bearing waste (SBW) at INL. Construction of the Integrated Waste Treatment Unit (IWTU) that will employ FBSR to treat INL sodium-bearing waste began in April 2007[18]. Cold commissioning of the IWTU was originally scheduled to begin in the 4th Quarter of 2010. These FBSR processes would produce a granular carbonate form that would likely be vitrified in DWPF at SRS or packaged in canisters for storage at INL. Extensive research and pilot-scale demonstrations have been performed for these potential applications (primarily substituting rhenium for technetium). However, the carbonate forms produced for SRS and INL applications would not be appropriate for Hanford LAW disposal; studies for treating Hanford LAW include adding clay during processing to form a granular, mineralized product to which a binder would be added for disposal in the Hanford IDF (as required based on an intruder scenario) [42].

Ecology considers "as good as glass" to be the standard for successful deployment of a supplemental treatment technology [22]. The FBSR treatment technology appears to be relatively mature and extensive pilot-scale testing has been performed on simulants for the SRS and INL applications; furthermore, this technology has been selected to treat the sodium bearing waste at INL. A long list of requirements (Table 6-2) [26] must be satisfied for an alternative technology to be accepted for Hanford LAW treatment and disposal [27]. Furthermore, Ecology emphasized that any "waste form resulting from any supplemental treatment must be proven to perform 'as good [*sic*] as glass'" [27].

As mentioned above, there are neither 1) standard tests that can determine the performance of a material with high confidence over long periods of performance nor 2) waste form-specific performance requirements for the disposal of treated Hanford LAW. This provides some degree of flexibility in how the performance of an alternative waste form could be assessed relative to that of the glass benchmark[19]. Such comparisons have typically been made using performance assessment models to predict the behavior of various waste forms under consideration; the performance of the mineralized form has been predicted to be comparable, if not better, than some comparable glasses.

The models used to predict the performance of both the FBSR mineralized waste form and glass tend to be similar [3], and thus some of the model errors may cancel as long as the underlying

[17] SRS Tank 48H contains approximately 250,000 gallons of a waste slurry containing potassium and cesium tetraphenylborate (CsTPB) remaining after the In-Tank Precipitation (ITP) process was tried for salt waste treatment and then abandoned. The slurry must be treated (including destroying organic compounds) and the tank emptied so it can be returned to service; however, the return to service of Tank 48H is not on the critical path for SRS.

[18] http://www.thortt.com/doe/idaho.php

[19] Results of leach tests such as the PCT, performance predictions considering significant uncertainties, and demonstrating that contaminants of concern (e.g., Tc-99) are successfully incorporated in the cage-like structures in the mineralized waste form would go a long way in demonstrating that the mineral waste form might be acceptable, including when compared to glass. However, care must be taken to verify this last result over the range of LAW compositions that would be treated (requiring uncertainty characterization and management).

assumptions in the models must be appropriate for both waste forms and the uncertainties resulting from the simplifications in the models must also be similar. Ecology is concerned that assumptions concerning contaminant partitioning and its effect on waste form performance are the same for both FBSR product and glass given the relative maturities of the technologies [22]. Furthermore, current methods used to develop performance assessments should be incorporated into any assessment of waste forms relative to glass to support alternative treatment technology evaluation for Hanford LAW [49, 50]. The short time horizon for selecting an alternative treatment method (Figure 6-2) makes developing the necessary technical support for a mineralized waste form and the necessary accord with Ecology difficult in the short time remaining. Furthermore, as noted by the EM-TEG, FBSR and the corresponding mineral waste form have not been developed to an adequate level that allows for a conclusive evaluation of performance or a cost-benefit analysis relative to vitrification and the glass waste form [13].

The paths forward diverge based on whether Ecology agrees with the evidence supporting a mineralized LAW form being “as good as glass” when disposed in the Hanford IDF. As noted above and elsewhere [29], there is some flexibility in terms of how this assessment would be made, but Ecology would be the “judge” (outside of a dispute resolution process [1]). If Ecology agrees with the early evidence supporting the assertion that the mineralized waste form would perform as well as glass and the mineralized waste form satisfies Specification 2 from the WTP Statement of Work Section C (Table 6-2) [26], then selecting FBSR as a supplemental treatment technology would appear to be provide a reasonable strategy to pursue. However, the use of FBSR to treat *all* Hanford LAW as proposed in the *Enhanced Tank Waste Strategy* would appear to be highly problematic from Ecology’s standpoint as it would require, among other things, a renegotiation of the TPA.

If Ecology does not agree with the evidence that the mineralized waste form would perform as well as glass, then the paths would be similar to the two proposed for using cementitious forms:

1) A subset of Hanford LAW would be found (if available) for which FBSR would be acceptable to Ecology for on-site disposal upon release of the vitrification standard for these wastes. There are significant technical, regulatory and programmatic concerns related to this path forward.

2) A related path forward would be to treat a subset of Hanford LAW for disposal off-site. However, the permitting and regulatory issues related to off-site disposal sites are complex and likely very time-consuming relative to the need to select an alternative treatment technology by 2015.

6.4.3.3 Application of vitrification and a vitreous waste form for Hanford LAW treatment

Vitrification of Hanford LAW into a glass waste form is the preferred treatment technology for both Hanford HLW and LAW [1]. A vitrification facility is currently being constructed at WTP that will treat less than 50 percent of the anticipated LAW feed from the Hanford tank farm using a Joule-heated ceramic-lined melter (JHCM) and a borosilicate glass waste form. Therefore, additional capacity is required to immobilize Hanford LAW to meet the treatment milestones in the TPA.

Various alternative treatment technologies including fluidized bed steam reforming (FBSR) and grouting have been researched to complement the first LAW treatment facility. However, as suggested above, the requirement imposed by Ecology that the waste form generated from an alternative LAW treatment technology be "as good as glass" makes employing any alternative technology difficult when considering current TPA milestones. However, there are still possible dimensions within the vitrification arena that can accelerate LAW treatment without the regulatory hurdles presented by alternative treatment technologies.

A second vitrification technology, bulk vitrification, has been researched for Hanford LAW treatment. Instead of employing a JHCM, the bulk vitrification process would 1) combine liquid LAW with soil and additives (B_2O_3 and ZrO_2) in a refractory-lined steel disposal container, 2) dry the resulting mixture, and 3) melt the mixture at approximately 1350 °C (a significantly higher temperature than used in a typical JHCM). Although the performance of the resulting sodium silicate glass has been deemed acceptable, the technical, safety, and programmatic issues identified with bulk vitrification [57] were considered too expensive to redress for use in treating Hanford LAW. However, there are options remaining that range from improving use of the current technology to new vitrification techniques.

As indicated by the EM-TEG, advanced formulation studies have shown promise to increase waste loading that would, in turn, reduce the number of LAW canisters produced [13]. Furthermore, advanced melter designs may significantly increase throughput allowing increased treatment of ILAW. Advanced formulations for borosilicate glasses that would be produced in either existing or advanced melter systems likely present little regulatory resistance and should thus be pursued vigorously to improve LAW processing. If a second vitrification facility is built to treat the remaining LAW, the lessons learned from the facilities currently being constructed should be considered in the design and construction of the new facility.

Other glass matrices have been studied for potential LAW treatment application. As mentioned above, the bulk vitrification process would produce a sodium silicate glass waste form that was deemed acceptable when compared to the current borosilicate glass benchmark from the 2001 Hanford ILAW performance assessment [24]. Various vitrification technologies (e.g., cold crucible induction melting and modular vitrification systems) and other waste glass formulations (e.g., iron phosphate, aluminosilicate, and lanthanide borosilicate) have been researched as potential waste forms. Each of these techniques and waste forms has potential benefits and drawbacks when compared to the borosilicate glass benchmark. Despite the potential benefits of these other glass formulations, there appears to be little time afforded by the TPA to generate the data and understanding necessary to demonstrate to Ecology's satisfaction that the new glass formulations would be acceptable when compared to the borosilicate glass benchmark for the range of LAW compositions that might be treated.

6.4.3.4 Summary of alternative Hanford LAW treatment technologies and waste forms

Because of the short time remaining to satisfy the TPA milestone to select an alternative treatment technology by 2015, only mature treatment technologies and well-characterized waste forms are reasonable to pursue. Other than vitrification (selected by Ecology as the preferred treatment technology for Hanford LAW), grouting and fluidized bed steam reforming (FBSR) appear to satisfy these criteria. Each alternative technology has potential advantages and disadvantages for treating Hanford LAW.

Grouting wastes into a cementitious waste form is a mature technology that typically presents a lower-cost remedial option than vitrification. However, concerns have been raised about the adequacy of a cementitious waste form to inhibit leaching of contaminants of concern and the costs related to making the waste forms retrievable [11]. The models that have been used in the past to predict the performance of cementitious waste forms incorporate grossly "conservative" assumptions, but it seems unlikely that a case can be made in time that would convince Ecology of that cement waste forms are acceptable for direct treatment of Hanford LAW. Therefore, unless there are changes made to the TPA and an accord can be reached with Ecology on the "good as glass" requirement for specific Hanford LAW wastes, the effort needed to select grouting as an alternative treatment technology may be prohibitive. This assessment would change if an off-site disposal site could be found for treating specific Hanford LAW directly by grouting or solidifying secondary wastes materials.

Fluidized bed steam reforming (FBSR) appears to be a relatively mature technology that typically costs between that of grouting and vitrification depending on the application. Although FBSR has not been applied to LAW, it has been selected to treat sodium-bearing waste at the Idaho Site. Technical work has progressed during the past decade to demonstrate the effectiveness of the FBSR mineralized waste form in immobilizing contaminants of concern (e.g., Tc-99) prior to possibly selecting the FBSR as an alternative treatment technology. Because there is only a brief window of opportunity (Figure 6-3), for this effort to succeed there will need to be upfront and ongoing collaboration with Ecology on the evaluation and development process. Issues that will need clear communication and thoughtful consideration include information needs, review criteria, consistency with schedule, and regulatory challenges.

Alternative waste treatment technologies and corresponding waste forms should be pursued in concert with Ecology if sufficient funding and time would be available to demonstrate that the waste forms would be "as good as glass." Advanced melter systems should be pursued based on the state of the technology, potential benefits, and ability to positively impact the treatment schedule. Compatibility with the existing WTP infrastructure would become a major factor in the decision to use an advanced melter system. Advanced borosilicate formulations for LAW treatment have shown promise to increase waste loading and should thus be vigorously pursued as a significant incremental step to reducing the number of LAW canisters produced.

6.4.4 Major Vulnerabilities

This section describes the major vulnerabilities identified from the EM-TWS review and potential strategies for mitigating the potential impacts. The vulnerabilities are discussed in terms of the alternatives described to the EM-TWS including the baseline, the Enhanced Tank Waste Strategy (ETWS), the Supplemental Treatment Strategy (STS), and the Vision 2020 (2020) as presented to the subcommittee.

6.4.4.1 The potential benefits that could be realized by use of an alternative supplemental treatment technology for Hanford LAW would be lost because the short time remaining to select such an alternative makes its selection difficult

If a treatment technology (e.g., grouting or steam reforming) other than vitrification is selected by DOE as an alternative for the remaining LAW (with the other being vitrification), then a Supplemental Treatment Technologies Report must be submitted by October 31, 2014. The alternative treatment technology for the remaining LAW feed must be selected by April 20, 2015 [1]. Previous experience indicates that years are often required to adequately plan and perform the necessary research to build the technical, programmatic and business cases for treatment technologies, design facilities, and to obtain necessary permits. The EM-TEG indicated that alternative treatment technologies and corresponding waste forms have not been developed to an adequate level to allow for a conclusive evaluation of performance or a cost-benefit analysis relative to vitrification / glass [13]. These factors would appear to make it very difficult to select an alternative treatment technology and corresponding LAW form despite any potential benefits from the cost, schedule, and risk reduction perspectives. Furthermore, the short time frame increases the risk of selecting an alternative that is later found to be wanting in some manner.

This vulnerability is pertinent to the baseline case and the Enhanced Tank Waste and Supplemental Treatment strategies. Because there is only a brief window of opportunity, there will need to be upfront and ongoing collaboration with Ecology on the evaluation and development process. Issues that will need clear communication and thoughtful consideration include information needs, review criteria, consistency with schedule, and regulatory challenges.

6.4.4.2 Uncertainty in how Ecology will adjudge the "as good as glass" benchmark puts the potential of selecting fluidized bed steam reforming (FBSR) at risk

Fluidized bed steam reforming (FBSR) is a relatively mature technology that has been selected to treat sodium bearing waste at the Idaho Site and is being considered for treating Tank 48H waste at the Savannah River Site. However, vitrification was selected by Ecology as the preferred treatment technology (under RCRA) for Hanford LAW, which has engendered the concept of the waste form resulting from any alternative treatment must be demonstrated to be "as good as glass." There are a large number of requirements, including performance, defined by Ecology that must be satisfied to meet this standard. Many of these requirements are straightforward; however, there are no waste form-specific performance requirements and thus there is some flexibility in how these requirements could be satisfied. Unless there is an upfront and ongoing collaboration with Ecology on how to meet the performance standard, there is a significant risk that there will be a dispute by Ecology if FBSR is selected as an alternative treatment technology as directed by the TPA.

This vulnerability does not impact the baseline or Vision 2020 strategies as an alternative treatment strategy is not part of these. For the Supplemental Treatment Strategy, the treatment technology for the remaining LAW will be selected from ILAW, bulk vitrification, grouting, or FBSR and thus there are potential cost, schedule, and regulatory impacts if FBSR would be selected. For the ETWS, it is assumed that FBSR will be used to treat *all* Hanford LAW, which is an idea that presents very high cost, schedule, and regulatory risks especially since it does not employ the preferred treatment technology (vitrification) and construction of the ILAW facility is over 60% completed. Furthermore, Ecology has indicated supplemental treatment would only be considered for a “small increment of the LAW feed material” [27] although this is not stated in the TPA. Thus, there are significant hurdles to implementing the ETWS. As suggested above, this vulnerability can be mitigated by an upfront and ongoing collaboration between DOE and Ecology to develop the accord and information needed to support the successful selection of FBSR as an alternative treatment technology.

6.4.4.3 The “as good as glass” benchmark makes selecting grouting of Hanford LAW for on-site disposal problematic from regulatory and public perception viewpoints

Grouting is a mature technology that has been used to treat SRS LAW and WVDP LLW and was originally planned for Hanford LAW treatment; however, this technology was terminated in the 1990s due to concerns with the adequacy of the resulting cementitious waste form to inhibit leaching and the costs related to making the waste forms retrievable. Grouting was replaced with vitrification as the preferred treatment technology engendering the concept that any alternative waste form (in this case, a cementitious waste form) must be “as good as glass.” Because of the nature of a cementitious waste form where waste constituents are not incorporated into the waste form matrix, performance comparisons to glass may be inadequate. However, none of this means that grouting certain wastes would not produce a waste form that adequately protects human health and the environment, especially for given applications. Thus a reasonable treatment technology would be dismissed based on a technology standard and not the likely performance of the waste form.

This vulnerability does not impact the baseline, ETWS, or Vision 2020 strategies as grouting as an alternative treatment strategy is not included. For the Supplemental Treatment Strategy, the treatment technology for the remaining LAW would be selected from ILAW, bulk vitrification, grouting, or FBSR and thus there are potential cost, schedule, and regulatory impacts if grouting would be selected including a likely dispute by Ecology. There are obvious hurdles to selecting grouting as an alternative treatment technology. As suggested above, this vulnerability may be mitigated by an upfront and ongoing collaboration between DOE and Ecology to determine if there is a “small increment” of Hanford LAW to which grouting could be applied without likely dispute. If possible, finding an acceptable off-site disposal site for LAW treated by grouting may also mitigate Ecology’s concerns over grouting.

6.4.4.4 The selection of bulk vitrification to treat Hanford LAW would present significant technical, safety, and management issues

Vitrification is a mature treatment technology that has been used to successfully treat SRS and WVDP high-level tank wastes using Joule-heated, ceramic-lined melters (JHCM); this technology has also been selected to treat Hanford HLW and LAW. Instead of employing a JHCM, the bulk vitrification process would 1) combine liquid LAW with soil and additives in a refractory-lined steel disposal container, 2) dry the resulting mixture, and 3) melt the mixture at a temperature significantly higher than that in a typical JHCM. Because this process would use vitrification to treat Hanford LAW (and the performance of the resulting sodium silicate glass was deemed acceptable), there are no *regulatory* issues likely to be encountered with this treatment process. However, outstanding technical, safety, and management issues were identified for the bulk vitrification process that were deemed too expensive to redress for use in treating Hanford LAW [57].

This vulnerability does not impact the baseline, ETWS, or Vision 2020 strategies as bulk vitrification is not included as an alternative treatment strategy. For the Supplemental Treatment Strategy, the treatment technology for the remaining LAW would be selected from ILAW, bulk vitrification, grouting, or FBSR, and thus there are potential cost, schedule, and regulatory impacts if bulk vitrification would be selected, especially because of the technical, safety, and management issues that have not been satisfactorily addressed. There are thus significant hurdles to selecting bulk vitrification as an alternative treatment technology for Hanford LAW. A cost-benefit analysis could be performed to determine if the research required to redress the outstanding technical and safety issues is warranted in the current atmosphere, and, if so, then the management issues could be addressed as part of the path forward. However, completing the research in time to select bulk vitrification appears unlikely.

6.4.4.5 The large uncertainties in the models that must be used to compare waste form performance make such comparisons very difficult to interpret

Despite the wealth of knowledge concerning vitreous and many other waste forms, the long-term performance of these waste forms must be predicted using source release and fate and transport models. As indicated above, the parameters used in the models as well as the models themselves may have very large uncertainties. Furthermore, source release and near field models may vary for different waste forms with differing degrees of uncertainties. The large resulting prediction uncertainties may vary over several orders of magnitude for the often long periods of performance may make waste form comparisons very difficult to interpret for decision-making purposes.

This vulnerability impacts the Supplemental Treatment and Enhanced Tank Waste Strategies, but would not impact the baseline or Vision 2020 paths forward (as waste form comparisons are not needed for these scenarios). The uncertainties in predicted performance for the waste forms to be compared should be managed transparently and consistently in assessments that provide information to decision makers.

6.4.4.6 Volatile and other important contaminants of concern may not be captured in the waste forms used for Hanford LAW

Previous performance assessments for the Hanford Site indicate that mobile, volatile radionuclides like Tc-99 and I-129 often drive the risks for low-activity wastes to be disposed on the Hanford Site. Thus, it is important that these types of contaminants of concern be immobilized in a durable waste form prior to near surface disposal. For example, high temperature treatment processes like vitrification often have difficulty capturing volatile contaminants in the vitreous waste form that then become issues concerning effluent treatment, off-gas systems, and/or recycle that may impact processing future waste batches. The EM-TEG noted a “surprisingly large gap and large uncertainties” in understanding the fate of Tc-99 given the amount of research conducted and the relative maturity of the treatment processes [13].

Additional work is needed to demonstrate that the fluidized bed steam reforming (FBSR) for Hanford LAW would incorporate important contaminants of concern in the cage-like structures of mineralized waste form. Grouting produces a cementitious waste form wherein contaminants are not bound within the matrix making these forms often problematic for mobile, long-lived radionuclides.

This vulnerability impacts all the treatment strategies considered in this evaluation because vitrification, steam reforming, or grouting is considered in each scenario. For vitrification, research is being conducted to determine intermediate forms to allow Tc-99 to remain in the melt and corresponding glass waste form to reduce the resulting off-gas, effluent treatment, and/or recycle issues. For steam reforming, research is being conducted to determine the leaching response of these materials and whether or not Tc-99 is incorporated into the cage-like structure comprising the mineralized waste form. For grouting, reducing grouts have been used to maintain the Tc-99 in a valence state that is reasonable immobile in the disposal environment. These research studies should continue to help inform the decision-making process. Furthermore, tank waste characteristics should be investigated for either difficult-to-process LAW for specialized treatment and for wastes requiring minimal treatment that could rely on less expensive waste forms such as grout. These actions would be predicated on an upfront and ongoing collaboration between DOE and Ecology.

6.4.4.7 Loss of knowledge in critical areas may impact the ability to respond effectively and efficiently to feed variabilities and process upsets with necessary waste forms modifications

A significant amount of time (more than a decade) will elapse between when Hanford LAW treatment processes and corresponding waste forms are first selected and the beginning of WTP operations. This time lag can result in the loss of significant knowledge concerning treatment processes, waste forms, and product acceptance. The loss of knowledge impacts the ability of the engineers supporting WTP to respond efficiently to feed variabilities and process upsets that require adjustments to waste form formulations while maintaining product acceptance. This may have cost and schedule implications and may also impact the time required to treat Hanford LAW.

This vulnerability impacts the treatment strategies considered in this evaluation except for the Vision 2020 strategy where LAW treatment would be accelerated to begin in 2016. The apparent strategies for mitigating the impacts of this potential loss of critical knowledge include: 1) incentivize those individuals with the critical knowledge to remain available, 2) develop a mentoring program to transfer the critical knowledge to qualified new employees, and/or 3) develop a knowledge capture system.

6.4.4.8 A significant amount of coal fines in the fluidized bed steam reforming process presents possible hazardous conditions

It has been reported that as much as 10-20 percent of carbon (coal) fines must be incorporated into the FBSR product. The presence of such a large amount of coal fines presents unknown issues related to the ability of the proposed mineralized waste form to satisfy product requirements. Furthermore, certain factors involving coal fines can lead to the creation of hazardous conditions including fires and explosions.

This vulnerability does not impact the baseline or Vision 2020 strategies as FBSR would not be used for these strategies. For the Supplemental Treatment Strategy, the treatment technology for the remaining LAW would be selected from ILAW, bulk vitrification, grouting, or FBSR and thus there are potential hazardous conditions related to coal fines if FBSR would be selected. For the ETWS, it is assumed that FBSR would be used to treat *all* Hanford LAW, which would likely increase the risks associated with the coal fines.

6.5 Recommendations

These are the recommendations to address the various findings and observations noted in Section 6.3 (starting on p. 6-9) and major vulnerabilities identified in Section 6.4.4 (starting on p. 6-30).

6.5.1 Prior to any downselection for Supplemental LAW treatment, DOE, in conjunction with its regulators, should develop an approach to development and implementation of a treatment process, waste form, and disposition pathway that explicitly addresses the challenging fractions of LAW that limit near surface disposal options and provides a viable option to a second LAW vitrification facility. This will likely necessitate consideration of a separation of Tc-99, and possibly other constituents, that drive near-surface disposal risk to the extent that Tc-99 may not be incorporated into vitrified LAW using the WTP LAW vitrification facility.

Ecology designated vitrification as the preferred treatment technology for Hanford LAW under RCRA and has declared that “as good as glass” is the benchmark by which any successful supplemental treatment technology would be judged. Based on the current milestones in the TPA, these requirements leave little, if any, margin for successfully selecting an alternative LAW treatment technology, even one with potentially significant benefits. Based on the highly variable characteristics of the wastes and forms in the tanks and the contaminants most likely to limit near surface disposal options, a more reasonable path would be to identify and address challenging LAW waste fractions to which a supplemental treatment technology can be successfully applied. Often the most challenging contaminants tend to be volatile, long-live radionuclides like Tc-99 that are difficult to incorporate into the LAW waste glass and are mobile when released into the biosphere. Because of the difficulties that may be encountered in gaining acceptance of any non-glass waste form, this path forward may require the separation of such difficult to manage contaminants (especially Tc-99) in concert with technology and waste form development. Because there is only a brief window of opportunity, for this effort to succeed there will need to be upfront and ongoing collaboration with Ecology on the evaluation and development process if an alternative treatment path way is to be developed. Issues that will need clear communication and thoughtful consideration include information needs, review criteria, consistency with schedule, and regulatory challenges.

6.5.2 DOE should include a targeted processing and treatment approach (that may include segregation and alternative treatment) based on an evaluation of waste characteristics including uncertainties in the system planning process.

There has often been a tendency in DOE to attempt global approaches to treat many different wastes when targeted approaches may make sense both programmatically and economically while meeting risk reduction and regulatory goals. Global approaches may allow the DOE to reduce certain programmatic and budgetary risks; however, there are technical and operational trade-offs that often may not provide adequate processing flexibility and have impacted choices regarding treatment technologies and waste forms.

There are large variations of composition, form, chemistry, and other important properties within the Hanford tank farm vessels. Previous evaluations of the best basis inventories have indicated that some of the contents perhaps would be appropriate for treating and sending to WIPP as TRU waste. Furthermore, contaminants of concern (e.g., Cs-137, Sr-90, Pu-239, Tc-99, I-129) and other important characteristics can vary widely from tank to tank. Because of previous reprocessing of Hanford wastes to capture Cs-137 and Sr-90, some tanks contain salt wastes with relatively low total activities. Thus, it may be possible to develop a targeted approach to treating Hanford LAW; for example:

- Treat high-risk wastes (e.g., those with large concentrations of long-lived, mobile radionuclides) with low concentrations of volatile contaminants of concern (e.g., Tc-99 and I-129) in the ILAW facility currently under construction[20].

- If the mineralized waste form is deemed acceptable by Ecology for on-site disposal, treat the remaining high-risk wastes that also have moderate to high concentrations of volatile contaminants of concern using fluidized bed steam reforming (FBSR). A second alternative would be to separate Tc-99 from select high-risk wastes for treatment with grout.

- If an offsite disposal location can be found, treat low-risk wastes using grouting for off-site disposal. Certain LAW streams (e.g., those from the offgas system) may be solidified for off-site disposal.

The above example is not exhaustive; however, it gives a flavor of the thought processes involved. A formal intentional blending evaluation (that also includes a cost-benefit analysis of constructing a new mixing / blending facility) should be conducted using the results of the targeted scenario analysis. Significant uncertainties should be accounted for in the evaluations to develop a robust strategy for treating Hanford LAW.

[20] It may be found to be advantageous to the overall treatment schedule to manage a “small increment” of very difficult to treat wastes outside the vitrification facilities currently under construction using specialized treatment techniques.

6.5.3 Implement previous recommendations that potentially impact alternative treatment technologies and forms for Hanford LAW

Previous recommendations were made by the 2009 External Technical Review (ETR) Team [58] that evaluated Hanford modeling and simulation tools and the 2010 EM-TWS [59] that should be implemented:

- Complete the enhancements to the HTWOS model to support life-cycle cost modeling and future high-level planning; important tank waste and processing chemistries and significant uncertainties must be incorporated in the planning model to inform System Planning and the alternative treatment technology and waste form selection processes.

- Institute recommendations made by the ETR Team to capture the significant knowledge concerning waste forms and product acceptance that may be lost because of the significant lag (more than a decade) between when Hanford LAW treatment processes and corresponding waste forms are first selected and the beginning of WTP operations.

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APPENDIX 7
In-Tank/At-Tank Technologies

7.1 Introduction

The Savannah River Site (SRS) Actinide Removal/Modular Caustic Side Solvent Extraction process (ARP/MCU) has treated nearly 1.5 million gallons of salt waste since beginning operations in April 2008. Full-scale deployment of ARP/MCU technology in the Salt Waste Processing Facility (SWPF) has been delayed from May 2013 to July 2014, albeit with nameplate capacity increasing from 5.7 million gallons per year to 6.8 million gallons per year due to the introduction of an improved cesium extractant. Without additional salt waste processing capacity, SRS will be unable to meet the Federal Facility Agreement commitment to remove the last old-style tank from service by 2022 or the Site Treatment Plan goals of completing waste removal operations by 2028. The construction, commissioning, and operation of the Small Column Ion Exchange Process (SCIX) is expected to not only eliminate this shortfall, but to accelerate the end of waste removal operations by three years to 2025 [1].

The River Protection Plan (RPP) System Plan 5 Base Case is predicated on the entire Hanford Waste Treatment Plant (WTP) starting hot commissioning in 2019 [2]. It is now expected that the WTP LAW facility will be available for hot commissioning in 2016. The Vision 2020 scenario has been proposed to take advantage of the early availability of the WTP LAW facility. This will require having a supply of treated LAW before the WTP PT facility starts hot operations.

The SRS SCIX project and Vision 2020 both utilize tank waste processing capacity technologies suitable for installation in or near existing storage tanks. Two other Hanford scenarios, Supplemental Treatment and the Enhanced Tank Waste Strategy also include tank farm processes for producing treated LAW. The SCIX project pretreatment scheme has three steps: (1) actinide removal, (2) filtration, and (3) cesium removal. Hanford requires two steps: (1) filtration and (2) cesium removal. The purpose of the In-Tank/At-Tank appendix is to review the history and current status of In-Tank and At-Tank technologies that have been considered for use at SRS and Hanford.

7.2 Charge

Task 3: Assess at-tank or in-tank candidate technologies for augmenting planned waste pretreatment capabilities.

This includes use of technologies currently being considered to perform some at- or in-tank pretreatment activities, such as rotary micro-filtration for solids separation and use of small-column ion exchangers for removal of cesium.

7.3 Background

Filtration

The tank farm salt waste treatment processes at SRS and Hanford require solids-free feed to the cesium removal step. The SRS in-tank SCIX process will use rotary microfilters. Hanford is considering rotary microfiltration for both in-tank and at-tank salt waste filtration processes. Crossflow filtration is a candidate for the Hanford at-tank process.

Crossflow Filtration

In crossflow filtration, slurry is recirculated through tubular filter elements at a very high velocity parallel to the filter surface (Figure 7-1). This produces shear forces that minimize solids buildup on the filtration surface.

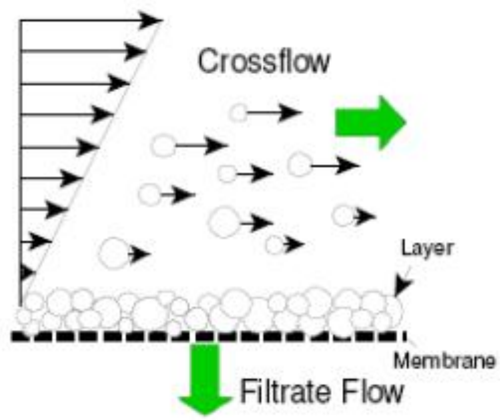

Figure 7-1. Crossflow Filtration

A slurry pump is used to recirculate slurry from a feed tank, through the filters, and back to the feed tank. The slurry pump also provides pressure to force filtrate through the filter membrane. A heat exchanger is usually required to remove heat generated by the pressure drop through the recirculation loop. Crossflow filtration often includes back pulsing at frequent intervals to disperse solids that accumulate on the filter membrane that occurs even in the presence of high slurry velocity. A typical crossflow filter installation is illustrated in Figure 7-2.

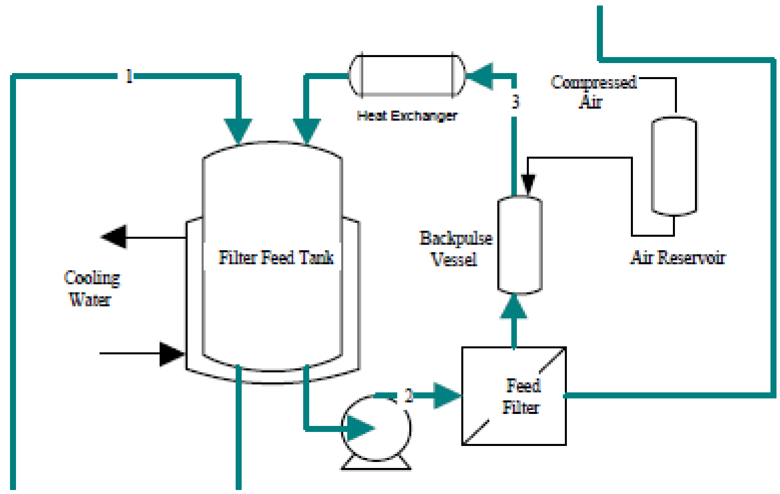

Figure 7-2. Typical Crossflow Filtration Schematic

Crossflow filtration has been used successfully at several DOE sites including the West Valley Demonstration Project and the Oak Ridge National Laboratory. It is currently being used at SRS where it has been operating in the ARP/MCU process since April 2008. During that time, roughly 1.5 million gallons of salt waste have been treated with high reliability and good process performance. The ARP/MCU crossflow filter contains a total of 230 square feet of filter surface. The permeate rate averages 7 gpm. The filter media is sintered stainless steel 316L, with a pore size of 0.1 µm [3].

Crossflow filtration was tested at engineering scale using Hanford simulant in the Process Engineering Platform (PEP) [4]. The Process Engineering Platform includes a prototype of the filters being installed in the Hanford WTP PT process, but with a reduced number of full-size filter elements compared to WTP PT. It has a total filter area of 72.3 square feet contained in two tube bundles of eight-foot long filter elements and three tube bundles of ten-foot long filter elements. The filter media is sintered stainless steel, having a pore size of 0.1 µm [4]. PEP filtration modules details are presented in Figures 7-3, 7-4, and 7-5. The conceptual Hanford at-tank CFF has two filter bundles, each containing 37 eight-foot long filter elements. The total effective filtration area is 77 ft^2 [5].

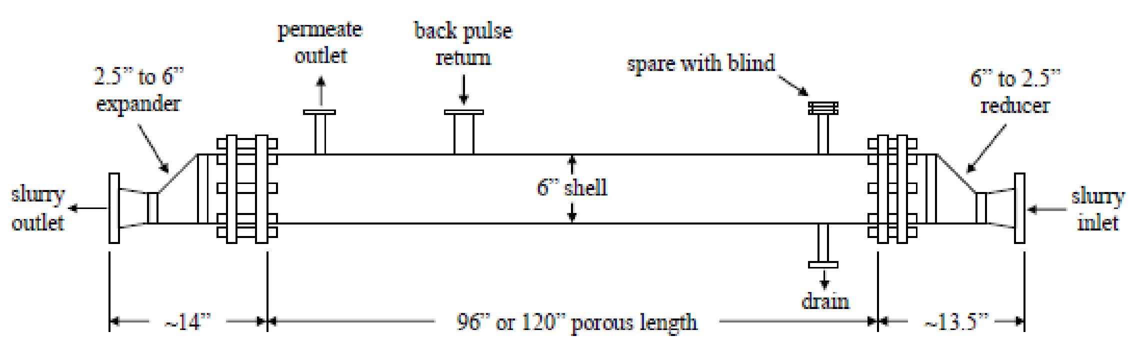

Figure 7-3. PEP Filter Module

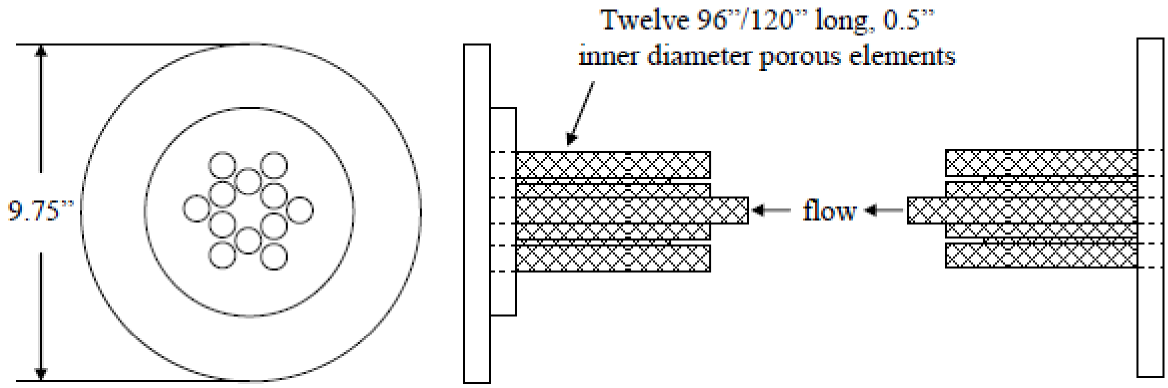

Figure 7-4. PEP Filter Tube Arrangement

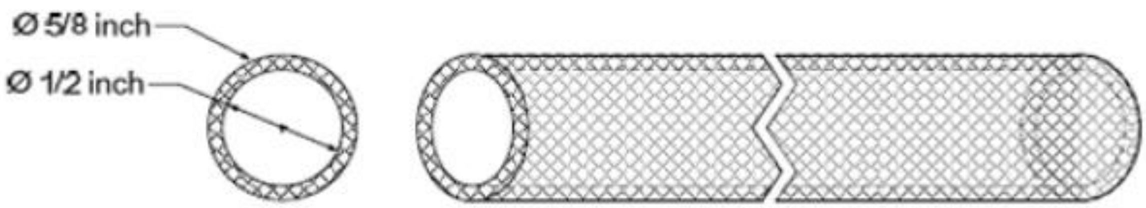

Figure 7-5. PEP Filter Tube

A variety of PEP filtration tests have been run using Hanford simulants. Low-Solids Scaling Test #1 is of particular interest since the 6.9 wt percent undissolved solids slurry used in that test approximates the upper range of solids concentrations expected to be encountered in the Hanford tank farm pretreatment process. Slurry was recirculated through the filter at 109 gpm, 26.5 °C and a trans-membrane pressure of 40 psid. The filter flux ranged from .03 to .07 gpm/sq ft, corresponding to 2 to 5 gpm. Filter flux as a function of time is shown in Figure 7-6.

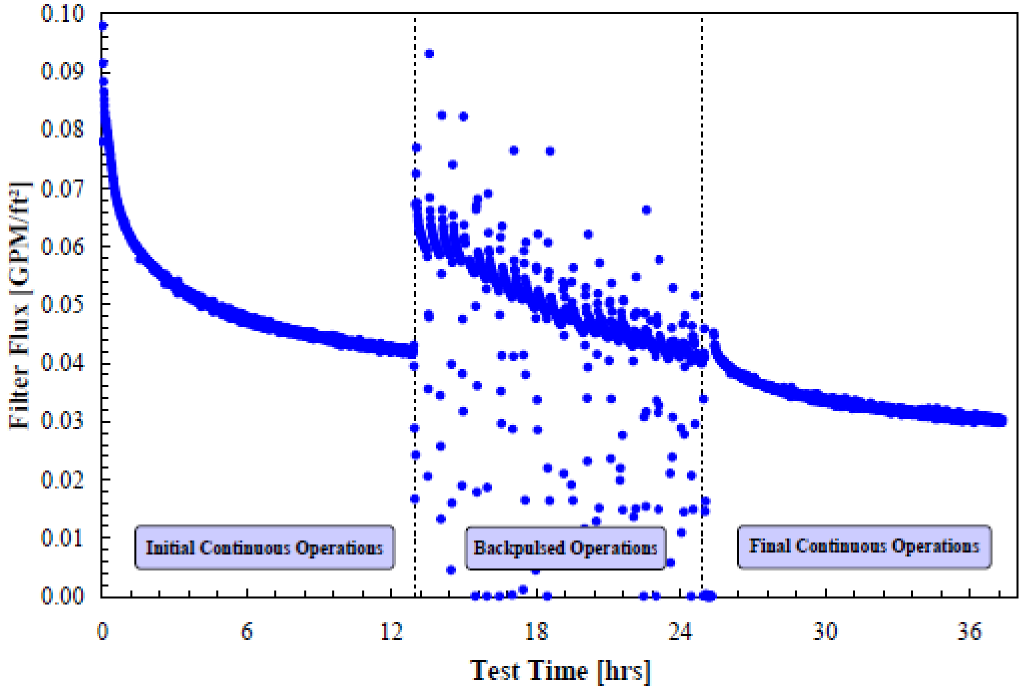

Figure 7-6. PEP Low-Solids Scaling Test #1 Filter Flux Results

The Cells Filtration Unit (CUF) contains a single two-foot-long filter tube. It is shown in Figure 7-7. The radial dimensions and filtration ratings of the CUF filter elements are identical to those used in the PEP and WTP PT [4]. Experience has shown that CUF results match the performance of full-size filter tubes. Tests have been run using the CUF on actual Hanford waste material from several individual tanks. There have also been more than 30 tests run on multi-tank samples representing over 80 percent of the Hanford waste types.

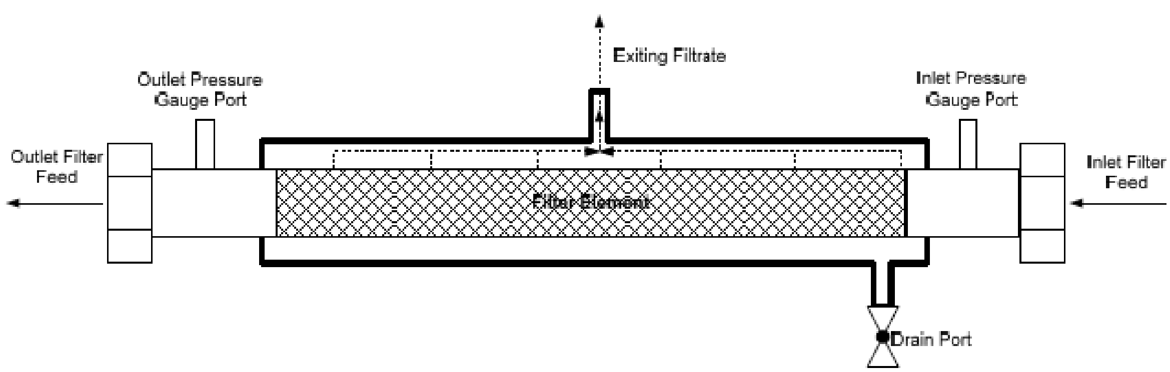

Figure 7-7. CUF Test Unit

Rotary Microfiltration

Rotary microfilters (RMFs) have been purchased for use in SRS SCIX. They are also being considered for Hanford in-tank deployment. The SpinTek RMF was developed jointly by the DOE and SpinTek. It has been tested at the Savannah River National Laboratory (SRNL) and modified for operation in a radioactive environment, including the use of radiation-tolerant materials of construction and a modular design that contains filter disc stacks, seals, and rotary unions all within a removable unit.

Each RMF unit contains 25 filter disks with 0.5-μm pore size membranes made of sintered 316L stainless steel. The disks are physically mounted on and hydraulically connected to a single hollow rotating shaft and enclosed within a vessel. The filter area of a single disk is 0.98 ft^2, providing an effective membrane area of 24.5 ft^2 per 25-disk unit. The volumetric hold up is approximately four gallons for a 25-disk unit. Each 25-disk unit is 14 inches diameter and 21 inches high, not including the motor.

Feed enters the filter assembly through an inlet on the side of the vessel wall. The trans-membrane pressure is set at 40 psid by restricting the outlet flow with a valve on the concentrate piping. A 25-disk unit RMF unit is expected to operate with a slurry feed rate of 25 to 50 gpm supplied to the RMF at 80 to 100 psig. Under these conditions, the permeate rate will be about 2 to 3 gpm.

Turbulence promoters are located between adjacent filter disks. The turbulence promoters generate eddies at the surface of the membrane, inhibiting the formation of a filter cake. Filtrate flows through the media and along a support mesh inside the disk into the hollow shaft then through the shaft to a rotary joint, which allows the spinning shaft to couple to stationary piping. The concentrated slurry exits the vessel through an outlet on the bottom. Figure 7-8 illustrates the flow paths through the SpinTek rotary microfilter.

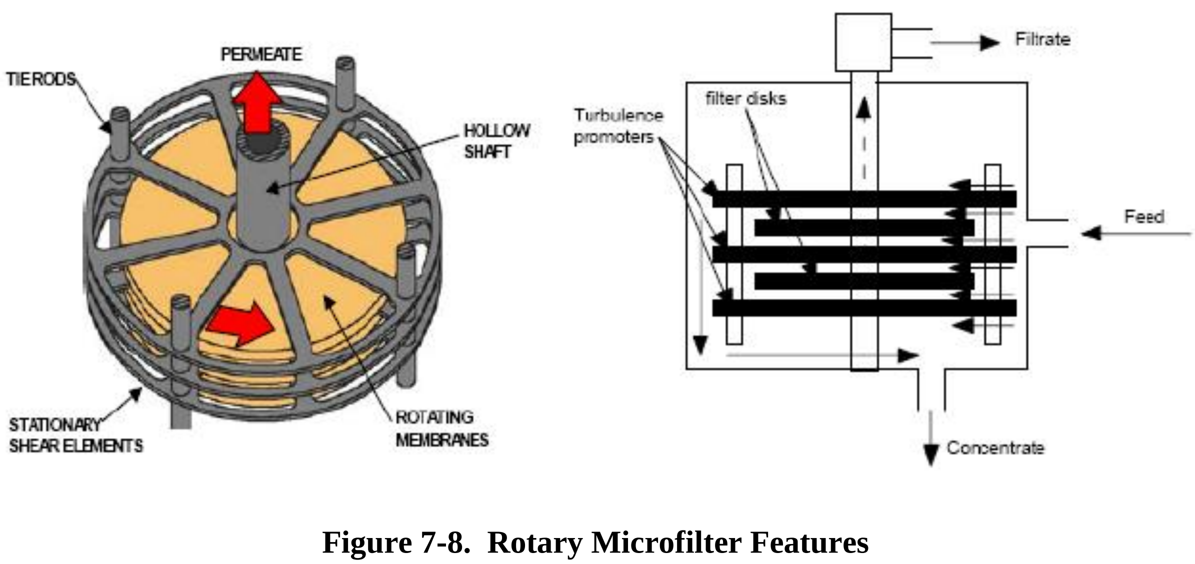

Figure 7-8. Rotary Microfilter Features

The RMF contains two rotating seals and a bottom bearing (Figure 7-9), all of which have been modified based on problems encountered over more than 3,500 hours of test operation with full-size units. The most recent 1,000 hours of operation has been uneventful, with no seal leaks observed during sludge washing trials using simulant up to 15 weight-percent solids.

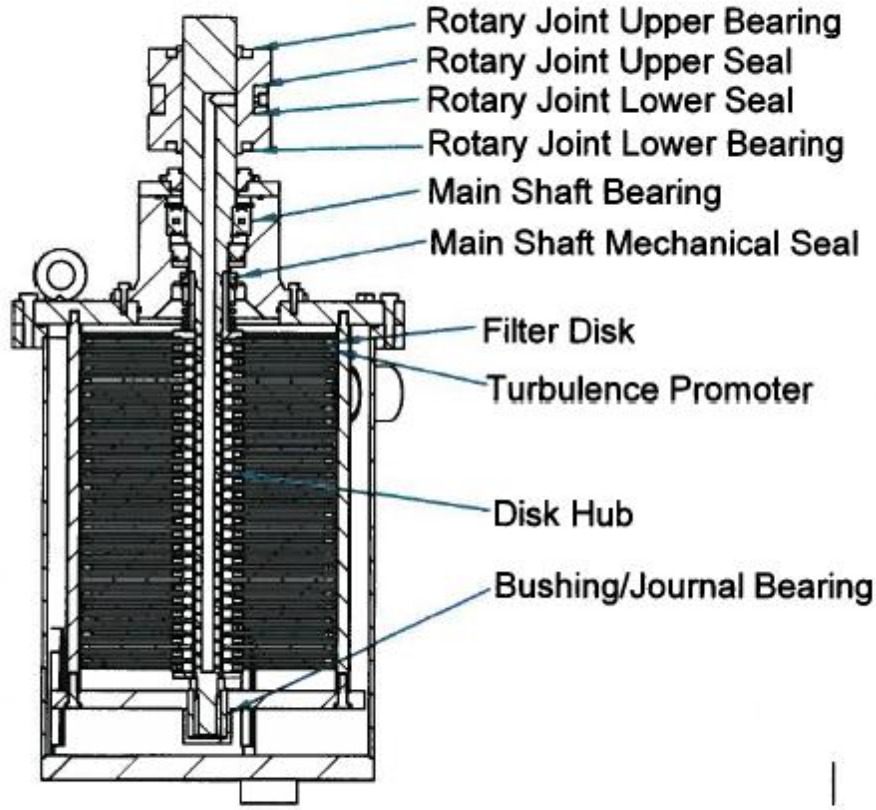

Figure 7-9. Filter Rotary Seals

RMF flux data for simulants and actual Hanford waste are summarized in Figure 7-10 [5]. Filter fluxes from about 0.05 to 0.20 gpm/sq ft (about 1 to 5 gpm for a 25-disk unit) were observed over a wide range of undissolved solids concentrations. In two tests, low filtration rates were encountered during tests with actual Hanford waste. This was attributed to running the tests without first cleaning the filter disks.

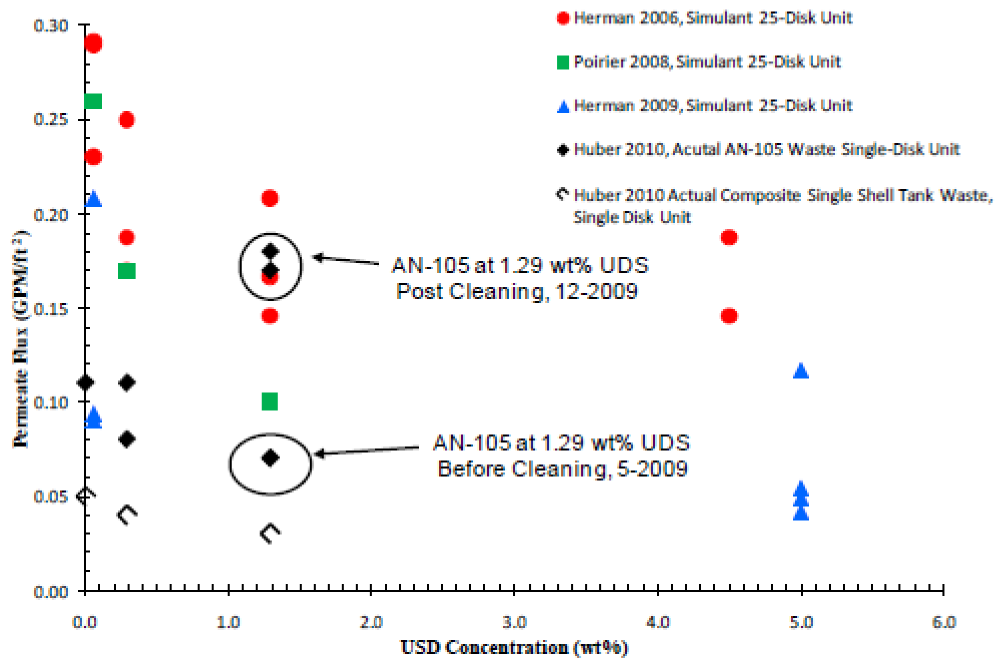

Figure 7-10. Rotary Microfilter Flux

Relative Performance: RMF vs. CFF

The following summary of filter performance is based on CFF operation in ARP/MCU and RMF test results for actual Hanford waste. While approximate, it provides perspective regarding the relative performance of these two filter types in salt waste service.

Filter Performance (Salt Waste/Supernate)		
	Rotary Micro Filter	Crossflow Filter
Filtration Area, sq ft	25	38
Permeate, GPM	~3	~1
Dimensions	14"D x 40"H	12"D x 120"L

Chemical Cleaning: RMF vs. CFF

It is necessary to chemically clean the RMF and CFF filter media, from time to time. It is expected that a rotary microfilter will require chemical cleaning as infrequently as once a year, compared with eight times each year for a crossflow filter. In this case, the total quantity of cleaning agent required for cleaning an RMF will be at least 80 percent less than what's needed to clean a CFF. Based on the current usage of about 17,000 gallons per year of oxalic acid used to clean the ARP/MCU CFF, it has been estimated that cleaning four 25-disk RMFs will require slightly less than 1,000 gallons of nitric annually [3].

Cesium Removal

CST was selected over sRF for use in the SRS SCIX process, based on a detailed downselect process [6]. CST was considered to be the more mature technology. It was concluded that sRF is more operationally complex because of additional processing steps required to elute the media. Finally, it could not be used at SRS without additional evaporator capacity, a strong disincentive. Crystalline silicotitanate and spherical resorcinol formaldehyde ion exchange resin are both being considered for use in the Hanford in-tank and at-tank processes [6, 7]. The downselect process is expected to be finished by September 2011.

Crystalline Silicotitanate History

CST was developed at Sandia National Laboratories and Texas A&M University. Patents have been issued for its preparation, with niobium-doped materials for removal of cesium from radioactive waste solutions. A near spherical engineered form of CST, IONSIV® IE-911, is commercially available. CST is discarded after one loading cycle and replaced with fresh material.

Ion exchange materials including CST, zeolite, and phenyl formaldehyde were evaluated in the early 1990s as potential replacements for precipitation processes for removal of cesium, strontium, and plutonium from salt solutions at SRS. It was reported in 1992 that "The SRS Ion Exchange Technology Assessment Team has determined that ion exchange technology has evolved to the point where it should now be considered as a viable alternative to the SRS reference ITP/LW/PH process [8]."

Several ion exchange materials were tested using bench-scale columns in 1995 at ORNL. Ion exchange performance was evaluated using MVST-27 supernate. The commercially available candidates were CST, RF, SuperLig® 644, and 3M-WWL. 3M-WWL was eliminated due to poor physical stability.

Zeolite was used at WVDP and was considered a widely available, low-cost alternative media. Some experimental work was done on zeolite as a substitute for CST. The lower purchase price per pound for zeolite was offset to a large extent by the much greater quantity required to treat the salt waste, the resulting cost to produce additional HLW canisters in the DWPF, and the cost to disposition those additional canisters to a waste repository [9].

CST was selected for use in the Cesium Removal Demonstration Process to treat Melton Valley Tank 27 supernate. IONSIV® IE-911 was used in skid mounted ion exchange columns, one foot in diameter. About 30,000 gallons of radioactive supernate were initially processed with minimal operating problems. It was reported: "After the demonstration, the skid-mounted ion-exchange system was modified and operated from 1997 through 2000 and was successfully deployed for 14 operational campaigns. During this period, the system processed more than 215,000 gallons of radioactive supernate and removed ~9000 Ci of ^{137}Cs from the supernate. The deployment of the skid-mounted system within existing containment facilities at ORNL was an important concept that was successfully demonstrated." In all, over 250,000 gallons of radioactive waste were treated using CST [9].

IONSIV® IE-911 was tested and reported to be suitable for removing cesium from SRS radioactive waste in 1999. Using salt solution from SRS Tank 44F, it was found that the treated waste met all Saltstone requirements for ^{137}Cs. It was also reported that "Leaching and precipitation of a proprietary component of IONSIV® IE-911 poses a problem with column plugging. During sodium hydroxide pretreatment of the packed column, the leached material plugged the test column [to a depth of one centimeter] [10]."

Column testing was also performed with IONSIV® IE-911 using Hanford AW-101 tank supernate. This waste supernate was relatively low in hydroxide with the following measured concentrations for selected species: 5.6 M Na^+, 0.5 M K^+, 0.57 M Al, and 2.54 M OH^-. Fifty percent cesium breakthrough was observed after processing approximately 700 bed volumes [11].

Other instances of clumping and bridging of CST in packed columns have been reported. It is believed that the clumping is associated with leaching of materials from the IONSIV® IE-911 and the formation of aluminosilicate bridges between individual particles. Excess reagents (Si, Ti, Nb) from the IONSIV® IE-911 manufacturing process are believed to be the main cause of this problem. It has been found that that these materials leach from IONSIV® IE-911 during caustic washing. Three-molar NaOH was found to be most effective at removing these materials, although they were difficult to wash away completely. Tank waste constituents may also contribute to clumping if the pH is too low. Tests using a caustic washed product, IONSIV® IE-911 CW, with bounding simulants revealed that only weak clumping occurs over several weeks with minimal impacts expected for real waste processing [11].

The capacity for high cesium loading presents a problem when using CST. This issue has been addressed by limiting the use of CST to small ion exchange column applications: "In the large CST columns (16 feet high with a diameter of 5 feet) evaluated for DWPF, the large ^{137}Cs source (up to 5.8 million curies) would generate enough heat to boil the salt solution within the column in about 33 hours should loss of flow occur. Boiling can be prevented by keeping the diameter of the column below 32 inches, limiting cesium loading, and cooling with ambient air and water.

Computer models were used to estimate conditions that would result from two scenarios: loss of permeate flow to a cesium loaded CST column and loss of both permeate flow and cooling water flow to a cesium loaded CST column. The report, *Thermal Modeling Analysis of CST Media in the Small Column Ion Exchange Project* [12], states: "The calculation results showed that for a wet CST column with active cooling through one central tube and four outer tubes and 35 °C ambient external air, the peak temperature for the fully-loaded column is about 63 °C under the loss of [permeate feed], which is well below the supernate boiling point. The peak temperature for the naturally cooled (no active engineered cooling) wet column is under 156 °C under fully loaded conditions, exceeding the 130 °C boiling point. Under these conditions, supernate boiling would maintain the column temperature near 130 °C until all supernate was vaporized. Without active engineered cooling and assuming a dry column suspended in unventilated air at 35 °C, the fully loaded column is expected to rise to a maximum of about 258 °C due to combined loss of coolant and column drainage accidents.

In order to avoid clumping and binding of the CST beads resulting from precipitation, which is enhanced at elevated temperatures, the project might consider adding a mechanism for emergency feed displacement from the column (though this will result in increased H_2 generation from radiolysis) [11]."

Spherical Resorcinol Formaldehyde Resin History

Resorcinol formaldehyde (RF) ion exchange resins were developed by Westinghouse at the Savannah River Technology Center in the late 1980s [13]. Two SRNL patents were issued for the preparation of monolithic RF and its application in a ground form for cesium removal from solutions containing high sodium ion concentrations. Patents have been issued to others for preparation of narrow particle size distribution spherical RF beads [14]. RF is a regenerable ion exchange resin. Resin in the Na^+ form is used to remove cesium from the ion exchange column feed. The cesium is removed from the resin by eluting with nitric acid. Six batches of sRF have been produced at two different commercial facilities.

Resorcinol formaldehyde ion exchange resin was tested in 1994 using simulants of Melton Valley, Savannah River, and Hanford wastes with promising results [13]. Also in 1994, plans were published describing the Initial Pretreatment Module, a project that would ultimately become the RPP WTP. Logic was presented for selection of ion exchange over solvent extraction for the cesium removal. Among the reasons, it was reported that organic cation exchange resins had been employed successfully at the Hanford Site on a plant-scale for many years to remove cesium from alkaline wastes. Two candidate ion exchange resins were specifically mentioned: granular resorcinol formaldehyde and Duolite® CS-100, a granular phenol formaldehyde resin manufactured by Rohm and Haas Company.

Interim Pretreatment Project reports described other methods for removing cesium from alkaline solutions as having disadvantages compared to the well-established organic ion exchange resins. Silicotitanates and zeolites were considered for cesium ion exchange, but it was said that they contained significant amounts of aluminum, silicon, and sodium, all limiting components in glass feed formulations. Various precipitation agents such as tetraphenyl boron, nickel ferrocyanide, and phosphotungstate, were eliminated as candidates because they were considered to be inappropriate for use in a continuous process. Solvent extraction processes employing extractants such as BAMBP, dipicrylamine, polybromides, and crown ethers were eliminated because they were not fully developed or might require the use of "toxic diluents such as nitrobenzene."

Ultimately, SuperLig® 644 (SL-644) was chosen for the RPP WTP Project, although the EM-TWS has not been able to locate documentation for the selection process. In 2002, due to ORP concerns over the risk posed by reliance on a single supplier for the WTP PT ion exchange resin, Bechtel National began work on finding an alternative material [15]. In addition to concerns about lack of multiple suppliers, the physical breakdown of SuperLig® 644 during repeated loading, elution, and regeneration cycles was identified as a problem.

BNI recommended that resorcinol formaldehyde resin be pursued as a potential alternative to SL-644. RF had been extensively tested to support the Initial Pretreatment Module project during the late 1980s to early 1990s. Both batch and column testing of the ground gel RF resin had been conducted at Pacific Northwest (National) Laboratory (PNL/PNNL) and the Savannah River Laboratory. The resin was found to have a high loading and selectivity for cesium from Hanford Site tank wastes, and cesium could be eluted from the resin under acidic conditions.

Side-by-side testing of spherical RF, ground gel RF, and SL-644 using AZ-102 simulant (a high cesium concentration waste form) showed that sRF had adequate capacity and kinetics, better elution performance, and lower pressure drop during column operations than the ground-gel RF and SL-644. BNI completed the first stage of the implementation plan by selecting the sRF resin because it provided the best combination of characteristics required for WTP operations.

DOE-ORP directed BNI to initiate second-stage testing designed to evaluate sRF resin for WTP. This included a requirement to determine the impact of manufacturer variation on sRF resin performance. Spherical RF had only been produced in small laboratory-scale quantities. The scaleup work was successful, and it was demonstrated that batch-to-batch variability was not an issue.

Ultimately, sRF resin was chosen over granular RF and SuperLig® 644 [16]. In March 2006, BNI recommended that ORP replace SuperLig® 644 with sRF as the first choice resin for the WTP PT cesium ion exchange process based on the lower cost compared to SuperLig® 644 and the superior physical stability of sRF over the course of multiple loading/elution/regeneration cycles [9, 17].

Swelling During Ionic Form Transitions

CST is an inorganic ion exchange material. It does not undergo significant volume change going from one ionic form to another. That is not the case for organic resins such as resorcinol formaldehyde. Reversible swelling for sRF resin (from H^+ to Na^+) is 20 to 25 percent [11]. For comparison, reversible swelling (from Cl^- to OH^-) for Amberlite IRA-402, a general purpose anion exchange resin used in a wide variety of water treatment applications, is 30 percent. It is routine commercial practice to design ion exchange systems to accommodate swelling through a combination of equipment design and operating procedures, such as avoiding ion exchange column physical features that constrain resin swelling and operating in an upflow mode during steps in which the resin expands.

Elutable vs. Single-use Resin

The Savannah River SCIX process is an in-tank process. The report, *Small-Column Ion Exchange Alternative to Remove ^{137}Cs From Low-Curie Salt Waste: Summary of Phase* [9], noted that one of the primary benefits of an in-tank SCIX process is that “It can be deployed in the SRS tank farms in existing facilities with minimal construction.” This is consistent with the explanation presented to the EM-TWS during fact-finding meetings at SRS in March 2011 that construction costs for an in-tank option would be considerably less than those for an at-tank process. It was also stated that the H Tank Farm does not have sufficient space for an at-tank configuration. The SCIX conceptual design is described in the Modular Salt Processing Project Y-491 CD-0 Package as follows:

> The SCIX process will consist of one process feed pump, four rotary microfilter units, two ion exchange column units, and one spent resin disposal system installed in risers in waste tank 41H. The basis for sizing the rotary microfilters and ion exchange columns is to eliminate salt only Defense Waste Processing Facility canisters from the lifecycle. This requires an additional 2.5 million gal/year salt solution treatment capacity above the Salt Waste Processing Facility capacity of 6 million gal/year. The salt solution will contain up to 5.25 Ci/gallon ^{137}Cs. Assuming continuous operation at 75 percent attainment requires a nominal SCIX processing rate of 10 gpm.
>
> The salt solution must be filtered prior to passing through the [ion exchange] units to remove insoluble solids in the feed stream which would foul the ion exchange column. Furthermore, filtration of the feed to the [ion exchange units] can help ensure actinides are not present in the SCIX effluent which is required by the Saltstone Production Facility Waste Acceptance Criteria.
>
> Prior to processing through the the [ion exchange units], a monosodium titanate (MST) slurry will be mixed with the salt solution to adsorb the actinides and [strontium] in the salt solution. The MST is expected to collect in the bottom of waste tank 41H for disposal through the Defense Waste Processing Facility. The SCIX effluent, decontaminated salt solution (DSS), will be transferred to the MCU DSS hold tank and then later transferred to the Salt Waste Processing Facility for eventual disposal as grout in the Saltstone Disposal Facility.
>
> The process utilizes a non-elutable ion exchange media, crystalline silicotitanate (CST) resin, for use in the [ion exchange] units to remove ^{137}Cs from the salt solution. CST can only be loaded with ^{137}Cs one time. Once loaded, the spent media must be removed and the [ion exchange units] replenished with fresh resin. Spent CST resin will be sluiced to the spent resin disposal system to reduce the particle size. The ground CST, laden with ^{137}Cs, is then transferred to a sludge batch for ultimate disposal at DWPF. The spent CST resin must be ground to facilitate transfer to tank 40H and to enable resuspension of the ground CST resin for transfer from tank 40H to the Defense Waste Processing Facility and to accommodate the Hydragard® sampler in the DWPF.
>
> Modeling and gamma monitoring will be performed to determine the actual CST resin replacement frequency. For the purposes of this document, the baseline assumption is that CST resin will be replaced once every two weeks, based on operating 24 hours a day, seven days per week [18].

The process is illustrated schematically in Figure 7-11.

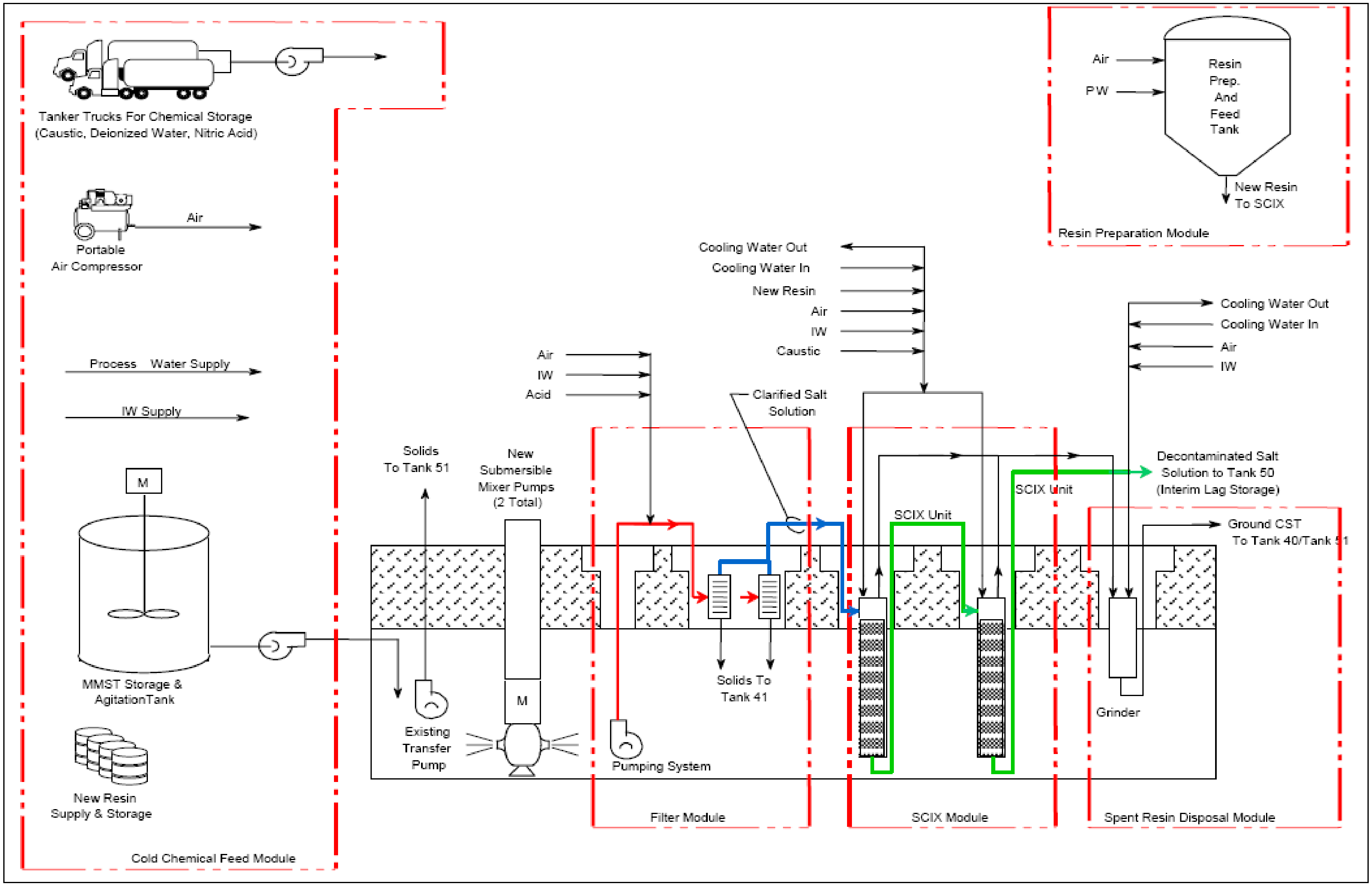

Figure 7-11. SRS SCIX Schematic Diagram

The capacity for high ^{137}Cs loading presents a problem when using CST. This issue has been addressed by limiting the size of ion exchange columns, limiting ^{137}Cs loading, and cooling with water [9]. The SCIX ion exchange columns will be 32 inches in diameter and include a central cooling water pipe similar to the conceptual design illustrated in Figure 7-12. Resin will be loaded in the 11-inch-wide annular space between the cooling pipe and the vessel wall.

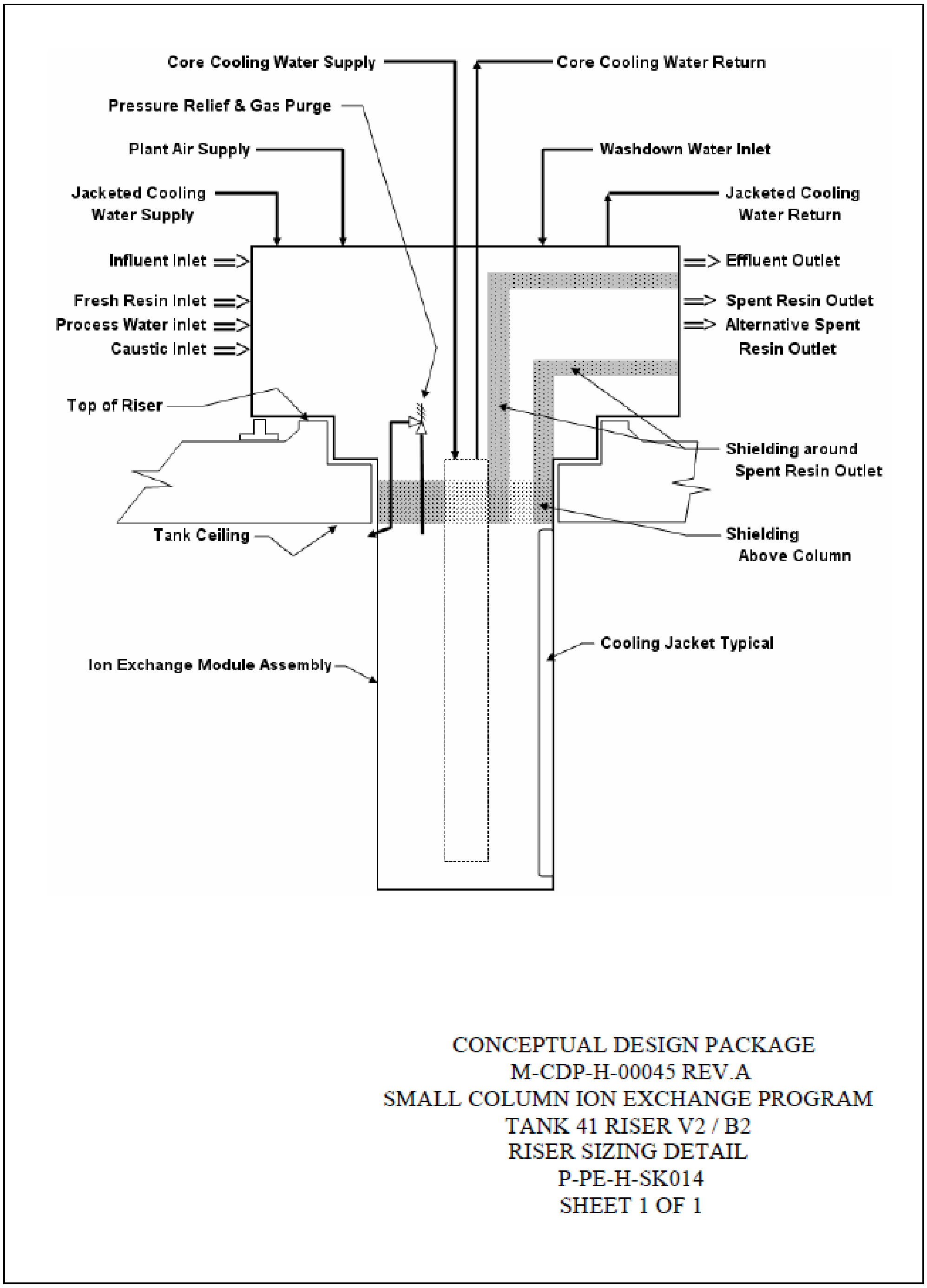

Figure 7-12. SCIX Ion Exchange Column Conceptual Design

The spherical resorcinol formaldehyde ion exchange option was eliminated during the SRS SCIX downselect process for ^{137}Cs removal primarily due to problems associated with the disposition of nitric acid eluent [6]. It was reported: "For sRF, the best option was a direct transfer [of eluate] to DWPF. This requires a new denitration evaporator to be considered a viable option. The nitrate from the 0.5M eluate causes the chemical process cell to become oxidizing and creates foaming problems in the melter. Also, the nitrate largely [will return] to the tank farm in the form of condensate from the acid evaporator, requiring storage and eventual treatment in SWPF."

Because of the complexity of the solution in DWPF, another option of sending the acidic eluate stream, after neutralization, to a tank farm evaporator was also considered. However this option can only be implemented on a temporary basis to achieve much needed tank space. Although the salt solution is processed through SPF, the concentrated cesium stream is returned to the tank farm and must be re-processed to disposition the cesium." This concern has been addressed in the design of the Hanford WTP PT process by including an evaporator to concentrate the eluent, and recycling nitric acid to the ion exchange system. The concentrated eluent is combined with other HLW materials and fed to the HLW glass plant.

In the ARP/MCU process, the MST strike step is done batchwise by mixing MST and salt waste in a 5000 gallon mechanically agitated process tank. The MST absorbs strontium and actinides. This is followed by filtration to separate the actinide loaded MST and other solids from the process stream prior to cesium removal by solvent extraction.

In SCIX, the MST strike will occur in a 1.3 million-gallon tank. Mixing will be through the use of three submersible mixing pumps. Although submersible mixing pumps have been used elsewhere in SRS, the combination of changing the MST strike mixing technology and significantly increasing the process scale contributes uncertainty to the SCIX process. The SCIX MST strike process has been extensively studied in an 800-gallon prototype tank. Due to the large size difference between the prototype tank and the actual tank, considerable work has been done to establish valid scaleup parameters. Process parameters, such as the number and size of the submersible mixing pumps, have been established based on scaleup from the prototype tank.

Spent CST, loaded with ^{137}Cs will be ground using an immersion mill installed in one of the tank 41 risers. A similar process, using an immersion mill installed inside a tank riser, has been used before at SRS for processing zeolite. No significant problems were encountered.

Models were used to assess thermal risks associated with discharging fully loaded, ground, CST into SRS storage tanks [12].

> Results for the in-tank modeling calculations clearly indicate that when realistic heat transfer boundary conditions are imposed on the bottom surface of the tank wall, as much as 450 gallons of ground CST (a volume equivalent to two ion exchange processing cycles) in an ideal hemispherical shape (the most conservative geometry) can be placed in the tank without exceeding the 100 °C wall temperature limit. Furthermore, in the case of an evenly distributed flat

layer, the tank wall reaches the temperature limit after the ground CST reaches a height of 8 inches.

Hanford At-Tank Pretreatment Process

The following is a description of the Hanford at-tank Supplemental Pretreatment System [5]. The details are subject to change based on work currently in progress to develop a CD-1 conceptual design package.

Figure 7-13 presents the daily material balance for the conceptual Hanford at-tank Supplemental Treatment Process. The instantaneous throughput rate is estimated to be 8,200 gallons per day (5.7 gpm) of treated LAW. This is about three times the rate that would be required for the Vision 2020 scenario, assuming an output of one LAW canister per day.

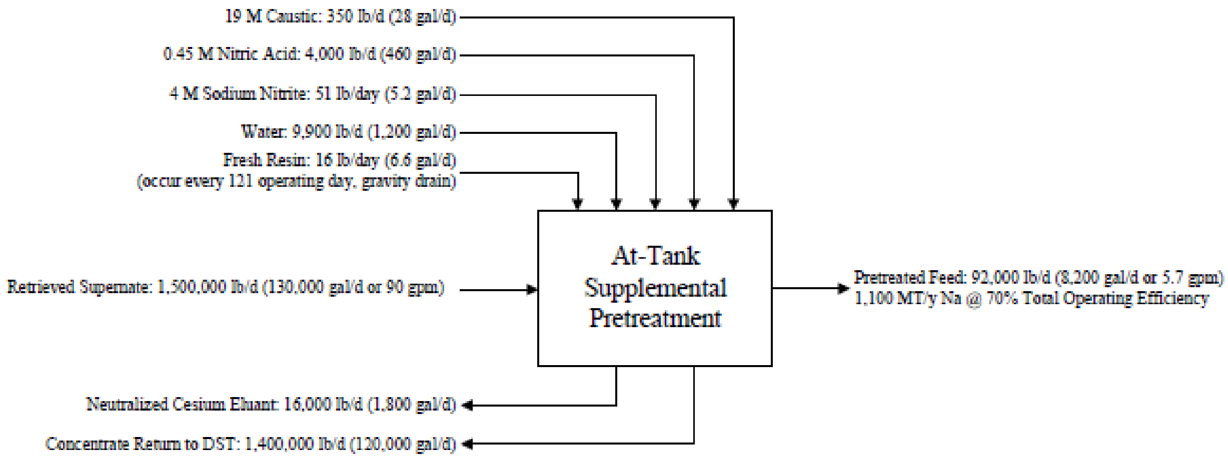

Figure 7-13. Hanford At-Tank Supplemental Pretreatment Process Mass Balance

Equipment that contains large radionuclide inventories is located in shielded vaults. Piping within these vaults is all welded to minimize potential leak points, with the exception of jumpers installed to facilitate equipment removal. Generally, components that may require maintenance or replacement (e.g., valves and instrumentation) are located in a central valve vault, on jumpers if necessary. Vault covers consist of removable concrete blocks to provide maintenance access to all locations within the vaults.

The crossflow filters will be accessed by remote piping connections to allow removal and replacement of the entire filter assembly. The recirculation pump will be located in the valve vault to allow accessibility for maintenance. All piping to the ion-exchange columns will include jumpers for replacing columns.

Process support equipment is located above grade. The process offgas, vault ventilation, recirculation air-handling units, sampling, and spent resin disposal cask offload are located in enclosed structures with personnel access for operation and maintenance. The chilled water system and chemical reagent tanks (with containment basins) are located outdoors on concrete pads. The process offgas and recirculation air-handling unit rooms are part of the secondary confinement boundary. Vehicle access must be provided for chemical reagent delivery and spent resin disposal cask delivery and transport.

The at-tank pretreatment process uses crossflow filtration technology similar to the WTP PT process. Elements are fixed in bundles containing 37 filters each. Two filter bundles are used, comprising an effective filtration area of 77 ft^2. Each filter bundle will be approximately 10 feet long. Filter tube lengths have been reduced to eight feet to decrease axial pressure drop as compared to the ten-foot long tubes in the WTP PT to reduce the axial pressure drop, which is expected to result in a more uniform filter cake along the length of the filter.

The at-tank cesium ion-exchange system is located in a shielded facility within the 200 West Area. The ion exchange system contains two columns, operated in series. Both columns are the same size and configuration. The ion exchange column bed diameter and resin bed height are 33 inches and 40 inches, respectively. The column is 67 inches high. Each resin bed contains 150 gallons of spherical resorcinol formaldehyde ion exchange resin.

The proposed at-tank crossflow filtration system operates at 25 °C, while the ion exchange columns operate at 35 °C. This is different from the in-tank process in which both operate at 35 °C. The 10 °C temperature difference between the crossflow filtration and cesium ion-exchange modules is used to minimize potential solid particle formation in the feed to cesium ion exchange.

The ion exchange process entails several steps. The first step is the loading, during which time ^{137}Cs is removed by passing RMF permeate through the lead and lag columns in series. Loading is followed by elution with nitric acid to remove ^{137}Cs from the resin. Finally, the resin is returned to the Na^+ form by regenerating with NaOH.

Spent resin will be removed from the ion exchange columns two to three times per year by fluidizing the column with water then transferring the suspended resin to a spent resin accumulation tank. Spent resin is removed from the system as a solid waste. The accumulated spent resin slurry is transferred from the spent resin tank into a cask with an internal screen. The liquid will be removed from the cask to comply with solid waste disposal criteria.

The process is shown schematically in Figure 7-14.

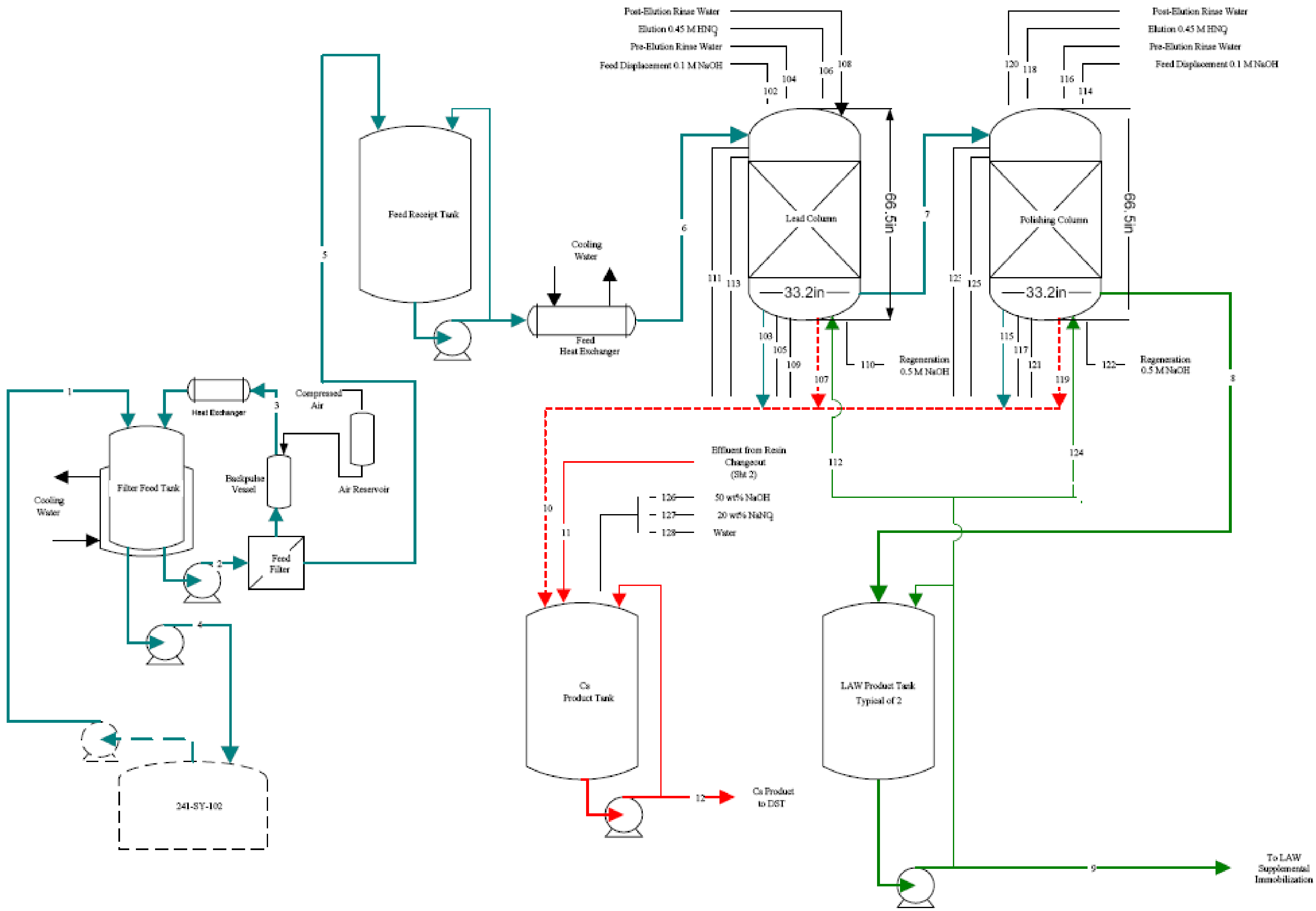

Figure 7-14. Proposed Hanford At-Tank Pretreatment Process[19]

Hanford In-Tank Pretreatment Process

The following is a description of the Hanford in-tank pretreatment process based on pre-decisional information provided to the EMAB TWS during meetings with ORP and WRPS. The details are subject to change based on work in progress to develop a CD-1 conceptual design package.

The Vision 2020 scenario in-tank Interim Pretreatment System is expected to operate for fifteen months beginning October 2016. It will continue to operate until January 2018, when the WTP PT system begins hot operation.

Figure 7-15 presents the daily material balance for the conceptual Hanford at-tank Supplemental Treatment Process. The instantaneous production rate of treated LAW is expected to average 12,500 gallons per day (1.8 GPM @ 70 percent TOE) over the 15-month operating period. This corresponds to the production of one canister of LAW glass per day.

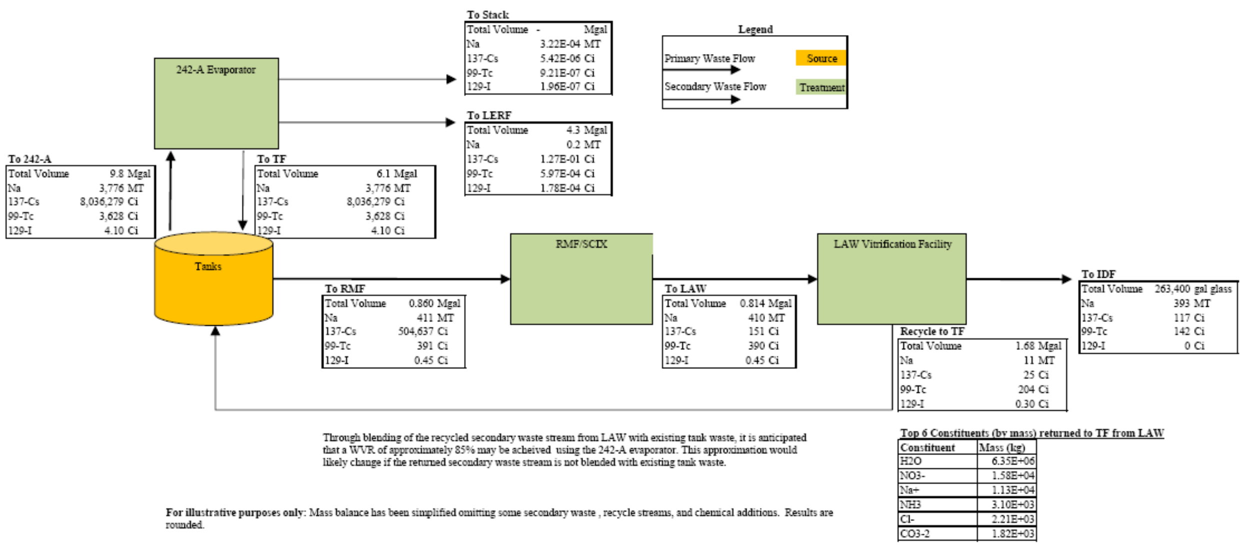

Figure 7-15. Pre-Decisional Hanford In-Tank Interim Pretreatment Process Mass Balance

The in-tank process equipment will include one rotary microfilter (RMF), an RMF feed pump, two ion exchange columns, and an eluent neutralization tank, all of which will be installed in existing risers in two double-shell storage tanks, AP-107 and AP-105. Existing concrete central pump pits located above the risers will serve as radioactive shielding and support platforms for the new process equipment. The Interim Pretreatment in-tank equipment is shown schematically in Figure 7-16.

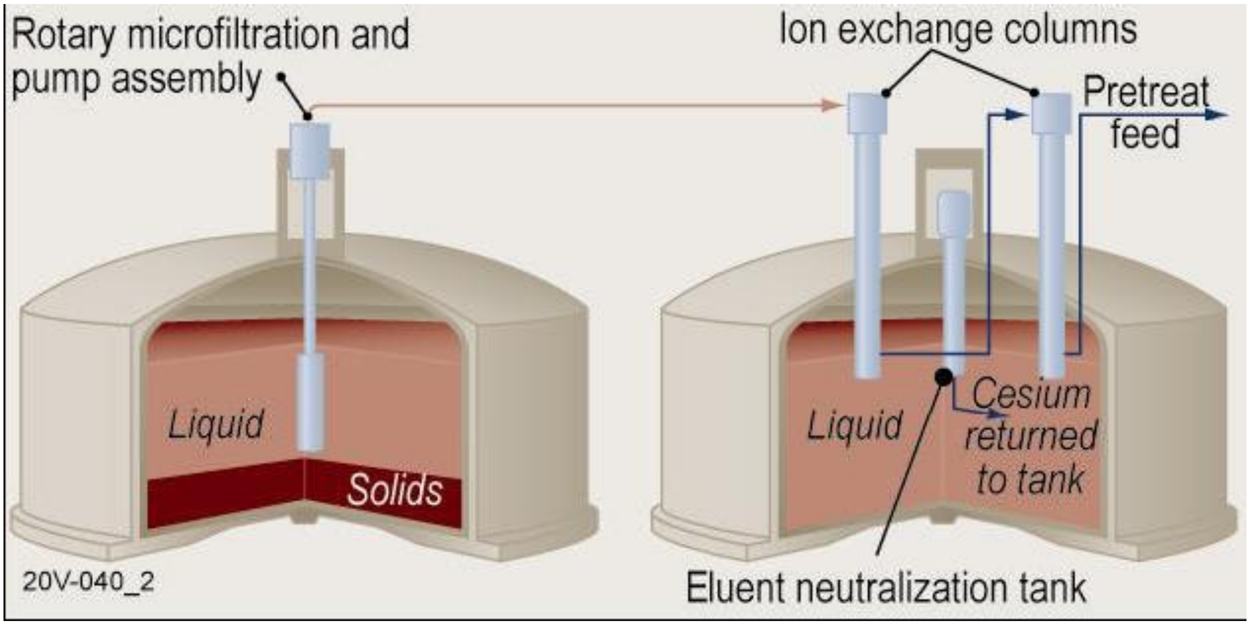

Figure 7-16. Pre-Decisional Interim Pretreatment RMF and SCIX Schematic

An assembly containing the filter feed pump and one rotary microfilter unit will be installed in tank AP-107. The RMF contains 25 filter disks with 0.5-µm pore size membranes made of sintered 316L stainless steel. The filter area of one RMF is 24.5 ft^2. The RMF is 14 inches in outer diameter by 21 inches in height, not including the motor.

The RMF feed pump supplies supernate feed to the filtration module at the required slurry feed flow rate and pressure. The permeate stream will flow directly from the RMF to the ion exchange system. Concentrated slurry will be returned from the RMF to tank AP-107.

The ion exchange system contains two columns in series. The first column is referred to as the "lead" column and the second column as the "lag" column. The ion exchange columns will be mounted in separate risers in Tank AP-105. The eluent neutralization tank will be installed in a third riser in Tank AP-105.

The ion exchange system produces two process streams: treated LAW that is cesium depleted and eluent that is an HLW ^{137}Cs-rich fraction. The ion exchange column bed diameter and resin bed height will be 18 inches and 40 inches, respectively. Each contains 45 gallons of spherical resorcinol formaldehyde ion exchange resin. The column height is 67 inches. Both columns are the same size and configuration.

The ion exchange process entails several steps. The first step is the loading, during which time ^{137}Cs is removed by passing RMF permeate through the lead and lag columns in series. Loading is followed by elution with nitric acid to remove ^{137}Cs from the resin. Finally, the resin is returned to the Na^+ form by regenerating with NaOH.

The ^{137}Cs-rich eluent stream is collected and temporarily stored in the eluent neutralization tank where it will be chemically adjusted to comply with the tank farm corrosion criteria. The treated eluent will be returned to tank AP-105 for eventual processing by WTP. The streams from the column rinsing and regeneration steps are also returned to tank AP-105.

Spent resin is removed from the system as a solid waste. It will be removed from the ion exchange columns two to three times per year by fluidizing the column with water then transferring the suspended resin to a spent resin tank. The accumulated spent resin slurry is transferred from the spent resin tank into a cask with an internal screen. The liquid will be removed from the cask to comply with solid waste disposal criteria.

The treated LAW feed will be stored in three new 15,000-gallon LAW product tanks. In addition, a series of supply tanks for 19 M sodium hydroxide solution, 4 M nitric acid, and 4 M sodium nitrite and water will support the ion-exchange processing steps and RMF cleaning. The process is shown schematically in Figure 7-17.

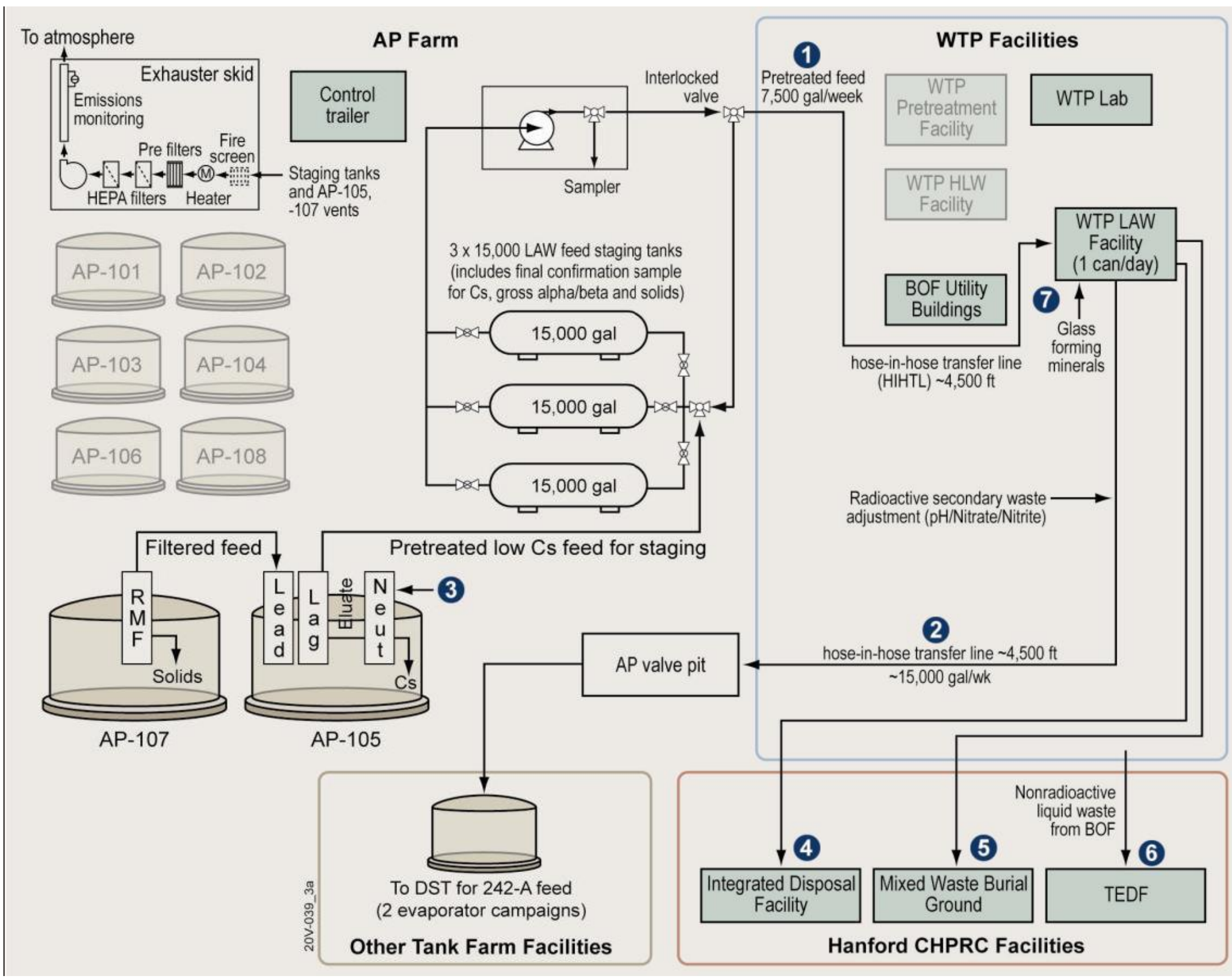

Figure 7-17. Predecisional Hanford In-Tank Pretreatment Process

7.4 Findings and Conclusions

Savannah River Site

1. EM-TWS agrees with the Savannah River Site's characterization of the SCIX process as a developmental process: "SCIX is a technology development and demonstration program. The SCIX activity will conduct an integrated full-scale operational test in order to obtain data and determine the feasibility for long-term deployment in an operational tank farm environment. Following that, DOE will make a determination (based on the results of testing and data evaluation) as to the potential for continued operations, or what if any capital improvements (engineering development) are needed to conduct long-term operations."

2. It has been reported that the in-tank SRS SCIX process is the lowest capital investment option because it can be deployed in the SRS tank farms in existing facilities with minimal construction. This is consistent with the explanation presented to the EM-TWS during fact-finding meetings at SRS in March 2011 that an in-tank option would cost considerably less to build than an at-tank configuration. The EM-TWS is not aware of any formal cost analysis supporting the choice of an in-tank option over an at-tank option.

3. EM-TWS agrees with the statement in *Literature Reviews to Support Ion Exchange Technology Selection for Modular Salt Processing* (WSRC-STI-2007-00609): "It appears that both ion exchange technologies [CST and sRF] are mature, well studied, and generally suitable for [the SRS SCIX process]. Technology selection will likely be based on downstream impacts or preferences between the various processing options for the two materials rather than on some unacceptable performance property identified for one material."

4. The spherical resorcinol formaldehyde ion exchange option was eliminated during the SRS SCIX downselect process for ^{137}Cs removal for several reasons. First, CST was considered to be a more mature technology. It was concluded that an sRF ion exchange system is operationally more complex because of the additional processing steps required to elute the media. It was determined that sRF technology could not be implemented at SRS without additional evaporator capacity, a strong disincentive. Finally, it was found that the most of the nitrate stream from the evaporator would return to the tank farm in the form of condensate, requiring storage and eventual treatment in SWPF.

5. An engineered form of CST, IONSIV® IE-911, was used in skid mounted ion exchange columns, one foot in diameter, at Melton Valley. About 30,000 gal of radioactive supernate was processed with minimal difficulty during the ORNL Cesium Removal Demonstration Process. After the demonstration, the skid-mounted ion-exchange system was modified and operated from 1997 through 2000 when it was successfully deployed for 14 operational campaigns. During this period, the system processed more than 215,000 gal of radioactive supernate. In all, over 250,000 gallons of radioactive waste were treated at ORNL using CST.

6. Laboratory-scale testing has been completed using IONSIV® IE-911 to treat SRS simulants and actual waste. In tests using salt solution from SRS Tank 44F, it was found that the treated waste met all Saltstone requirements for ^{137}Cs.

7. IONSIV® IE-911 is known to form agglomerates in salt waste service. This has been attributed to leaching of materials from the IONSIV® IE-911 and the formation of aluminosilicate bridges between individual particles. Excess reagents from the IONSIV® IE-911 manufacturing process, such as Si, Ti, Nb, are believed to be the main cause of this problem, although tank waste constituents may also contribute if pH is too low. It has been reported that Ti, Zr, and Nb leach from IONSIV® IE-911 during caustic washing. Three molar NaOH was found to be effective at removing these materials, although they were difficult to wash away completely. Tests using a caustic washed product, IONSIV® IE-911 CW, with bounding simulants resulted in only weak clumping over several weeks with minimal impacts expected for real waste processing [11].

8. Heat generation due to the high cesium loading capacity of CST has been addressed by limiting the use of CST to small ion exchange column applications. Computer modeling, completed in 2010, provided an estimate of conditions that would result from two scenarios: loss of permeate flow to a loaded CST column and loss of both permeate and cooling water flow to a loaded CST column. Loss of permeate flow could possibly occur due to loss of electricity, feed pump mechanical failure or CST an ion exchange column. Cooling water flow could be caused by loss of electricity or cooling water pump failure, among other things.

   The report, *Thermal Modeling Analysis of CST Media in the Small Column Ion Exchange Project* [12], states:

   > The calculation results showed that for a wet CST column with active cooling through one central tube and four outer tubes and 35°C ambient external air, the peak temperature for the fully-loaded column is about 63°C under the loss of [permeate feed], which is well below the supernate boiling point. The peak temperature for the naturally cooled (no active engineered cooling) wet column is under 156°C under fully loaded conditions, exceeding the 130°C boiling point. Under these conditions, supernate boiling would maintain the column temperature near 130°C until all supernate was vaporized.

   The SCIX Conceptual Safety Design Report identified ion exchange column over-pressure and explosion as a credible scenario if this occurs [19].

9. Spent CST, loaded with ^{137}Cs will be ground using an immersion mill installed in one of the Tank 41 risers. A similar process, using an immersion mill installed inside a tank riser, has been used before at SRS for processing zeolite. No significant problems have been encountered in that service.

10. Models were used to assess thermal risks associated with discharging fully loaded, ground, CST into SRS storage tanks [12]. "Results for the in-tank modeling calculations clearly

indicate that when realistic heat transfer boundary conditions are imposed on the bottom surface of the tank wall, as much as 450 gallons of ground CST (a volume equivalent to two ion exchange processing cycles) in an ideal hemispherical shape (the most conservative geometry) can be placed in the tank without exceeding the 100 °C wall temperature limit. Furthermore, in the case of an evenly distributed flat layer, the tank wall reaches the temperature limit after the ground CST reaches a height of 8 inches"

11. Crossflow filtration is currently being used at SRS where it has been operating in the ARP/MCU process since April 2008. During that time, roughly 1.5 million gallons of salt waste have been treated at a demonstrated filter flux of 0.03 gpm/sq ft. Filter availability has exceeded 90 percent since the beginning of ARP/MCU hot operation.

12. Rotary microfiltration has not yet been used to process actual salt waste at full scale in an operating environment. Single disk units have been run using actual waste from SRS and Hanford. Full-size filters have operated for over 3,500 hours on simulants, demonstrating both salt waste filtration and sludge washing capabilities. Operation on actual wastes in a tank farm environment will occur during the SCIX system startup beginning in June 2012.

13. The rotary microfilter contains two rotating seals and a bottom bearing, all of which have been modified based on problems encountered over more than 3,500 hours of operation with full-size units. The most recent 1,000 hours of operation have been uneventful, with no seal leaks observed during sludge washing trials using stimulant up to 15 weight-percent solids (SRNL-STI-2011-00008). While these results are very encouraging, mechanical reliability and maintainability have not been demonstrated during hot operation in an actual tank farm environment.

14. The ARP/MCU actinide removal process begins with batch mixing of MST and salt waste in a 5,000-gallon mechanically agitated process tank. The MST absorbs strontium and actinides. This is followed by filtration to separate the actinide loaded MST and other solids from the process stream prior to cesium removal using solvent extraction.

    In SCIX, the MST strike will occur in a 1,300,000-gallon tank. Mixing will be through the use of three submersible mixing pumps. Although submersible mixing pumps have been used elsewhere in SRS, the combination of changing the mixing technology and significantly increasing the process scale contributes uncertainty to the SCIX process. The SCIX MST strike process has been extensively studied in an 800-gallon prototype tank. Due to the large size difference between the prototype tank and the actual tank, considerable work has been done to establish valid scaleup parameters. Process parameters, such as the number and size of the submersible mixing pumps, have been established based on scaleup from the prototype tank.

Hanford Site

1. In 2002, due to ORP concerns over the risk posed by reliance on a single supplier, Bechtel National began work to find an alternative to SuperLig® 644 ion exchange resin. Batch and column testing of ground resorcinol formaldehyde resin was conducted at Pacific Northwest

(National) Laboratory and the Savannah River Laboratory. The RF resin was found to have high cesium loading capacity and selectivity for Hanford tank waste. Side by side testing of spherical RF, ground RF, and SL-644 using AZ-102 simulant showed that the spherical resin had adequate capacity and kinetics, better elution performance, and lower pressure drop during column operations than the ground RF and SL-644. In addition to concerns about lack of multiple suppliers, the physical breakdown of SuperLig® 644 during repeated loading, elution, and regeneration cycles was a serious problem. Ultimately, spherical RF resin was chosen over SuperLig® 644 [16].

2. Results for two bench scale tests using actual Hanford waste from AP-101 and AN-102 were reported to be acceptable. The results agreed with models and simulant testing. Exhaustive testing has been performed with Hanford simulants, including tests in a two-foot diameter column, which is close to the size proposed in the Hanford in-tank and at-tank conceptual designs.

3. Computer modeling was used to analyze the consequences of various scenarios in small column ion exchange including loss of both permeate flow and cooling water flow to a ^{137}Cs loaded sRF column. It was determined that the temperature would not reach the permeate boiling point [20].

4. CST ion exchange is being considered for in-tank and at-tank cesium removal processes at Hanford. During bench scale column testing of Hanford AW-101 supernate, over 700 bed volumes were treated with CST before reaching 50 percent cesium breakthrough.

5. In the SRS SCIX process, spent CST, loaded with ^{137}Cs will be ground using an immersion mill installed in one of the Tank 41 risers. A similar process, using an immersion mill installed inside a tank riser, has been used before at SRS for processing zeolite. No significant problems were encountered. Presumably a similar arrangement would be used at Hanford. The EM-TWS does not have any specific information on the deployment of a CST process at Hanford.

6. Using CST at Hanford is complicated by the fact that cesium loaded CST will be comingled with sludge in the Hanford waste storage tanks for many years before being treated in the WTP. Little if anything is known about the long-term chemical behavior of CST mixed with Hanford tank waste, an environment that is high pH and saturated with aluminum and other compounds. There is also potential for the CST to agglomerate and harden, making waste retrieval difficult. It is not known how the presence of CST in sludge will affect the WTP PT performance.

7. Models were also used to assess thermal risks associated with discharging fully loaded, ground CST into SRS storage tanks [12]. However, they may not apply to the Hanford tanks, which differ from SRS tanks in a number of ways, including sludge properties, potential number of mixing pumps, and tank internals.

8. Crossflow filtration was tested at engineering scale using Hanford simulant in the Process Engineering Platform (PEP) [14]. The Process Engineering Platform includes a prototype of

the crossflow filters being installed in the Hanford WTP PT process, but with a reduced number of full-size filter elements.

9. Crossflow filtration is currently being used at SRS where it has been operating in the ARP/MCU process since April 2008. During that time, roughly 1.5 million gallons of salt waste have been treated at a demonstrated filter flux of 0.03 gpm/sq ft. Filter availability has exceeded 90 percent since the beginning of ARP/MCU hot operation. It is reasonable to expect similar results treating Hanford salt waste.

10. Rotary microfiltration has not yet been used to process actual supernate or dissolved saltcake at full scale in an operating environment. Single disk units have been run successfully using actual waste from SRS and Hanford. Full-size filters have operated for over 3,500 hours on simulants, demonstrating both salt waste filtration and sludge washing capabilities. Operation on actual wastes will occur during the SCIX system startup beginning in June 2012.

11. The rotary microfilter contains two rotating seals and a bottom bearing, all of which have been modified based on problems encountered over more 3,500 hours of operation with full-size units. The most recent 1,000 hours of operation has been uneventful, with no seal leaks observed during sludge washing trials using stimulant up to 15 weight-percent solids. While these results are very encouraging, mechanical reliability and maintainability has not been demonstrated during hot operation in an actual tank farm environment.

7.5 Major Vulnerabilities

EM-TWS has identified two high-risk in-tank/at-tank technology vulnerabilities.

	Technical	Schedule	Cost	Regulatory	Safety
Difficulty retrieving sludge from Hanford double-shell storage tanks when using CST ion exchange	High	High	High	Low	High

Little if anything is known about the long-term behavior of CST comingled in Hanford tank waste, an environment that is high pH and saturated with aluminum and other compounds. The situation is complicated by the variability of chemical environments in the storage tanks.

There are many possibilities for chemically altering the CST. The CST matrix could break down, aluminosilicates could precipitate out on the CST, or various other chemical reactions could occur. The loaded CST may be at elevated temperature, so chemical reactions might proceed faster and be more of a problem. There is potential for the CST to agglomerate and harden, making waste retrieval difficult.

There is also the question of how cesium loaded CST would affect the WTP PT facility which includes two leaching processes. All of this can be tested, but it will take a dedicated effort and a considerable amount of time.

	Technical	Schedule	Cost	Regulatory	Safety
CST IX column overheating (Hanford and SRS)	Low	High	High	Low	High

Heat generation due to the high cesium loading capacity of CST has been addressed by limiting the use of CST to small ion exchange column applications. Computer modeling, completed in 2010, provided an estimate of conditions that would result from two scenarios: loss of permeate flow to a loaded CST column and loss of both permeate and cooling water flow to a loaded CST column. Loss of permeate flow could possibly occur due to loss of electricity, feed pump mechanical failure or CST an ion exchange column. Cooling water flow could be caused by loss of electricity or cooling water pump failure, among other things.

The SCIX Conceptual Safety Design Report identified ion exchange column over-pressure and explosion as a credible scenario if this occurs [19]. It may be possible to eliminate this risk using passive remedies such as the designing the ion exchange column to withstand the pressure caused by temperature excursion.

7.6 Recommendations

Savannah River Site

1. ***EM-TWS recommends that SRS document the SCIX alternatives down- select process, including financial analysis, in support of the decision to select in-tank treatment over other options.***

2. ***Steps must be taken to mitigate the risk of CST agglomeration.***

   a. ***Only the caustic-washed version of CST, IONSIV® IE-911-CW should be used in the SCIX process.***

   b. ***Storage stability specifications should be established and requisite testing should be part of the QA process.***

   c. ***Provision should be made for robust on-site washing of CST ion exchange media using 3M NaOH shortly before the CST is transferred into the SCIX ion exchange column, unless storage stability testing demonstrates this is not required.***

   IONSIV® IE-911 is known to form agglomerates in salt waste service. Excess reagents from the IONSIV® IE-911 manufacturing process, such as Si, Ti, Nb, are believed to be the main cause of this problem, although tank waste constituents may also contribute if pH is too low. It has been reported that Ti, Zr, and Nb leach from IONSIV® IE-911 during caustic washing. EM-TWS understands that a caustic washed version of CST, IONSIV® IE-911-CW, will be used in the SCIX process. Additional leaching of IONSIV® IE-911-CW can be expected to occur during resin storage. Current SRS plans only include minimal on-site caustic pre-treatment.

3. ***EM-TWS recommends that a detailed safety basis and HAZOP review be conducted to document passive safety design for the SCIX ion exchange process.***

   Cesium-loaded CST ion exchange media will generate a significant amount of heat. Simultaneous losses of permeate feed and cooling water flow to a SCIX ion exchange column, containing cesium loaded CST, will result in column temperatures exceeding the boiling point of the process liquid. The SCIX Conceptual Safety Design Report identified ion exchange column over pressure and explosion as credible scenarios.

   Wall temperatures exceeding 100 °C may adversely affect the integrity of waste storage tanks. Based on models used to assess thermal risks associated with discharging cesium loaded CST (ground and unground) into SRS storage tanks, it was concluded that depending on assumptions regarding the quantity and geometry it may be possible to have wall temperatures exceeding 100 °C.

   Hydrogen generation from radiolysis caused by cesium loaded CST ion exchange resin is also of concern in the ion exchange column and in storage tanks containing ground cesium loaded CST.

4. ***EM-TWS recommends full scale testing to ensure that a homogeneous bed of IONSIV® IE-911-CW can be established and operated without channeling which could adversely affect ^{137}Cs removal.***

   CST ion exchange media will be loaded in the 11-inch wide annular space between the vessel wall and the central cooling pipe. Although it's reasonable to expect column hydraulics will be satisfactory, this is an unusual design that should be verified by testing at full scale using IONSIV® IE-911-CW and a salt solution with density and viscosity similar to that of actual salt waste.

5. ***EM-TWS recommends that the 1.3 million gallon tank mixing design be reviewed by an external panel to assure the design will meet MST strike performance objectives.***

   Mixing technology/scale up are critical technology elements of the SRS SCIX process. The current ARP/MCU includes a step called MST strike, in which actinides and strontium are absorbed using monosodium titanate in a 5,000-gallon, mechanically agitated process tank. The proposed SCIX process uses submerged mixing pumps to disperse MST in a 1.3 million gallon storage tank. Although considerable work has been completed on scale up strategy and mixing related aspects of the MST strike have been studied in an 800-gallon tank, external design review should be completed by outside subject matter experts.

Hanford Site

1. ***Spherical resorcinol formaldehyde ion exchange resin meets the technical requirements for cesium removal in the short duration Vision 2020 scenario. However, EM-TWS recommends evaluation of other potentially simpler options for Vision 2020, such as those presented in Appendix 11 of this report.***

   A significant amount of development work has been completed using sRF ion exchange resin in support of the decision to use it for the WTP PT cesium ion exchange process. While it is clear that an sRF-based cesium removal process will meet the technical objectives of the Vision 2020 scenario, other options such as those described in Appendix 11 (Vision 2020) may be simpler and less expensive to deploy.

2. ***EM-TWS recommends the use of spherical resorcinol formaldehyde ion exchange resin for long-term in-tank and at-tank cesium removal processes.***

   sRF is the preferred choice for the Hanford tank farm long-term pretreatment options using an ion exchange cesium removal process. This is based on the extensive development work already completed on sRF for use as an ion exchange resin for Hanford and its selection for use in WTP PT.

   CST ion exchange is being considered for in-tank and at-tank cesium removal processes at Hanford. Bench scale column testing of CST treating actual Hanford supernate indicates that CST is able to do a good job of removing cesium from Hanford salt waste. The high cost of CST and the fact that it cannot be eluted work against its selection for treating large quantities of Hanford waste.

   Using CST at Hanford is complicated by the fact that cesium loaded CST will be comingled with sludge in the Hanford waste storage tanks for many years before being treated in the WTP. Little if anything is known about the long-term behavior of CST mixed with Hanford tank waste, an environment that is high pH and saturated with aluminum and other compounds. There is potential for the CST to agglomerate and harden, making waste retrieval difficult. It is also not known how the presence of CST in sludge will affect the WTP PT performance.

3. ***EM-TWS recommends crossflow filtration for processing Hanford AP tank farm supernate. An in-tank CFF option should be evaluated for the Vision 2020 scenario.***

   Crossflow filtration has been tested using Hanford simulants at engineering-scale testing in the Process Engineering platform. More importantly, CFF has been proven in similar service during three years of successful operation at SRS in the ARP/MCU process.

   Based on permeate flux rates demonstrated at ARP/MCU, it may be possible to meet the Vision 2020 process requirements with a single filter bundle approximately 15 inches in diameter and ten feet long. A unit of this size could be installed inside a tank riser.

4. ***EM-TWS recommends a comprehensive experimental program with actual samples of AP tank farm supernate using the CUF module and bench-scale sRF ion exchange columns before declaring Vision 2020 as having reached the CD-2 milestone.***

   Crossflow filtration and sRF ion exchange resin are fully expected to meet the requirements of the Vision 2020 scenario. Bench-scale testing with samples of AP tank farm supernate is needed to validate and refine the design basis for the Vision 2020 scenario.

5. ***EM-TWS recommends proceeding with additional RMF testing with a range of actual Hanford tank waste samples using the single disk RMF. Mechanical reliability and maintainability need to be demonstrated during actual operation of the SRS Tank 41 SCIX process before deploying RMF technology at Hanford.***

   The SCIX project is a technology development and demonstration program that includes an integrated full-scale operational test to obtain data and determine the feasibility for long-term deployment in an operational tank farm environment. It would be premature to deploy a second RMF at Hanford before proving the first one at SRS. However, if additional testing of Hanford waste is done using the single disc RMF test unit in parallel with the SRS SCIX project, it should be possible to compress the schedule for advancing rotary microfiltration to CD-6.

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APPENDIX 8
Melter Technologies

8.1 Introduction

The EM-TWS has been tasked to evaluate the different technologies that are available to stabilize nuclear waste. Our prime focus is high-level nuclear waste (HLW) (at Idaho National Laboratory (INL), Hanford, and Savannah River Site (SRS)) and low-activity nuclear waste (LAW) (at Hanford and sodium-bearing waste at INL). We evaluated review papers, reports, feasibility studies, etc. that looked at a range of technologies and critically evaluated their pluses and minuses for application at the DOE sites.

The objective of this chapter is to identify the best melter candidate for the future operation of the vitrification facilities at SRS, Hanford, and Idaho. In determining the best candidate, technological feasibility, potential economic advantages, and the ability to implement within the current infrastructure were considered.

The evaluations of each technology considered:

1. State of development (i.e., the Technology Readiness Level (TRL) ratings); note however that the cost of development was not estimated for all of the technologies;
2. Effects of various glass choices;
3. Ease of installation in replacing the current joule-heated melter;
4. Benefits and drawbacks; and
5. Risks.

8.2 Charge Statement

Task 4 charge was stated as follows:

> Over the last 15 to 20 years the EM program has considered various melter technologies and operational strategies to increase the efficiency of tank waste vitrification processes. This task will entail review of the different approaches and technologies that would be considered as second-generation (at Hanford), or third/fourth generation (at SRS) replacement melters, (e.g. cold crucible melters and advanced joule heated melters). The Subcommittee will consider the merits of different glass formulations, both borosilicate and other glass types, e.g., iron phosphate, as they apply to the advanced melter technologies above.

8.3 Conclusions and Findings

Conclusions on this melter study were as follows:

1. Implementing a new technology in an already operating hot facility is very risky. Since the facility is already hot, either all upgrades must be done remotely or the area decontaminated sufficiently to allow hands-on work. Either option involves high levels of risk to both the

project cost and the schedule that have not likely been adequately considered in the financial analysis that provided the justification for the change.

2. Supplemental LAW vitrification melter technology will be based on limited feed stream data; therefore, the EM-TWS recommends current joule-heated technology with continuous improvement for process efficiency and performance.

   Waste feed sequencing must be established with evaluation of various blending strategies prior to consideration of any new melter technology decision process. Construction authorization of supplemental LAW vitrification should be contingent on accommodating advanced melter technology with flexibility and contingency both for process and for infrastructure based on operating experience of the first LAW facility. Supplemental LAW vitrification should incorporate technology performance data for technology selection and process system planning.

3. Implementation of new melter technologies in order to achieve major increases in throughput are likely to be limited by other bottlenecks in the system such as retrieval rates from the tank farms, pretreatment, waste handling, off gas treatment, and canister cool down. The potential for bottlenecks in other parts of the process needs to be carefully examined and the costs accrued for their remedy within the cost/benefit analysis for the installation of a new melter technology.

4. Implementation of melter improvement technology (such as higher temperature or bubblers, as was done at the Defense Waste Processing Facility (DWPF) and will be done at the Waste Treatment and Immobilization Plant at Hanford (WTP) in order to improve waste loading—other than for new glass formulations—is the modification least likely to encounter bottleneck issues because the throughput changes are relatively small and the surrounding processes and waste form do not change.

5. Joule-heated melter technology without bubblers has been proven a reliable process in both the SRS and West Valley operations. Indeed, the lifetimes of this type of melter have exceeded original expectations by a factor of more than two [1]. Modifications of this basic technology by adding bubblers or changing insulation or electrode types can probably be made and tested in operation with little risk to the operational integrity and long-term project schedule. They can be reversed if the changes prove to be counterproductive.

6. Increasing the operating temperatures of joule-heated melters to improve waste loading is likely to result in unintended negative consequences in fission product loading in the glass (for instance, Cs and Tc due to higher volatility) as well as increased wear rates for electrodes, bubblers, and refractories.

7. Cold crucible induction melting (CCIM) is the most advanced alternate melter technology and has the greatest potential for producing significant changes in terms of increased temperature and alternate glass performance. Development will be required in terms of mixing and slurry feed (both LAW and HLW) and total throughput (LAW).

8. CCIM may be useful for increasing the waste loading through increased operating temperature without the negative effects on refractories and electrodes that would be experienced by joule-heated melters. However, fission product retention would still be an issue as well as total waste throughput.

9. High-temperature steam reforming appears to be a viable candidate for new LAW immobilization facilities if the waste form it produces has about the same leachability as LAW glass and is accepted by the regulators involved. However, it still does not have a proven operational track record in design, construction, and operation with Hanford LAW, and so claims as to its cost effectiveness are currently without foundation.

10. The use of bottom drains will allow for better removal of residual HLW glass, reducing the radioactive fields resulting from a melter failure. Water-cooled melter shells will also allow for further removal of residual waste glass, also lowering final radiation fields as well as mass off the melter [2].

11. An upstream change that could be made to improve the operation of the melters at WTP is the installation of a flexible tank blending system. This would allow troublesome wastes such as phosphates, chromium and sulfates to be diluted by the majority of the waste which is relatively easy to process in a joule heated melter. In order to make best use of melters at all sites, good chemistry based system models that can be used to develop an optimized feed that minimizes the concentration of troublesome wastes would also aid in this endeavor.

8.4 Background

Slurry-fed, joule heated ceramic melters (JHCMs) were first chosen as the baseline process for vitrifying HLW for the DWPF in the late 1970s. This decision then drove the choice for the West Valley project in the early 1980s. The West Valley JHCM was successfully operated for the duration of the project. The DWPF JHCM at Savannah River Site was then brought online and has successfully operated since 1995. In 1995, DOE, the Washington Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) renegotiated the Tri-Party Agreement (TPA) and identified vitrification of LAW as the preferred strategy at Hanford. DOE subsequently decided to vitrify at least a portion of the Hanford LAW in its Record of Decision (ROD) for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS). Alternate technologies were considered in the early 1990s for vitrifying LAW at Hanford; but, due to the more mature state of development of the JHCMs and the perceived short timeframe for implementation, the use of the JHCM with a borosilicate glass formulation was chosen as the baseline technology for Hanford WTP for both the HLW and the LAW.

The choice of the slurry-fed JHCM was somewhat based on the selection of this technology by the Federal Republic of Germany for their PAMELA (**P**ilot**A**nlage **M**ol zur **E**rzeugung **L**agerfähiger **A**bfälle, or, in English, “Mol pilot plant for the production of waste suitable for storage”) Plant (Figures 8.1 and 8.2), which has operated since 1985 in Mol, Belgium. It was viewed as the best technology available at the time to handle the very high sodium levels of the HLW, which would likely foul the then-operating French AVM process (Atelier de Vitrification

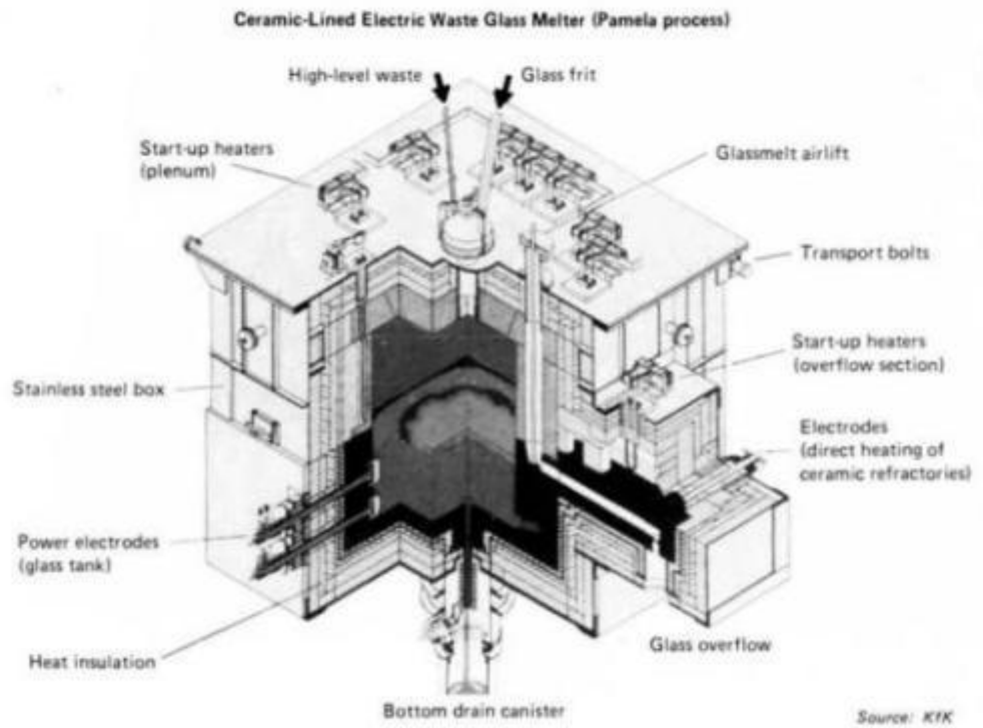

Figure 8-1. PAMELA Slurry-Fed Joule-Heated Ceramic Melter [3]

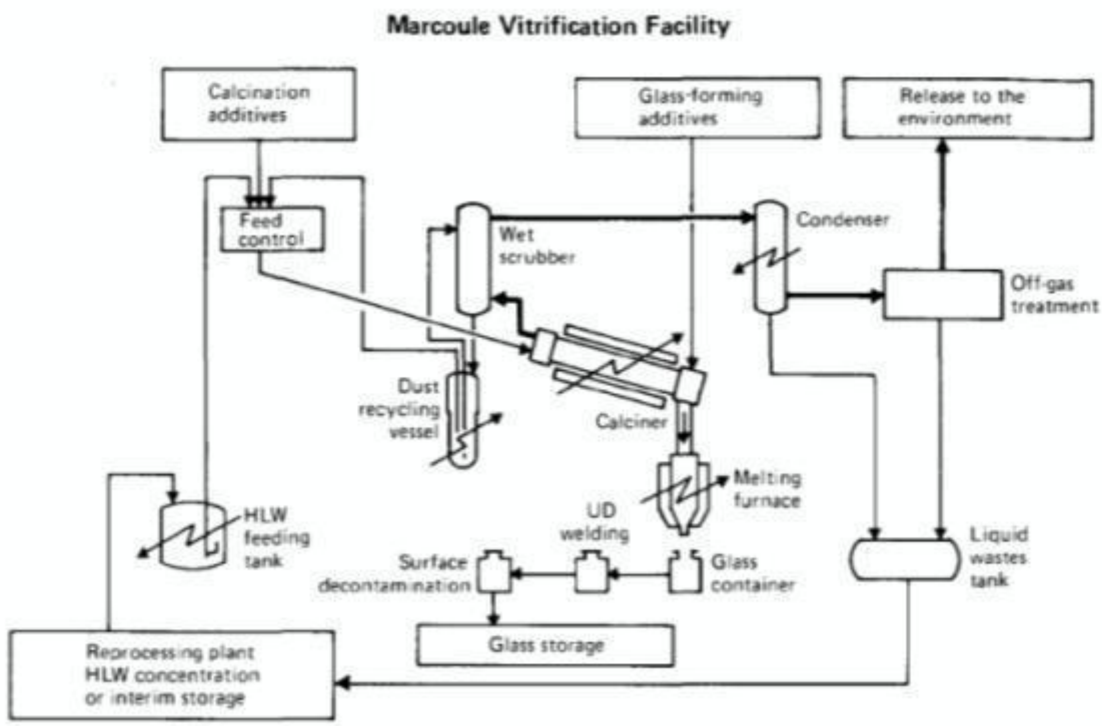

Figure 8-2. PAMELA Process Diagram [3]

Marcoule), which used calcination followed by vitrification in a hot-wall inductively coupled melter (Figure 8-3). In addition, the throughput capability of the induction-heated melter at that time was lower than the anticipated rates that would be required for the U.S. HLW facilities.

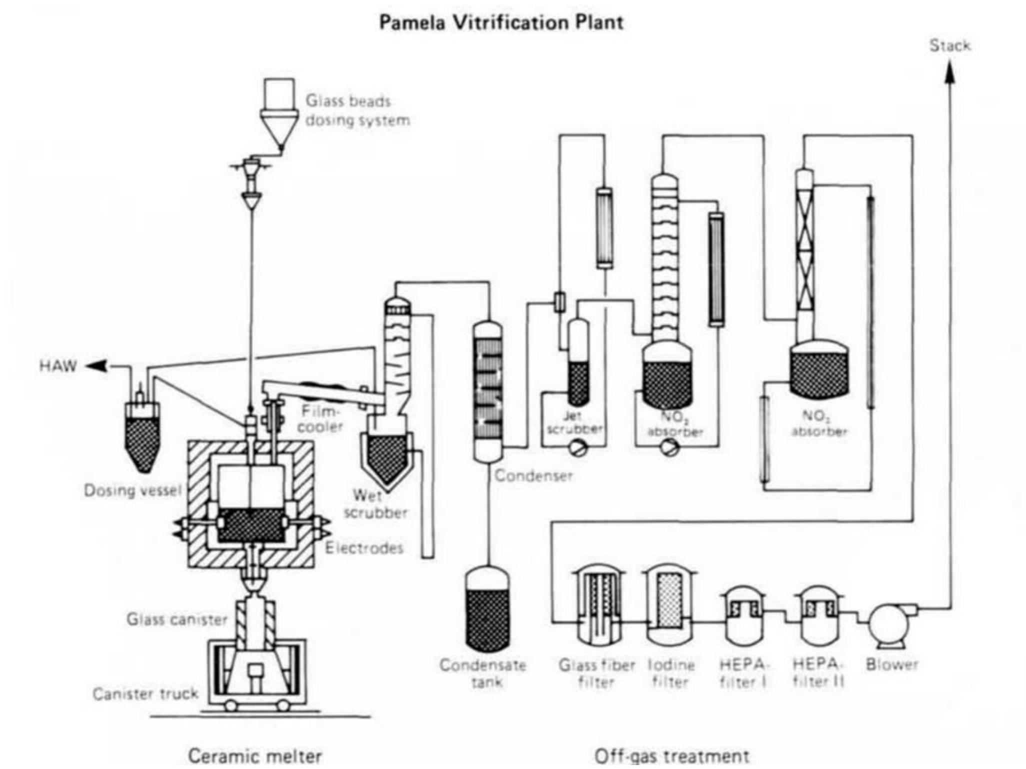

Figure 8-3. French AVM Process [3]

The slurry-fed JHCM has a long history of successful operation both in the U.S. and in Europe. Its throughput can be easily controlled by increasing the melter and electrode areas to meet the throughput requirements. In conjunction with the alumina-borosilicate glass waste form, it has successfully vitrified thousands of canisters of HLW and is accepted by all stakeholders. At Hanford, however, testing has indicated that there are some chemical components of the wastes stored in the Tank Farms that may pose a problem by forming a second phase that is insoluble in the borosilicate oxide phase. A second phase is generally assumed to have a negative impact since it is likely to be more leachable than the oxide-phase glass. They also tend to form second phases in the melter that float on the surface and cause excessive corrosion of the electrodes and refractories [4]. These include sulfur, chlorine, chromium, and fluorine as well as feeds that are high in iron or aluminum. The high Fe and Al feeds begin the formation of crystalline phases (e.g., spinels) that build up and clog the melter. Bubblers appear to lessen the problem by eliminating cold spots in the melter and by minimizing the size of the crystals thus allowing them to exit the melter in the pour stream. In addition, there are concerns about the ability of this type of melter to capture such elements as technetium and iodine, which are volatile in the oxidized state. There is also the issue of noble metal precipitation. In the environment of the glass in this melter, the noble metals tend to precipitate and, due to their density, collect on the bottom of the melter [4]. Since the U.S. uses a side-pour design (Figure 8-4) as opposed to the PAMELA bottom-pour design (to mitigate issues with the unintended spilling of HLW glass), these noble metal precipitates can form a conductive path across the bottom of the melter and short out the electrodes before corrosion of the electrodes would normally signal the end of the melter's useful life. The complexity of the melter, due to the need for many water and electrical connects, the inability to repair in place, and its high cost are drawbacks to its use. However, the complexity issue is likely to be an issue with any technology and the cost of the melter is minor in comparison with that of the overall treatment facility.

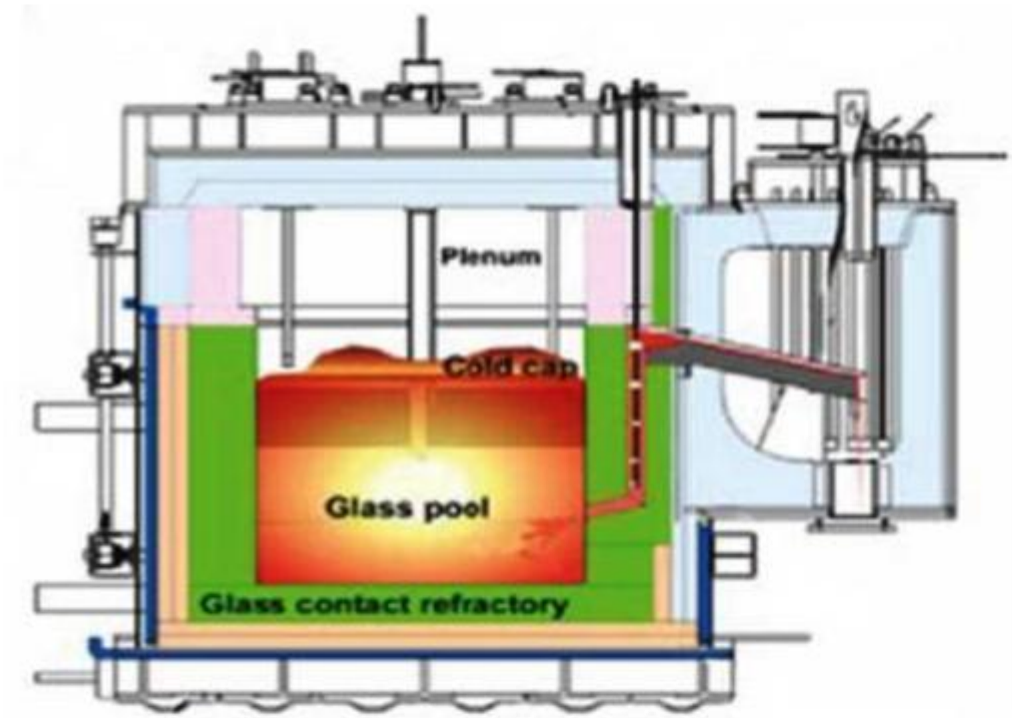

Figure 8-4. U.S. Version of Joule-Heated Ceramic Melter with Side Pour [5]

8.5 Evaluation of available waste solidification technologies

The following alternative technologies were evaluated in this report:

- Improvements to the JHCM;
- Cold and hot crucible melting/induction heating;
- Steam reforming;
- Plasma torch continuous melter;
- Hot wall and induction-heated in-can melter ;
- Rotary plasma arc melter;
- Slurry-fed cyclone combustor;
- Bulk vitrification;
- Microwave melter; and
- Gas-fired submerged combustion melter.

The state of development of these technologies ranges from bench-scale with simulants (TRL 4) to large-scale tests with simulants under realistic conditions (except radioactivity) (TRL 5) to large-scale use in actual plants (TRL 6 to 9). Evaluating these systems therefore requires some degree of skepticism since there are very few papers or reports available that reported negative results.

8.5.1 Potential Improvements to the Joule-Heated Melter

Many modifications to the basic JHCM have been proposed to address issues such as the size of the melter, corrosion of the refractories and electrodes, and the melt rate. Several of the proposals that have been tested [6] are:

1. **Use of dried feed and a water-cooled shell – Envitco, Inc., and Vectra Technologies, Inc.** This concept seeks to increase the rate of glass production in the same overall footprint by using a dryer to produce a solid feed to a joule-heated melter that uses water-cooled walls to form a corrosion-resistant "skull" of glass over the water-cooled wall. This type of melter can run at a higher temperature and thus be less sensitive to the corrosive effects of the glass. The dryer allows the use of either electrically or gas-heated hot air or superheated steam to efficiently remove moisture from the melter feed to reduce the thermal load on the melter. The overall result during testing was a rate of ~2600 kg/m^2/day, which is less than that of a CCIM, but more than the standard JHCM. The water-cooled wall or the dried feed approaches can be used either together or individually. Testing was conducted in the Envitco EV-16 melter at Clemson University, Clemson, South Carolina, using sidewall molybdenum rod electrodes and a proprietary mechanically controlled drain system. Envitco used a spray dryer made by the Hosokawa Bepex Corporation using the Bepex Unison spray-drying process. Vectra [7] used a fluidized bed calciner. Slurry feed was also successfully used in the Envitco melter with the molybdenum electrodes and water-cooled walls [8].

2. **High-temperature joule-heated melter with sidewall molybdenum electrodes – Penberthy Electromelt International (PEI), Incorporated, Seattle, Washington [6], and Envitco [8].** The PEI melter feed system mixes the liquid LAW with absorbent glass-forming additives in screw chargers that deliver a moist granular solid feed directly to the melter. Multiple chargers with multiple drop points are used to maintain full batch blanket coverage and suppress volatile component losses. The mix-in-the-charger feed system is less complicated than preparing radioactive dry or calcined feeds and avoids mixing and slurry rheology issues associated with slurry feed, but requires accurate metering of dry glass-former and liquid LAW. The PEI approach has an estimated 2,000 kg/m^2/day melt rate, which is about the same as that of the current JHCMs. The Envitco system was successfully operated with both dried and slurry feeds.

3. **Carbon Electrode Melter – U.S. Bureau of Mines.** This approach also used predried feed but increased the Joule heating by using large, submerged graphite electrodes and lower voltage. Although the production rate of the melter was increased, the high melting temperatures produced higher volatilization rates than the cold-top joule-heated melter technologies. Glass melt rates ranged from 3,360 to 8,760 kg/m^2/d. This technology would be appropriate for a slurry-fed melter since a cold cap could be maintained with minimal

solids carryover when operated as a submerged arc. However, testing has shown that the corrosion rate of the graphite electrodes is higher due to the water content [9].

These improvements can be rated at TRL 4. Limited large-scale work has been done with LAW simulants, but not in a radioactive environment. While pre-drying the feeds to the melter will reduce the energy drain on the melter and increase the production rate, it also removes the spreading cold cap cover that appears to be effective in capturing the more volatile components such as Tc and Cs. The water-cooled shell has the potential to increase the surface area of the melter for a given footprint and reduce corrosion issues while allowing thermal cycling without the damage that refractories normally encounter. However, the cost is somewhat higher, and energy losses and therefore melter capacity is lower. In addition, continuous water flow is required so that the structural integrity of the melter is not challenged. This approach may be very beneficial for operation of the melter at higher temperatures. However, the issue of corrosion is more pronounced on the electrodes, which may affect melter life more than corrosion of the refractory. Molybdenum electrodes must be used if melt temperatures are above 1200 °C. Above this temperature, Inconel® electrodes lose their mechanical strength [4].

Some of the considerations that would arise from the use of improvements to the current JHCM technology are:

1. The capacity of the surrounding subsystems could be exceeded if a higher rate melter (~32 percent) was used in the existing HLW or LAW facilities. This would not apply to a new LAW facility.
2. If the improvements to the current JHCM were made before the current HLW or LAW facilities went into hot operation, moderate modifications would be required to decrease operating duration to match melter capability [5].
3. The operating permits would need to be reviewed and possibly revised (potentially delaying operation by 12 to 18 months) [5].
4. Due to the higher operating temperature, total canister generation should be on the order of 10 percent lower than baseline. In addition, increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the current JHCM are removed due to the higher operating temperature and lack of refractories.
5. Use of water-cooled skull formation also allows for the future implementation of new and more corrosive glasses such as $FePO_4$. The advantage of $FePO_4$, for instance, is that the sulfate loading can be increased by up to a factor of five [10] compared to that for borosilicate glasses. In addition, there are a number of phosphate containing tanks at Hanford that will be difficult to process with borosilicate glasses unless diluted.
6. Long-term operation with molybdenum electrodes is not proven; therefore, a long-term test program would be needed.
7. Asset preservation depends upon the continuous supply of cold water to the melter. A loss of cold water could lead to uncontrolled dumping of molten HLW or LAW glass or deformation/destruction of the melter body if a skull type of wall is used.
8. Technetium and cesium retention may be reduced as a result of higher temperature..

8.5.2 Cold crucible melting/induction heating

There are two fundamentally different induction heated melter technologies: cold-wall high-frequency induction melters, such as those presently under development in France and Russia and in use in France [1], and hot-wall, low-frequency, induction-heated Inconel crucible melters, such as those used by the French and British (see Figure 8-3 above) since the 1970s. Although dried or calcined feed has been used, slurry feeds can also be used, though the production rate will be lower by a factor of 1 to 5 [1] due to the higher heat load. Cold-wall (or cold crucible) melters cool the wall with internal water flows. The glass is heated by a high-frequency electromagnetic field. Forced convection through bubblers or stirrers is needed to distribute the heat within the melter. While the CCIM itself is not temperature-limited, the bubblers or stirrers may limit the ultimate operating temperature. Current developments are aimed at this type of induction melter.

Hot-wall induction melters (HWIMs) are Inconel crucibles that are heated by low-frequency induction. Production began in this type of melter in France in the late 1970s, and it has continued successfully since (see Figure 8-3 above). Unlike a joule-heated melter, the production rate of a hot-wall crucible melter cannot be increased by simply increasing melt surface area because of the difficulty of transferring energy from the crucible to the bath [11]. In addition, the HWIM is limited to about 1150 °C and is susceptible to metallic solids precipitation from noble metals, which can short out the HWIM tubes [1].

Cold crucible induction melting (shown in Figure 8-5) is the basis of the new melters in France. The technology uses an induced current to heat the glass inside a water-cooled metal shell. The cold wall from water cooling forms a skull of highly viscous and solid glass that protects the metal shell from thermal corrosion and erosion. Since no refractory or electrodes are used, the CCIM is able to achieve much higher operating temperatures than the JHCM. Throughput testing of SRS HLW batch #4 simulant feed on a prototypic melter indicates a melt rate on the order of 2,800 $kg/m^2 \cdot day$ at 1,250 °C, which is ≈2.5 times the current WTP HLW baseline. Increasing the temperature by 100 °C to 1250 °C has increased the waste loading to ≈40 percent by weight (dependent on waste composition) [5]. Increases of up to 50 percent may be possible (ref. 13). Although the induction melter technology is currently being used with borosilicate glass at the AREVA facility in LaHague, France, the sodium level of this waste is much lower than for the U.S. HLW or LAW [1]. In addition, the AREVA melters are not fed with a slurry of glass formers, but with dry solids. Therefore, the TRL of this technology is rated at 4 (operated at full scale with similar production materials, but with a need for the changes of slurry feed and the addition of bubblers).

A drawback of the CCIM technology is the limited throat area that can be effectively heated. While not a constraint for the HLW, the much larger throughputs required for the LAW waste means that a significant effort must be made in designing a larger melter system. A basic design utilizing induction sources located beneath the melt is being investigated. This arrangement allows for a larger melt surface than appears feasible using a right-circular cylinder coil arrangement. Due to the requirement for a new design for the melter, the CCIM for LAW has a TRL of 3.

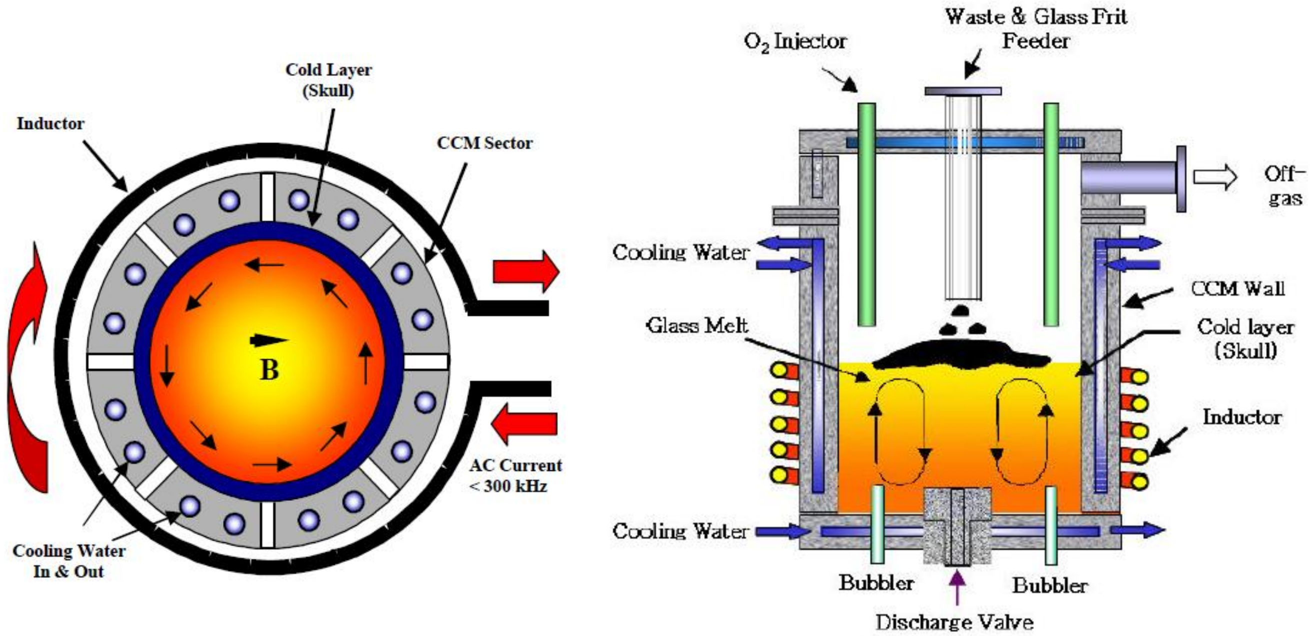

Figure 8-5. Cross-Section View of the Nuclear Engineering and Technology Institute (NETEC) CCIM [12]

Some of the considerations that could arise from the use of the CCIM technology versus the current JHCM technology are:

1. The capacity of the surrounding subsystems could be exceeded if a higher throughput rate melter (~32 percent) was used in the existing HLW or LAW facilities (not a new LAW facility). A systems study at DWPF indicated that significant modifications would be required to install two CCIMs in place of the current single HLW JHCM. This would effectively double the HLW capacity of DWPF. These modifications, while significant, could be carried out. An added benefit would be that the melters could operate at 1250°C instead of the current 1150 °C [13].

2. If the conversion to the CCIM technology was completed before the current HLW or LAW facilities went into hot operation, modifications would be required [5] but would be much easier to carry out.

3. The operating permits would need to be reviewed and possibly revised (causing a potential delay of 12 to 18 months) [5].

4. Due to the higher operating temperature that allows higher waste loadings, total canister generation should be about10 percent lower than baseline. In addition, increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the JHCM are removed due to the higher operating temperature and lack of refractories.

5. Melter life is anticipated to be five years or more with no deleterious effects due to noble metals, sulfates, or other undesired components. Due to the small size of the melter and the

fact that it can be completely drained, it is expected that the equipment waste will be much smaller than that of an equivalent-sized JHCM and of much lower activity [1].

6. Control of the melter and asset preservation depends upon the continuous supply of cold water to the melter. A loss of cold water could lead to uncontrolled dumping of molten HLW or LAW glass or deformation/destruction of the melter body.

7. Technetium and cesium retention may be reduced as a result of higher temperature and stirring versus bubbling.

8. CCIM technology is size-limited to about 1.4 m diameter; any additional throughput increases would require additional CCIM melters, or advanced glass formulations may be required for LAW applications.

9. Because there are no refractory materials or electrodes, the use of alternate glass formulations such as $FePO_4$ would be much easier to implement. However, there would likely be limitations due to the rest of the WTP, HLW, and LAW facilities if these alternate formulations were implemented.

The estimated cost of bringing CCIM technology to TRL 6 for LAW is about $33M [5]. Additional work for HLW operations is estimated at $30M [5]. We believe that this development number is very optimistic, likely by a factor of from 3 to 5.

In summary, CCIM is a proven technology in France but not in the U.S. for HLW vitrification using borosilicate glasses. The use in the current cold HLW or LAW facilities or at a new LAW facility at Hanford may offer a benefit by increasing waste loading in borosilicate glass or if a new glass matrix such as $FePO_4$ is chosen. Backfitting the DWPF or the WTP is not likely to be as economically attractive due to the lost production time, uncertain costs to work in a radioactive facility, and potential bottlenecks in surrounding processes. In addition, due to the short duration of the SRS mission, the projected need for only two or three DWPF melter change-outs, and the existence on site of one new melter and parts for a second, and the length of time it will take to modify DWPF for CCIM, makes the idea of using CCIM there highly unlikely.

8.5.3 Steam reforming

Fluidized-bed steam reforming (FBSR) utilizes a bed of particles fluidized by upward flowing steam into which the liquid nuclear waste is sprayed. The particle bed is partially formed by carbon (coal) solids that are reformed by reactions with steam to produce reformed products and intermediate products that create a reactive, chemically reducing environment to destroy nitrates and nitrites in the feed. Environmentally benign N_2, H_2O, and CO_2 (see Figure 8-6) are then produced from the waste. DOE has tested the FBSR process [5] for sodium-bearing wastes at Idaho and Tank 48H waste at Savannah River. FBSR is the technology basis for the nearly complete construction of the Integrated Waste Treatment Unit for the 900,000 gallons of liquid sodium bearing waste managed and stored as HLW in INL. Both of these applications involve the production of carbonate waste forms. The FBSR process has been tested at bench and engineering scale on Hanford LAW and WTP secondary waste simulants to produce a sodium aluminosilicate (NAS) waste form. This process was proposed as a supplemental treatment process in 2002 but was not selected. Bench-scale testing is currently underway with actual waste, including Hanford tank wastes. The FBSR would not be suitable for treating either HLW or LAW within the current HLW and LAW facilities. However, it is being proposed for the additional LAW facility.

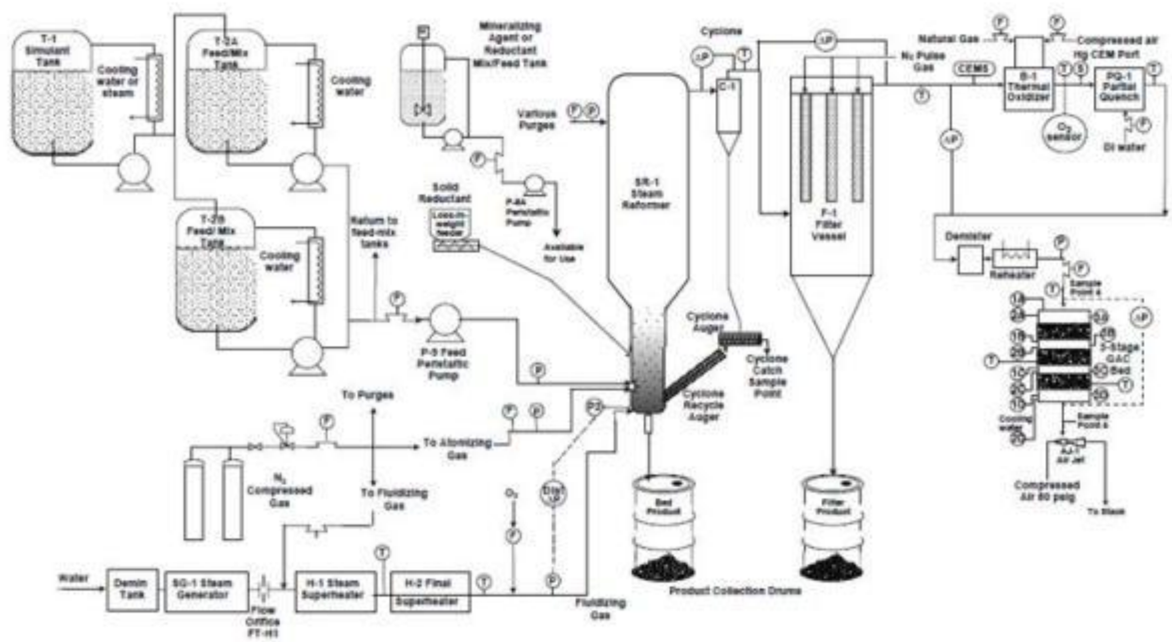

Figure 8-6. Process flow diagram for the fluidized bed mineralizing steam reforming demonstration with Hanford LAW simulant [14]

The FBSR system has a TRL of 4 because Hanford tank waste simulants have been tested. This technology has been demonstrated in industry and other nuclear applications, and engineering-scale tests with Hanford LAW simulants have been successfully completed. The solids produced from this process have not been designated as an acceptable solidified waste form. The primary advantages of this process are:

- Problematic constituents for vitrification processes (e.g., Tc, S, Cl, F, and Na), which limit waste loading in glass do not appear to challenge the FBSR process [5, 14].
- The FBSR process does not produce secondary liquid wastes.

Considerations on the use of this process are:

1. Stakeholder acceptance of the FBSR process or product has not been established for LAW. Long-term performance of the waste form (either in granular or in any potential monolithic form) has not been established and would likely require significant effort. However, testing to date appears to produce a highly durable mineral waste form that appears to be as good as, or better than, glass in terms of long-term performance.

2. Although FBSR is a common industrial process, its operational flexibility, including adaptability to variations in feed in this operation, has not been established. Maintenance of fluidized beds with variable feeds can be very difficult.

3. It has been accepted for two other significant DOE applications and has more than 10 years use for treating commercial low-level waste.

4. Residual coal (a process additive to reduce NO_x formation) adds mass for disposal, and it is not clear whether it has a deleterious effect on the final waste form. Tests on simulants of Hanford LAW and INL sodium-bearing waste show that the waste product has a leachability similar to LAW glass when clays are added and carbonate form products are avoided [15].

5. The technology is relatively immature for LAW application, and there is a significant risk that the estimated cost and schedule time for LAW implementation would increase.

6. Due to the different waste form, total LAW canister generation should be lower.

7. There would likely be lifecycle cost reductions due to the increased capacity and lower waste canister count.

FBSR was also tested on the bench and pilot scale on a Tank 48 waste simulant [16]. These tests indicated that the FBSR was able to destroy most of the organics and nitrates. A dissolvable carbonate-based solid was produced that contained all the stable ions in the feed and could be fed to the HLW melter after dissolution in the tank farm. The testing indicates that, although this is not a vitrification application, the technology was stable and versatile. In this service, the FBSR is likely to be acceptable if the Tank 48 waste cannot be co-fed with the normal feed materials to the HLW melter as a liquid slurry.

In summary, the primary advantages of FBSR is that problematic constituents for vitrification processes (e.g., Tc, S, Cl, F, and Na) do not appear to be limiting and could significantly reduce the LAW volume to be vitrified. However, the waste form is not accepted and, due to the limited development of its use of stabilizing LAW, the cost and time for a full-scale implementation are not known. The final volume of the LAW waste would be slightly larger than the volume of the glass-based waste.

8.5.4 In-can melter

In-can melters offer the potential of a very simple process with a big reduction in melter corrosion. This technology can be fed directly with the waste-plus-glass-former slurry [17] or can utilize a dryer or calciner to treat the feed into a solid. The canister heating system (typically consisting of resistance or induction heaters) then heats the contents to above the glass melting point. Since a new canister is used each time, there are no issues with melter corrosion or disposal of a contaminated melter. This process has several disadvantages that have kept it from being used at any of the DOE sites. These include:

1. The in-can melter technology has a low production rate due to the low heat transfer area. While the lower rate can be mitigated somewhat by the use of internal fins inside the canister in the case of resistance heaters or graphite receptors for induction heaters, it adds cost but still cannot achieve the very high throughput rates (~330 kg/day for the highest rate induction with graphite liner system [18] and ~500 kg/day for a heated wall melter, [19]) that are needed for HLW and LAW vitrification. The low throughput rates leads to high capital costs since more installations are required as compared to the JHCM vitrification technology.

2. For maximum throughput, the waste must be calcined before being put into the can for melting; otherwise, the throughput is reduced due to the added heat load needed for drying and calcining. However, drying and calcination of the high-sodium LAW and HLW wastes and glass formers without the formation of any liquid phases can be very difficult and can lead to extensive fouling of the heat transfer surfaces [17]. Powder feeding was found to lead to high dust carryovers [17].

3. Mass losses were relatively high [17] at 13 to 15 percent for temperatures up to 1100 °C and 15 to 20 percent for temperatures up to 1500 °C. However, Cs retention was found to be greater than 95 percent [17].

4. The waste feeds must be homogeneous to guarantee that phase separation does not occur in the melt in the can. Experimental results reported in [17], pp. 4-112 to 4-113, indicate that large amounts of crystalline second phases are formed. Even so, those results are superior to those obtained using a joule-heated melter (see Table 8.1). Not only was the waste loading about twice that for the in-can melter versus the joule-heated melter, but all the leach test data indicated superior results.

5. The operating permits will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months).

6. There would likely be lifecycle cost increases due to the decreased capacity or higher capital costs associated with an increased number of installations to meet the current production rates.

Although the in-can melter approach gives superior glass results and may result in a simplified process, it is likely only applicable to low-volume operations. It is not suitable for the Hanford or DWPF vitrification operations due to its low-throughput capabilities, especially when used with a slurry feed.

Table 8.1 – Properties of HLW-98-31 (Joule-Heated Melter Glass) vs. the Advanced Vitrification System (AVS) Waste Form [17]

Parameters	VSL HLW98-31	DIAL-R-02-LM-60
Waste Loading (wt percent [M-1])	29.88	60
Density (g/ml at 20°C)	2.75	3.2
Glass Transition Temperature, T_g (°C)	458	660
Crystallinity	**About 0.1 vol percent of high-Fe spinel crystal at glass crucible interface**	**About 0.5 vol percent of high-Fe spinel with lower concentration of ZrO_2**
7-Day PCT		
Element	**Normalized Concentration (g/L)**	
B	0.7259	0.12
Li	0.5217	NA
Na	0.3757	0.22
Si	0.3154	0.08
pH	9.84	8.0
TCLP		
Element (UTS Limit)	**mg/l**	**mg/l**
Ag (0.14)	< 0.003	
As (3.0)	< 0.049	.0012
Ba (21.00)	0.026	.029
Cd (0.11)	0.067	.073
Cr (0.60)	0.023	.0004
Pb (0.75)	0.031	.0177
Se (3.70)	0.086	.001

8.5.5 Rotary plasma arc melter

The rotary plasma arc melter was developed to apply a high-intensity plasma arc directly onto a rotating drum of solid material. The arc is controlled by a robotic arm. The intention is to spread the high-energy intensity of the plasma arc around the material such that no area became overheated. A computer model of this process is shown in Figure 8-7 [20]. The rotating drum is on the left with the offgas pipe coming off the top of the drum and the plasma torches located in the top of the drum. This batch process produced a high-quality glass that was easily extruded from the tank. This indicated that the melt product was uniform with no large inclusions of unmelted material. Maximum melt temperatures are about 1800 °C. LAW simulant glass compositions were not melted. However, a glass composition similar to the LAW glass was used for testing (Figure 8-8). Process rates of about 600 kg/day were achieved, although previous testing has demonstrated the capability of up to 6,000 kg/day. The life of the particular plasma torches used in this work was about 100 hours.

Figure 8-7. Solidworks® Drawing of Plasma Arc Melter

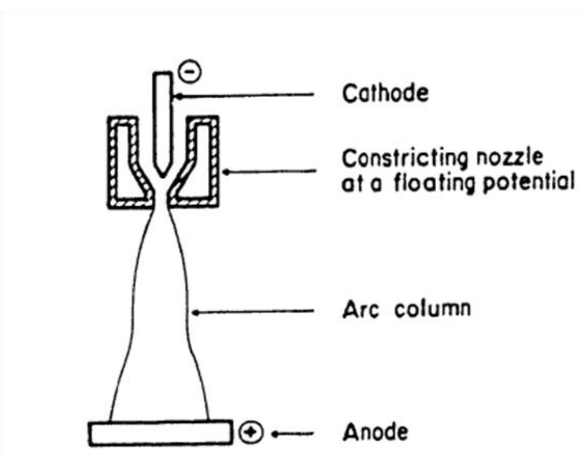

Figure 8-8. Transferred Arc Plasma Torches [21] in Glass Melting Operation [20]

Some of the considerations that would arise from the use of the rotary plasma technology versus the current JHCM technology are:

1. The capacity of the surrounding subsystems could be exceeded if a higher rate melter (~32 percent) was used in the existing HLW or LAW facilities. This would not, of course, apply to a new LAW facility.

2. If the conversion to the rotary plasma technology was done before the current HLW or LAW facilities went into hot operation, moderate modifications would be required to decrease operating duration to match melter capability [5].

3. The operating permits will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months) [5].

4. Due to the higher operating temperature, total canister generation should be about 10 percent lower than baseline. In addition, increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the JHCM are removed due to the higher operating temperature. The use of refractories may limit the ultimate temperature that is used. Water-cooled walls may allow for higher temperatures.

5. Plasma torch life is currently limited to 100 to 1,000 hours. Maintenance of torches will be an issue. Melter shell life is anticipated to be five years or more with no deleterious effects from the presence of noble metals, sulfates, or other undesirable components.

6. Control of the melter and asset preservation depends upon the continuous supply of cold water to the melter. A loss of cold water could lead to uncontrolled dumping of molten HLW or LAW glass or deformation/destruction of the melter body.

7. Technetium and cesium retention is likely to be reduced as a result of higher instantaneous temperatures and higher temperatures (if used) and the lack of a cold cap [22].

8. Rotary plasma technology is capable of a capacity of two to three times that of the JHCM.

The rotary plasma technology is at TRL 3 for LAW since it has been demonstrated at a reasonably large scale on glass similar to LAW. The plasma torch lifetime is the component that limits this rating.

In summary, rotary plasma melters are a relatively proven technology for vitrification using borosilicate glasses. Use in the current cold HLW or LAW facilities or at a new LAW facility at Hanford may offer a benefit by increasing waste loading in borosilicate glass or if a new glass matrix such as $FePO_4$ is chosen. Backfitting the DWPF or the WTP is not likely to be as economically attractive due to the lost production time, uncertain costs to work in a radioactive facility, and potential bottlenecks in surrounding processes.

8.5.6 Bulk Vitrification

Bulk vitrification was developed for hazardous and low-level mixed waste applications. It consists of mixing LAW with soil and other additives and forming a dry solid that is placed in a large metal container. Electrodes are then put into the soil along with graphite powder to add conductivity and a current is then applied (Figure 8-9). The current melts the waste and additives into a vitrified state and the container is then filled, covered, and disposed of in the LAW burial area.

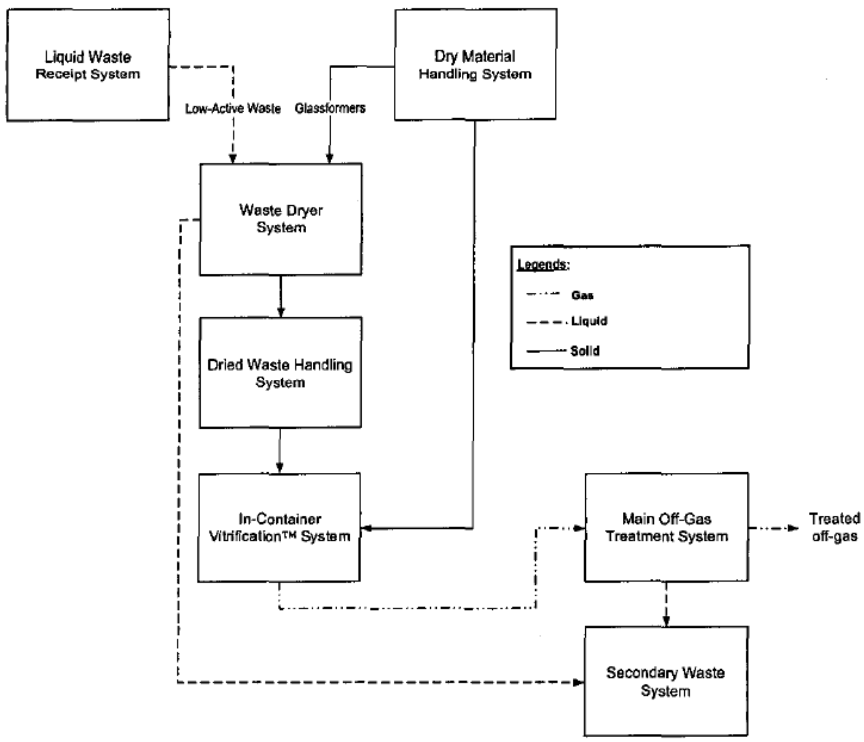

Figure 8-9. Process Flow Diagram for the Demonstration Bulk Vitrification System [23]

The benefit of this process is the ability to produce large amounts of vitrified LAW at a relatively low capital cost since a melter is not needed. Several dozen small-scale crucible melts were carried out, including melts with actual tank wastes. Twenty engineering-scale tests were conducted, including two that used a mixture of simulated and actual tank waste, and eight full-scale melt demonstrations were conducted with simulated tank waste. However, issues became apparent as these tests were carried out, and further work was stopped on development. Presuming that the technical issues could be overcome, the bulk vitrification technology for immobilization of LAW is at a TRL of 5. One issue that continues is the ability of the process to uniformly vitrify the material in the container. For instance, soluble forms of rhenium (a surrogate for Tc-99) were found in the waste package but outside of the glass. In 2008, DOE suspended its efforts on bulk vitrification since it became apparent that it had fewer advantages over other potential immobilization technologies than previously thought. Specifically, these testing results indicated that waste loading to avoid phase separation of sulfur and the distribution of technetium within the treated waste and the offgas treatment system remain as critical issues and would not likely be resolved in the timeframe needed to meet the 2018 hot operations date for additional supplemental treatment.

Considerations on the use of bulk vitrification are:

1. Since the vitrification process has a minimum of mixing, and an uneven temperature distribution, the same elements of concern for JHCMs are also of concern for bulk vitrification; namely, sodium, sulfur, technetium, iodine, and cesium.

2. The resolution of remaining technical issues could impact the design or operation; thus, there is uncertainty in the lifecycle costs.

3. The long-term performance of the waste form package due to the presence of soluble salts in the package but outside the glass is not known.

4. The operating permits will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months).

5. Technetium and cesium retention may be reduced since a cold cap would not be formed.

6. There would likely be some lifecycle cost reductions due to the increased LAW vitrification capacity.

In summary, bulk vitrification does not provide the required control of melting conditions that is required to guarantee an acceptable waste form, and there do not appear to be sufficient cost savings as compared to other process alternatives to justify its development and implementation.

8.5.7 Plasma Arc Melter

Westinghouse Science and Technology Center (WSTC) demonstrated a plasma torch-fired cupola furnace (Figure 8-10). It operates by injecting the LAW-powdered frit glass former slurry into the hot (~5000 °C) outlet gas stream of the plasma torch (Figure 8-11). The flow rate of the LAW/glass formers is adjusted until the required outlet temperature (>1150 °C) is reached. The demonstration at its Waltz Mill facility in 1994 operated at about 7,000 kg glass/d. Due to the high temperature of the outlet stream, it is likely that Tc and Cs [6] would have unacceptable volatility since there was no cold cap to capture the volatile materials. Due to the very high temperature capabilities of the operation, there would likely be no significant issues with capturing the S, Cl, F, and Na into the glass. However, due to the use of refractories in the tuyere and the crucible, it would be expected that there would be corrosion and erosion issues with higher corrosivity glasses such as $FePO_4$.

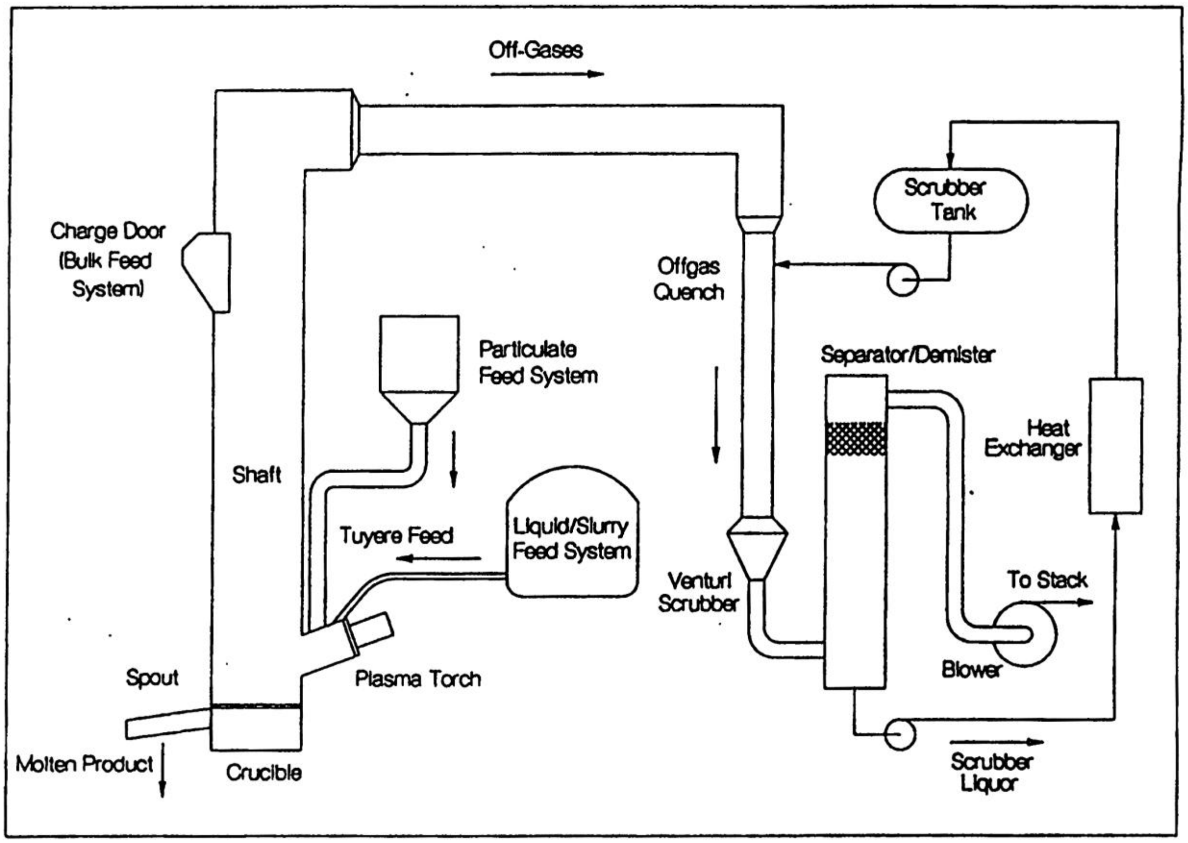

Figure 8-10. Westinghouse Plasma Arc Vitrification Process [24]

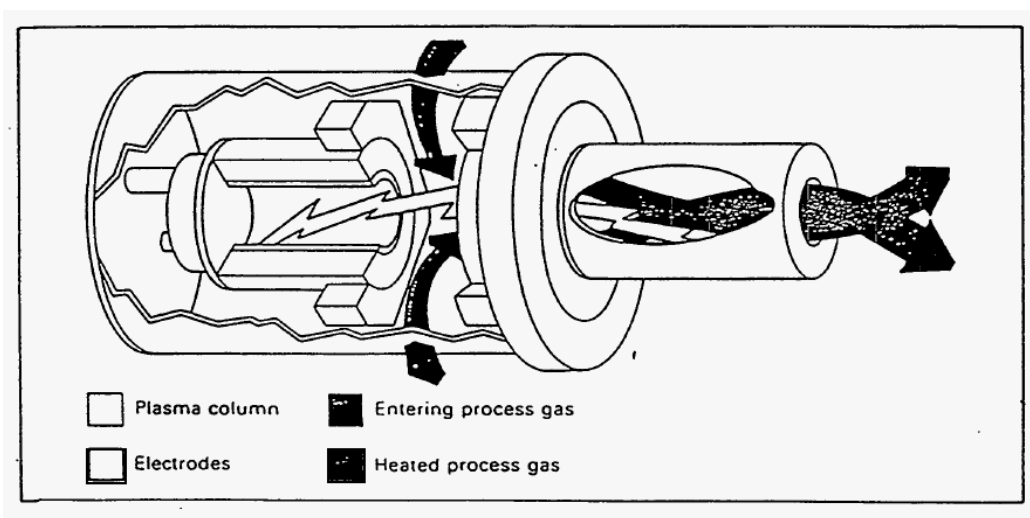

Figure 8-11. 700 to 1400 kW(e) Plasma Torch Schematic [24]

This process is compact with a very high glass production rate. Offgas plugging is not an issue due to the high steam concentrations and gas flow rates. Remote maintenance of the plasma torches would be difficult, and backfitting this process as a replacement for current HLW or

LAW JHCMs would be difficult. However, use in a new LAW facility could be accomplished as long as torch maintenance (mainly replacement of electrodes) could be accommodated.

Some of the considerations that would arise from the use of the plasma arc melter technology versus the current JHCM technology are:

1. The capacity of the surrounding subsystems could be exceeded if a higher rate melter (~32 percent) was used in the existing HLW or LAW facilities. This would not, of course, apply to a new LAW facility.

2. If the conversion to the plasma arc melter technology was done before the current HLW or LAW facilities went into hot operation, moderate modifications would be required to decrease operating duration to match melter capability.

3. The operating permits will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months).

4. Due to the potential for higher operating temperature, total canister generation should be about 10 percent lower than baseline due to the capability to handle increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the JHCM.

5. Maintenance issues would likely be greater for the plasma arc melter as compared to the JHCM.

6. Technetium and cesium retention may be reduced as a result of higher temperature and lack of a cold cap, but could also be increased due to the ability to control the redox potential of the gas and glass. Since the molten glass is poured immediately into a canister, there are no issues with noble metal buildup in the melter.

7. There would likely be lifecycle cost reductions due to the increased capacity and lower waste canister count.

The plasma arc melter technology is at TRL 4 for LAW since it has been operated at large scale on simulants [6].

In summary, the plasma arc melter is a proven technology for LAW vitrification using borosilicate glasses. Use in the current LAW facilities or at a new LAW facility at Hanford may offer a benefit by increasing waste loading in borosilicate glass due to higher-temperature operation. The major issue with this technology is that it needs to be made suitable for performing remote maintenance on the plasma torch electrodes and tuyeres.

8.5.8 Microwave Melter

The concept of using microwaves to supply the required energy in a melter is not new. The use of microwaves have several advantages, the primary one being that the power can be transmitted through waveguides from generators located outside of the radioactive hot cell area where routine generator maintenance can be performed in a hands-on environment. Waveguide windows can effectively isolate the generator from the hot cell [25]. An issue with using microwaves is the depth of penetration of the microwave power into the material. The correct wavelength must be used so that the power is absorbed more or less evenly throughout the bulk of the material. This can be difficult with a melter that contains materials in several phases including a slurry on the top, solid dried glass formers on the interface of the molten glass and the slurry, and the molten glass. This issue can be ameliorated somewhat by choosing the appropriate heating frequency (915 MHz or 2450 MHz) for the application [25]. Finally, the microwave process is self-starting at room temperature since the glass can absorb microwave power throughout its temperature range. Joule-heated melters are not self-starting since the dc conductivity of glass is very poor and current will not pass between electrodes at room temperature [25]. This capability eliminates a major operations issue currently faced by JHCMs; namely, the potential for an extended power loss that would result in the freezing of the glass and the need to prematurely discard a melter. Interest in this technology is continuing, with one of the latest versions shown in a patent application in 2007. Practical systems would be limited to about the 100 to 300 kw range, which would limit glass throughput [26]).

8.5.9 Slurry-Fed Cyclone Combustor

Babcock & Wilcox demonstrated a slurry-fed cyclone combustion melter system. The B&W vitrification technology is based on cyclone combustion technology developed for large fossil fuel-fired boilers used in the electric utility industry. In the case of vitrification of LAW, a LAW/glass former slurry is injected into the cyclone (a horizontal cylinder attached to the wall of the main furnace cavity), producing a molten slag. Glass drains from the cyclone through a notch in the back baffle of the cyclone to a sump in the main furnace cavity. When operating, a layer of frozen glass skull forms on the water-cooled walls of the cyclone furnace and inhibits corrosion and erosion of the furnace. This technology is considered to be at a TRL of 3 since it has been operated at an engineering scale (600 kg/day) on a LAW simulant.

The main issues with this technology are the volatile component and offgas entrainment losses, which higher than any of the other technologies considered here. However, this technology is capable of high throughputs in a compact unit.

Some of the considerations that would arise from the use of the plasma arc melter technology versus the current JHCM technology are:

1. The capacity of the surrounding subsystems (especially the offgas scrubber systems) could be exceeded if a higher-rate melter was used in the existing HLW or LAW facilities. This would not, of course, apply to a new LAW facility.

2. If the conversion to the cyclone combustor melter technology was done before the current HLW or LAW facilities went into hot operation, modifications would be required to decrease operating duration to match melter capability.

3. The operating permits will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months).

4. Due to the potential for higher operating temperature, total canister generation should be about 10 percent lower than baseline due to the capability to handle increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the JHCM. Because the combustor uses hydrocarbon fuels for heat, there would likely be issues with carbonate formation and unburned carbon. The system could be either reducing or oxidizing in nature, depending on the fuel/oxidizer ratio.

5. Maintenance issues would likely be greater for the cyclone combustor than the JHCM due to erosion from the high velocity flow of solids.

6. Technetium and cesium retention may be reduced as a result of higher temperature and lack of a cold cap, but could also be increased due to the ability to control the redox potential of the gas and glass. Since the molten glass is poured immediately into a canister, there are no issues with noble metal buildup in the melter.

7. There would likely be lifecycle cost reductions due to the increased capacity and lower waste canister count.

In summary, the cyclone combustor melter is a potential technology for LAW vitrification using borosilicate glasses. Use in the current LAW facilities or at a new LAW facility at Hanford may offer a benefit by increasing waste loading in borosilicate glass due to higher temperature operation. The major issue with this technology is to reduce the entrainment and volatilization of Tc and Cs.

8.5.10 Submerged Combustion Melter

This technology utilizes a gas-fired oxygen burner that comes in from the bottom of a water-cooled wall melter (Figure 8-12).

This technology has been extensively tested at the 50 kg/hr and the 1,000 kg/hr scale. It has the highest production rate of any of the pool melters (~1 ton/day/ft^2) and the potential to operate at temperatures up to 1500 °C. The burners act as both a heat source (from the combustion of natural gas and oxygen) and mixers (upward flow of the combustion gases). This technology may also have the potential of being able to stop and start the melter by maintaining gas flow (air or nitrogen) without adding natural gas until the glass melt hardens. Restart would be by reigniting the gas burners. Since there are no refractories, there are no thermal shock issues and minimal corrosion issues. Testing carried out at the 1 ton/hr level reported in [27] for a non-cold cap application indicated some issues with carryover.

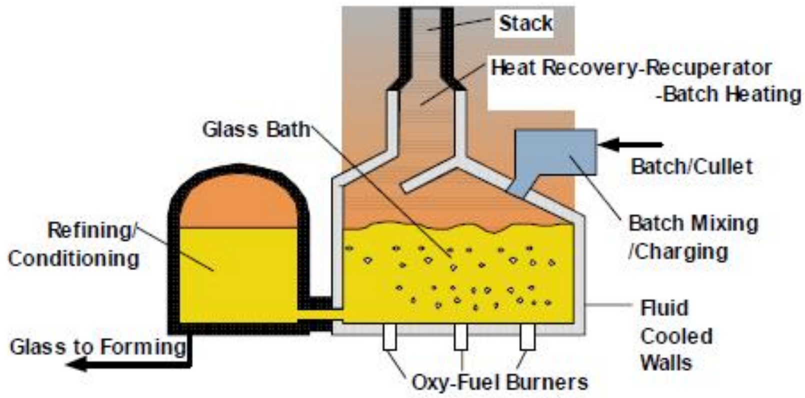

Figure 8-12. Diagram of Submerged Gas Burner Melter [27]

Some of the considerations that would arise from the use of submerged gas burner melters are:

1. The capacity of the surrounding subsystems could be exceeded if a higher rate melter (~32 percent) was used in the existing HLW or LAW facilities. This is especially true for this technology due to the higher gas flows. This would not apply to a new LAW facility.

2. If the submerged gas burner melter was used to replace the current JHCMs before the current HLW or LAW facilities went into hot operation, moderate modifications would be required to decrease operating duration to match melter capability [5].

3. The operating permits, especially gaseous emissions permits, will need to be reviewed and possibly revised (potentially causing a delay of 12 to 18 months) [5].

4. Due to the higher operating temperature, total canister generation should be about10 percent lower than baseline. In addition, increased loadings of sulfates, phosphate, and other waste components that currently raise issues with the operation of the current JHCM are removed due to the higher operating temperature and lack of refractories.

5. The use of water-cooled skull formation also allows for the future implementation of new and more corrosive glasses such as $FePO_4$. The advantage of FeP, for instance, is that the sulfate loading can be increased by up to a factor of five [10] compared to borosilicate glasses.

6. Long-term operation of this melter is not proven, and replacement of gas jets may be difficult. Therefore, a long-term test program would be needed.

7. Asset preservation depends upon the continuous supply of cold water to the melter. A loss of cold water could lead to uncontrolled dumping of molten HLW or LAW glass or deformation/destruction of the melter body.

8. Technetium and cesium retention may be reduced as a result of higher temperature if a cold cap is not used.

In summary, the submerged gas burner melter offers many advantages over joule-heated melters in terms of size, temperature capability, and start/stop capability. However, maintenance of the gas jets may be difficult, and long-term testing would be required. The TRL level of this technology is 3.

8.5.11 Comparison of Technology Options

The technologies listed above (except for high-temperature steam reforming) were evaluated in 1994 on the basis of carryover of material, volatilization of components, quality of the glass produced, and NO_x generation [28]. Performance data on the technologies listed below are summarized and presented in Tables 8.2 through 8.5:

- B&W – gas-fired cyclone combustion melter with slurry feed;
- WSTC – plasma torch-fired cupola furnace, slurry feed;
- U.S. Bureau of Mines (USBM) – carbon electrode melter, pre-reacted dry feed;
- Vectra – high-temperature joule-heated melter with molybdenum electrodes, slurry feed; and
- Duratek – low-temperature joule-heated melter, Inconel electrodes, slurry feed.

Several technologies were not included in the 1994 study. They were standard JHCM, CCIM, in-can melting, and microwave-heated melters. In all three cases, the performance of these technologies would likely be similar to the data represented by Duratek and Vectra. For dried solids feed, the Envitco data would be representative.

As shown in Table 8.2, all technologies were able to produce a vitrified product that exceeded the required levels. Table 8.3 presents the carryover of each of the technologies. All the joule-heated melters had gross carryovers much lower than the carryover of the plasma technologies. This is due to the cold cap that is formed on the surface of the glass pool and the quiescent nature of the melting action. NO_x generation is presented in Table 8.4. Again, the joule-heated melters had the lowest emission levels. The USBM had the lowest emission level, which is not surprising due to the reducing action of the electrodes. Surprisingly, the B&W cyclone combustor had the highest NO_x emission levels even though this was gas-fired. The volatilization of various elements is presented in Table 8.4. In almost all cases, as with the carryover reported in Table 2, the joule-heated melters outperformed the other technologies. Therefore, based on these evaluations, the joule-heated technologies are the most desirable, with the dried feed approach represented by the Envitco technology being the best performing of all.

Again, this is likely because the Envitco cold cap has the least perturbation of all these technologies. This technology, however, will require an additional unit operation (predrying of the feed), which will be difficult to implement in the current plant, but may be feasible in the Second LAW facility. Table 8.5 presents data on the loss of selected feed components to offgas during the testing, which was measured by dividing the percentage of volatile loss by the percentage of total loss.

Table 8.2 – Summary of Target and Measured Major Oxide Glass Compositions and Glass Product Consistency Test Results from Various Technologies [28]

Oxide	DSSF	B&W		WSTC		USBM			Vectra		Duratek		Envitco	
	Target	Target	Meas.	Target[a]	Meas.	Target	Meas. WHC1	Meas. WHC3	Target	Meas.	Target	Meas.	Target	Meas.
Al_2O_3	12.62	10.00	14.9	17.72	18.57	10.00	12.47	9.93	10.00	9.50	6.14	6.24	12.00	10.6
B_2O_3	--	5.00	1.9	9.45	7.31	5.00	2.71	4.01	8.00	7.08	6.15	6.37	9.00	8.12
CaO	0.01	5.00	5.61	4.65	4.14	5.00	7.31	10.21	2.90	2.94	7.80	7.05	--	0.71
Fe_2O_3	0.01	--	0.66	0.5	0.65	--	1.17	1.48	1.00	1.03	7.50	6.26	--	0.34
K_2O	5.71	1.52	1.02	1.43	1.02	1.52	0.97	1.24	1.52	0.64	3.68	3.44	1.52	1.32
LiO_2	--	--	--	0.83	0.80	--	--	--	--	--	--	--	--	--
Na_2O	75.22	20.00	13.7	18.82	19.93	20.00	16.11	18.10	20.00	15.43	18.82	17.66	20.00	17.41
SiO_2	--	56.78	59.11	42.9	36.38	56.78	58.17	53.59	52.78	57.91	42.22	41.16	55.78	58.33
TiO_2	--	--	0.23	--	0.041	--	0.39	--	--	0.23	1.00	0.86	--	0.19
ZrO_2	--	--	0.064	2.10	2.06	--	0.0082	--	--	0.45	5.09	4.61	--	0.32
Other	6.43[b]	1.7	--	1.6	--	1.7	--	--	3.8[c]	--	1.6	--	1.7	--
Total	100	100	--	100	--	100	--	--	100	--	100	--	100	--
T at 100 poise (°C)[d]		1296	--	1215	--	1296	--	--	1224	--	1096	--	1325	--
PCT norm. Na (g/m^2/day)		0.074[d]	0.018[e]	0.034[d]	0.020[e]	0.074[d]	0.037[e]	--	0.078[d]	0.025[e]	0.102[d]	0.081[e]	0.046[d]	0.0163[e]
PCT pH (final)[e]		--	10.5	--	10.7	--	11.2	--	--	10.4	--	11.4	--	10.1
Fe^{2+}/total Fe[e]		--	0.59	--	0.043	--	1.11	--	--	1.02	--	0.053	--	0.593

[a] WSTC target values incorporate an assumed 15% loss of waste oxides to volatility. Neglecting the assumed volatility, the Na_2O target would be 21.1 wt%.
[b] DSSF "Other" includes CaO 0.01, Cr_2O_3 0.16, Cs_2O 0.58, MgO 0.01, MnO_2 0.01, MoO_3 0.59, SrO 0.43, P_2O_5 0.74, SO_3 0.83, Cl 1.38, F 1.15, and I 0.52 wt%.
[c] Includes 2.1 wt% MgO.
[d] Laboratory measurement from crucible melts of the target composition.
[e] Evaluation of results from pilot-scale testing. Fe^{2+}/Fe total ratios >1 indicate analytical error.

Table 8.3 – Percent Gross Entrainment Estimates [28]

Vendor	% Gross entrainment
B&W	8.7
WSTC	2.7
USBM WHC-1	1.2
Duratek	0.6
Vectra[b]	0.6
Envitco	0.05

[a]No data available for USBM WHC2 and WHC3 tests. Results from WHC1 are assumed to apply.
[b] Slurry feeding. Entrainment was 0.07% for calcined feed and 0.4% for simulated calcine.

Table 8.4 – NO_x Generation for Various Melter Systems

Vendor	NO_x yield to offgas as mol% of nitrate and nitrite in melter feed
B&W	68
WSTC	CD[a]
USBM WHC1	0.03[b]
USBM WHC3	No data
Vectra	2.6
Duratek	13
Envitco	~33[b]

[a]Conflicting data; see text below.
[b]Melter feed contains reduced levels of nitrite/nitrate due to the feed preparation process.

Table 8.5 – Loss of Selected Feed Components to Offgas during Testing of Various Melter Systems (percent Volatile Loss)/(percent Total Loss) [28]

Oxide	B&W	WSTC	USBM WHC 1	USBM WHC 3	Vectra	Duratek	Envitco
B_2O_3	67/70	22/24	51/52	18/19	14, (6.8[a, b])/15	~0[a]/0.6	0.14[a]/0.2
Cl	87/88	88/88	82/82	97/97	64/64	47.8/48	1 to 13[a]/1 to 13
Cs_2O	83/85	84	63/63	39/40	41/41	13.2/14	0.6[a]/0.6
F[c]	~92/93	~91/91	~91/91	~99.7/99.7	~15[a]/16	~53/53	~< 0.85[a]/0.90
I	94/95	>98/98	95/95	N/A	83/83	82/82	10/10
K_2O	51/55	48/49	35/36	25/26	15, (8.5[a, b])/16	0[a]/0.6	0[a]/0.05
LiO_2	N/A	2.8/5.4	N/A	N/A	N/A	N/A	N/A
MoO_3	60/64	24/26	47/48	45/46	SE	0.2[a]/0.8	0[a]/0.05
Na_2O	35/41	15/17	21/22	6.5/7.6	13, (3.6[a, b])/13.5	~0[a]/0.6	0[a]/0.05
P	~41/46	43/45	41/42	54/55	1.1[a]/1.7	N/A[a]	0[a]/0.05
S	>51/55	34/36	88/88	94/94	85, (56[a, b])/85	N/A[a]	53/53

[a] Estimates based on aerosol sampling data. Other data are from tie calculation using glass and feed composition data.

[b] Because of uncertainty, both tie component and aerosol measurement volatility results are presented for some analytes. There is reason to suspect aerosol measurements may under-represent the volatility. Tie component values are based on target feed compositions due to inadequate characterization of melter feed.

[c] Analysis systematically under-reported fluoride content in feed. Feed targets were used to determine all fluoride volatility results. Uncertainty may also exist with respect to fluoride glass and Method 5 analyses. Therefore, all fluoride results are considered questionable.

N/A = Not available. Data are unavailable on which to base a defensible estimate.

SE = Source error. Because of a source from erosion of molybdenum electrodes, no estimate is possible.

Predrying the feed will require a significant amount of test work since the high sodium levels of the LAW feed may cause significant fouling of any heat transfer surfaces. Therefore, the use of direct heat transfer via hot gases in a calciner or in a fluidized bed is the most likely to succeed as long as the drying temperature is kept low.

Another evaluation criterion is the ability of a melter technology to decrease the number of waste canisters that are generated. The current number of HLW canisters is estimated at 11,557 for Hanford [5] and 7,557 [29] for DWPF. At an estimated cost of between $1 and $2 million[1] per canister, plus savings from reduced mission life of about $500 million to $1 billion per year, savings in this area would be significant.

To realize these savings, two options currently exist: raise the glass melting temperatures to 1250 °C, thereby increasing waste loading by about 10 percent [5] for an estimated savings of $2 billion; or transition to FeP glass, which would increase waste loading by about 40 percent [5] for an estimated savings of $8 billion. Both of these changes increase the corrosivity of the melts and challenge the structural integrity of the melters.

Table 8.6 presents the various technologies and their estimated ability to handle the transition to FeP glass and higher temperatures. The vitrification methods without direct electrode emersion (microwave, CCIM), water-cooled melters that form skulls (CCIM, Vectra), and slurry feed to a quiescent pool can overcome the corrosion and possibly the Cs and Tc volatilization issues. It is clear that the current slurry-fed JHCM technology can be improved by the use of skull-forming water-cooled melters to replace the corrosion-prone ceramic insulation. However, it is not clear that the electrodes can be made to operate at either higher temperatures or in $FePO_4$ glass (as an example). Molybdenum electrodes may prove useful, but they will have to be extensively tested before they are used. Bubblers can help, but their corrosion resistance would be in question. While CCIMs would alleviate the electrode and insulation corrosion issue, they have not been extensively tested with bubblers or slurry feed. Microwave heating could potentially eliminate the need for predrying and obviate the electrode corrosion issue.

[1] Estimated cost for Yucca Mountain is $96 billion for 60,000 tons of waste or $1.5 million per ton. Each canister has ~1.5 tons of glass, so the cost is about $2.25 million per canister. Since the HLW canisters would require less shielding and have less heat generation than spent fuel, it is assumed that the cost is reduced to between $1 and $2 million per canister.

Table 8.6 – Ability of Various Melter Technologies to Accept Higher Melt Temperatures and FeP Glass for HLW Vitrification

Vitrification Technology	$FePO_4$ and 1250 °C Capability
Current JHCM with slurry feed and bubblers	No –thicker insulation required, decreasing throughput for total footprint; also, likely unacceptable electrode corrosion.
B&W - gas-fired cyclone combustion melter with slurry feed	No– though skull approach protects equipment and no electrodes, volatilization of Tc and Cs would likely be unacceptable.
WSTC - plasma torch-fired cupola furnace, slurry feed	No– though skull approach protects equipment and no electrodes, volatilization of Tc and Cs would likely be unacceptable.
USBM - carbon electrode melter, pre-reacted dry feed	Yes – If water-cooled melter is used.
Vectra – high-temperature joule-heated melter with molybdenum electrodes, slurry feed	Yes – likely acceptable corrosion rates and Cs and Tc vaporization rates.
Duratek – low-temperature joule-heated melter, Inconel electrodes, slurry feed	No – likely unacceptable corrosion rates and thicker insulation required, decreasing throughput for total footprint.
Microwave heating with slurry feed and water-cooled shell	Yes – likely acceptable corrosion rates and Cs and Tc vaporization rates.
CCIM	Yes – likely acceptable corrosion rates and Cs and Tc vaporization rates.

8.5.12 Implementation of Advanced Melter Technology

It is axiomatic that alternate technologies always look better than the existing technology until they are actually implemented in a production facility. This is particularly true in the HLW and LAW areas since backfitting and maintenance issues and costs are compounded when operating remotely. However, considering the huge savings that can result from the use of new technology, the question becomes one of what technology to implement and how to implement it in a way that does not impact the schedules for DWPF, WTP, and INL.

For DWPF, the risk is that any changes in vitrification technology will result in lost production time that will nullify any economic gains that result from the use of advanced technology. Since the footprint of the melters is set, it would seem most prudent to make no dramatic changes to the JHCM technology. An example is the bubblers that have already been installed to help increase the rate of melting and perhaps increase the inclusion of Tc and Cs. Use of higher temperatures could be tried on an incremental basis to minimize any negative impacts. As technology is tested and proven at DWPF, it can be implemented at WTP.

For WTP, the use of a CCIM with microwave-assisted drying of a slurry-fed melter with water-cooled walls operating at 1250 °C would seem to be the best approach for HLW and LAW vitrification. In order to maintain the schedule, implementation of the current technology at 1150 °C should continue. If the alternate technology proves out in large-scale simulant testing, installation of the alternate technology could likely be carried out while the facility is still cold. If it takes longer, then a decision could be made as to the benefit of delaying the startup of WTP versus implementing the alternate technology as the first replacement melter. The approach would be the same for both HLW and LAW.   Due to the development effort still required for CCIM, it would not likely be used until 2025 or later.

8.5.13 Implementation Costs and Time

A final issue that needs to be considered is the cost and time involved in getting technologies up to the level of knowledge that will allow installation in any of the HLW or LAW facilities. The major technology changes that could be implemented while still meeting Cs and Tc carryover requirements are:

1. Water-cooled melters that eliminate the corrosion issues for refractories; and
2. Indirect heating methods like microwave and CCIM that eliminate the electrode corrosion issues.

Estimates [5] for incremental improvements in the current JHCM technology are about $20 million and two years. Estimates for the CCIM were $35 million and three years. Use of a water-cooled melter with microwave heating would probably have about the same cost and time as for the CCIM, although all are probably significantly underestimated based on previous developmental experience.

8.6 Vulnerabilities

The choice of melter is a joule-heated ceramic melter. Incremental changes should be pursued to improve operability in time. With this as a basis, there are no major vulnerabilities due to the selection of the joule-heated melter technology. Selection of alternate technologies will add vulnerabilities since they have not been proven with the high sodium waste that we have at the DOE sites.

Minor vulnerabilities are concerned with minimizing the amount of glass is produced and the total time of operation. The issues are:

1. Retention of Tc in the HLW and LAW glasses
2. Loading of certain problem components such as sulfates and phosphates in the sodium silicate glass

Work that is currently proceeding at the Vitrification Laboratory at CUA to mitigate the issue on the retention of Tc in glass has indicated that this may not be a significant issue. To verify this, vapor/liquid equilibrium data needs to be generated for the various options. This issue is being mitigated.

Mitigation of the loading of troublesome components is straightforward. Since the troublesome components are on average relatively dilute, installation of a flexible mixing plant as the interface between the tank farm and WTP will allow these components to be stabilized in the currently accepted borosilicate glass waste form. To facilitate this approach, a chemistry based modeling tool to generate the optimum tank processing scenarios should also be developed and used.

8.7 Recommendations

Recommendations from this melter study are:

1. Joule-heated melter technology is still the only proven technology for use in the vitrification of U.S. high-sodium wastes. Therefore, it should remain the baseline technology for vitrification until another technology has been proven superior in an appropriate operating environment.

2. Improvements in the operation of joule-heated melters should be the main objective in the near term for DOE melter development funding. Such items as glass formulation, bubblers, molybdenum electrodes, and water-cooled skull technology are examples.

3. The choice of melter technology will not significantly affect the capital or operating costs of the projects at any site. It is far more important to choose technology that has significant operating experience and is more likely to keep the projects on schedule.

4. In order to minimize vitrified waste, installation of a flexible blending facility is recommended at WTP to allow potentially troublesome wastes (e.g., sulfates, phosphates) to be diluted. To aid in the scheduling, a chemistry-based systems model that would allow optimum scheduling of the tanks to be processed is also recommended.

5. If an alternative is needed, CCIM is the recommended technology due to its more mature state of development compared with the other alternatives and its potential for higher temperature operation with new glass forms such as $FePO_4$ that can increase waste loading.

6. Cold operation in pilot test facilities (i.e., at least 1/10 scale) is required before hot operation can be contemplated at any scale [2]. Hot operation at bench scale should then be carried out on actual waste to verify that there are no unexpected issues before larger-scale design work is initiated.

7. The joule-heated melter is the preferred treatment for supplemental treatment. Such a facility should be built with enough flexibility to accommodate new technology in the future if there is a compelling need for doing so. Development of an alternative technology should only be pursued if the compelling need is adequately defined. Any alternative technology should be demonstrated in a separate facility at or near full scale before being implemented in one of the primary processing facilities.

8. Backfitting of alternate technologies in operating HLW facilities is not recommended unless the replacement technology has a TRL of no less than 7 in similar service in a Critical Decision (CD) process and it offers very significant advantages in terms of waste loading and reliability.

9. Backfitting to LAW facilities using new technology with a TRL of not less than 7 may be cost-effective as long as there are no other rate-limiting processes, adequate allowances have been made for the downtime and cost of working in radioactive facilities, and there are significant advantages in terms of waste loading and reliability. To aid the future use of an alternate technology, allowance for space, power supplies, etc. could be made in the construction of additional LAW facilities at Hanford.

10. FBSR (Fluidized Bed Steam Reforming) technology shows some promise. However, it has not yet been operated for a significant time on Hanford LAW waste and the waste form it produces has not yet been accepted by the Washington State regulatory body. Due to the time that it would take to accomplish these two tasks, it would be better to go forward with a technology such as the JHCM or CCIM technology that is well proven and produces a waste form that already acceptable to all.

8.8 References

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APPENDIX 9
Evaluation of the Reliability of Waste Delivery Plans

9.1 Introduction

The U.S. Department of Energy (DOE) Environmental Management Advisory Board (EMAB) Tank Waste Subcommittee (EM-TWS) has been charged to evaluate the reliability of high-level tank waste feed delivery plans for the Hanford and Savannah River Sites. These wastes are considered to pose the highest environmental and human health risks in their corresponding States. At both sites, tank wastes are *retrieved*, *pretreated* including separation of the waste into higher and lower activity fractions and then *treated* in separate facilities before the resulting waste forms are *disposed* in different locales (Figure 9-1 and Figure 9-2). However, differences between these major DOE sites impact the ability of each site to reliably deliver feeds for treatment. The differences between sites include the stage of tank waste processing, the nature of the wastes to be processed, the retrieval methods and endpoints for closure, the pretreatment and treatment methods and waste forms, and the interim storage and disposal options. There is also a critical balancing act in terms of retrieving, pretreating, qualifying, and treating the different types of tank wastes at the two sites to ensure processing effectiveness and a timely end of mission without a preponderant need for special treatment (e.g., producing salt-only waste forms).

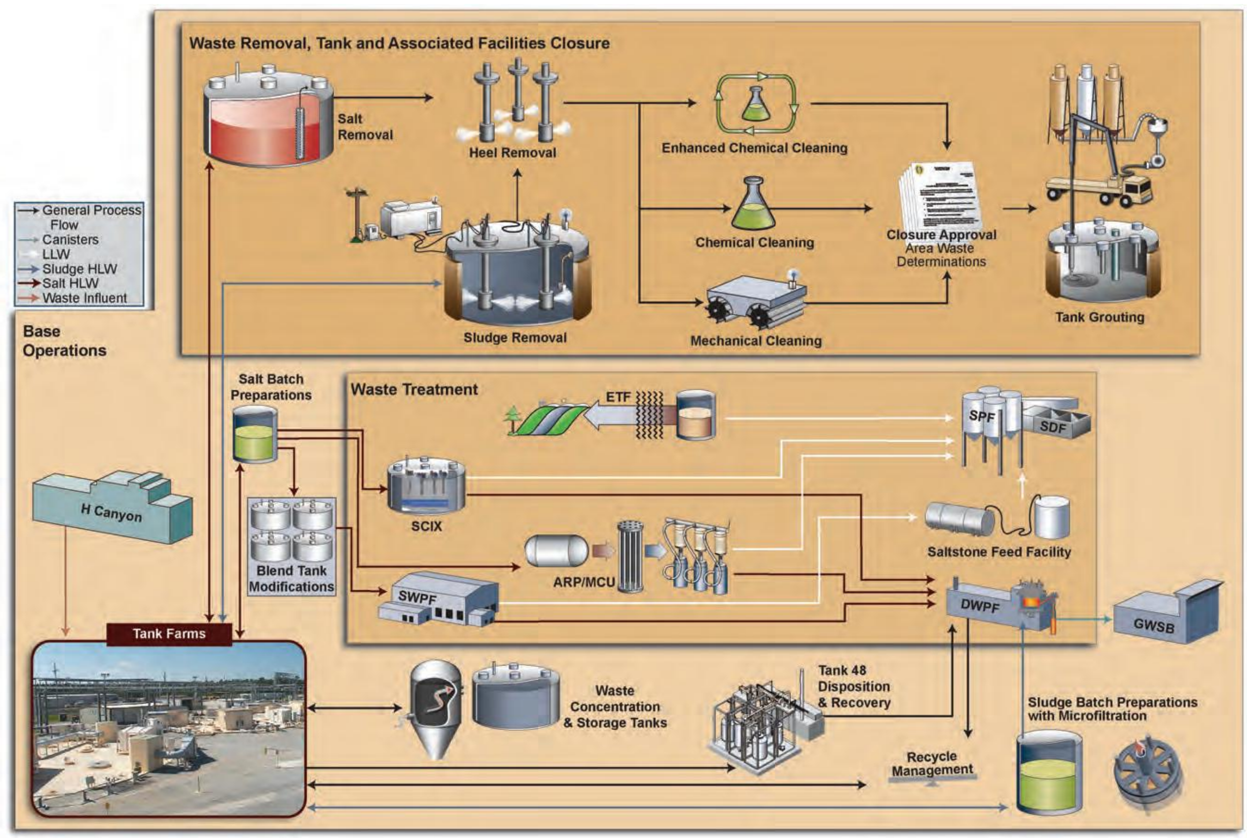

Figure 9-1. Savannah River Site Tank Waste Processing Flow Sheet [1]

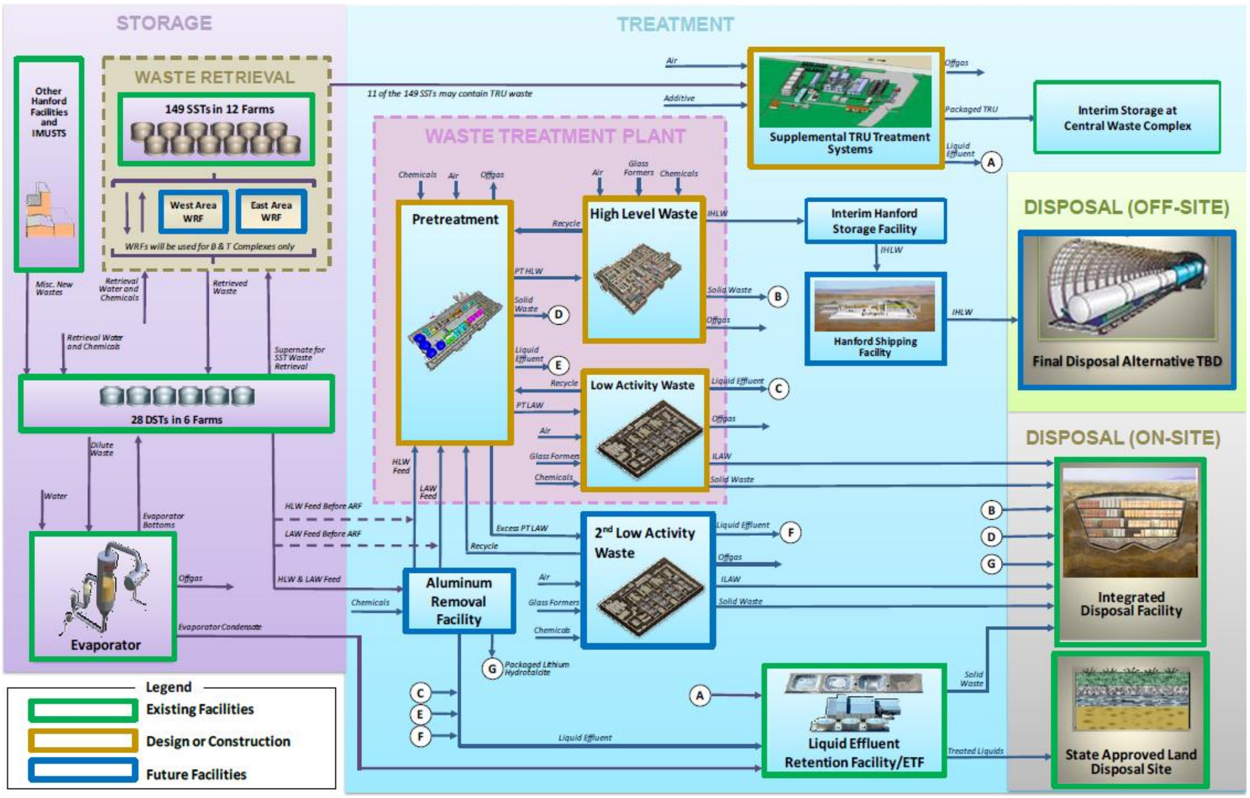

Figure 9-2. Simplified Hanford Process Flow Diagram [2]

The primary differences between the two sites are the stage of the waste treatment processing at each site and the corresponding need and schedule for waste feed delivery. At the Savannah River Site (SRS), treatment and disposal of low-activity waste (LAW) in the Saltstone Processing and Disposal Facilities began in 1990. Vitrification of the high-level, insoluble sludge portion of the tank waste began in the Defense Waste Processing Facility (DWPF) in 1996. To date, 6 of the projected 17 total sludge batches have been treated at SRS. Processing of the high-activity salt portion of the tank waste began in 2007 with the Deliquification, Dissolution, and Adjustment (DDA) process on the Tank 41H waste (completed in 2008). Additional salt processing began in 2008 with the Actinide Removal Process (ARP) / Modular Cesium Removal Unit (MCCU) and will continue until the Salt Waste Processing Facility (SWPF) begins production. To balance the treatment of the high-activity salt and sludge tank wastes through the SWPF and DWPF will require a significant increase in the retrieval, pretreatment, and qualification of SRS tank wastes.

Construction of the Hanford Tank Waste Treatment and Immobilization Plant (WTP) is approximately 50 percent complete. The WTP is scheduled to begin radioactive operations in 2019. The WTP will treat (using vitrification) the entire high-activity fraction of the tank wastes (for off-site disposal) and up to 50 percent of the corresponding low-activity waste (LAW) fraction for onsite disposal. Of the 177 high-level waste tanks at the Hanford Site, 149 are single-shell tanks (SSTs), many of which have leaked or were suspected of leaking in the past. These single-shell tanks were declared a non-compliant treatment, storage, and disposal (TSD) facility under the Resource Conservation and Recovery Act (RCRA) [3]. Because of concerns with risks associated with the SSTs, the tank waste retrieval process planned at Hanford consists of two general phases: 1) retrieving wastes from SSTs for transfer to double-shell tanks (that are RCRA-compliant) for staging and subsequent tank closure activities and 2) mixing, staging, and delivery of the SST waste to treatment facilities [2].

Tank waste characterization, retrieval, and consolidation operations have been continuing at the Hanford Site in preparation for beginning WTP radioactive operations. The wastes from seven Hanford single-shell tanks (SSTs) have been retrieved to the criteria[1] defined in the Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement or TPA) [4] A maximum of three retrievals were completed in 2006. However, waste retrievals must increase dramatically over the next 2½ decades (to a maximum of 12-14 in a single year) to support the current treatment schedule [2] and to satisfy TPA milestones [4]. The waste acceptance criteria (WAC) for the Hanford tank waste treatment facilities and the disposal facilities have not been finalized making the limits on and targets for Hanford waste feed delivery uncertain.

Successful treatment of Hanford and SRS tank wastes would require improvements in various feed delivery processes including retrieval, pretreatment, and qualification. Treatment improvements would be needed at Hanford and would help SRS accelerate its treatment schedule and reduce lifecycle costs. Because of the advanced state of operations at SRS, reasonable options include improved separations and filtering technologies (Appendix 7 of this report), waste glass formulations [5], and Joule-heated, ceramic-lined melters (Appendix 8 of this report). The potential options for improving feed delivery and treatment at Hanford are more open-ended, especially because operations have not yet begun and some facilities have not been selected. Alternative scenarios are being evaluated for completing and accelerating the Hanford treatment schedule including:

- *Baseline* – assumes all pre-treatment is completed in the Pretreatment (PT) Facility and that a 2nd LAW vitrification facility (ILAW) like the first currently under construction at WTP will be built to treat the remainder of the LAW feed.

- *Supplemental Treatment* – assumes that 2nd LAW treatment facility is selected from ILAW, Bulk Vitrification, Grouting, or Fluidized Bed Steam Reforming (FBSR) and is predicated on successful deployment of pre-treatment technologies (in-tank Rotary Microfiltration (RMF) / Small-Column Ion Exchange (SCIX) or at-tank filtration / ion exchange).

- *Enhanced Tank Waste Strategy* – assumes that vitrification would not be used to treat *any* Hanford LAW—instead three FBSR units would be used. This strategy is also predicated on successful deployment of in-tank pre-treatment technologies (RMF / SCIX).

- *Vision 2020*– assumes a path to achieve earliest possible hot operations of WTP facilities (e.g., sequential facility completions, Operational Readiness Reviews, etc. starting with

[1] The requirements for Hanford waste retrieval (using the 99 percent retrieval target) are residual waste volumes not to exceed 360 cubic feet for 100-series tanks or 30 cubic feet for 200-series tanks, or the limit of retrieval technology capability, *whichever is less* [4]. If the waste in a tank cannot be retrieved to these limits, then DOE submits a detailed explanatory report to the EPA and Ecology. Procedures for modifying retrieval criteria are provided in Appendix H to the TPA.

LAW / Balance of Facilities (BOF) / Laboratory (LAB)). This strategy provides an opportunity to produce LAW glass early (2016) and continue until the Pretreatment facility is commissioned. Pretreatment technologies (in- or at-tank filtration / ion exchange), new transfer lines to direct feed LAW and lines from LAW to the Effluent Treatment Facility (ETF), a single LAW melter operating, and offgas recycle to the double shell tanks (DSTs) are needed.

9.2 Charge

A key component of the tank waste programs at Hanford and SRS is the ability to reliably provide feed materials to existing and planned waste treatment facilities. At SRS this has been demonstrated, but further reduction of life-cycle costs will require enhancements to current waste retrieval and delivery processes. For Hanford this will require an evaluation of proposed plans to finalize waste acceptance criteria (WAC) for treatment facilities, optimally sequence tank waste delivery to meet the WAC, and identify specific vulnerabilities to achieving waste delivery. The Hanford baseline waste feed delivery approach to date consists of two major phases of operation – single-shell tank (SST) waste retrieval into the double-shell tank (DST) system for waste staging prior to treatment, and mixing and delivery of DST waste to the treatment facilities. The Subcommittee will consider the SST retrieval and waste staging options to enable timely, reliable feed delivery.

9.3 Findings and Conclusions

The findings and conclusions enumerated here were derived from a review of the presentations and technical reports provided by DOE personnel during face-to-face meeting and from data calls for this charge.

9.3.1 There is a critical need to balance the retrieval, pretreatment, and qualification processes and the treatment of the resulting low-activity and high-activity tank waste feeds at both the Savannah River and Hanford Sites.

A requisite balance must be established and maintained between the preparation of tank waste feed material (retrieval, pretreatment, and qualification) and its subsequent treatment to satisfy various contract requirements and programmatic needs including minimizing the potential mismatch between the treatment of the higher and lower activity waste fractions. At SRS, such a balance appears to have been struck between the production of qualified sludge and salt feed batches in the tank farm (including DDA and ARP / MCCU for salt treatment) and the treatment processes in DWPF and Saltstone Processing and Disposal Facilities. The changes that have been made to the DWPF melter to increase throughput (and potentially waste loading) and the construction and startup of the Salt Waste Processing Facility (SWPF) will require an increase in the production and qualification of waste material for subsequent treatment and the striking of a new balance between feed preparation and treatment at SRS.

A balance similar to that which was struck at SRS must be established and maintained at the Hanford Site. The delivery of qualified feed to the WTP is more complicated than that at SRS because there are more tanks at Hanford with more waste types—some of which are inter-mixed and recalcitrant, resulting in more complicated characterization, retrieval, pretreatment, and qualification to produce feeds for the much higher contract rates for treatment at the WTP. As more information is obtained, the second Hanford LAW treatment facility can be sized to help strike such a balance. The valuable information that has been learned from the pretreatment and delivery of waste at SRS for the past 15+ years can be applied at both sites.

9.3.2 To satisfy current schedules and milestones and to balance feed delivery and treatment of LAW and HLW, there will be a need to increase the production of qualified salt and sludge feeds at both the Savannah River and Hanford Sites

In terms of waste feed delivery for subsequent treatment, the primary differences between the Savannah River and Hanford Sites are the stage of the waste treatment processing at each site and the corresponding need and schedule for waste feed delivery. At the Savannah River Site (SRS), treatment and disposal of low-activity waste (LAW) in the Saltstone Processing and Disposal Facilities began in 1990 and the corresponding vitrification of high-activity, insoluble sludge portion of the tank waste began in the Defense Waste Processing Facility (DWPF) in 1996. Processing of the high-activity salt portion of the tank waste began in 2007 and will accelerate when the Salt Waste Processing Facility (SWPF) begins production. To balance the treatment of the SRS high-activity salt and sludge tank wastes through the DWPF and Saltstone Disposal Facility as currently planned will require a significant increase in the retrieval, pretreatment and qualification of SRS tank wastes.

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is under construction and is currently scheduled to begin radioactive operations in 2019. The WTP is designed to treat the entire high-activity insoluble fraction of the tank wastes and perhaps 50 percent of the corresponding low-activity salt fraction. Of the 177 high-level waste tanks at the Hanford Site, 149 are single-shell tanks (SSTs), many of which were overfilled, have leaked, or were suspected of leaking in the past and represent the majority of the risk posed by tank wastes at the site. Tank waste characterization, retrieval, and consolidation operations have been ongoing at the Hanford Site in preparation for commencing WTP radioactive operations. To date the wastes from seven single-shell tanks (SSTs) have been retrieved to the criterion defined in the TPA [4] with a maximum of three retrievals in 2006 [2]. However, the waste retrievals (with corresponding pretreatment and qualification) must increase dramatically over the next approximately 2½ decades (to a maximum of 12-14 in a single year) to support the current treatment schedule [2] and to satisfy TPA milestones [4].

9.3.3 The feeds and tank farm operations (especially those involving single-shell tanks) at the Hanford Site are complex, interdependent, and highly constrained, which may impact waste feed delivery and thus treatment

At SRS, the Plutonium Uranium Reduction Extraction or PUREX process (which included the H-Area Modified or HM PUREX process) was used to separate plutonium; whereas at Hanford the PUREX process was used in conjunction with the Bismuth Phosphate and REDuction OXidation (REDOX) separations processes [6]. At SRS, the resulting PUREX and HM sludge wastes were neutralized and stored in separate tanks to the extent possible. At Hanford, many of the tank wastes were reprocessed to recover uranium and fission products, and wastes were often intermixed based on tank availability. Thus, when compared to SRS, there are more waste tanks containing more waste types (that often were mixed) resulting in more variable wastes, including some that are recalcitrant, making characterization, retrieval, processing, and qualification more difficult than at SRS. There are also significant constraints on the order that waste tanks (i.e., the single-shell tanks) will be processed based on the milestones in the Consent Decree in *Washington v. DOE*, Case No. 08-5085-FV and Hanford TPA [4].

9.3.4 Upgrades will be needed to the Hanford Effluent Treatment Facility (ETF) to treat liquid wastes generated from the WTP

The ETF is a state-permitted facility that receives (via the Liquid Effluent Retention Facility) and treats liquid wastes from various sources on the Hanford Site. The ETF treatment processes remove radioactive and hazardous contaminants from the wastewater for storage until tests confirm that various contaminants have been removed or lowered to levels making it acceptable for discharge to a state-approved disposal site in Hanford's 200 Area. Treating wastewater from the WTP will require upgrades at ETF to manage increased throughput (approximately twice the 28 Mgal currently treated) and increased corrosion potential from WTP effluents. There may also be a concern with the level of volatile radioactive constituents (e.g., Tc-99 and I-129) from the LAW melter off-gas system that may exceed acceptable levels for ETF treatment.

9.3.5 The waste acceptance criteria (WAC) for the Hanford tank waste treatment facilities and corresponding disposal facilities have not been finalized, which may impact waste feed delivery

Before pretreated waste can be fed to Hanford treatment facilities, samples must be collected and tested to assure that the waste meets waste acceptance criteria (WAC) for the treatment facility. Two such treatment facilities are currently under construction at the Hanford WTP. The high-level waste vitrification (IHLW) facility has been designed to treat the entire expected high-activity insoluble portion of the Hanford tanks wastes and the Cs-137 in the salt wastes that poses the major source of radiation. The low-activity vitrification (ILAW) facility currently under construction is designed to treat a portion of the low-activity fraction of the salt wastes, and thus supplemental treatment will be necessary to treat the remaining salt waste to meet TPA milestones [4].

The key interface for success of the ORP tank waste treatment mission is the waste feed delivery interface that ensures the timely, efficient, and compliant delivery of feed from the tank farm to the WTP. The WAC and physical and administrative details for the feed delivery interface are described in *ICD 19 – Interface Control Document for Waste Feed*. Important aspects of this critical interface are being resolved including the WTP waste acceptance data quality objectives and an evaluation of the ability to adequately mix, sample, and deliver individual feed batches to the WTP for treatment. Because key aspects of the feed delivery interface have not been finalized, the limits on and targets for Hanford waste feed delivery are uncertain[2]. Furthermore,

[2] For example, projected feeds from the baseline case will continue to be evaluated against "screening criteria," including the LAW and HLW specifications in the WTP Contract [7], hydrogen generation limits, and criticality safety limits to identify potential issues for future resolution [2]. Previous evaluations indicated that some delivered feed would be expected to fall outside the screening criteria.

the acceptance criteria and permits required for the disposal facilities for both the high-level and low-activity waste forms that will be produced from the Hanford WTP have not been finalized (or, in some cases, have not been started).

9.3.6 Representative mixing and sampling in the large Hanford tank farm tanks that will be necessary to support waste feed delivery for treatment in the WTP will likely be problematic

Pretreated wastes at Hanford must be sampled and analyzed to demonstrate that they satisfy waste acceptance criteria (WAC) and feed specifications for the corresponding treatment facility per *ICD 19 – Interface Control Document for Waste Feed* [8].These requirements translate into the need to satisfy appropriate requirements to high confidence (i.e., 95 percent confidence for fissile components and 90 percent for others). Representative sampling cannot be assured in the large tanks that will be used to stage wastes for delivery to WTP. An evaluation is currently underway of the ability in the tank farm to adequately mix, sample, and deliver individual feed batches to the WTP for treatment [2]. If methods cannot be identified or developed to allow limits to be satisfied to the high confidence required, additional sampling and analysis may be required that would impact pretreatment, qualification, and delivery schedules. Resulting delays would impact treatment schedules and possibly jeopardized the making of important treatment milestones.

9.3.7 Options may be needed to temporarily store treated TRU, low-activity and high-level waste forms at the Hanford Site to manage waste feed delivery and treatment schedules and to satisfy milestones

The current plan is to send treated TRU waste to the Central Waste Complex (CWC) in the Hanford 200 West Area assuming that the waste would be acceptable for interim storage at the CWC (an interim status RCRA facility) pending a determination of final disposition. The treated LAW would be sent to the Hanford Integrated Disposal Facility (IDF) and disposed in the cell permitted as a RCRA Subtitle C landfill system; however, the IDF performance assessment is pending completion of the Tank Closure and Waste Management (TC & WM) Environmental Impact Statement (EIS) and Record of Decision (ROD). The treated HLW will be stored at the Interim Hanford Storage Facility (IHSF) in the 200 East Area, which is expected to be operational by 2018 even though the design and construction of this facility have not been planned in detail [2].

Current schedules indicate that if sufficient funding is provided and no unforeseen difficulties arise during permitting activities, then the required storage and disposal facilities will be available to support WTP operation. However, if there are difficulties in funding, building or permitting the HLW storage facilities or in permitting the Integrated Disposal Facility for treated LAW or the CWC for planned TRU wastes, then options may be needed to temporarily store treated TRU, HLW, and/or LAW forms. Under these circumstances, a lack of such storage would impact WTP treatment operations as well as feed delivery and ultimately tank farm operations.

9.3.8 The Hanford 242-A Evaporator is a single-point of failure that may impact waste feed delivery even if additional evaporator capacity is introduced

The 242-A Evaporator must continue to operate throughout the lifetime of the River Protection Project (RPP) mission, as it is the only such facility to support SST retrieval operations, to maintain the appropriate sodium concentration in the feed delivered to WTP, and to manage space in the DSTs. Additional evaporator capacity is being researched (e.g., wiped or thin film evaporation technologies); however, the technologies being considered are not appropriate to replace the 242-A Evaporator functionality and their implementation would rely on resolving a number of technical and budgetary issues. Without additional evaporative capacity of the type provided by the 242-A Evaporator, a significant failure of the 242-A Evaporator requiring a long-term outage might impact available DST space, SST retrievals, and ultimately the timely delivery of feed to the WTP for treatment. Furthermore, plans will require much higher annual availability of the 242-A Evaporator beginning in 2030 when the Evaporator will be over 50 years old through 2040 where the risk of failure would likely increase with the age of the evaporator [2].

9.3.9 Fouling may still be an issue in the Savannah River 242-16H (2H) Evaporator System

The 242-16H or 2H-Evaporator system at SRS is used to evaporate the recycle stream coming from DWPF. In 1997, the 2H-Evaporator began processing silicon-rich wastes from the DWPF recycle that were mixed with an alumina-rich stream from H-Canyon reprocessing operations [9]. The evaporator became fouled and was finally shut down in October 1999. A method was developed to successfully clean the evaporator pot with dilute nitric acid [10]. Despite improvements in cleaning the evaporator pot, fouling still occurs in the 2H-Evaporator system and the need to increase feed production and/or changes in recycle composition resulting from possible melter and off-gas changes as well as waste composition and frit changes may impact fouling in the evaporator system.

9.3.10 Factors have changes that may make fluidized bed steam reforming (FBSR) not the most appropriate technology to destroy organics in the SRS Tank 48H waste

Tank 48H contains approximately 250,000 gallons of a salt solution containing 22,000 kg of tetraphenylborate (TPB) and 400,000 Ci of Cs-137. Fluidized bed steam reforming was selected to process this unique organic waste. Since the selection of FBSR to treat the Tank 48H waste, a number of factors have resulted in a review of the costs, schedule, and technical maturity criteria. This review has led to the evaluation of competing technologies including direct vitrification and a copper catalyzed chemical oxidation process that was not considered in previous evaluations.

9.3.11 A large number of projects (approximately 30) must be completed to pretreat and feed low-activity waste to the ILAW facility

There are numerous projects (perhaps as many as 30) that must be completed before Hanford low-activity tank wastes can be retrieved, pretreated, qualified, and staged for treatment in the LAW vitrification facility currently under construction in the WTP. According to the information obtained from presentations and data calls, there is a reasonable chance that each of these projects can be completed to meet the TPA milestones as long as budget requests are met. However, difficulties in securing the proper funding and/or attempting to accelerate treatment in the ILAW facility may significantly decrease the chance of completing all the necessary projects by the time needed.

9.4 Background/Overview

Both the Hanford and Savannah River Sites have facilities that were used to separate plutonium from spent fuel for weapons production. At SRS, only the Plutonium Uranium Reduction Extraction (PUREX) separation process was used (that included the H-Area Modified or HM PUREX process); whereas at Hanford, the PUREX process was used along with the older and less reliable Bismuth Phosphate and REDuction OXidation (REDOX) separations processes [6]. The Hanford Site also reprocessed some wastes in the U-Plant to recover uranium, and many wastes were reprocessed in B-Plant to recover cesium and strontium (stored in capsules in the Hanford Waste Encapsulation and Storage Facility or WESF). The wastes from the Hanford reprocessing operations were often inter-mixed; whereas, the PUREX and HM wastes were kept separated at SRS. Therefore, there are large differences in the characteristics and compositions of the tank wastes at these two sites.

Despite the differences, there are also similarities among the tank wastes at the two sites including the physical forms of the wastes. The tank wastes at both sites are primarily composed of three physical forms: insoluble sludges (precipitated upon neutralization of acidic separations streams for storage in carbon steel tanks), supernatant liquid, and saltcake (formed from evaporation of supernatant liquid typically to free up tank farm space). The supernatant liquid and saltcake wastes together are often denoted *salt wastes*.

Recent estimates of the volumes and activities for these physical forms in the tanks at the Savannah River and Hanford Sites are illustrated in Figure 9-3[3] and Figure 9-4 / Figure 9-5, respectively. As can be seen from these illustrations, the volume (approximately 53×10^6 gallons) of Hanford tank wastes is larger than that (approximately 37×10^6 gallons in 2010) at Savannah River, but there is higher total activity (352 MCi in 2010) in the SRS wastes than that (193 MCi) in the Hanford tanks (due to reprocessing to remove fission products at the Hanford Site). At SRS, the salt waste represents more than half of the total activity in the tank waste with almost 95 percent of the salt waste activity in the supernatant phase. Furthermore, the quantity of salt waste at Savannah River is greater (and less concentrated) than that at Hanford [6]. At Hanford, the total activity is approximately split between the 149 single-shell and 28 double-shell tanks.

[3] Figure 9-3 illustrates the impacts of recycle, pretreatment processes, and ongoing H Canyon operations on the SRS treatment process: activity may decrease significantly (17 percent) due to treatment, but volume increases marginally (2 percent) over short periods of time.

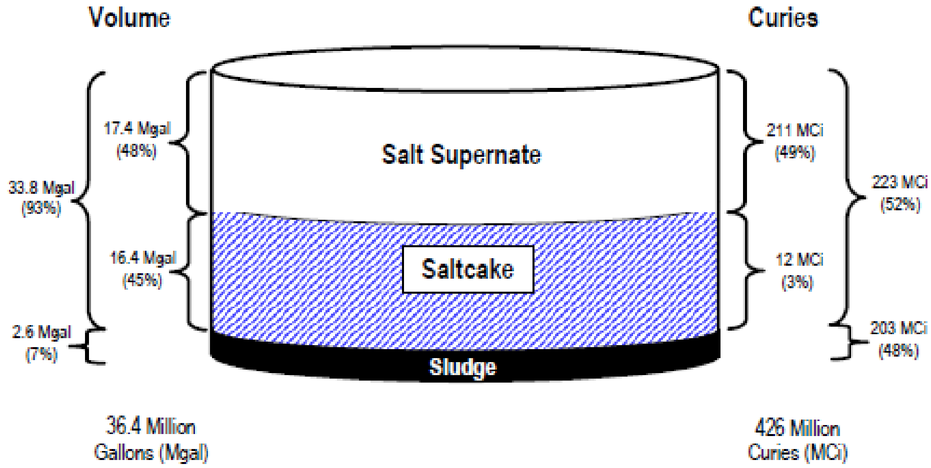

Figure 9-3(a) Inventory as of December 2004

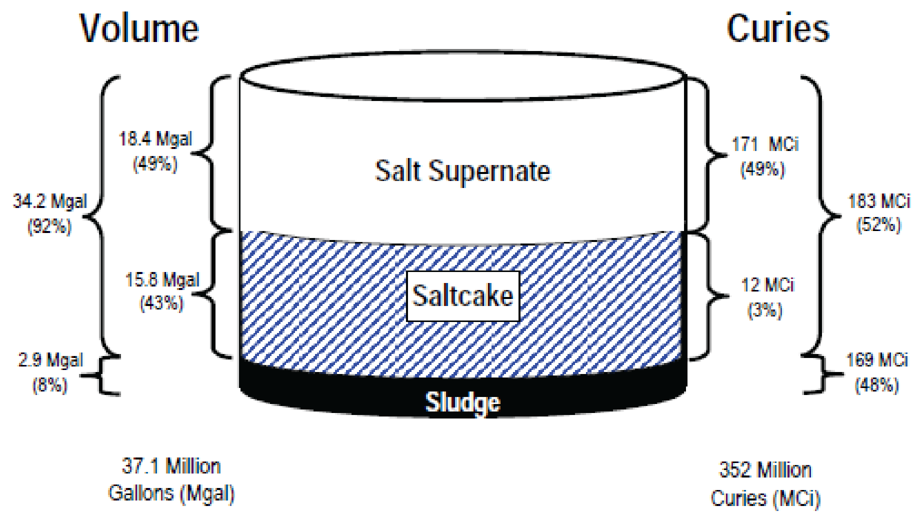

Figure 9-3(b) Inventory as of June 2010

Figures 9-3. Savannah River Site Tank Waste Composite Inventory

9.4.1 SRS tank waste characteristics

Starting in 1951, SRS produced nuclear material for national defense, research, medical, and space programs [1]. Fissionable material was separated from targets irradiated in SRS reactors and spent fuel; the separation resulted in a large volume of chemical wastes containing radioactive constituents. As of June 2010, approximately 37×10^6 gallons of radioactive waste was stored in the SRS tank farm system (Figure 9-3(b)). The SRS tank waste is a complex mixture of chemical and radioactive constituents generated during the acid-side separation of nuclear materials from irradiated targets and spent fuel using the PUREX process in F-Canyon and the modified PUREX process in H-Canyon (HM process) [1]. Caustic was added to the waste stream to reduce its corrosion potential for storage in large carbon steel tanks; metal oxides precipitated and then settled as sludges, and supernate was evaporated to form saltcake.

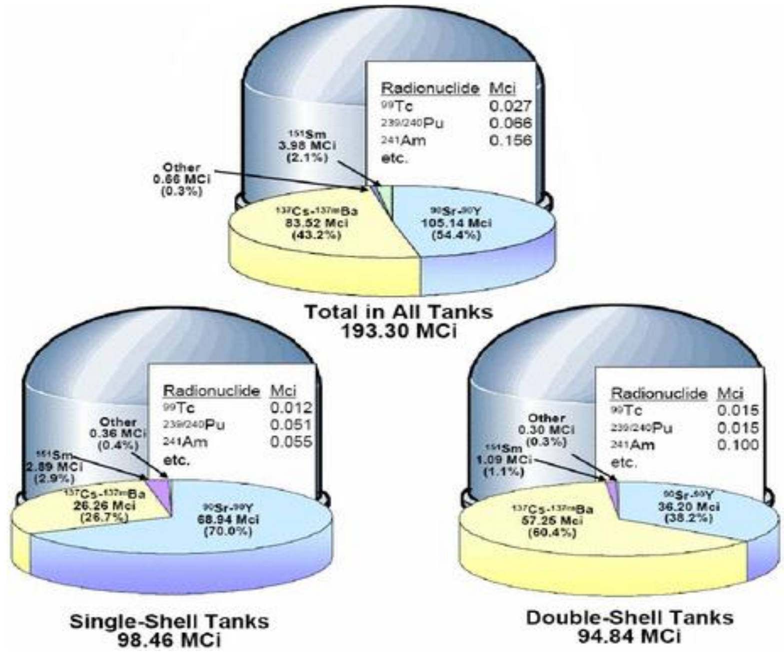

Figure 9-4. Radioactivity in Hanford Tank Wastes (as of January 2004)

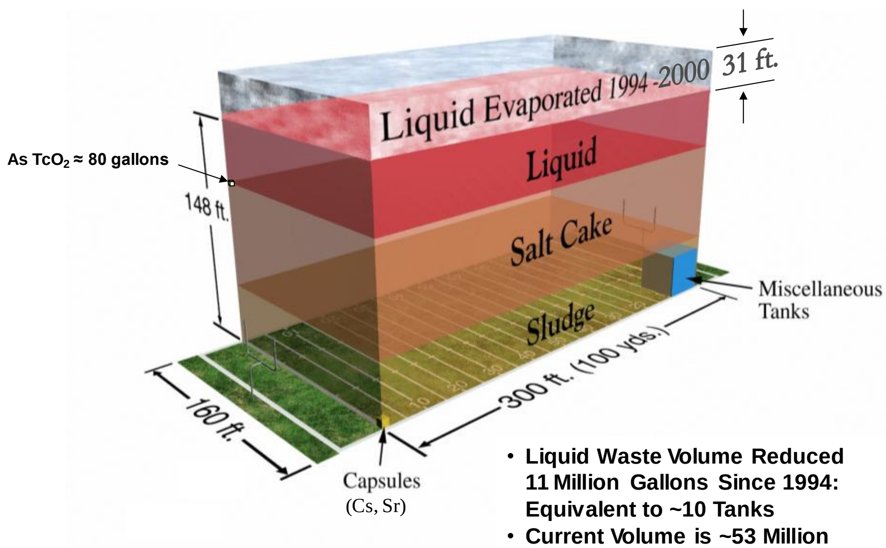

Figure 9-5. Hanford Tank Waste Composite Volume[4]

Despite the fact that, in general, only a single separation process (namely, PUREX) was used at SRS, there is significant variability in the radionuclide and chemical content of the resulting tank wastes. Waste streams from the 1st-cycle (higher heat) and 2nd-cycle (lower heat) extractions were stored in separate tanks (from each Canyon) to better manage waste heat generation [1]. Upon caustic addition (for corrosion control), metal oxide precipitates settled, resulting in four

[4] Presentation by Dr. Gene Ramsey to the EM-TWS on January 26, 2011, entitled *Technetium Issues: WTP LAW and Recycle*.

characteristic sludge forms (i.e., higher and lower heat PUREX and HM) generally found in their original tanks. Fission product concentrations were approximately three times higher in both PUREX and HM higher-heat waste sludges, and differences in the PUREX and HM processes produced variations in the concentrations of major sludge components (e.g., iron, aluminum, manganese, nickel, and uranium) in the corresponding sludges.

The corresponding salt wastes have not been managed as four distinct waste forms due to tank farm processing and space management issues; however, saltcake was originally maintained in separate salt tanks. The salt wastes were blended to reduce soluble wastes into general PUREX and HM salts and concentrates. Soluble salt solutions were evaporated to provide working space in the tank farms; the evaporation process resulted in crystallized salts that deposited with overlying and interstitial concentrated salt solutions [1]. Recently salt solutions have been transferred between the H-Area and F-Area Tank Farms because of space limitations and to support waste preparation, staging, and delivery operations including sludge washing, saltcake removal, and DWPF recycle processing. Such blending of PUREX and HM salt wastes will continue until the Salt Waste Processing Facility (SWPF) begins operations (currently targeted for 2015).

9.4.2 Historic SRS feed delivery activities to support waste treatment

As illustrated in Figure 9-1, waste processing and treatment at SRS can be generally divided into those actions needed to 1) retrieve and prepare sludge for transfer to and treatment in the Defense Waste Processing Facility (DWPF) and those required to 2) retrieve and prepare the salt wastes for treatment of the lower-activity fraction in the Salt Waste Processing and Disposal Facilities and the higher-activity fraction in the DWPF (coupled with the sludge). Salt waste treatment began in the early 1990s and sludge treatment began in 1996 with the startup of the DWPF; six sludge macrobatches have been processed to date. Treatment of the low-activity soluble portion of the salt waste began with the opening of the Saltstone Disposal Facility (SDF) in 1990. Processing of the high-activity salt portion of the tank waste (including coupled operations in DWPF), that began in 2007 with the Deliquification, Dissolution, and Adjustment (DDA) process on the Tank 41H waste, is continuing with the Actinide Removal Process (ARP) / Modular Cesium Removal Unit (MCU) process until the Salt Waste Processing Facility (SWPF) comes on line. As discussed in Appendix 7 of this report, supplemental treatment using at-tank or in-tank Small-Column Ion Exchange (SCIX) and filtration is also under research to treat SRS salt waste and accelerate the SRS treatment mission.

As of March 2011, the DWPF poured 12×10^6 pounds of glass containing 35 MCi into over 3,100 canisters that are being stored at SRS for ultimate disposal in a geologic repository. The first Saltstone Disposal Unit (SDU) (denoted Vault 1), approximately 100 feet wide, 600 feet long, and 25 feet tall, has been filled with treated LAW. A second rectangular SDU (Vault 4), approximately 200 feet wide, 600 feet long, and 26 feet high, is currently being filled [1]. These existing vaults are shown in Figure 9-6. An additional disposal unit (Vault 2) is currently under construction at SRS (Figure 9-6) that is a cylindrical unit approximately 150 feet in diameter and 22 feet high. Additional SDUs will be constructed on a just-in-time basis considering salt waste processing rates [11].

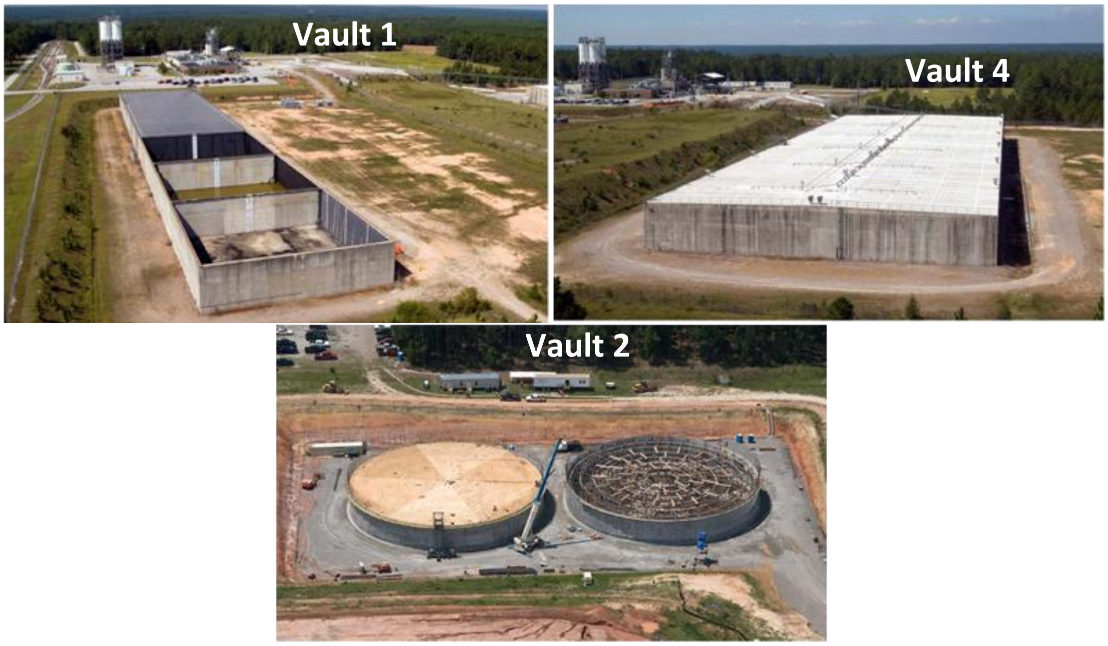

Figure 9-6.   Existing Savannah River LAW Disposal Units

9.4.2.1 Waste Removal Activities at SRS

The first step in the disposition of tank wastes is removal of wastes from the tanks. At SRS, this initially entails a bulk waste retrieval effort (BWRE) whereby sludge is transferred to one of two feed preparation tanks (i.e., Tank 42H beginning in 2013 for aluminum dissolution or Tank 51H otherwise) and saltcake is dissolved, removed, and staged in Tank 21H or Tank 23H for pretreatment in ARP / MCU, SCIX, or SWPF.

Liquid is added to the tank adequate to suspend the sludge solids. Existing supernate or DWPF recycle is used when available to reduce the introduction of new material into the tank farm system [1]. Three or four mixing pumps are then used to suspend the sludge solids that are then transferred from the tank as slurry. These operations are repeated including a periodic lowering of the mixer pumps until removal becomes ineffective.

Salt waste removal instead uses a modified density gradient process (Figure 9-7) followed by mechanical agitation of the contents [1]. Initially a disposable transfer pump is placed at the bottom of the tank well to pump out the interstitial liquid from the tank until the well is dry. Liquid (e.g., DWPF recycle when available) is added to the tank to dissolve the salt, which produces a near-saturated solution that is pumped from the well. As the dissolution process progresses, the dissolution rate slows significantly; a submersible mixer pump (SMP) is then used to suspend and remove the remaining insoluble solids in a manner similar to sludge removal [1].

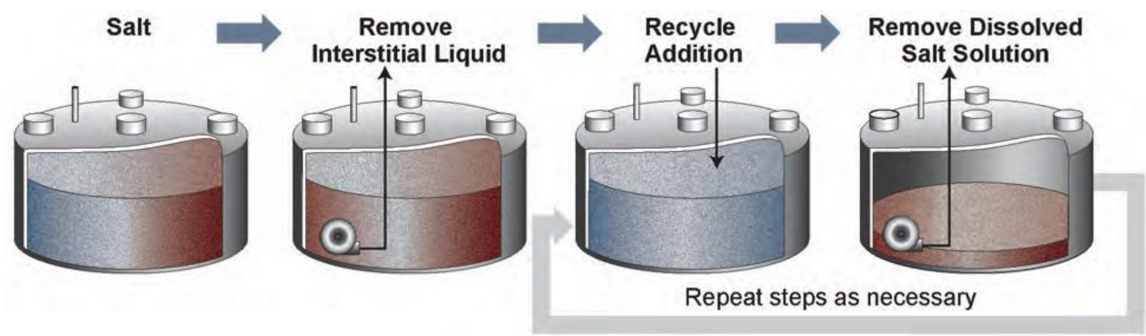

Figure 9-7. The Modified Density Gradient Process to Remove SRS Salt Waste

After the BWRE has removed the amount of material practical using the aforementioned technologies, heels are removed using typically first mechanical and then chemical cleaning methods. Mechanical removals first use SMPs to suspend and remove waste until approximately 5,000 gallons remains and then may use more aggressive methods including hydro-lancing robotic crawlers [1]. Chemical cleaning using oxalic acid is employed (perhaps in cycles with mechanical methods) when mechanical methods have not removed waste to the extent technically practicable and the highly radioactive constituents to the maximum extent practical [1].

9.4.2.2 Sludge Processing at SRS

The basic steps involved in processing sludge at Savannah River are: 1) removing sludge from the tanks, 2) blending and washing the retrieved sludge solids, 3) staging, qualifying, and feeding washed sludge solids to the DWPF, and 4) treating the sludge in DWPF. Currently sludge processing at SRS is limited by the efficiency of the sludge washing process, tank space, and DWPF processing rates.

Sludge preparation is performed in Tank 51H. Preparations are underway to use Tank 42H as a second sludge preparation tank to increase the availability of sludge feed availability for treatment in DWPF as indicated in Figure 9-8. Washed sludge is transferred as a slurry to the DWPF where it is mixed with the high-activity salt waste stream and a glass frit (i.e., “coupled operations”) for vitrification in the DWPF melter. The waste glass is poured into stainless steel canisters for on-site storage pending disposal in a geologic repository.

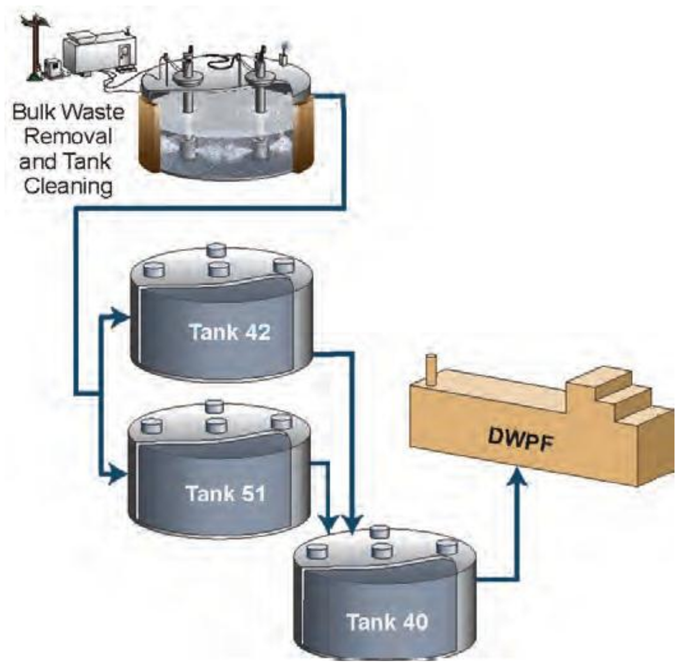

Figure 9-8. Future Sludge Feed Preparation at SRS [1]

DWPF melter performance has historically been the primary factor limiting treatment rates (215 canisters / year for the last 10 years) at SRS. The following canister production rates can currently be supported for the following systems [1]:

- Sludge washing and feed preparation – 250 canisters / year
- DWPF melter feed preparation – 325 canisters / year
- All other DWPF plant systems – 400+ canisters / year

Plans have been made to improve the canister production rate at SRS to reach a nominal rate of 400 canisters per year, which approaches the original design production capacity (of more than 400 canisters per year) for DWPF. The improvements include 1) retrofitting the DWPF melter with bubblers and improving the melter offgas system (completed in September 2010) and 2) improving the DWPF feed preparation system (e.g., introducing an alternative reductant for melter REDOX control and adding the frit dry), and implementing operational improvements (e.g., minimizing canister decontamination water). Coupled operations will continue with processing the cesium strip effluent in the Slurry Mix Evaporator (SME) that is the final control point for the production of acceptable melter feed in DWPF.

9.4.2.3 Salt Waste Processing at SRS

Processing of a lower-activity fraction of SRS salt waste began in 1990; however, the original process to treat the higher-activity portion of the SRS salt wastes was abandoned and sludge-only operations were carried out in DWPF from startup in 1996 until 2007 when the Deliquification, Dissolution, and Adjustment (DDA) process (Figure 9-9) was commenced to prepare the salt waste from only Tank 41H for treatment. The Tank 41H material, which had a relatively low radioactive content, was selected because the DDA process alone could produce a waste feed stream that satisfied the Salt Processing Facility (SPF) waste acceptance criteria. The Tank 41H salt was first deliquified by draining and pumping, the deliquified salt was dissolved by adding water, and the salt solution was then transferred and mixed with other wastes to feed the SPF.

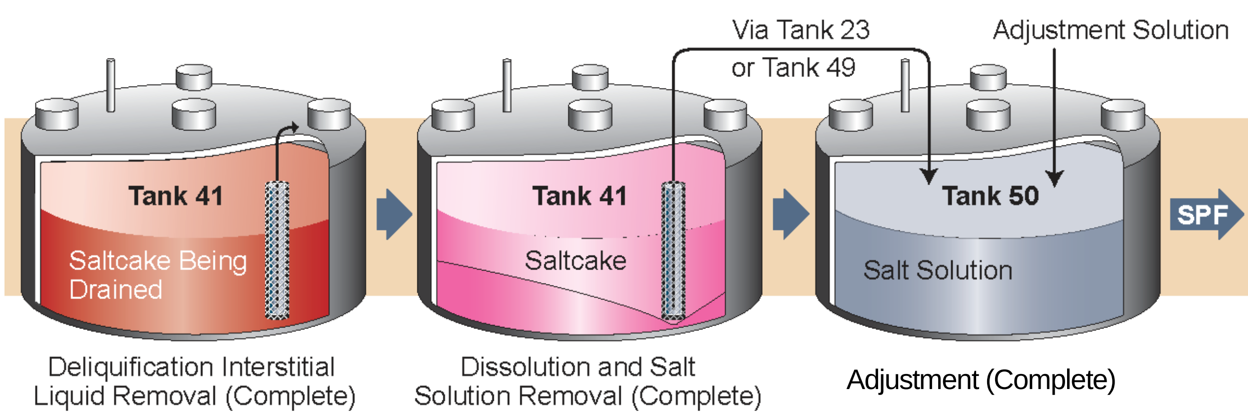

Figure 9-9. The Deliquification, Dissolution, and Adjustment (DDA) Process for Preparing SRS Tank 41H Salt Waste [12]

The DDA process was evaluated during development of the National Defense Authorization Act (NDAA) Section 3116 basis for supporting the waste determination of treated SRS salt waste [13]. As illustrated in Figure 9-10, approximately 2.5 of the 3.0 to 5.0 MCi (or 50 to 83 percent) of the activity ultimately disposed of in the SRS Saltstone Disposal Facility (SDF) would come from the DDA process. Despite the large percentage of activity coming from the DDA process, the 3116 determination for the process concluded that the overall salt waste treatment process described in Figure 9-10, including DDA, ARP / MCU, and SWPF would satisfy the "removal to the maximum extent practical" standard in Section 3116 of the NDAA. This standard was described as follows [13]:

> Removal to the extent "practical" is not removal to the extent "practicable" or theoretically "possible." Rather, a "practical" approach to removal is one that is "adapted to actual conditions," "adapted or designed for actual use; useful," a method that is selected "mindful of the results, usefulness, advantages or disadvantages, etc., of [the] action or procedure." The considerations that bear on whether radionuclide removal will be accomplished to the maximum extent practical will therefore vary depending not only on the theoretically possible or available technologies that may be deployed but also the overall costs and benefits, not only economic but more broadly considered, of deploying them with respect to a particular waste stream. The "maximum extent practical" standard contemplates room for the exercise of expert judgment in weighing, for example, environmental, health, timing or other exigencies; the risks and benefits to public health, safety, and the environment arising from further radionuclide removal as compared with countervailing public health and considerations that may ensue from delay; the reasonable availability of proven technologies; the usefulness of such technologies; and the sensibleness of utilizing such technologies. What may be removal to the maximum extent practical at one point in time may not be that which, on balance, is practical, feasible, or sensible at a prior or later point in time.

The use of DDA, ARP / MCU, and SWPF was predicted to remove 98.7 percent of the activity in the salt waste for treatment in the DWPF and ultimate disposal in a geologic repository; whereas, the remaining activity disposed of in the SDF would primarily result from short-lived Cs-137 (and its daughter Ba-137m). The DDA and ARP / MCU processes were seen as interim steps; the majority of the salt waste and its activity would be processed through the SWPF with its much higher removal efficiency. Furthermore, the interim processing was seen as necessary to put DOE in the position to continue treating wastes, especially those from tanks that lack full secondary containment, until SWPF commences operations [13]. The treated salt waste from DDA would satisfy the Class C concentration limits and its disposal in SDF would meet 10 CFR Part 61, Subpart C, performance objectives [13]. Thus, the overall strategy was deemed to satisfy the "maximum extent practical" standard in Section 3116 of the NDAA. The DDA process began with Tank 41H salt waste in 2007 and completed operations in 2008.

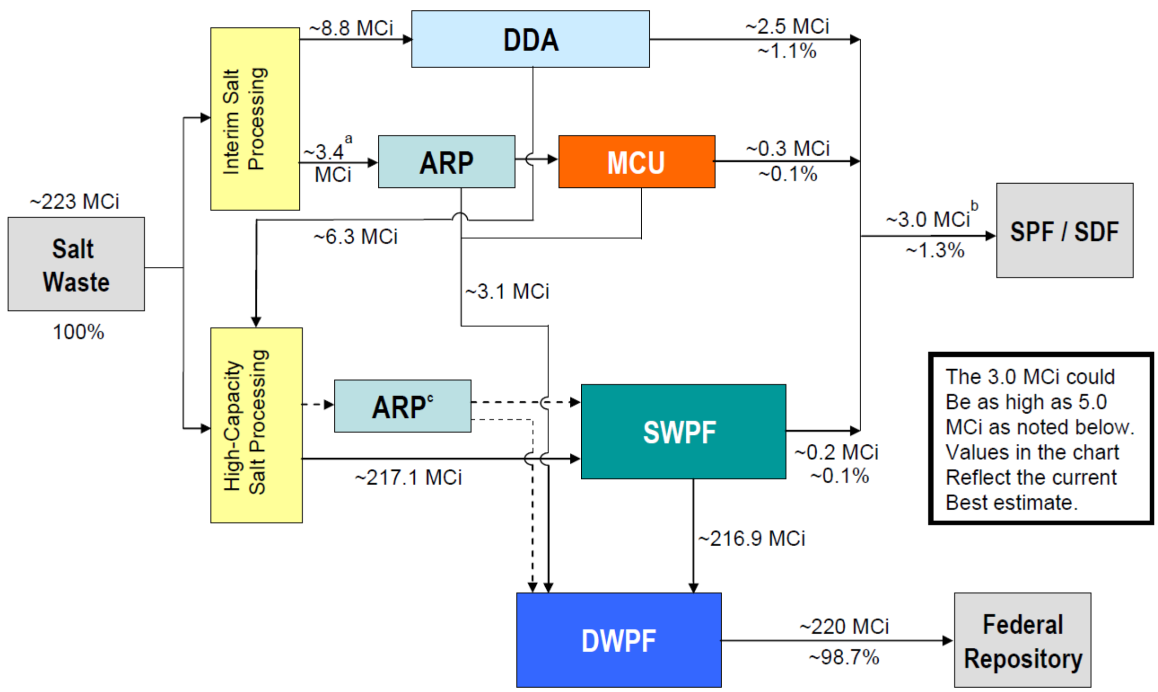

Figure 9-10. Salt Processing Pathways and Corresponding Activities [13]

After completion of DDA on Tank 41H salt waste, a second interim salt processing operation was begun in 2008 employing the ARP / MCU. ARP, which was implemented by modifying two existing SRS sites, consists of striking salt waste with monosodium titanate (MST) in alternating tanks to remove strontium and actinides, filtering until approximately 5 percent solids accumulate (where these solids are then transferred to DWPF for treatment), and transferring the remaining clarified liquid (less 99.997 percent of the incoming strontium) to the MCU for cesium removal. The MCU removes cesium to a decontamination factor of approximately 12. The cesium strip effluent is transferred to DWPF for treatment and the decontaminated salt solution is sent to Tank 50H for processing and disposal in the Saltstone Processing and Disposal Facilities (SPF / SDF). The ARP / MCU will be operated until six months before SWPF commences operations to allow necessary connections to be made to the SWPF.

The SWPF will treat the majority of the volume and activity in the SRS salt wastes using the same basic technology as the ARP / MCU but at a significantly higher rate and decontamination factor. Thus, SWPF is the cornerstone of the SRS salt waste processing strategy [13]. The decontaminated salt stream from the SWPF when treated in the SPF / SDF is expected to satisfy Class A concentration limits for Cs-137, Sr-90, and actinides and add less than 0.2 MCi to the overall SDF inventory as illustrated in Figure 9-10 [13].

As indicated in Figure 9-1, small-column ion exchange (SCIX) is being evaluated at SRS to provide additional salt processing capacity to accelerate salt waste processing and ultimately salt tank closure. The SCIX process utilizes a non-elutable crystalline silicotitanate (CST) resin to remove Cs-137 from the salt solution. Upon loading with Cs-137, the resin is discharged and ground to reduce the size to that approximately in the range of SRS sludge before transfer to the DWPF for treatment. The SCIX was not considered in developing the 3116 basis to support the waste determination of treated SRS salt waste. However, if the decontamination efficiency of the CST resin is demonstrated to be at least equivalent to that assumed for SWPF in the 3116 basis report [13], then introduction of SCIX to treat SRS salt waste would seem reasonable from both technical and regulatory standpoints.

9.4.2.4 Tank 48H

Tank 48H was isolated in 1983 because of risks posed by the tank contents. It contains approximately 250,000 gallons of a salt solution containing 22,000 kg of tetraphenylborate (TPB) and other solids. The TPB was used to separate 400,000 Ci of Cs-137 from salt waste for disposal in the DWPF. However, it was discovered that TPB can release sufficient benzene to the tank head space potentially creating flammable conditions. It is important to the DOE-SR mission to remove, process and dispose the unique organic waste in Tank 48H to eliminate the hazard it presents and to make possible its return to service [14].

Various options have been considered to destroy the organic material that might deleteriously impact the DWPF melter. The primary options considered include wet air oxidation (WAO) and fluidized bed steam reforming (FBSR). Both appeared viable with FBSR being considered the more mature technology. In 2007, FBSR was selected as the primary option with WAO as the backup. It is assumed for all cases that the heel material can be processed in the Saltstone Processing and Disposal Facilities for on-site disposal.

Since the initial selection of FBSR to treat the Tank 48H waste, a number of factors have resulted in a review of the costs, schedule, and technical maturity criteria[5]. Significant progress eliminated the critical path need to return Tank 48H to service. This reduced the weight associated with schedule and opened a window to develop closely competing technologies including a copper catalyzed process that was not considered in the previous evaluations.

The completion of DWPF enhancements (i.e., bubblers and flow sheet changes) has provided previously unavailable capacity to directly vitrify the Tank 48H waste in the DWPF melter. The original direct vitrification concept was to add the waste with sludge for vitrification. The current concept for direct vitrification would be a dedicated, end-of-life campaign consisting of 1-3 years of operation. It would appear on the surface that if implementing the current direct vitrification option would extent DWPF operations by 1-3 years, then other options that could be integrated with existing processing schedules without extending DWPF operations would seem preferable.

9.4.2.5 Other operations that may impact the mission

SRS will continue to stabilize nuclear materials in the SRS H-Canyon facility for subsequent storage and disposition. Tank 35H will continue to receive wastes from H-Canyon operations and shutdown activities through 2022. The H-Canyon waste contains plutonium discards that must be ultimately managed in DWPF to satisfy fissile material concentration limits. In part these actions necessitate the continued and efficient operation of the 2F Evaporator system; salt

[5] K. Subramanian, presentation entitled *Tank 48 Treatment Project Table-Top Engineering Evaluation Review and Charter*. SRR-STI-2011-00319, May 25, 2011.

waste must also be continuously removed from Tank 37H to allow the 3H Evaporator system to continue operations. Extended, unanticipated outages of these evaporator systems can impact H-Canyon operations, delay sludge batch preparations, and/or delay tank removals from service [1].

The DWPF recycle stream is the largest influent stream to the SRS Tank Farm system. When possible the recycle is used for salt dissolution and adjustment of salt solution feed prior to processing. The 2H-Evaporator is used to concentrate the recycle that is not used for such beneficial purposes. Thus, reliable operation of the 2H-Evaporator system is necessary prior to the startup of SWPF to ensure that the DWPF recycle stream can be managed effectively. The rate of recycle depends on the canister production rate and Steam Atomized Scrubber (SAS) operation. Startup of the SWPF will likely require a second SAS to be operated in the DWPF off-gas system and doubling of the recycle rate. Only the 2H-Evaporator system can be used to concentrate DWPF recycle due to chemical incompatibilities with other wastes.

For four decades, SRS evaporators successfully operated with only minor and occasional problems. However, in 1997, the 2H-Evaporator system began processing silicon-rich wastes from the DWPF recycle stream that were mixed with an alumina-rich stream from H-Canyon reprocessing operations [9]. The evaporator became increasingly difficult to control and was finally shut down in October 1999. A research program was initiated and a cleaning method developed that used dilute nitric acid to successfully clean the evaporator pot [11]. Despite improvements in cleaning the evaporator pot, fouling still occurs in the 2H-Evaporator system and the need to increase feed production and changes in recycle composition resulting from possible melter and offgas changes as well as waste composition and frit changes may impact fouling in the evaporator system.

Description of current SRS waste feed delivery plans

A recent snapshot of the conditions in the SRS waste tanks is provided in Figure 9-11. The Salt Waste Processing and Disposal Facilities began operations in 1990 and DWPF in 1996. Treatment of the high-activity salt waste began with DDA in 2007 and will continue with ARP / MCU until SWPF commences operations. As echoed in Figure 9-3, significant quantities of sludge and salt wastes remain to be treated to meet regulatory milestones (Table 9-1) in the SRS Federal Facilities Agreement (FFA) [15]. The most recent plans to remove, prepare, and treat SRS sludge and salt waste are described in Revision 16 of the SRS Liquid Waste System Plan (SRS SP-16) [1].

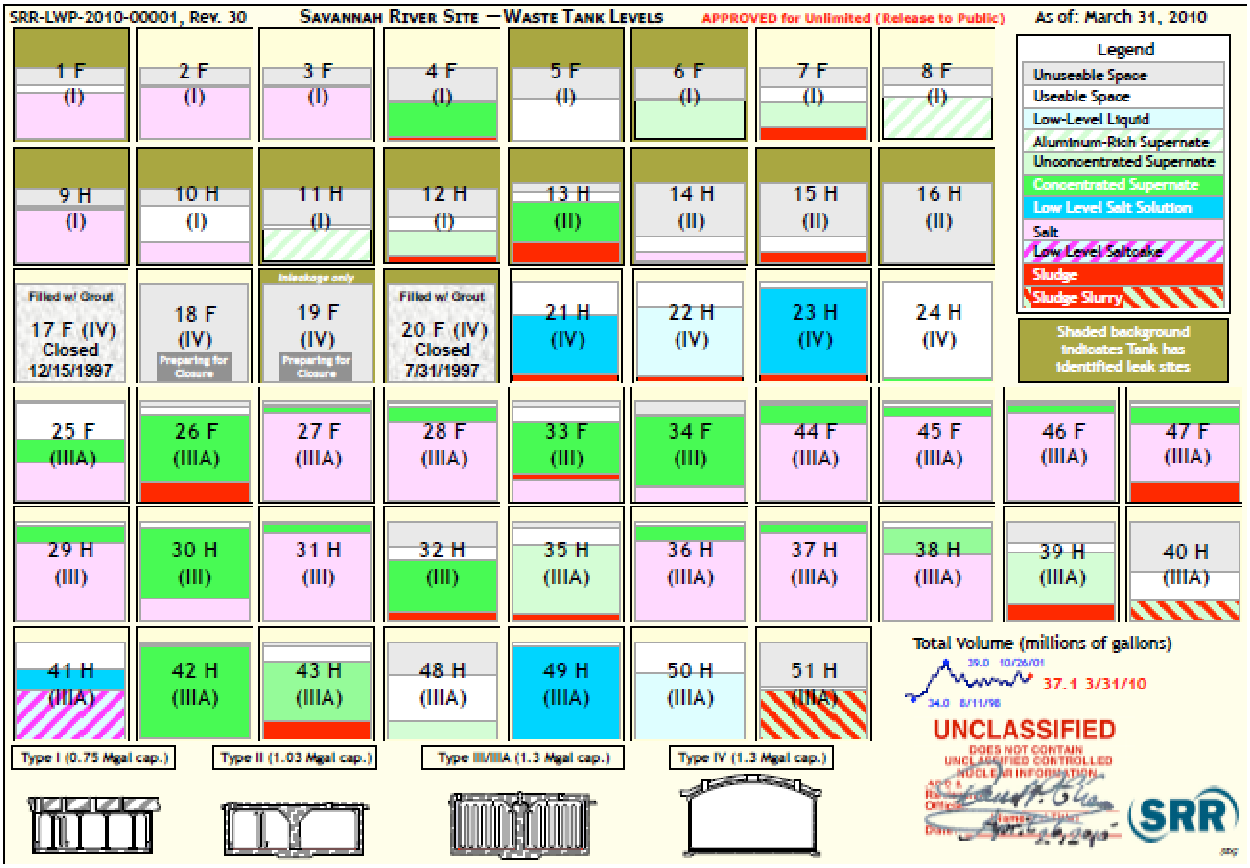

Figure 9-11. Snapshot of the states of SRS tank wastes (as of March 2010) [16]

Table 9-1. Selected Milestones for SRS Tank Waste Treatment [1]

Milestone	Revision 15	Revision 16
Date last Liquid Waste facility closed	2032	2026
Date when BWRE complete for Type I, II, and IV tanks	Mar 2016	Nov 2016
Date when all Type I, II, and IV tanks removed from service	Jun 2018	Sep 2018
DWPF processing complete	2031	2025
Total number of canisters produced	7,235	7,557
– Salt only canisters produced	250	0
Glass Waste Storage Building #3 Required	Jul 2015	Sep 2015
Initiate ARP / MCU Processing	Apr 2008 (Actual)	Apr 2008 (Actual)
– Deploy next-generation extractant at MCU	n/a	Jan 2012
Initiate SCIX Processing	n/a	Oct 2013
Initiate SWPF Processing	May 2013	Jul 2014
– Salt Solution Processed via DDA-solely	2.8 Mgal	2.8 Mgal (Actual)
– Salt Solution Processed via ARP / MCU	5.2 Mgal	5.4 Mgal
– Salt Solution Processed via SCIX	n/a	26.8 Mgal
– Salt Solution Processed via SWPF	89 Mgal	61 Mgal
Total Salt Solution Processed	97 Mgal	96 Mgal
Number of Salt Disposal Units (SDUs)	40	41
Salt Processing Complete	2030	2024
Tank 42 Available as Sludge Blend Tank	Oct 2011	Oct 2011

Milestone	Revision 15	Revision 16
Tank 48 Available as Salt Blend Tank	Jan 2015	Oct 2016
Tank 28 Available as Salt Blend Tank	n/a	Oct 2015
Tank 35 Available as Salt Blend Tank	Mar 2014	Oct 2013
SWPF facility removed from service	2031	2025
DWPF facility removed from service	2031	2026
SPF facility removed from service	2032	2026

The current SRS liquid waste processing system plan is based on the following key assumptions and bases [1]:

- *Funding*: The funding required to support the planned projects and operations in SRS SP-16 would be available, when needed.

- *Regulatory Drivers*: The SRS Federal Facility Agreement [15] and Site Treatment Plan (STP) [17] are the key regulatory requirements that the plan satisfies.

- *Waste Removal and Tank Removal from Service*: For Types I, II, and IV tanks, wastes would be removed and the tanks removed from service per the SRS FFA (where salt is removed to support SWPF startup). For Type III / IIIA tanks, wastes would be removed per the STP (where these tanks would not have to be isolated and grouted to meet the STP). Upon acceptable removal of wastes, the SRS tank farm areas would be closed according to: 1) F-Tank Farm, 2) H-Tank Farm West Hill, and 3) H-Tank Farm East Hill. SCDHEC reviews and approves tank removals from service using a process that would be documented in the respective General Closure Plan. Two Waste Determinations (F-Tank Farm and H-Tank Farm) would be issued pursuant to NDAA §3116 for tank and ancillary equipment residuals.

- *DWPF Production*: Sludge batches would be prepared and treated in DWPF (at maximum throughput) to satisfy the Sludge Batch Plan [18]. Melter replacement outages would require four months every 72 months of DWPF operation. Improvements would allow a production rate of 400 canisters / year after the next melter outage (beginning April 2014 and coinciding with Sludge Batch 8 at a 40 percent waste loading).

- *Salt Program (ARP / MCU)*: These operations would be used to process salt wastes until six months before SWPF startup (when ARP / MCU operation will cease) and would not be operated during melter replacement outages. A next-generation cesium extractant would be introduced (requiring a three-month outage) for Salt Batch #4. The ARP strike function would be relocated (to allow FBSR processing for Tank 48H). DOE and SCDHEC would approve operation of ARP / MCU facilities to align with a SCDHEC approved delay in SWPF startup.

- *Salt Program (SCIX)*: Processing using SCIX would begin in October 2013 where the decontaminated stream from the SCIX would be equivalent to that from SWPF. The nominal rate is based on a 100 percent availability of feed from the tank farm and DWPF. Tank farm modifications are required including an additional H-Tank Farm blend tank (e.g., Tank 35H), readiness of Tank 41H for SCIX processing, and enhanced transfer capabilities using dedicated transfer routes.

- *Salt Program (SWPF)*: SWPF would become operation in July 2014 and SCDHEC would approve the required modification of the SWPF permit (for the delay from September 2011). SWPF operations would require a 4-month DWPF outage and 2-month SPF outage. The nominal rate is based on a 100 percent availability of feed from the tank farm and DWPF. The next-generation cesium extractant used in SWPF would not impact either DWPF or SPF operations. Tank farm feed preparation modifications are required that include H- and F-Tank Farm blend tank readiness, Tank 49H readiness for feeding SWPF, mixing capabilities, and enhanced transfer capabilities using dedicated transfer routes.

- *Tank 48H Return to Service:* Organic destruction of the Tank 48H waste material (350 kgal) would be completed using fluidized bed steam reforming by October 2016[6]. The resulting Tank 48H heel material would be acceptable for mixing with other wastes and processing in SWPF. The coal fraction of the FBSR product would be treated in DWPF. Two sludge processing tanks (Tank 42H and Tank 51H) would be available to receive the stream. The coal contribution to the total organic carbon in the melter feed is not expected to impact throughput, flammability, or REDOX conditions.

- *Saltstone Production*: SPF would be capable of processing at rates adequate to treat salt wastes at the nominal processing rates for the ARP / MCU, SWPF, and SCIX processes. The SPF must demonstrate that it can operate at the required capacity (approx. 350 kgal / week) before SWPF operations begin. Modifications would be made to provide sufficient contingency storage capacity to minimize impacts to SWPF, SCIX, MCU, or ETF due to SPF or SDF outages. Vault 4 is available to receive treated salt waste and additional SDUs will be constructed on a just-in-time basis.

The current version of the liquid waste system plan (e.g., Figure 9-12) indicates that SRS can satisfy FFA removal, treatment, and closure milestones [1]. The current plan appears to be intended to not only satisfy FFA milestones but to accelerate removal and treatment operations to the extent possible. However, to meet the FFA and/or accelerated milestones requires that new salt waste pretreatment processes (SWPF and SCIX) be implemented and modifications be made to the tank farm

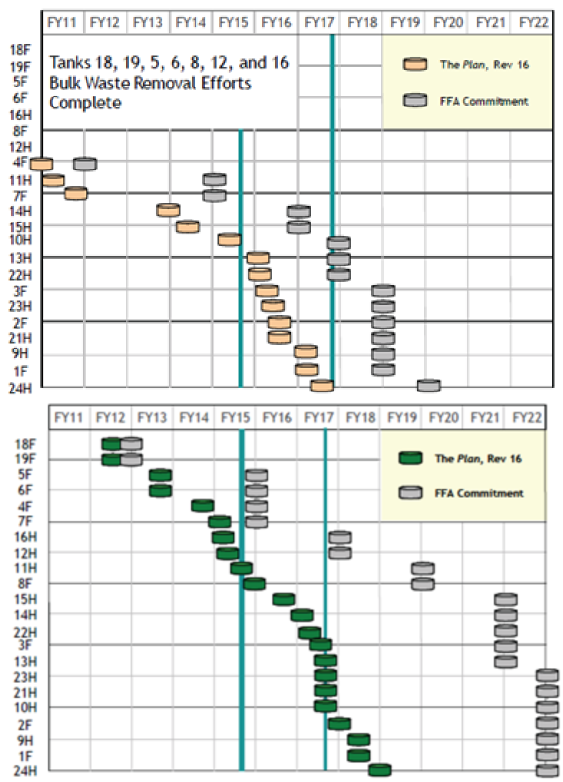

Figure 9-12. Bulk Waste Removal Efforts and Corresponding Removal of SRS Tanks from Service [1]

[6] The use of FBSR to treat the Tank 48H wastes is being reevaluated, as described in Section 9.4.2.4.

infrastructure to allow qualified sludge and salt feeds to be produced at much higher rates. DWPF operations and processes must also be modified so that feeds can be treated at a sufficiently high rate to strike the necessary balance to complete the tank waste treatment mission in a timely fashion without the need for significant and costly salt-only glass production.

9.4.4 General Hanford tank waste characteristics

The Hanford Site was created in 1943 to produce plutonium from spent nuclear fuel (SNF) as part of national defense activities. Recovery of plutonium from spent fuel at the Hanford Site began in late 1944 using the bismuth phosphate separation process, which recovered plutonium (but not uranium) while producing large quantities of waste [19]. The higher-activity liquid wastes from the bismuth phosphate process were neutralized to reduce their corrosion potential and stored in carbon steel underground tanks. Subsequent efforts were made to recover uranium from the waste originally generated from the bismuth phosphate process, which changed the nature of waste. The first successful, continuous solvent extraction process for recovering both plutonium and uranium recovery was the Hanford REDuction OXidation (REDOX) process beginning in 1952. The REDOX process generated less waste than the bismuth phosphate process; the waste was again neutralized and stored in carbon steel tanks.

In 1956, a new solvent extraction process, Plutonium and Uranium Recovery by Extraction (PUREX), began use at the Hanford Site [19]. PUREX, which was the only process used at SRS as described in Section 9.4.1, used a different organic solvent and nitric acid and produced highly radioactive, self-boiling wastes that were again neutralized and stored in large carbon steel tanks. As a result of separations and subsequent reprocessing activities (that included mixing of different wastes), Hanford tank wastes are composed of many different chemical compositions and physical characteristics and exhibit much more tank-to-tank variability than their SRS counterparts. In general, only one percent of the Hanford tank waste mass is radioactive, but this small percentage is sufficient to make the tank contents very dangerous [19].

The chemical separation processes (bismuth phosphate, REDOX, and PUREX) used at Hanford generated high-level, low-level, and transuranic (TRU) waste streams. In general, the LLW streams generated from these processes were either disposed or mixed with HLW in the Hanford tank farm system. What are currently considered TRU wastes in the Hanford tank system consists of nine tanks of contact-handled TRU waste from the bismuth phosphate process as well as tanks of remote-handled TRU waste from the PUREX process and the Plutonium Finishing Plant (PFP) [19][7]. Hanford tank wastes will be separated into a low-activity fraction for treatment and on-site disposal and a high-activity fraction for treatment at the Hanford Site Waste Treatment and Immobilization Plant (WTP) for on-site storage before ultimate disposal in a geologic repository.

9.4.5 Description of the proposed Hanford waste feed delivery plans

More than 40 years of plutonium production at Hanford has yielded a challenging environmental legacy. Approximately 53 million gallons (Mgal) of radioactive and chemically hazardous

[7] Estimates ranging from 11 to 20 such tanks have been made during recent presentations to the EM-TWS.

wastes (Figure 9-5) are stored in 177 underground tanks located on Hanford's Central Plateau. The waste composition and forms vary widely, likely necessitating a variety of waste removal and treatment methods. There are 149 SSTs, many of which are known or suspected leakers. These SSTs are decades past their original intended useful life. As much as 1 Mgal of radioactive liquid waste may have been inadvertently released into the environment contaminating soil and groundwater and ultimately threatening the Columbia River [2].

The integrated system of tank waste storage, pretreatment, treatment and disposal facilities in is various stages of design, construction, operation, and planning to support the River Protection Project (RPP) mission of safely storing, treating and disposing the Hanford tank wastes. In addition to the 177 storage tanks, there are miscellaneous underground storage tanks, waste transfer systems, the 242-A Evaporator, the WTP, and various other facilities [2]. Additional pretreatment, evaporation, and LAW treatment facilities are under consideration. No Hanford tank wastes have been treated to date and thus there may be alternatives that improve on the baseline and contract requirements without introducing additional long-term risk. Some of these options perhaps could significantly reduce the long-term risks associated with the wastes to be disposed of on the Hanford Site.

9.4.5.1 Hanford Waste Storage

Many facilities are involved in the storage of waste at Hanford; however, the primary storage units are the 149 SSTs and 28 DSTs located in the 200 West and 200 East operating areas, as illustrated in Figure 9-13. The 149 SSTs were constructed between 1943 and 1964, with 66 located in the 200 East Area and 83 in the 200 West Area. As many as 67 of the SSTs are known or assumed to have leaked in the past [2]. The 28 DSTs, which have not leaked, were constructed between 1968 and 1986 with three located in the 200 West Area and the remaining 25 in the 200 East Area.

The SSTs were declared a non-compliant treatment, storage, and disposal (TSD) facility under RCRA [3]. Furthermore, there was a Congressional mandate that prohibited waste additions to Hanford SSTs after January 1, 1981[8]. Because of concerns with risks resulting from SSTs, the tank waste retrieval process currently planned at Hanford consists of two general phases: 1) retrieving wastes from SSTs to DSTs (that are RCRA-compliant) for staging and subsequent tank closure and 2) mixing of the retrieved and staged SST waste and delivery to treatment facilities at the WTP [2].

[8] Berman presentation on July 29, 2009, entitled "Hanford Single-Shell Tank Integrity Program." Available at www.em.doe.gov.

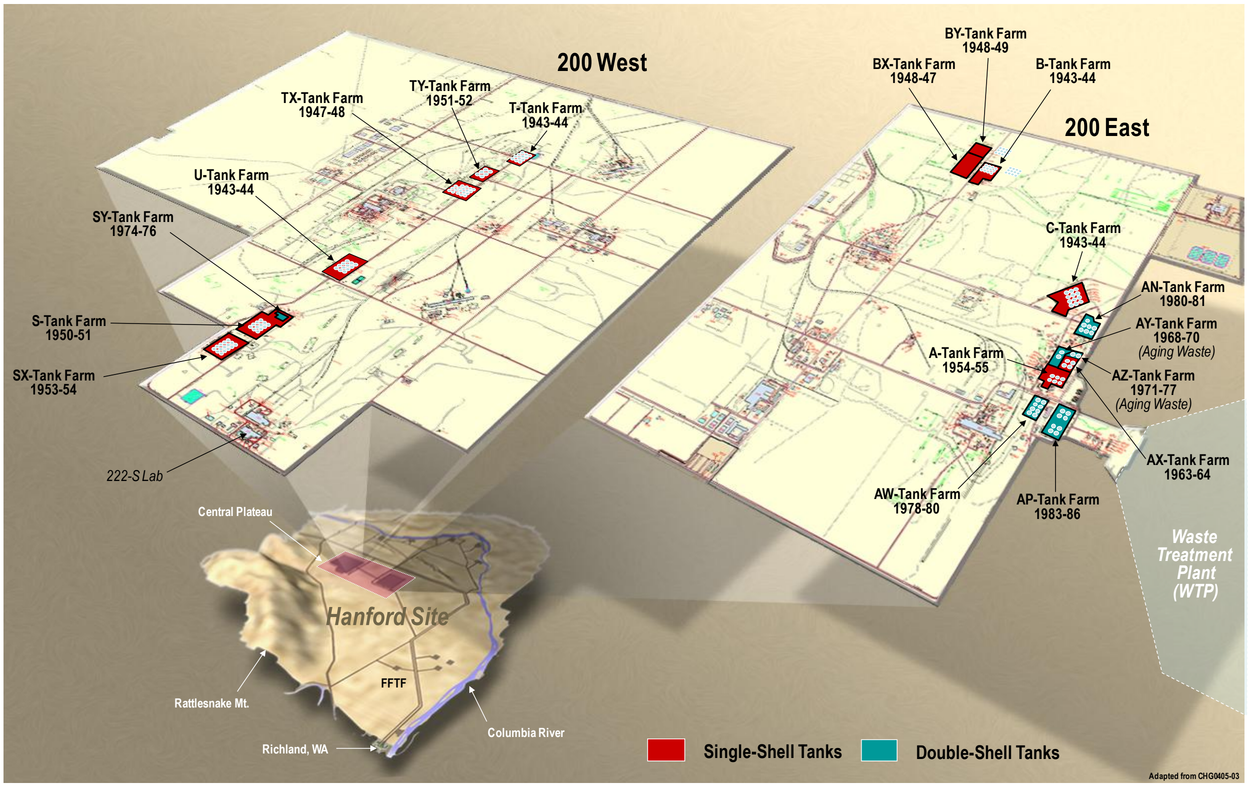

Figure 9-13. Locations of the 200 East and 200 West at the Hanford Site[9]

The Hanford SSTs are currently used only for storage and have had nearly all free liquid removed as part of the Interim Stabilization Program leaving primarily solidified sludges and crystallized salts with only incidental amounts of liquid. An SST integrity program was begun in 2009 to identify those activities that would be needed to extend the life of selected SSTs. However, it would appear unlikely that SSTs in a TSD that was declared noncompliant under RCRA could be used for processing activities unless the declaration was overturned or modified. Furthermore, even if the tanks were deemed complaint, processing activities would likely include transfers into the SSTs that might violate the aforementioned Congressional mandate.

The Hanford DSTs generally contain liquids and settled salts or sludge. The DSTs play an integral role within the RPP system, including [2]:

- Receiving SST wastes
- Supporting 242-A Evaporator operations
- Staging feed for delivery to treatment processes

The effective and efficient management of the space available in the Hanford DST system is critical to the success of the overall RPP mission [2].

[9] Thomas Crawford, presentation to EM-TWS on January 25, 2011, entitled "RPP System Plan."

Although DSTs are used for waste retrieval and staging activities, the majority of the DST space will ultimately be used for storage. DST headspace must also be reserved to accommodate operating constraints, including [2]:

- Safety basis headspace – represents unfilled space in a DST containing waste that has an associated safety (e.g., flammability) issue.
- DST emergency space – represents the space needed (in accordance with DOE M 435.1-1) to receive waste from a DST that might leak.
- WTP feed headspace – represents unfilled space in a DST containing waste feed staged for delivery to the WTP.

There are other DST space management issues that are related to the characteristics of the wastes in the tanks [2]:

- Liquid and solids must be carefully managed in a tank to avoid buoyant displacement gas release events (BDGREs)[10] and tank bumps[11]. The controls needed to prevent these events limit the depth of solids and supernate in the tank and/or the decay heat load and thus require careful coordination with SST retrieval plans especially before waste treatment processes are online. Washington River Protection Solutions (WRPS), who is responsible for retrieving, treating, storing, and ultimately disposing Hanford tank wastes, is reevaluating the analysis that led to the current restrictions on sludge and liquid levels to determine if it would be possible to relax the requirements (gaining storage space) on some tanks without compromising safety. The current Hanford System Plan assumes that current BDGRE controls are relaxed for deep-sludge tanks.

- Wastes that contain high phosphate concentrations may pose problems due to their tendency to precipitate or form gels during transfers (which is a known plugging issue), after evaporation and cooling (potentially impacting critical evaporator operations), or when mixing with other wastes. A tank containing phosphate gel might also retain flammable gases leading to a gas release event. Controls have been established for the transfer of phosphate wastes; however, these transfer controls are not currently explicitly modeled for life-cycle mission planning purposes.

- Tanks AN-102 and AN-107 currently store waste that includes high supernate concentrations of complexed strontium and TRU constituents. Because these components are in the soluble phase, they must be removed prior to vitrification in the ILAW facility. Although the WTP PT Facility has the capability to precipitate out these components, the current plan is to precipitate these constituents in the DST system and then incidentally blend the precipitates with other HLW solids for vitrification in the WTP IHLW facility.

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[10] A BDGRE is the rapid release of gas that may be retained in a settled solids layer resulting in the temporary creation of a flammable mixture in the headspace of the tank; this has only been observed in liquid-over-sediment waste configuration [19].

[11] A tank bump is the rapid release of gas, mostly water vapor, causing the tank headspace to pressurize, and is distinguished from a gas release event by 1) the physical mechanism for release involving vaporization of locally superheated liquid and 2) the gases emitted are not flammable [20].

9.4.5.2 Hanford Waste Transfer Systems

DSTs and SSTs undergoing retrieval are equipped with transfer pumps or equivalent systems to remove waste and transfer it to DSTs, to the WTP, or, when available, to a TRU waste treatment facility. Tank farms typically employ underground pipes to pump waste between tanks, between tank farms, between the 200 East and 200 West Areas, and to and from other facilities. For protection, pipelines use an encased pipe-in-pipe design with leak sensors. For SST waste retrieval, aboveground hose-in-hose transfer lines have been used directly or in combination with existing transfer routes to permit more rapid deployment, reduce costs, and provide flexibility [2].

Upgrades to the Hanford waste transfer system are required before tanks can be retrieved, staged and delivered to the WTP. These upgrades include installation or replacement of transfer pumps, installation of mixer pumps, replacement of some valves in the pits, and extension of some pipe encasements through pit walls. If the LAW vitrification facility is to be started up early (e.g., in 2016), new transfer lines would be required to direct feed the LAW facility and new transfer lines would also be needed from the LAW facility to ETF. Some needed upgrades (e.g., those in the SY Tank Farm) have been started.

However, as many as 30 projects must be completed before Hanford low-activity tank wastes can be retrieved, pretreated, qualified, and staged for treatment in the LAW vitrification facility currently under construction in the WTP. According to the information obtained from presentations and data calls, there is a reasonable chance that each of these projects can be completed to meet the TPA milestones as long as budget requests are met. However, difficulties in securing the proper funding and/or attempting to accelerate treatment in the ILAW facility may significantly decrease the chance of completing all of the necessary projects in time[12].

9.4.5.3 Hanford Waste Retrieval Facilities

The Tank Operations Contract (TOC) baseline currently includes provisions for the design, construction, and operation of two Waste Retrieval Facilities (WRFs): one in the 200 East Area and one in the 200 West Area [2]. Current system plan modeling assumes the use of these facilities. Each WRF would provide [2]:

- Six 150,000-gal receipt tanks with pumps, transfer lines, and ancillary equipment to allow recycle of supernate during waste retrieval thereby minimizing waste generation during retrieval operations. These tanks would provide additional space for the temporary storage of retrieved waste to help alleviate the near-term limits on DST storage space.

- The transfer lines from the WRFs to DSTs and pumps necessary to transfer the retrieved waste slurries at high solids loadings to the DST storage tanks (several miles away), without exceeding allowable pressure ratings.

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[12] A Bonferroni-type of analysis can demonstrate the sort of difficulties when relying on a large number of distinct outcomes for overall success: the probability of success for 30 independent outcomes (each of which has a probability of success of 95 percent) is approximately 20 percent, and the probability is less than 75 percent for 30 independent outcomes, each with a probability of success of 99 percent.

An enhanced WRF concept was under consideration in which the base capabilities would be augmented to include mixing, blending, sampling, qualification and filtration of retrieved waste to provide a more uniform feed to WTP [2]. Work on the enhanced WRF is currently on hold pending direction from ORP. However, it would appear that such a facility would add needed flexibility and alleviate the difficulties in representatively sampling and transferring waste from the DSTs. A formal cost-benefit analysis could be performed to support the decision.

9.4.5.4 The Hanford 242-A Evaporator System

Construction of the Hanford 242-A Evaporator was completed in 1977. The primary mission of the Hanford 242-A Evaporator is to support tank farm operations by reducing dilute waste volume. Evaporator availability will be critical to the success of the overall RPP mission especially because space within the DSTs will be limited and there are no plans to build an additional evaporator with the functionality provide by the 242-A facility or additional large, underground double-shell tanks. Adequate evaporative capacity is needed to continue SST waste retrieval operations and to adjust sodium levels in waste feeds to meet WTP feed requirements.

The 242-A Evaporator has historically been operated on a campaign basis using lengthy outages between campaigns to repair and upgrade the facility as needed. As illustrated in Figure 9-, availability of the 242-A Evaporator would need to increase dramatically around 2030 when the evaporator will be over 50 years old and must continue at the increased availability through the end of the tank retrieval mission in 2040. Although the evaporator was originally designed for a ten-year mission, major upgrades were performed in 1987 and between 1989 and 1994 to extend

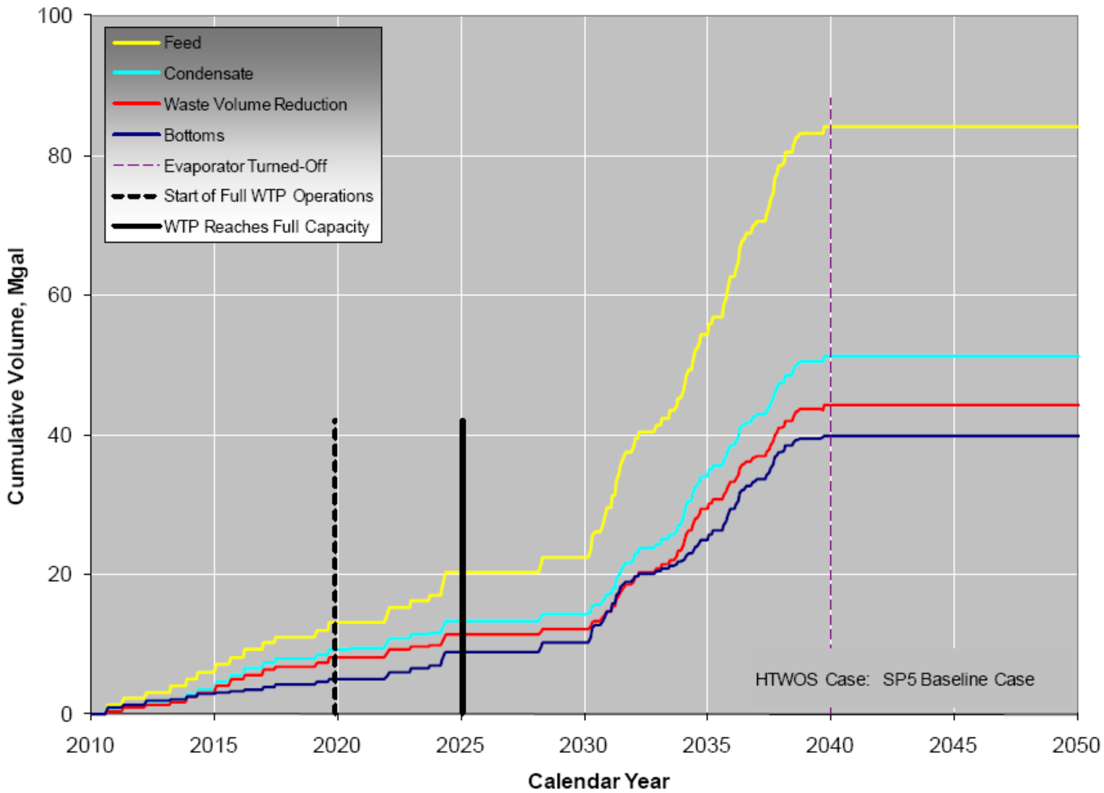

Figure 9-14. Projected Operation of the Hanford 242-A Evaporator

the facility mission. Continuous upgrades are planned to extend the evaporator life into the early 2040s. However, as the facility ages, the likelihood of failure becomes greater and the aggressive schedule for Evaporator use may make upgrading the facility in a timely enough fashion difficult. The 242-A Evaporator represents a single point of failure that is critical to the RPP mission that might be offset by construction of a new Evaporator facility providing the same functionality as the 242-A facility or additional DST space.

9.4.5.5 Proposed Hanford Waste Retrieval Activities

Because of the risks posed by the Hanford SSTs, the general strategy for Hanford Site remedial action is to first retrieve wastes from the 149 SSTs, which have been declared a non-compliant TSD under RCRA, for consolidation in the 28 RCRA-compliant double-shell tanks (DSTs). To reduce the risk of additional liquid waste leaking into the environment, the pumpable liquid was transferred from the SSTs to the DSTs under the Interim Stabilization Program leaving primarily saltcake and sludge in the tanks. To date waste retrieval activities have been completed for seven SSTs (Table 9-2); the waste in three other tanks has been retrieved to the limits of current technology, and the waste in two other tanks is being retrieved [2].

The baseline schedule for waste retrievals from Hanford SSTs is presented in Figure 9-15, as indicated by the volume of the original waste remaining in the SSTs over time. The C Tank Farm is the first that will be retrieved (where completion is projected for 2013) with all SSTs projected to be retrieved by the 2039 or 2040 timeframe. There will be minimal DST space available to support SST retrievals between 2018 and 2022, and there is uncertainty in meeting the projected retrieval completion date for the nine additional SSTs (assumed to be from the A and AX Farms) as required by the Consent Decree in *Washington v. DOE*, Case No. 08-5085-FVS [2]. Depending on the final waste feed delivery mixing requirements for feed characterization or remobilization and blending of waste, DST space could be further constrained which would further jeopardize the timing of retrieval of the nine additional SSTs per the aforementioned Consent Decree [2].

Table 9-2. Hanford Tank Retrieval Information [2]

Tank	Retrieval completion date	Waste volume removed (gal)	Final waste volume (gal)	Waste volume removed (%)	Waste activity removed (Ci)[a]	Final waste activity (Ci)[a]	Final Tc-99 (Ci)[b]	Final Cs-137+ Ba-137m (Ci)[b]	Final Sr-90+ Y-90 (Ci)[b]	Technologies used
C-106	Dec-2003	194,000	2,800	98.6	8,900,000	132,000	0.16	2,600	120,000	Modified sluicing/ acid dissolution
C-203	Mar-2005	2,500	140	94.7	1,100	460	0.0023	23	420	Vacuum retrieval
C-202	Aug-2005	1,300	150	89.7	2,600	960	0.0025	16	880	Vacuum retrieval
C-201	Mar-2006	720	140	83.7	560	540	0.0026	18	460	Vacuum retrieval
C-103	Aug-2006	69,000	2,500	96.5	2,700,000	19,700	0.045	1,600	18,100	Modified sluicing
C-204	Dec-2006	1,300	140	90.3	440	310	0.0032	11	280	Vacuum retrieval
S-112	Mar-2007	612,000	2,400	99.6	608,000	130	0.14	6	98	Saltcake dissolution/ modified sluicing
Total		**880,820**	**8,270**	**99.1**	**12,212,700**	**154,100**	**0.36**	**4,300**	**140,000**	

a. The activities were decayed to different times, about 4 years apart.
b. TWINS information.

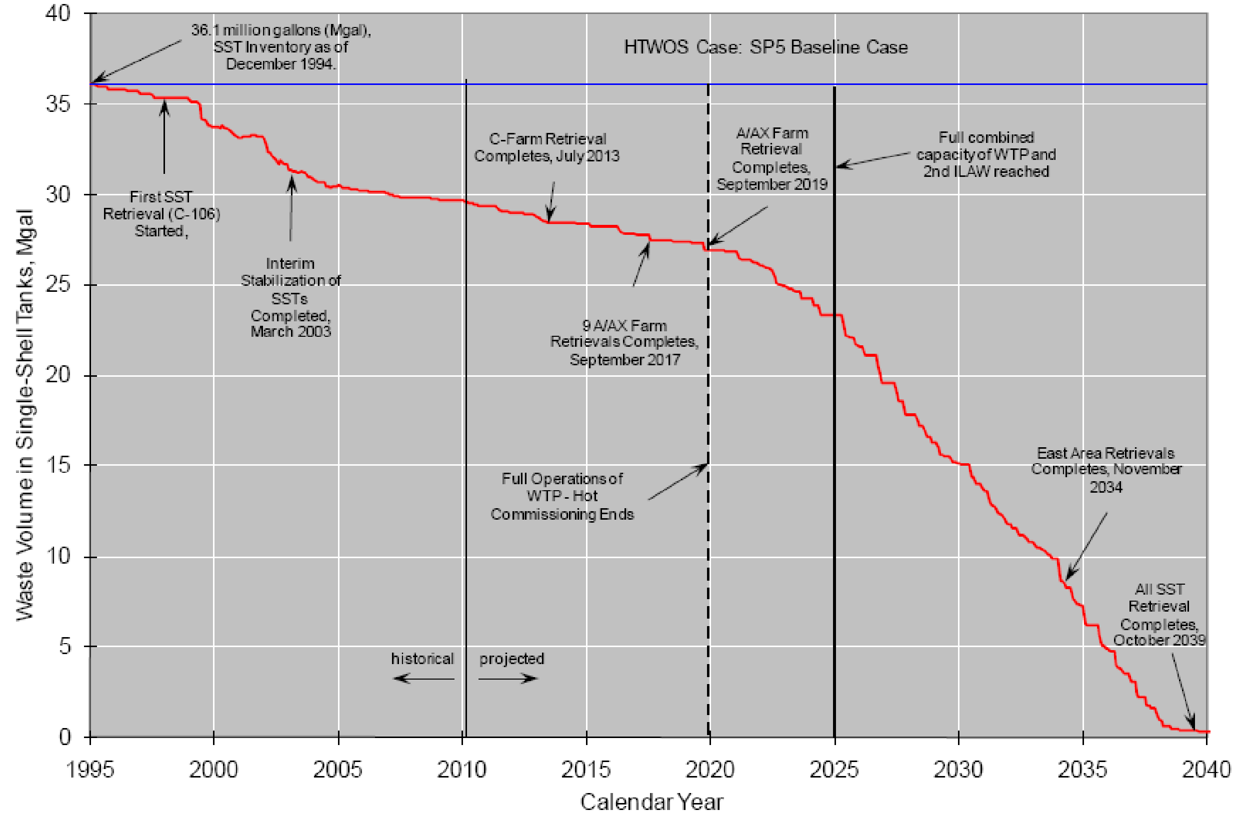

Figure 9-15. Overall Hanford Single-Shell Tank Retrieval Progress [2]

Figure 9-16[13] indicates the number of SST retrievals that have been completed or are projected to be completed during each calendar year through the RPP mission. The number of retrievals that must be completed each calendar year increases significantly after 2026 (including a jump from zero to nine in 2026), when all treatment facilities (including Supplemental LAW Treatment) are expected to be online and running at their contract throughput rates. Going from zero to nine retrievals in a single year

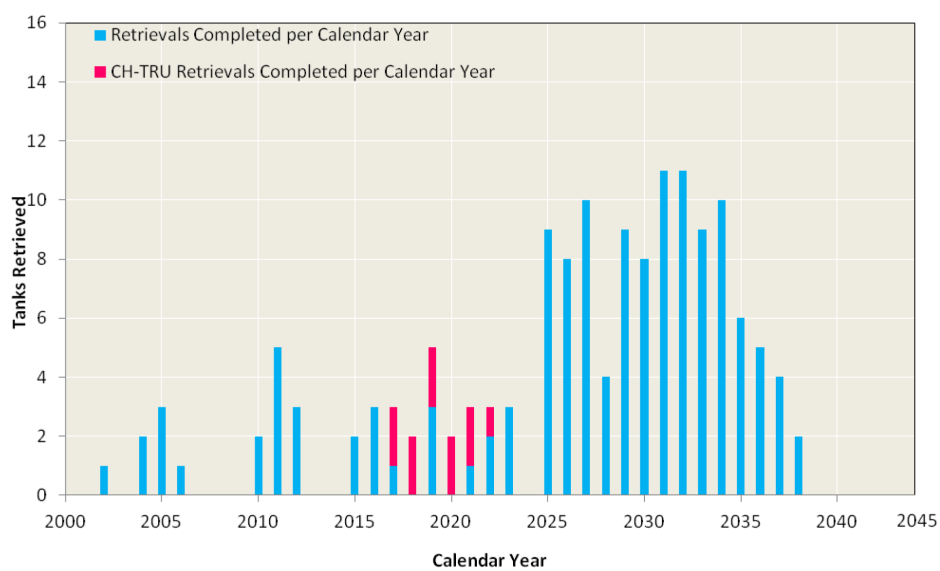

Figure 9-16. Hanford Single-Shell Tank Retrievals Completed Each Calendar Year

[13] Burrows and Saunders presentation to EM-TWS on May 5, 2011, entitled "Charge #1B, Data Calls 8, 9, and 20: SST Retrieval Status."

would appear ambitious, considering that to date, only three SST retrievals have been completed in a single year (2006).

Different schemes have been considered to help alleviate some of the logistical issues related to retrieving wastes from the SSTs. For example, concentrating retrievals in the Tank Farms provides significant operational and logistical improvements versus spreading SST retrievals among different farms. However, the trade-off is a diminished incidental (or unavoidable) blending of the retrieved SST wastes with a corresponding increase in the number of canisters that would be produced. It has been demonstrated that intentional blending within Tank Farms may help to offset the increased number of canisters produced [2] and additional research in this area should be pursued.

The sequence and timing of the projected SST retrievals are indicated in Figure 9-17. The available DST tank space is extremely limited for the SST retrievals represented by the two yellow ovals in the 2017 – 2027 timeframe [2]. There may be significant unallocated DST space (as much as 3 Mgal); however, much of this space may be unusable as it may be spread among several tanks and not directly accessible without implementing a complicated series of waste transfer and evaporator staging operations. Furthermore, as the DST system nears capacity, SST retrieval and staging operations become increasingly difficult [2]. If inadequate DST would be available, the start of the impacted SST retrievals would likely be delayed several years to avoid having the tanks and associated retrieval equipment sitting idle. Therefore, DST space management is critical to the success of the RPP mission.

9.4.5.6 Alternatives for Hanford Waste Retrieval and Corresponding Treatment

The requirements for Hanford waste retrieval (using a 99 percent retrieval target) are residual waste volumes not to exceed 360 cubic feet for 100-series tanks or 30 cubic feet for 200-series tanks, or the limit of retrieval technology capability, *whichever is less* [4]. Each of the completed retrievals was demonstrated (to the 95 percent confidence interval) to satisfy the residual volume criteria. As one can see from Table 9-2, the manner in which retrievals are performed to the limits set in the TPA translates into approximately a 99-percent retrieval of wastes by volume (with perhaps a slightly lower percentage by activity). These retrievals thus satisfy the overall target given in the TPA, but this does not necessarily mean that the actual risks to human health and the environment are also reduced by approximately 99 percent.

For example, a quick review of the Final Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) gives an insight into the variations in the contents and risks posed by the Hanford tanks [22]. Two of the cases evaluated in the TWRS EIS indicated the following:

- Ex Situ/In Situ *Combination 2 alternative* – waste from approximately 25 tanks (or approximately 30 percent of the waste by volume) selected based on their potential contributions to long-term risk would be retrieved and the remaining tanks would be filled and disposed of in-place. This alternative suggested that retrieval of about 30 percent of the tank waste would result in an approximate 85 percent long-term risk reduction.

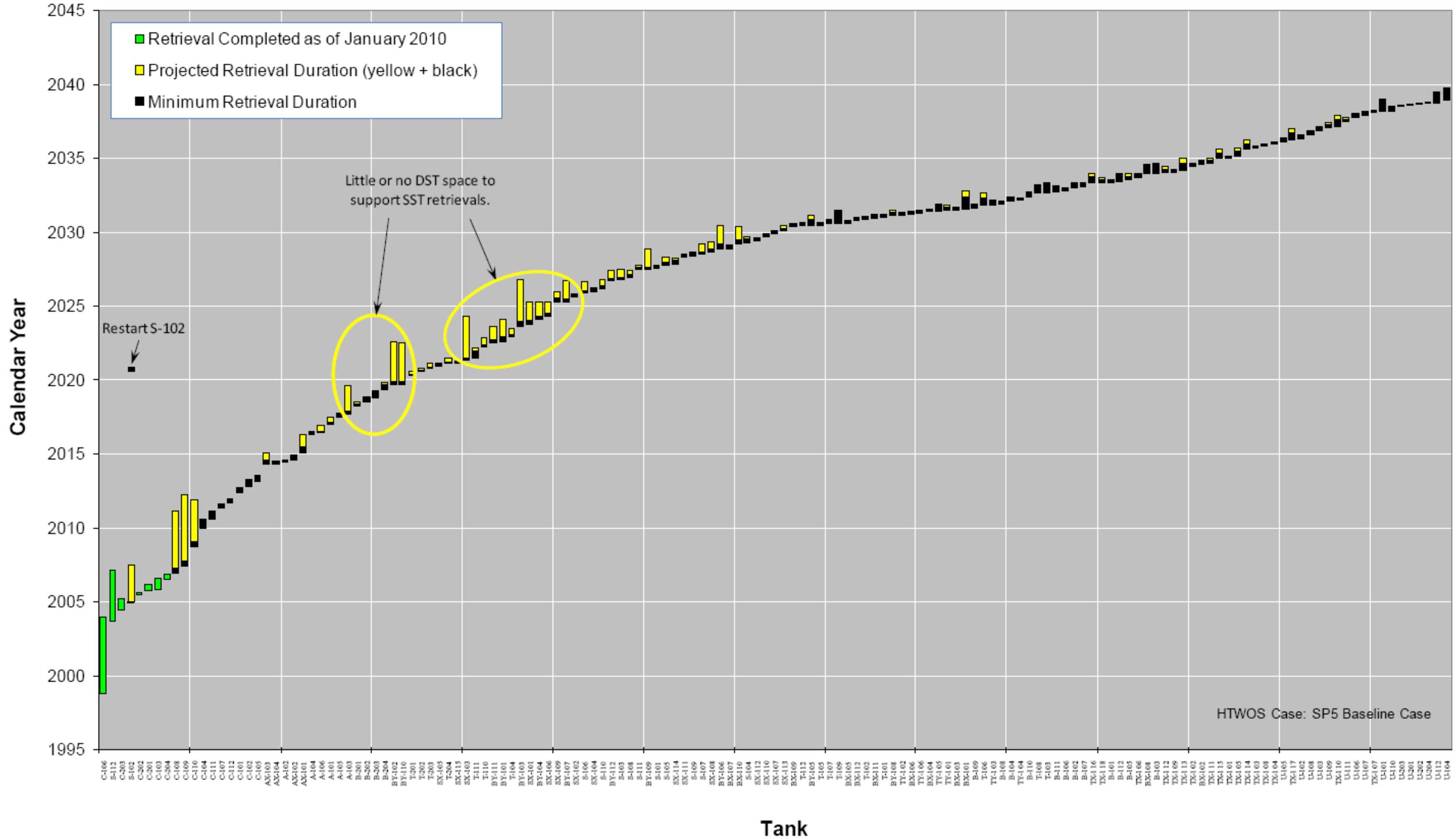

Figure 9-17. Hanford SST Retrieval Sequence and Timing for the Baseline Case from SP5 [2]

- Ex Situ/In Situ *Combination 1 alternative* – waste from approximately 70 tanks (or approximately 50 percent of the waste by) selected based on their potential contributions to long-term risk would be retrieved and the remaining tanks would be filled and disposed of in-place. This alternative suggested that retrieval of ~50 percent of the tank waste would result in an approximate 90-percent risk reduction or that retrieval of an addition 20 percent (by volume) of the highest risk waste with the concomitant costs and worker risks would only reduce risks by an additional 5 percent.

Because of the variation in contents, the retrieval of certain tank wastes (e.g., high-heat PUREX waste) would significantly reduce more of the long-term risks than other wastes.

Another illustration may provide additional insight to the variation in the radionuclide concentrations in, risks posed by, and characteristics of the Hanford tank wastes. Figure 9-18 illustrates a recent snapshot of the total radionuclide inventories and cumulative waste volume for all 177 waste tanks. The total radionuclide concentration (using the best basis inventory) varies by almost six orders of magnitude from Tank 241-T-202 (with the lowest total activity at approximately 25 Ci) to Tank 241-AZ-101 (with the highest total activity at approximately 20 MCi). However, the radionuclides that comprise the inventory and their properties (e.g., half-lives and environmental mobilities) can also make a significant difference on the resulting risks posed. Figure 9-18 provides an indication of the risk posed by the wastes in the tanks: approximately 40 of the tanks contain wastes that would satisfy the NRC Class C classification *without treatment*. Other analyses have indicated that perhaps as many as 20 tanks could be classified as containing TRU wastes. These analyses would be improved if the characteristics of the wastes in the tanks were evaluated further to see what types of wastes (e.g., low-heat waste from the bismuth phosphate process) correspond to the lowest risks in Figure 9-18.

Therefore, in times when there are severe financial constraints on waste processing, it would appear wise to target retrieval and treatment actions to those wastes that pose the vast majority of the long-term risk. For example, note the obvious differences between the ordering in Figure 9-18 (showing radionuclide inventories) and the SST retrieval sequence previously indicated in Figure 9-17. Some of the differences may be attributable to logistics and operational issues or regulatory constraints; however, the potential marginal benefits of retrieving those SST wastes (especially to the 99 percent target) that could potentially be dispositioned as TRU wastes or do not pose significant long-term risks must be weighed against the costs that would be incurred (and the potential benefits of using the funding elsewhere).

It would appear that a targeted waste retrieval and treatment strategy based on the highest risk wastes (and perhaps including direct feeding of some tank wastes) could be developed that would reduce the risks from the tank wastes to essentially the same level as that currently considered in the baseline. There may also be treatment pathways including separation of the difficult to manage constituents (e.g., Tc-99 and I-129) that would translate into substantially lower long-term risks than those represented by the baseline or other alternatives considered in the current System Plan.

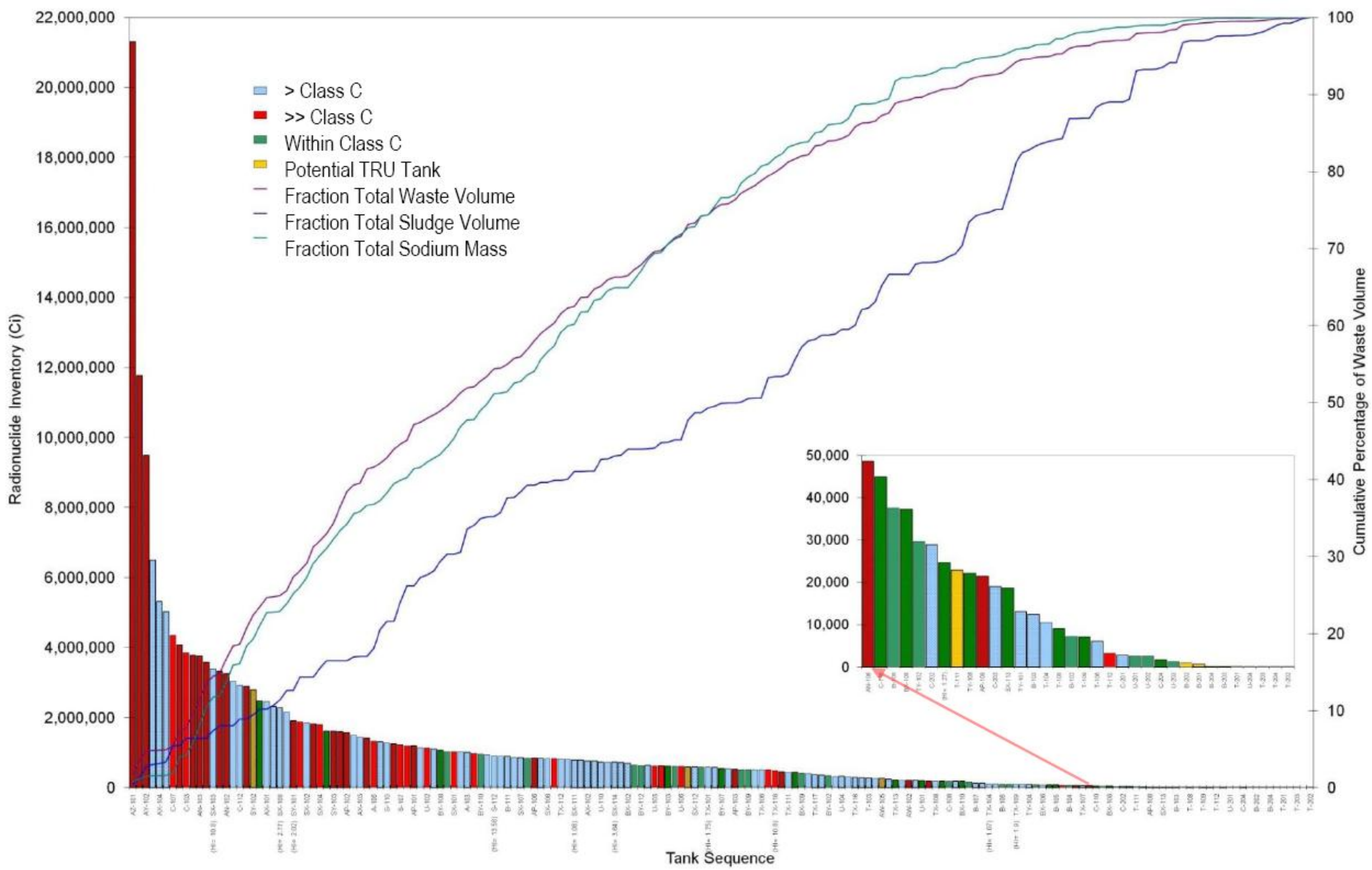

Figure 9-18. Variation in the Hanford tank radionuclide inventories and concentrations

The evaluation illustrated in Figure 9-18 also leads to a related analysis concerning the potential Vision 2020 scenario. A major part of this scenario is to begin treating low-activity waste (LAW) in one of the two ILAW melters in 2016 and running the process for approximately 15 months. One prerequisite of the scenario is the ability to separate Cs-137 and filter the feed to the LAW melter to satisfy solids and contact-handing limits (among others). Another potential option would be to examine the supernate phases currently residing in the DSTs to determine if any would be candidates for little or no pretreatment prior to directly feeding the LAW melter (and thus bypassing the Pretreatment Facility).

The best-basis Cs-137 concentrations for the Hanford DSTs are illustrated in Figure 9-19. The radionuclide limit in ICD-19 that would apply to transfer of supernate from DSTs to the Pretreatment Facility for Cs-137 is 1.2 Ci/L (except for AZ-101 and AZ-102 where the limit is 3.0 Ci/L) [8]. However, for direct feeding the LAW melter, the concentration would have to be less than 2.8×10^{-4} Ci per gallon [7.4×10^{-5} Ci/L] based on the safety and shielding design of the LAW treatment facility [23]. As illustrated in Figure 9-19, none of the supernate in the DSTs would be a candidate for direct feeding a Hanford LAW melter (where the minimum Cs-137 concentration in any of the 28 DSTs is approximately 0.01 Ci/L).

A cursory look was also taken at the salt wastes in the Hanford SSTs to discern if there might be candidates for feeding the ILAW melter after some minimal treatment along the lines of the DDA process used at Savannah River (described in Section 9.4.2.3 on p. 9-15)[14]. For example, Figure 9-20 illustrates the best-basis Cs-137 concentrations in the saltcake layers for the 13 Hanford SSTs that only contain salt wastes [2]. Two of the tanks (241-B-102 with 81 kL of saltcake and 241-T-109 with 197 kL of saltcake) contain less than 0.0025 Ci/kg of saltcake solids. Depending on the results of treatability studies, the concentration of Cs-137 for these wastes might satisfy the LAW vitrification facility limit. There are also limits on maximum solids and other radioactive and non-radioactive constituents (i.e., Specification 7 in the Bechtel contract [7]) that would have to be satisfied, but at least, this provides an idea of one alternative that might be considered for early startup of an ILAW melter.

Therefore, technically feasible options for treating Hanford tank wastes may be available based on the very large variations in the contents, forms, and risks posed for the various waste forms in the Hanford tanks. Alternatives should be considered in a holistic, risk-informed manner considering trade-offs in risks, costs and other important considerations. Because the window for success is brief, there will need to be an upfront and ongoing collaboration with Ecology on the alternatives evaluation and development process. Issues that will need clear communication and thoughtful consideration include information needs, review criteria, consistency with schedule, and regulatory challenges.

[14] The Deliquification, Dissolution, and Adjustment (DDA) process at SRS was used to prepare Tank 41H low-activity waste for treatment in Saltstone. Approximately 2.5 of the 3.0 to 5.0 MCi (or 50 to 83 percent) of the total activity that will ultimately be disposed of in the SRS Saltstone Disposal Facility (SDF) came from the DDA process (which was completed in 2008). The use of DDA in conjunction with other pretreatment processes (ARP / MCU and SWPF) satisfied the standards in Section 3116 of the NDAA.

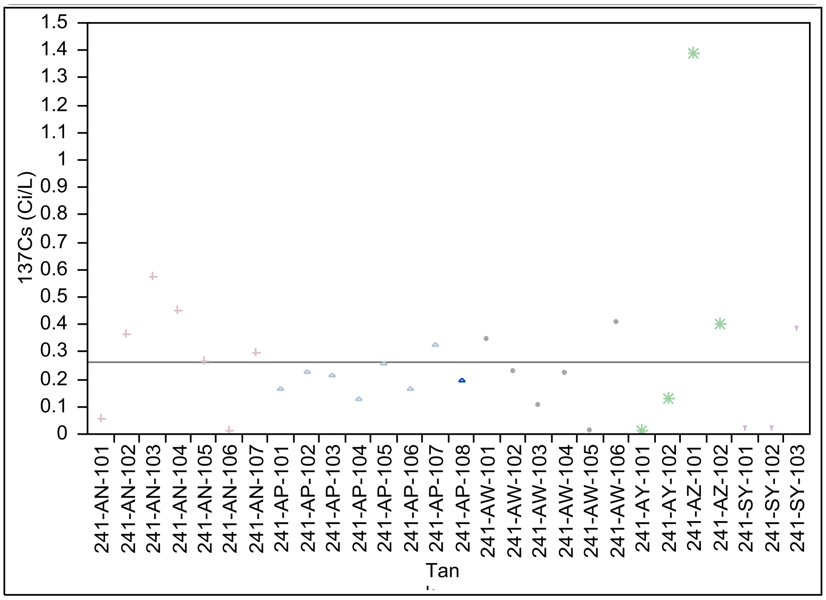

Figure 9-19. Cs-137 best-basis concentrations in the supernate phase for Hanford DSTs

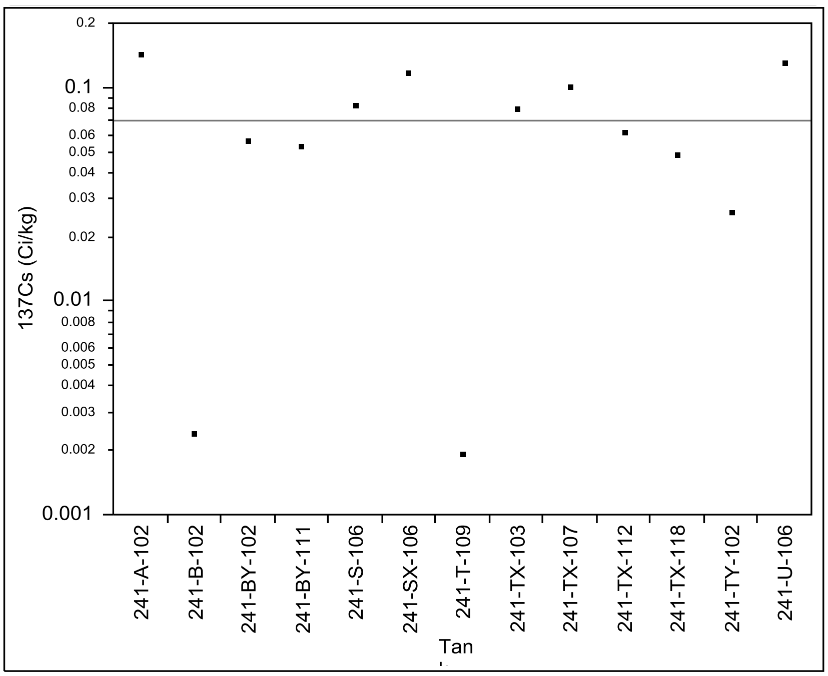

Figure 9-20. Cs-137 best-basis concentrations in the saltcake phase for those Hanford SSTs containing only salt wastes

9.4.6 Major Vulnerabilities

This section describes the major vulnerabilities identified from the EM-TWS review and potential strategies for mitigating the potential impacts. The vulnerabilities are discussed in terms of the alternatives described to the EM-TWS including the baseline, the Enhanced Tank Waste

Strategy (ETWS), the Supplemental Treatment Strategy (STS), and Vision 2020 (2020) as presented to the subcommittee.

9.4.6.1 Because of the potential difficulties in balancing the retrieval, pretreatment, qualification, and treatment of tank waste at both the Savannah River and Hanford Sites, there is a risk of needing special treatment for a large quantity of waste (e.g., salt-only glass at Savannah River), extending the operation of the tank farm and treatment facilities past current schedule dates, or both

A requisite balance must be established and maintained between the preparation of waste feed material and its treatment to satisfy various contract and programmatic requirements including the minimization of the potential mismatch between the treatment of the high-level and low-activity waste fractions. The changes that have been made to the DWPF melter to increase throughput and the construction of the Salt Waste Processing Facility (SWPF) would require an increase in the production and qualification of waste material for subsequent treatment including infrastructure and operational changes that may make striking the appropriate balance difficult. Improved planning models and requisite financial support should help mitigate the impacts from these issues. Because of the large expense in operating the DWPF (assuming $140 million per year) and support facilities, any significant production of salt-only waste glass would likely present a very high cost and schedule impact to SRS.

The delivery of qualified feed to the WTP will be more complicated than that at SRS because there are more tanks at Hanford with more waste types—some of which are inter-mixed and recalcitrant, resulting in more complicated characterization, retrieval, pretreatment, and qualification to produce feeds for the much higher contract rates for treatment at the WTP. There are also significant constraints imposed on the SST retrieval from both the TPA and Consent Decree that may make balancing the operations problematic. This vulnerability can be mitigated by additional tank characterization efforts, uncertainty management, improved planning models (that incorporate chemistry and uncertainties), continued Operations Research and modeling, and additional DST space. The valuable information that has been learned from the pretreatment and delivery of waste at SRS for the past 15+ years can be applied. This vulnerability is pertinent to the WTP acceleration strategies considered by the EM-TWS except the Vision 2020. Because of the significantly higher operating cost expected for the WTP (assuming $1 billion per year), even a modest need to produce salt-only or other special waste forms using the WTP presents very high schedule and cost risks.

9.4.6.2 Because of likely difficulties in increasing the production of qualified salt and sludge feeds, there may be difficulties in satisfying current schedules and milestones at both the Savannah River and Hanford Sites

To balance the treatment of the high-activity salt and sludge tank wastes through the DWPF and SWPF as currently planned will require a significant increase in the retrieval, pretreatment and qualification of SRS tank wastes including additional tankage. The necessary increase in the production of qualified waste feed for future SRS operations to accommodate increased HLW treatment throughput and SWPF has not been demonstrated with the existing infrastructure. Pretreatment is performed in the tank farm and often suffers from a lack of tank space;

furthermore, when tanks are emptied, they are not typically used for processing, but instead readied for closure. The various steps needed to plan the pretreatment and qualification of feeds are highly labor-intensive and are often only completely understood by a few. A mentoring program and committing more of the expert information to the model may help mitigate potential impacts. These conditions may make a significant increase in the production of qualified feeds for treatment at SRS problematic.

The Hanford WTP is under construction and is currently scheduled to begin radioactive operations in 2019. The WTP is designed to treat the entire high-level waste fraction and a portion of the corresponding low-activity waste fraction. Of the 177 high-level waste tanks at the Hanford Site, 149 are SSTs, many of which are known or suspected leakers; the wastes in the SSTs represent the majority of the risk posed by the tank wastes. Tank waste characterization, retrieval, and consolidation operations have been continuing at Hanford in preparation for commencing WTP radioactive operations. To date, the wastes from seven SSTs have been retrieved with a maximum of three retrievals in 2006. However, the waste retrievals (with corresponding pretreatment and qualification) must increase dramatically to support the current treatment schedule and to satisfy TPA milestones, which may be difficult due to logistics and funding limitations. If possible, a slower and earlier ramping up of retrievals, if possible, might help mitigate the potential impacts. This vulnerability applies to both baseline and the Vision 2020 scenario.

9.4.6.3 Because of the complex, interdependent, and highly constrained nature of the feeds and tank farm operations at the Hanford Site may impact waste feed delivery as well as current schedules and milestones

At Hanford, the PUREX process was used in conjunction with the bismuth phosphate and REDOX separations processes. Many of the tank wastes were reprocessed to recover uranium and fission products and wastes were intermixed often based on tank availability. Thus, when compared to SRS (where only the PUREX process used and wastes were segregated), there are more waste tanks at Hanford containing more waste types (that often have been mixed) resulting in more variable wastes, including some that are recalcitrant, making characterization, retrieval, processing, and qualification more difficult than at SRS. There are also significant constraints on the waste tanks that will be processed (e.g., the single-shell tanks) and their order based on the Hanford Consent Decree and TPA. Additional characterization activities, improved modeling, and intentional blending may help mitigate the impacts of this issue. This vulnerability applies to the baseline, STS, and ETWS scenarios.

9.4.6.4 The need to upgrade the ETF to treat liquid wastes generated from the WTP may impact treatment and thus feed delivery schedules and milestones

The ETF is a state-permitted facility that receives and treats liquid wastes from various sources on the Hanford Site. The ETF treatment processes remove radioactive and hazardous contaminants from the wastewater for storage until tests confirm that various radioactive and hazardous contaminants have been removed or lowered to levels making it acceptable for discharge to a state-approved disposal site. Treating wastewater from the WTP would require upgrades at ETF to manage significantly increased throughput and increased corrosion potential.

These upgrades must be funded and completed on time to treat effluent from the WTP. There may also be a concern with the level of volatile radioactive constituents (e.g., Tc-99 and I-129) from the LAW melter offgas system that may exceed acceptable levels for ETF. Alternative treatment of the offgas streams may be considered to help mitigate the impacts of this issue. These concerns apply to the scenarios considered (i.e., baseline, STS, and ETWS) except for the Vision 2020 scenario.

9.4.6.5 The waste acceptance criteria (WAC) for the Hanford tank waste treatment facilities and corresponding disposal facilities have not been finalized introducing significant uncertainties in the limits on feed delivery and treatment; significant delays in finalizing these criteria may impact waste feed delivery and treatment schedules and milestones

Before pretreated waste can be fed to Hanford treatment facilities, samples must be collected and tested to assure that the waste meets waste acceptance criteria (WAC) for these facilities. The key interface for success of the ORP tank waste treatment mission is the waste feed delivery interface that ensures the timely, efficient, and compliant delivery of feed from the tank farm to the WTP [2]. The WAC and physical and administrative details for the feed delivery interface are described in *ICD 19 – Interface Control Document for Waste Feed* [8]. Important aspects of this critical interface are being resolved including the WTP waste acceptance data quality objectives and an evaluation of the ability to adequately mix, sample, and deliver individual feed batches to the WTP for treatment [2]. The limits on and targets for Hanford waste feed delivery will remain uncertain until these key aspects of the feed delivery interface have been finalized. Furthermore, the acceptance criteria and permits required for the disposal facilities for both the high-level and low-activity waste forms that will be produced from the Hanford WTP have not been finalized (and, in some cases, have not been started). The potential impact of violating these acceptance criteria, once finalized, include resampling and return of feeds to the tank farm and corresponding delays in treatment schedules. The necessary acceptance criteria must be defined as soon as possible to allow their potential impacts to be taken into account during in planning. These concerns apply to all scenarios considered (i.e., baseline, STS, ETWS, and Vision 2020).

9.4.6.6 The inability to representatively mix and sample the large Hanford tank farm tanks needed to support waste feed delivery for treatment will impact waste treatment schedules and milestones

Wastes at Hanford must be sampled and analyzed to demonstrate that they satisfy waste acceptance criteria and feed specifications for the corresponding treatment facility per *ICD 19 – Interface Control Document for Waste Feed* [8]. These requirements translate into the need to satisfy appropriate requirements to high confidence (i.e., 95 percent confidence for fissile components and 90 percent for others). An evaluation is currently underway of the ability in the tank farm to adequately mix, sample, and deliver individual feed batches to the WTP for treatment [2]. If methods cannot be identified or developed to allow limits to be satisfied to the high confidences required, additional sampling and analysis may be required that will impact pretreatment, qualification, and delivery schedules. Resulting delays would impact treatment schedules and possibly jeopardized the making of TPA milestones. One way to potentially mitigate the impacts of this issue would be to implement the enhanced Waste Retrieval Facility to include mixing, blending, sampling, qualification and filtration of retrieved waste that would also provide a more uniform feed to WTP. The technical risk associated with mixing, sampling, and delivery of feed from these large tanks for slurries in very high. Because of the very high operating expense for WTP, any delays from additional sampling or return of feed to the tank farm for additional processing translates into very high cost and schedule risks. These concerns apply to all scenarios considered (i.e., baseline, STS, and ETWS) except for the Vision 2020 scenario.

9.4.6.7 The potential lack of temporary storage for treated low-activity and high-activity waste forms at the Hanford Site may impact treatment and thus waste feed delivery and treatment schedules and milestones

Current schedules indicate that if sufficient funding is provided and no unforeseen difficulties arise during permitting activities, then the required storage and disposal facilities will be available to support WTP operations. However, if there are difficulties in either funding, building or permitting the HLW storage facilities, in permitting the Integrated Disposal Facility for treated LAW, or changing the permit for the Central Waste Complex (CWC), then options may be needed to temporarily store treated HLW, LAW, or TRU waste forms. A lack of such storage might impact WTP treatment operations as well as feed delivery and ultimately tank farm operations. Early planning is needed to mitigate potential impacts. These concerns apply to all scenarios considered (i.e., baseline, STS, ETWS, and Vision 2020).

9.4.6.8 The Hanford 242-A Evaporator system is a single-point of failure; long-term outages of this system would impact waste feed delivery and thus treatment schedules and TPA milestones

The 242-A Evaporator must operate throughout the lifetime of the RPP mission, as it is the only such facility to support SST retrieval operations, to maintain the appropriate sodium concentration in the feed delivered to WTP, and to manage space in the DSTs. Additional evaporator capacity is being researched (e.g., wiped- or thin-film evaporation technologies); however, the technologies being researched would not replace the 242-A Evaporator functionality. A significant failure in the 242-A Evaporator system would impact the timely delivery of feed to the WTP for treatment. Furthermore, plans would require much higher annual availability of the 242-A Evaporator beginning in 2030, when the Evaporator will be over 50 years old, through 2040, where the risk of failure would likely increase with the age of the evaporator. The aggressive schedule for Evaporator use may make the continuous upgrades planned for the facility difficult to execute in a timely enough fashion. Because of the critical nature of the operations carried out using the 242-A Evaporator, any failures requiring longer than anticipated outages present very high cost and schedule risks. Construction of a new evaporator with functionality akin to that of the 242-A Evaporator or additional DST space would help mitigate the potential impact of a failure in the 242-A Evaporator system. This vulnerability is pertinent to the strategies considered by the EM-TWS (i.e., baseline, STS, and ETWS) except Vision 2020.

9.4.6.9 Significant fouling, which has been known to occur in the SRS 242-16H (2H) Evaporator System, may impact waste pretreatment and treatment activities

The 2H-Evaporator system at SRS is used to evaporate the recycle stream coming from DWPF. In the past, the evaporator has become fouled requiring it be shut down for cleaning. Despite improvements in cleaning the evaporator pot, fouling still occurs in the 2H-Evaporator system and the need to increase feed production and changes in recycle composition resulting from possible melter and off-gas changes as well as waste composition and frit changes may impact fouling in the evaporator system. Periodic cleaning of the evaporator (especially during outages) may help mitigate potential impacts.

9.4.6.10 Fluidized bed steam reforming (FBSR) may not be the most appropriate technology to destroy organics in the SRS Tank 48H waste based on cost, schedule, and technical maturity

Tank 48H contains approximately 250,000 gallons of a salt solution containing 22,000 kg of tetraphenylborate (TPB) and 400,000 Ci of Cs-137. TPB can release sufficient benzene to the tank head space potentially creating flammable conditions and a resulting safety hazard. Fluidized bed steam reforming was selected to process this unique organic waste. Since the selection of FBSR to treat the Tank 48H waste, a number of factors have resulted in a review of the costs, schedule, and technical maturity criteria. This review has led to the evaluation of competing technologies including direct vitrification and a copper catalyzed process that was not considered in previous evaluations. Since return of Tank 48H to service is no longer on the critical path, using FBSR instead of a competing technology could have a significant cost impact on SRS operations. To help mitigate this vulnerability, competing technologies should be evaluated in the System Planning process including:

- Fluidized bed steam reforming
- Copper-catalyzed chemical oxidation process
- Direction vitritification as an end-of-mission campaign
- Direct vitrification by slow addition (or “bleeding”)

9.4.6.11 A large number of projects must be completed to pretreat and feed low-activity waste to the Hanford ILAW vitrification facility by 2016 to support the Vision 2020 scenario

There are numerous projects (perhaps as many as 30) that must be completed before Hanford low-activity tank wastes can be retrieved, pretreated, qualified, and staged for treatment in the LAW vitrification facility currently under construction in the WTP. There appears to be a reasonable chance that each of these projects can be completed on time as long as budget requests are met. However, difficulties in securing proper funding and/or attempting to accelerate treatment in the ILAW facility may significantly decrease the chance of completing all the necessary projects, especially when so many projects must be completed on such a compressed schedule to support the Vision 2020 scenario under increasingly tight fiscal conditions. The impact to the schedule by as may be as much as 12 months including delay of starting the single ILAW melter until 2017 or later.

9.5 Recommendations

These are the recommendations to address the various findings and observations noted in Section 9.3 (starting on p. 9-4) and vulnerabilities identified in Section 9.4.6 (starting on p. 9-36).

9.5.1 DOE, in conjunction with its regulators, should establish consensus on strategies, infrastructure, models, and processes to provide adequate flexibility in waste feed preparation and treatment

There will be a need at both SRS and Hanford to balance as well as significantly increase the retrieval, preparation, qualification, feed and treatment of high-level and low-activity wastes to meet treatment schedules and milestones. The variation in the characteristics of the tank wastes at both sites dictates that there should be adequate flexibility in the processes used to prepare and deliver as well as treat tank wastes. DOE, in conjunction with its regulators, should establish a consensus on strategies, infrastructure, models, and processes to provide the flexibility needed. Because the window of opportunity at either site will likely be brief, an upfront and ongoing collaboration with regulators will be needed. Issues that will need clear communication and thoughtful consideration include information needs, review criteria, consistency with schedule, and regulatory challenges.

9.5.2 DOE should formally evaluate the single-point failure impact of 242-A in the planned mode requiring much higher annual availability versus the current campaign mode and also address the need for additional capacity to supplement the 242-A evaporator in case of failure

Continued operation of the 242-A Evaporator is critical to the RPP mission. The likelihood of failure will increase and the evaporator ages. According to current plans, much higher availability of the evaporator will be required at a time when the evaporator is more than half a century old. The aggressive use of the evaporator to support tank farm operations may increase the likelihood of failure and impact the ability to make the continuous improvements planned to maintain the system. The technology currently being researched (i.e., thin or wiped-film evaporators) does not appear to be an adequate replacement for the functionality provided by the 242-A Evaporator. Additional evaporative capacity of the type needed could be provided by a building a new evaporator, using the existing evaporator facility in 200 West Area, or employing off-the-shelf technologies that would supplement the 242-A Evaporator without the need for significant research and development. The construction of additional double-shell tanks would also help alleviate issues associated with failures of the 242-A Evaporator system.

9.5.3 The waste acceptance criteria (WAC) for the Hanford tank waste treatment facilities and disposal facilities should be finalized as soon as possible to reduce the potential impact on waste feed delivery and treatment schedules and milestones

Before pretreated waste can be fed to Hanford treatment facilities, samples must be collected and tested to assure that the waste meets WAC for these facilities. Important aspects of the waste feed delivery interface are being resolved including the WTP waste acceptance data quality objectives and an evaluation of the ability to adequately mix, sample, and deliver individual feed batches to the WTP for treatment. The limits on and targets for Hanford waste feed delivery will remain uncertain until these key aspects of the feed delivery interface are finalized. Furthermore, the acceptance criteria and permits required for the disposal facilities for both the high-level and low-activity waste forms have not been finalized. These acceptance criteria must be finalized as soon as possible to reduce the potential impact on Hanford treatment milestones.

9.5.4 DOE should develop a mitigation strategy for the potential inability to adequately and efficiently mix, sample, and deliver wastes to the WTP.

Pretreated wastes at Hanford must be sampled and analyzed to demonstrate that they satisfy waste acceptance criteria and feed specifications for the corresponding treatment facility. These requirements translate into the need to satisfy appropriate requirements to high confidence (i.e., 95 percent confidence for fissile components and 90 percent for others). An evaluation is currently underway of the ability in the tank farm to adequately mix, sample, and deliver individual feed batches to the WTP for treatment [2]. If methods cannot be identified or developed to allow limits to be satisfied to the high confidences required, additional sampling and analysis may be required that would potentially impact pretreatment, qualification, and delivery schedules and ultimately treatment milestones. A potential mitigation would be to implement the enhanced Waste Retrieval Facility to include mixing, blending, sampling, qualification and filtration of retrieved waste that would also provide a more uniform feed to WTP.

9.5.5 DOE should evaluate in the System Planning process the various options for processing the SRS Tank 48H waste

Tank 48H contains approximately 250,000 gallons of a salt solution containing 22,000 kg of tetraphenylborate (TPB) and 400,000 Ci of Cs-137. Fluidized bed steam reforming was originally selected to process this unique organic waste. However, a number of factors have resulted in a review of the costs, schedule, and technical maturity criteria. This review has led to the evaluation of competing technologies including direct vitrification and a copper catalyzed chemical oxidation process that was not considered in previous evaluations. DOE should evaluate available technologies in the System Planning process including:

- Fluidized bed steam reforming
- Copper catalyzed process
- Direction vitritification as an end-of-mission campaign
- Direct vitrification by slow addition (or “bleeding”)

9.5.6 Implement previous recommendations that potentially impact alternative treatment technologies and forms for Hanford LAW (cross-cutting)

Previous recommendations were made by the 2009 External Technical Review (ETR) Team that evaluated Hanford modeling and simulation tools and the 2010 EM-TWS that should be implemented:

- Complete the enhancements to the HTWOS model to support life-cycle cost modeling and future high-level planning; important tank waste and processing chemistries and significant uncertainties must be incorporated in the planning model to inform System Planning and the alternative treatment technology and waste form selection processes.

- Institute recommendations made by the ETR Team to capture the significant knowledge concerning SRS sludge feed preparation.

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APPENDIX 10
Identify Other Tank Waste Vulnerabilities at SRS and Hanford

Charge 6; identify other tank waste vulnerabilities at SRS and Hanford. This was segregated into 2 sections:

- **Section 10 A: Charge 6 A- Identification of other tank waste vulnerabilities at Hanford**
- **Section 10 B: Charge 6 B:- Identification of other tank waste vulnerabilities at SRS**

The team that did the review is noted below:

EM-TWS Lead: Dennis Ferrigno
EM-TWS Support: Kevin Brown, Bob Hanfling, Ed Lahoda, Alan Leviton, Larry Papay, Rod Strand
EM-TWS Technical Support: Mark Frei, Bob Iotti, Barry Naft, Herb Sutter, Tom Winston
EM-TWS DFO: Kristen Ellis
EM-TWS Administrative Support: Elaine Merchant

10A.1: Overview / Objective for Hanford Tank Waste Vulnerabilities

During the course of performing the tasks above, the Subcommittee should identify other Hanford vulnerabilities not specifically encompassed by those tasks and propose any recommendations to mitigate those vulnerabilities.

10A.2: Options and constraints to be considered

Exhibit 10A.1 summarizes the scope of the analysis for the vulnerability assessments as it relates to Mission, Overall Objectives and Overall Major Issues as it relates to Tank Waste at Hanford.

Exhibit 10A.2 delineates the methodology used for the vulnerability assessment as it relates to very low to very high-risk issues. As the risk / vulnerability was considered, the EM-TWS listed possible mitigation steps that could lower the risk to the program objectives. It should be noted that the risk monetization considers both Life Cycle Cost decreases and / or Life Cycle Cost increases. The analysis reflects Current Dollar determination (not Net Present Value determination), which is consistent with established DOE-EM business planning practice.

10A.3: Schedules

Exhibit 10A.3 a, b, c compares the Hanford baseline schedule with those of Vision 2020, Supplemental Treatment, and Enhanced Treatment.

Exhibit 10A.1

Mission Requirements for the Three Major Scenarios			
Current Baseline	**(1) Vision 2020**	**(2) Supplemental Treatment Project**	**(3) Enhanced TW Strategy**
Current Baseline mission requirements are reflected in System Plan 5.	Earliest possible hot operations of completed WTP facilities (sequential facility completions starting with LAW/BOF/LAB). LAW operating hot while PT and HLW are being commissioned. Feed tank waste pretreated using filtration / ion exchange directly to LAW. Hot operations period for all facilities after completion of capital construction and before compliance date (2022) for WTP full operations milestone.	Supplement WTP PT and LAW capacity over and above current design to match HLW capacity and meet mission requirements. Additional LAW immobilization (selected from vitrification, FBSR, or grouting). Additional pretreatment options include in-/at- tank (using filtration / ion exchange).	Save seven years from baseline using transformational technologies. Deployment of 3 FBSR units (2 in 200 East Area, 1 in 200 West Area; no LAW vitrification). Deployment of in-tank pretreatment technologies (using filtration / ion exchange / other technologies). Upgraded WTP HLW vitrification capacity, and enhanced tank farm delivery capacity.

Key Assumptions for the Three Major Scenarios			
Current Baseline	**(1) Vision 2020**	**(2) Supplemental Treatment Project**	**(3) Enhanced TW Strategy**
Current Baseline assumptions are reflected in System Plan 5.	Tank Farm pretreatment and LAW vitrification startup 12/16. Tank Farm PT runs until WTP PT startup in 3/18 (nominally 15 months). Early opportunity to debottleneck LAW operations and resolve potential startup and operational issues. Opportunity to accelerate staffing, training and certification, and gain operational and management experience. Accelerate commissioning of all WTP facilities to create a hot operations continuous period before continuous operations.	Tank Farm pretreatment and first alternative immobilization hot commissioning 1/18. Deployment of either an enhanced second LAW vitrification line or in-tank/at-tank pretreatment, alternatives plus alternative LAW immobilization technologies for full mission duration.	Tank Farm pretreatment and first alternative immobilization hot commissioning 1/18. Assumes deployment of in-tank pre-treatment technology for full mission duration to supplement WTP PT capacity. Assumes alternate LAW immobilization technology capacity will eliminate the requirement for WTP LAW facility. Assumes enhanced tank farm delivery capacity is greater than current baseline.

Major Issues that Relate to the Three Major Scenarios

Current Baseline	(1) Vision 2020	(2) Supplemental Treatment Project	(3) Enhanced TW Strategy
Baseline program mission is vulnerable to schedule and cost increases from potentially added construction and total project operations. Increases could be due to dilution of resources, complexity of additional engineering, added construction, and additional operational readiness requirements for added systems, risk mitigation measures, and inability to obtain increased funding over the near-term budget period.	Impact of WTP PT and HLW construction and commissioning in hot environment after LAW operations begin. Delays in commissioning of LAW and or other WTP facilities could delay startup. Potentially inadequate treatment of secondary waste from LAW vitrification facility Filtration / ion exchange integrated design and technology issues could delay startup. Delays in developing ETF upgrades could impact PT commissioning acceleration. Delays in HLW and PT operations could increase LAW-only operation beyond 15 months, creating problems in managing secondary LAW.	If FBSR is selected, it will be a first of a kind, large facility application, assuming Idaho facility is operational based on current baseline. Acceptance of a non vitrified, alternate waste form by the cognizant regulatory authorities. Regulatory "as good as glass" stakeholder and legal issues. Potential for substantially higher operating, transportation, and disposal costs due to increased waste volume of non-vitrified product.	Impact of WTP PT and HLW construction and commissioning in hot environment after LAW operations begin. Acceptance of a non vitrified, alternate waste form by the cognizant regulatory authorities. Regulatory "as good as glass" stakeholder and legal issues. Additional FBSR capacity would require rebalancing of integrated WTP operations. Cost and schedule and technical maturation may eliminate currently perceived benefits of FBSR deployment. Additional FBSR capacity would require revision to tank farm feed strategy. Abandonment of time and capital investment in WTP LAW facility would be a program change that could discredit DOE as it relates to Congressional and stakeholder confidence in DOE decision making.

Exhibit 10A.2
Methodology used for the vulnerability assessment

Consequence	Threshold Definition
Very Low	Small, acceptable change in project or facility performance, risk is minor threat to facility mission; opportunity would result in minor benefit; possibly requires minor facility operations or maintenance changes without redesign. Cost change threshold: < $15 million. Schedule change threshold: < 1 month on a noncritical path item. Technical or other: Design feature must be changed due to small degradation from baseline performance or interface problem.
Low	Small change in project or facility performance; risk is small threat to facility mission; opportunity could result in small benefit; possibly requires minor facility redesign or repair, significant environmental remediation. Cost change threshold: $15 million to $40 million. Schedule change threshold: 1-3 months on a noncritical path item. Technical or other: Redesign of noncritical path item or increased potential for regulatory intervention.
Medium	Medium change in facility performance; risk is serious threat to facility mission; opportunity could result in medium benefit; possible comletion of only portions of the mission or requires major facility redesign or rebuilding, extensive environmental remediation. Cost change threshold: $40 million to $100 million. Schedule change threshold: 3-6 months on a critical path item. Technical or other: Threat to mission, environment, or people that requires some redesign, repair, or significant additional environmental remediation.
High	Substantial change in facility performance; risk is critical threat to facility mission; opportunity could result in substantial benefit; risk may cause loss of mission, long-term environmental abandonment. Cost change threshold: $100 million to $200 million. Schedule change threshold: 6-12 months on a critical path item. Technical or other: A major project goal will not be met, or an outside regulator shuts down the job for an indefinite period.
Very High	Very substantial change in facility performance; catastrophic threat to facility mission; opportunity could result in great benefit; risk may result in loss of mission, long-term environmental abandonment. Cost change threshold: > $200 million. Schedule change threshold: >12 months on total project completion. Technical or other: Project cannot be completed.

Notes: First-of-a-kind risks will receive special attention because they are often associated with project failure. First-of-a-kind risks should receive medium, high or very high consequence values unless there is a compelling argument for lesser consequence.

The following compares the summary baseline schedule to the three options under consideration:

Exhibit 10A-3a: Vision 2020 consideration as compared to current baseline sequential ORR BCP commissioning

	Construction Complete		Hot Commissioning	
	WTP Baseline[5]	Vision 2020	WTP Baseline[6]	Vision 2020
Laboratory	5/12	12/13	12/16	9/16
Low Activity Waste Facility (LAW)	3/14	10/14	12/16	9/16
Pretreatment Facility (PT)	2/16	2/16	6/18	12/17
High-Level Waste (HLW) Facility	5/16	5/16	7/18	5/18
Interim Pretreatment System	N/A	12/15	N/A	9/16
End Interim Pretreatment Operations	N/A	N/A	N/A	removal decision in 3/20

Exhibit 10A-3b: Supplemental Treatment consideration as compared to current baseline

	Construction Complete		Hot Commissioning	
	WTP Baseline	Supplemental Treatment	WTP Baseline	Supplemental Treatment
Laboratory	5/12	2/14	12/16	3/17
Low Activity Waste Facility (LAW)	3/14	5/15	12/16	3/17
Pretreatment Facility (PT)	2/16	3/16	6/18	3/19
High Level Waste Facility W)	5/16	12/16	7/18	4/19
Supplemental Treatment Technology	N/A	N/A	N/A	1/18
Immobilization Technology	N/A	N/A	N/A	1/18

[5] WTP baseline construction complete dates based on substantial completion

[6] WTP start of hot commissioning dependent on successful ORR which is outside the control of the project

Exhibit 10A-3c: Enhanced Treatment consideration as compared to current baseline

	Construction Complete		Hot Commissioning	
	WTP Baseline	Enhanced Treatment	WTP Baseline	Enhanced Treatment
Laboratory	5/12	3/14	12/16	3/19
Low Activity Waste Facility (LAW)	3/14	3/15	12/16	LAW does not operate
Pretreatment Facility (PT)	2/16	6/16	6/18	1/18
High Level Waste Facility (HLW)	5/16	12/16	7/18	4/19
Alternative LAW Treatment & Immobilization	N/A	1/17	N/A	1/18

Assumptions common to all scenarios:

Workforce: The personnel required for operation will be selected, trained and certified to meet mission schedule compliance. Those personnel in already commissioned facilities are in addition to the continuing commissioning staff.

Commissioning: All options will be sequentially commissioned with turnover to operations as ready to assure mission schedule compliance. There will no delays in prior facility commissioning that impact other facilities down the sequence.

Regulatory

- LAW immobilization will produce a final waste form that complies with the intent of Appropriations Bill Section 3116 waste determination provisions. A currently acceptable method for compliance with these provisions has been provided in the NRC provisional approval letter of June 9, 1997 (C.J. Peperiello to J. Kinzer)[1].

- Permits will be required for the new supplemental pretreatment facilities such as ETF upgrades and additional HLW storage capability. These will constitute RCRA permitted facilities and will require submittal of a part B permit. Permitting will be done in accordance with section 9.2.2 of the HFFACO (Tri-party agreement) with its contents defined by WAC 173-303-806. The schedule for this part B process can vary, but at Hanford, it historically requires more than 2 years to complete. A permitting plan will establish a mission compliant schedule and deliverables for completion of the Part B permits in a timely manner, and the requisite 413.3B DOE review and concurrences will also be provided in a timely manner

10A.4: Vulnerability Methodology

Based on Exhibit 6A-2, Vulnerability Assessment Criteria, the following vulnerabilities were identified and categorized for the three program strategies:

- Vision 2020
- Supplemental Treatment
- Enhanced Treatment

10A.5: Vulnerability Listings for the three program strategies

The vulnerabilities are listed by TWS charges:

- Charge 1, Life Cycle Cost Analysis
- Charge 2,Waste Form
- Charge 3, In Tank / Out of Tank Treatment
- Charge 4, Melter Technology
- Charge 5, Waste Delivery Plan
- Charge 7, Vision 2020

10A.5.1: Vulnerability Assessment: Vision 2020

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
Charge 7: Global Issues								
1	Tight Schedule	Med	Very High	High	Very High	Med	The ability of the project to successfully implement a very tight schedule so that it does not lose its mission effectiveness. The risk of not being able to obtain multiple permits and approval of the Tank Closure and Waste Management EIS and ROD The Performance Assessment that is required for the IDF cannot be started until the EIS and ROD are completed (EM-1 position).	Focus on the Vision 2020 deliverables and the schedule. Review and modify a complete Risk Register (maintain currency). The EM-TWS recommends a quarterly Risk Register review and execution. Permitting: start partnering with Ecology immediately. Establish single-line accountability with Ecology to execute permit agreements. Establish program strategy that the PA does not delay operations.
Charge 1: LCC								
	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
1	Minimal reliable & defensible LCC basis of cost and schedule estimates	Low	Very High	Very High	Very High	Low	This project is pre-CD-1. There are no approved cost and schedule estimates.	Develop detailed CD-2 cost and schedule estimates and baseline with appropriate programmatic approval.
2	DOE System-wide consistent processes are not deployed for LCC cost estimating	Low	Very High	Very High	Low	Low	EM does not uniformly apply a system-wide LCC Methodology (process) for cost estimating such as that maintained by the National Institute for Standards and Technology (NIST) (BLCC5) for DOE. Planning models are lacking for	Use a system-wide process for cost and schedule estimating such as BLCC5. Provide documented NPV and Current Dollar calculations when selecting alternatives and report baseline LCC cost savings and

							development and testing of scenarios.	monetized risks in current year funded dollars.
3	Selection of technology alternatives may be incorrect based on failure to use NPV calculations	Low	Low	High	Low	Low	GAO 12-step cost estimating process recommends utilization of NPV cost analysis for selection of alternate technologies (Reference 19) Technology selection, based on cost needs to be made on total cost, which includes system costs, facilities, regulatory and other related costs for total system LCC.	Use of Net Present Value to compare scenarios
4	Long-term workforce jurisdiction determination will be driven by short-term 2020 requirements	Very Low	Very High	Very High	Low	Low	Accelerating the institutional decision may weaken DOE's best value determination of workforce jurisdiction.	Start workforce jurisdiction analysis now.
5	Lack of required funding eliminates the benefit of the 2020 option	Very Low	Very High	Very Low	Very Low	Very Low	Elimination of the 2020 option does not impact the current System Plan 5 baseline; however, the execution of the 2020 option could significantly decrease the risk associated with the baseline.	
6	Unanticipated difficulties in construction of new systems in an operating nuclear conduct of operations area	Very Low	High	High	Med	Med	Based on experience, delays could be expected for executing new capital construction in nuclear conduct of operation controlled areas.	Review all areas system-wide of lessons learned and establish clear owner/operator control for capital construction of nuclear facilities.

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
7	Work stoppage at WTP due to spills, Notices of Violation, or operational incidents	Very Low	Very High	Very High	Med	Med	Unanticipated work stoppage could shut down the construction site for unknown periods of time.	N/A
Charge 3: In-Tank/Out-of-Tank								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	ETF availability	Very Low	Very Low	Very Low	Very Low	Low	The current plan is to recycle back to the tanks, which increases tank volume.	Added evaporation capability Shipment of LAW melter overheads offsite
2	Intermittent operation	Low	Very Low	Very Low	Very Low	Very Low	Intermittent operation may impact melter performance (burning off cold cap)	N/A
3	242-A Evaporator availability	Very Low	Low	Very Low	Very Low	Very Low	The 242-A Evaporator is critical to operation of 2020 performance.	Prior to start of the LAW melter for Vision 2020, ORP needs to plan to have sufficient tank capacity to receive six months of recycle without 242-A Evaporator availability
4	Safety of nitric acid elution of sRF IX column (both in-tank and at-tank processes)	Low	Low	Low	Med If RCRA Part B permit is needed	Med.	DST corrosion issues	HAZOP or equivalent work process
5	RMF rotating seal reliability	Low	Med.	Med.	Low	Low	RMF has not operated in actual tank farm in-tank hot environment	SCIX process operation in SRS Tank 41
6	Difficulty retrieving sludge from Hanford DSTs when using CST ion exchange	High	High	High	Low	High	If CST is used, discharging ground CST, loaded with ^{137}Cs, may adversely affect sludge retrieval.	Use disposable high integrity containers configured as ion exchange canisters

7	CST clumping	Med .	Med	Low	Low	Low	If CST is used, CST requires caustic washing to extract materials that result in agglomeration of CST particles. If CST is used, CST storage stability may be problem.	Only purchase CST as caustic-washed IONSIV® IE-911-CW grade. Robust NaOH washing equipment near point of use.
8	CST IX column flow in-homogeneity	Low	Low	Low	Low	Low	If CST is used, need to demonstrate ability to set uniform IX bed in annular column.	Engineering-scale test with prototype column. Should be full-size or near full-size since dimensions are small.
9	CST IX column overheating	Low	High	High	Low	High	If CST is used, simultaneous loss of permeate feed and cooling water flow may cause unacceptably high temperatures.	HAZOP or equivalent work process
Charge 5: Waste Delivery								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	A large number of modification projects are needed to support needed transfers	Med	Very High	Med	Med	Med	Approximately 30 project modifications needed to support necessary transfer operations must be completed to support the Vision 2020. Completion of the necessary projects by the original 2018 date appeared reasonable; however, the acceleration needed for 2020 drives this to high risk.	Order and base funding on those needed to support accelerated operations without compromising WTP startup…

Comments to Vulnerability Assessment for Vision 2020:

1. The Vision 2020 would achieve earliest possible hot operations of WTP facilities (e.g., sequential facility completions, ORRs and CD-4s, starting with LAW/BOF/LAB) and the opportunity to produce LAW glass early (2016) and continue until Pretreatment is commissioned. Pre-treatment technologies (in-tank Rotary Microfiltration (RMF) / Small-Column Ion Exchange (SCIX) or at-tank filtration / ion exchange), new lines to direct feed LAW and lines from LAW to ETF, a single LAW melter operating, and off-gas recycle to the DSTs are needed to support the Vision 2020.
2. Delay in selecting the operating contractor for the combined Tank Farms and WTP operations, has a risk of labor disruption, with negative consequences on schedule and lifecycle costs.
3. Completion of the mission in the scheduled time depends on the ability of the Tank Farms to retrieve the SST into the DSTs to then feed the WTP. Approximately, 6-10 tanks need to be retrieved per year, while at present only about 2 are being retrieved. The number of tanks to be retrieved for WTP also depends on the supplemental LAW facilities that might be deployed, as well as the disposition of tanks that potentially contain TRU waste. WIR determination per DOE O 435.1 to declare those tank wastes as TRU waste is required.

4. The SST tank retrieval, does not directly impact the Vision 2020, but it does impact the long-term mission and consent decree milestones. Effort should be made to provide the requisite enhancements so that the DST space does not become full. Early operation of the LAW Facility at some considerable capacity, limited by a concomitant (if staged) upgrade of the throughput of ETF, provides the best assurance that the DSTs will never reach capacity, and enable continued retrieval of the SSTs.
5. Some of the modifications required to feed the LAW will be located with the PT Facility. When interim LAW operations are initiated, it will be necessary to continue commissioning activities in the PT concurrently with this operation. Radioactive operations within an active commissioning site (and possibly one where construction is not yet complete) will result in more complex logistical, safety, and security issues

10A.5.2: Vulnerability Assessment: Supplemental Treatment

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
Charge 1: LCC								
1	Minimal reliable & defensible LCC basis of cost and schedule estimates	Med	Very High	Very High	Very High	Low	This project is pre-CD-1. There are no approved cost and schedule estimates.	Develop detailed CD-2 cost and schedule estimates and baseline with appropriate programmatic approval.
2	DOE System-wide consistent processes are not deployed for LCC cost estimating	Med	Very High	Very High	Low	Low	EM does not uniformly apply a system-wide LCC Methodology (process) for cost estimating such as that maintained by the National Institute for Standards and Technology (NIST) (BLCC5) for DOE. Planning models are lacking for development and testing of scenarios.	Use a system-wide process for cost and schedule estimating such as BLCC5. Provide documented NPV and Current Dollar calculations when selecting alternatives and report baseline LCC cost savings and monetized risks in current year funded dollars.
3	Selection of technology alternatives may be incorrect based on failure to use NPV calculations	Low	Low	High	Low	Low	GAO 12-step cost estimating process recommends utilization of NPV cost analysis for selection of alternate technologies (Reference 19) Technology selection, based on cost needs to be made on total cost, which includes system costs, facilities, regulatory and other related costs for total system LCC.	Use of Net Present Value to compare scenarios
Charge 2: Waste Forms								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	Fluidized Bed Steam	Med	Very High	Very High	Very High	Low	All LAW treated by FBSR; thus mineralized waste form must be	There could be a general acceptance of a mineral waste form, benchmarks, and

	Reforming (FBSR) / mineralized waste form						acceptable (including Tc-99 and other COCs). “Good as glass” and prescriptive nature of RCRA obfuscates important issues. There is no single test to qualify waste form performance so performance comparisons are difficult.	testing requirements for a treatment technology similar to that for HLW (borosilicate glass). Should provide performance-based instead of technology-based. Defense-in-depths strategies could be pursued (as with HLW).
2	FBSR coal fines potential explosion hazard	Med	Low	Low	Med	High	Coal fines explode in feed or transit areas or in FBSR due to spark discharge.	
3	ILAW / borosilicate glass	Low	Low	Low	Low	Low	Because of questions that may arise as a mineral waste form is pursued for Hanford LAW, there is some degree of risk to the acceptance of borosilicate glass as the “best available” waste form / technology.	Perform a performance assess seek early regulatory concurrence
4	Bulk vitrification / sodium silicate glass	High	High	High	Low	Med	Technical, safety and management issues were identified (GAO report) with using bulk vitrification to immobilize Hanford LAW. Considered too expensive to re-address outstanding issues.	If cost-benefit analysis so justifies, perform the research needed to manage the observed technical and safety issues in a program that deals with the management weaknesses identified previously.
5	Grouting / Cast stone	Low	Med	Med	Very High	Low	Originally, grout and glass were identified in the original TPA for treating Hanford LAW. The prescriptive nature of RCRA makes this difficult.	Identify treatment technologies (under RCRA) / performance-based criteria that would be protective of human health and the environment for a RCRA disposal.
6	Contaminant capture	Med	Med	High	Very High	Low	Volatile and other important contaminants of concern (e.g., Tc-99 and I-129) and may not be captured in the waste forms used for Hanford LAW	Improve capture rate through operations / recycle or new technology application
7	Loss of knowledge	Med	Low	Med	Low	Low	Loss of knowledge concerning waste forms and acceptance	Knowledge archiving and mentoring programs; cost incentives

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
	and expertise in critical areas						because there is a lag of over a decade between the design date and when WTP operations would commence.	
Charge 3: In-Tank/Out-of-Tank								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	ETF availability	Very Low	Very Low	Very Low	Very Low	Low	The current plan is to recycle back to the tanks, which increases tank volume.	Added evaporation capability Shipment of LAW melter overheads offsite
2	Intermittent operation	Low	Very Low	Very Low	Very Low	Very Low	Intermittent operation may impact melter performance (burning off cold cap)	N/A
3	Safety of nitric acid elution of sRF IX column (both in-tank and at-tank processes)	Low	Low	Low	Med If RCRA Part B permit is needed	Med.	DST corrosion issues	HAZOP or equivalent work process
4	Difficulty retrieving sludge from Hanford DSTs when using CST ion exchange	High	High	High	Low	High	If CST is used, discharging ground CST, loaded with ^{137}Cs, may adversely affect sludge retrieval.	Use disposable high integrity containers configured as ion exchange canisters
5	CST clumping	Medium	Med	Low	Low	Low	If CST is used, CST requires caustic washing to extract materials that result in agglomeration of CST particles. If CST is used, CST storage stability may be problem.	Only purchase CST as caustic-washed IONSIV® IE-911-CW grade. Robust NaOH washing equipment near point of use.
6	CST IX column flow in-homogeneity	Low	Low	Low	Low	Low	If CST is used, need to demonstrate ability to set uniform IX bed in annular column.	Engineering-scale test with prototype column. Should be full-size or near full-size since dimensions are small.
6	CST IX column overheating	Low	High	High	Low	High	If CST is used, simultaneous loss of permeate feed and cooling water	HAZOP or equivalent work process

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
							flow may cause unacceptably high temperatures.	
Charge 4: Melter Technology for Supplemental Treatment								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	Alternate technology to Joule-heated melter for Second LAW	Med to very high	Med to Very High	Med to Very High	Low to Very High	Low	Risk comes from limited experience with any alternative with Hanford waste	**Testing program that provides large experience base for feeds in any new technology. Prefer a TRL of at least 7**
	• Bulk vitrification	Med	High	High	Med	Med	Potential issues with cost and waste form variability and QA	Develop a method for QA of final product
	• Cold crucible induction	Med	Low	Low	Low	Low	Widely used by French and UK but on low sodium waste	Test program in 2nd LAW facility that removes technological issues
	• Fluidized bed steam reforming	Med	High	High	Med	Med	Potential issues with acceptability of waste form and lack of operating experience in radioactive environment on high sodium waste	Seek State regulatory agencies to accept waste form; Run at Idaho on SBW to gain experience with a TRL of at least 6
	• Cast stone	Low	Low	Low	Very High	Low	Potential issues with acceptability of waste form	Seek State regulatory agencies to accept waste form
	• Joule-heated ceramic	Very Low	Very Low	Very Low	Very Low	Very Low	Current baseline technology with long experience	
	• Plasma arc	High	Very High	Very High	Med	Low	No DOE radioactive experience and vaporization of Tc, Cs and other volatile components	Extensive program in non-radioactive service then in radioactive service
	• Microwave	Med	Med	Med	Low	Low	No DOE high activity radioactive experience or experience on an industrial scale	Extensive program in non-radioactive service then in radioactive service
	• In-can melter (hot wall)	Med	Med	High	Low	Low	Low production rate requiring many installations. Issues with room and production rate and QA of product; experience in Europe shows potential system failure.	Extensive program in non-radioactive service then in radioactive service
	• AVS (inductive-	Med	Med	High	Low	Low	Moderate production rate requiring many installations. Issues with room	Extensive program in non-radioactive service then in radioactive service

	ly heated in-can melter)						and production rate and QA of product	
	• Hot crucible induction	Low	Low	Low	Low	Low	Widely used by French and UK, but on low-sodium waste	Test program in 2nd LAW facility that removes technological issues
	• Cold wall Joule-heated	Very Low	Very Low	Very Low	Very Low	Very Low	Widely used industrial process but no experience in radioactive environments. Must maintain cooling water to protect asset	Test program in 2nd LAW facility that removes technological issues
	• Cyclone Melter	Very High	Very High	Very High	Very High	High	No radioactive experience and vaporization of Tc, Cs and other volatile components	Extensive program in non-radioactive service then in radioactive service
2	Molybdenum Electrode	Low	Very Low	Very Low	Very Low	Very Low	Tested in nonradioactive environment	Testing is non-radioactive environment until corrosion issues and other operating issues are well known and then transitioned to radioactive service. Needs TRL of 6 in non-radioactive service
3	General Comment: Retention of Tc in LAW glass	Very High	Low	Med	High	Low	Tc is not retained in LAW glass as planned. There are likely to be technological fixes for this issue	Determine thermodynamic gas/liquid equilibrium of Tc and then verify in testing. If an issue, then experiment with various technological fixes (such as redox control) at small scale and implement when TRL is 6
Charge 5: Waste Delivery								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	Need to balance (logistics) LAW / HLW pretreatment and treatment processes	High	Very High	Very High	High	Low	Need to achieve feed rates that balance treatment of LAW / HLW	Additional tank waste characterization, intentional blending at ORP, planning models, Operations Research (OR) models and research, gap analyses, etc.
2	Potentially difficult	Low Med	Med	Med	Low	Low	Tank farm operations impacted by complex, interdependent, and highly	See #1 above. Also conduct gap analysis…

	logistics involved with tank farm operations						constrained nature of the feeds and operations.	
3	Needed ETF upgrades and issues related to Tc-99 and other Contaminants of Concern (COC)	Med	Med	Med	Med	Low	ETF upgrades needed (more than double throughput) where access is restricted. Issues related to Tc-99 / other COCs / permits / corrosion properties that must be addressed.	Funded R&D and construction projects are needed and must be realistically integrated into schedules…
4	Sampling in and transfer from high level tanks is problematic	Med	Low	Low	Med	Low	Representative sampling in 10^6-gal tanks is not practicable. This also makes it difficult to consistently transfer waste during operations. Because of potential segregation, there may also be a safety issue.	Change safety and/or feed acceptance criteria. Construct a set of mixing and blending tanks. Implement wiped-film evaporator technology (2013) to add freeboard.
5	242-A Evaporator is a single point of failure	Med	Very high	Very high	Low	Low	This is an issue even if wiped-film evaporators are introduced. Reliability and availability of the 242-A is a major concern.	Wiped-film evaporators can off-set some of the load and risk. Other pretreatment and treatment options may reduce the need and risk. Review a treatment plan that could include a new evaporator, new tankage, wiped film evaporator and other treatment strategy.
6	Meeting waste compliance requirements for feed to WTP may be problematic	High	Med	Med	Med	Low	System Plan 5 indicates that projected feeds do not meet screening criteria including LAW / HLW envelopes, H_2 generation and criticality limits (while requirements are being developed). The criticality limits may be overly conservative.	Develop reasonable and credible feed requirements. Separate wastes by treatment difficulty and investigate specific treatment options.

10A.5.3: Vulnerability Assessment: Enhanced Treatment

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
Charge # 1: LCC								
1	Minimal reliable & defensible LCC basis of cost and schedule estimates	Med	Very High	Very High	Very High	Low	This project is pre-CD-1. There are no approved cost and schedule estimates.	Develop detailed CD-2 cost and schedule estimates and baseline with appropriate programmatic approval.
2	DOE System-wide consistent processes are not deployed for LCC cost estimating	Med	Very High	Very High	Low	Low	EM does not uniformly apply a system-wide LCC Methodology (process) for cost estimating such as that maintained by the National Institute for Standards and Technology (NIST) (BLCC5) for DOE. Planning models are lacking for development and testing of scenarios.	Use a system-wide process for cost and schedule estimating such as BLCC5. Provide documented NPV and Current Dollar calculations when selecting alternatives and report baseline LCC cost savings and monetized risks in current year funded dollars.
3	Selection of technology alternatives may be incorrect based on failure to use NPV calculations	Low	Low	High	Low	Low	GAO 12-step cost estimating process recommends utilization of NPV cost analysis for selection of alternate technologies Technology selection, based on cost needs to be made on total cost, which includes system costs, facilities, regulatory and other related costs for total system LCC.	Use of Net Present Value to compare scenarios
Charge 2: Waste Forms								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	FBSR / mineralized waste form	Very High	Very High	Med	High	Low	All LAW treated by FBSR; thus mineralized waste form must be acceptable (including Tc-99 and other COCs). “Good as glass” and prescriptive nature of RCRA obfuscates important	There could be a general acceptance of a mineral waste form, benchmarks, and testing requirements for a treatment technology similar to that for HLW (borosilicate glass). Should

							issues. There is no single test to qualify waste form performance so performance comparisons are difficult. Assumes WTP LAW vitrification facilitity will not be used to handle LAW; only FBSR will be used.	provide performance-based criteria instead of technology-based. Defense-in-depths strategies could be pursued (as with HLW).
2	FBSR coal fines potential explosion hazard	Med	Low	Low	Med	High	Coal fines explode in feed or transit areas or in FBSR due to spark discharge.	
3	Contaminant capture	Very High	Med	High	Very High	Low	Volatile and other important contaminants of concern may not be captured in the waste forms At this time there is no technical justification that the Tc-99 is captured in the FBSR waste form.	Improve capture rate through operations / recycle or new technology application
4	Loss of knowledge and expertise in critical areas	Med	Low	Med	Low	Low	Loss of knowledge concerning waste forms and acceptance because there is a lag of over a decade between when these were designed and WTP would start operations.	Knowledge archiving and mentoring programs; cost incentives
Charge 3: In-Tank/Out-of-Tank								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	ETF availability	Very Low	Very Low	Very Low	Very Low	Low	The current plan is to recycle back to the tanks, which increases tank volume.	Added evaporation capability Shipment of LAW melter overheads offsite
2	Intermittent operation	Low	Very Low	Very Low	Very Low	Very Low	Intermittent operation may impact melter performance (burning off cold cap)	N/A
3	Safety of nitric acid elution of sRF IX column (both in-tank	Low	Low	Low	Med If RCRA Part B	Med.	DST corrosion issues	HAZOP or equivalent work process

	and at-tank processes)				permit is needed			
4	Difficulty retrieving sludge from Hanford DSTs when using CST ion exchange	High	High	High	Low	High	If CST is used, discharging ground CST, loaded with ^{137}Cs, may adversely affect sludge retrieval.	Use disposable high integrity containers configured as ion exchange canisters
5	CST clumping	Medium	Med	Low	Low	Low	If CST is used, CST requires caustic washing to extract materials that result in agglomeration of CST particles. If CST is used, CST storage stability may be problem.	Only purchase CST as caustic-washed IONSIV® IE-911-CW grade. Robust NaOH washing equipment near point of use.
6	CST IX column flow in-homogeneity	Low	Low	Low	Low	Low	If CST is used, need to demonstrate ability to set uniform IX bed in annular column.	Engineering-scale test with prototype column. Could be full-size or near full-size since dimensions are small.
7	CST IX column overheating	Low	High	High	Low	High	If CST is used, simultaneous loss of permeate feed and cooling water flow may cause unacceptably high temperatures.	HAZOP or equivalent work process
Charge 5: Waste Delivery								
	Issue	**Tech Risk**	**Schedule Risk**	**Cost Risk**	**Regulatory Risk**	**Safety Risk**	**Comments**	**Mitigation Potential**
1	Need to balance (logistics) LAW / HLW pretreatment and treatment processes	High	Very High	Very High	High	Low	Need to achieve feed rates that balance treatment of LAW / HLW	Additional tank waste characterization, intentional blending at ORP, planning models, Operations Research (OR) models and research, gap analyses, etc.
2	Potentially difficult logistics involved with tank farm operations	Med	Med	Med	Low	Low	Tank farm operations impacted by complex, interdependent, and highly constrained nature of the feeds and operations.	See #1 above. Also conduct gap analysis.
3	Needed ETF upgrades and	Med	Med	Med	Med	Low	ETF upgrades needed (more than double throughput) where access is restricted.	Funded R&D and construction projects are needed and must be realistically

	issues related to Tc-99 and other Contaminants of Concern (COC)						Issues related to Tc-99 / other COCs / permits / corrosion properties that must be addressed.	integrated into schedules…
4	Sampling in and transfer from high level tanks is problematic	Very High	Very High	Very High	Med	Low	Representative sampling in 10^6-gal tanks is not practicable. This also makes it difficult to consistently transfer waste during operations. Because of potential segregation, there may also be a safety issue.	Change safety and/or feed acceptance criteria. Construct a set of mixing and blending tanks. Implement wiped-film evaporator technology (2013) to add freeboard.
5	242-A Evaporator is a single point of failure	Med	Very high	Very high	Low	Low	This is an issue even if wiped-film evaporators are introduced. Reliability and availability of the 242-A is a major concern.	Wiped-film evaporators can offset some of the load and risk. Other pretreatment and treatment options may reduce the need and risk. Develop a treatment plan that could include a new evaporator, new tankage, wiped film evaporator and other treatment strategy.
6	Meeting waste compliance requirements for feed to WTP may be problematic	High	Med	Med	Med	Low	System Plan 5 indicates that projected feeds do not meet screening criteria including LAW / HLW envelopes, H_2 generation and criticality limits (while requirements are being developed). The criticality limits may be overly conservative.	Develop reasonable and credible feed requirements. Separate wastes by treatment difficulty and investigate specific treatment options.

10A.6 References

1. Letter from NRC (C. J. Peperiello) to J. Kinzer dated June 9, 1997

10B.1 Overview / Objective for SRS Tank Waste

During the course of performing the tasks above, the Subcommittee should identify other SRS vulnerabilities not specifically encompassed by those tasks and propose any recommendations to mitigate those vulnerabilities.

10B.2 Options and constraints to be considered

Exhibit 10B.1 summarizes the scope of the analysis for the vulnerability assessments as it relates to Mission, Overall Objectives, and Overall Major Issues.

Exhibit 10B.2 delineates the methodology used for the vulnerability assessment as it relates to very low to very high risk issues. As the risk / vulnerability was considered, the EM-TWS additionally listed possible mitigation steps that could lower the risk to the program objectives. It should be noted that the risk monetization considers both Life Cycle Cost decreases and /or Life Cycle Cost increases. The analysis reflects Current Dollar determination (not Net Present Value determination).

Exhibit 10B.1

Mission Requirements for In-Tank Treatment and Fluidized Bed Steam Reforming		
Current Baseline	**(1) In-Tank Treatment SCIX**	**(2) Tank 48 FBSR Treatment**
Complete current baseline mission requirements are reflected in System Plan 16.	Accelerate treatment as workaround to SWPF delays and to align salt waste processing schedule with DWPF sludge processing schedule. Meet the STP commitment to remove tank waste by 2025 (three years early).	Treat and dispose of organic liquids from Tank 48 using FBSR.
Key Assumptions for SCIX and Tank 48 Treatment		
Complete current baseline assumptions are reflected in System Plan 16. SWPF operations initiation delayed to July 2014 from May 2013. Deploy next-generation extractant to SWPF to increase processing rate to a nominal 7.2 Mgal/year from 6.0 Mgal/yr.	SCIX provides additional salt processing capability of 2.5 MGal/yr beginning in October 2013. Accelerate liquid feed to SWPF / DWPF to recover three-year delay in schedule.	Steam reforming completed and Tank 48 returned to service October 2016.

Major Issues that relate to Two Major Scenarios

Baseline program is vulnerable to increased construction schedule based SWPF delays.	Construction in a nuclear conduct of operations environment (Tank Farms). Technology Development for RMF may add additional risk of deployment.	Period of Rate of Return is a two-year campaign; the financial risk for funding is a major concern. DWPF operations improvements based on bubbler deployment and lessons learned have provided an alternate delivery potential that could eliminate the need for capital spending for FBSR. In a net present value (NPV) analysis, the increased canister requirements may in fact be tolerated due to significant savings based on eliminating capital construction and startup of the FBSR.

Consequence	Exhibit 10B.2 Methodology used for Vulnerability Assessment – Threshold Definition
Very Low	Small, acceptable change in project or facility performance, risk is minor threat to facility mission; opportunity would result in minor benefit; possibly requires minor facility operations or maintenance changes without redesign. Cost change threshold: < $15 million. Schedule change threshold: < 1 month on a noncritical path item. Technical or other: Design feature must be changed due to small degradation from baseline performance or interface problem.
Low	Small change in project or facility performance; risk is small threat to facility mission; opportunity could result in small benefit; possibly requires minor facility redesign or repair, significant environmental remediation. Cost change threshold: $15 million to $40 million. Schedule change threshold: 1-3 months on a noncritical path item. Technical or other: Redesign of noncritical path item or increased potential for regulatory intervention.
Medium	Medium change in facility performance; risk is serious threat to facility mission; opportunity could result in medium benefit; possible comletion of only portions of the mission or requires major facility redesign or rebuilding, extensive environmental remediation. Cost change threshold: $40 million to $100 million. Schedule change threshold: 3-6 months on a critical path item. Technical or other: Threat to mission, environment, or people that requires some redesign, repair, or significant additional environmental remediation.
High	Substantial change in facility performance; risk is critical threat to facility mission; opportunity could result in substantial benefit; risk may cause loss of mission, long-term environmental abandonment. Cost change threshold: $100 million to $200 million. Schedule change threshold: 6-12 months on a critical path item. Technical or other: A major project goal will not be met, or an outside regulator shuts down the job for an indefinite period.
Very High	Very substantial change in facility performance; catastrophic threat to facility mission; opportunity could result in great benefit; risk may result in loss of mission, long-term environmental abandonment. Cost change threshold: > $200 million. Schedule change threshold: >12 months on total project completion. Technical or other: Project cannot be completed.

Notes: First-of-a-kind risks will receive special attention because they are often associated with project failure. First-of-a-kind risks should receive medium, high or very high consequence values unless there is a compelling argument for lesser consequence.

Table 10B.3
Summary of key baseline milestones and processing features from System Plan 16

Key Milestones		Processing Features	
Deploy next generation extractant at MCU	Jan 2012	Total Salt Solution Processed	96 Mgal
Initiate SCIX Processing	Oct 2013	Salt Solution Processed via ARP/MCU	5.4 Mgal
Initiate SWPF Processing	Jul 2014	Salt Solution Processed via SCIX	26.8 Mgal
Tank 48 Available	Oct 2016	Salt Solution Processed via SWPF	61 Mgal
Salt Processing Complete	2024	Total number of HLW canisters produced	7,557
SWPF facility removed from service	2025		
DWPF processing complete	2025		
DWPF facility removed from service	2026		

10B.3 Vulnerability Methodologies

Based on Exhibit 10B-2, Methodology used for Vulnerability Assessment, the following vulnerabilities were identified and categorized based on the two program strategies:

- In-Tank Treatment
- Tank 48 Treatment Strategy Enhanced Treatment

Section 10B.4 addresses vulnerabilities and possible mitigation options.

10B.4 Vulnerability Listings for the two program strategies

Exhibit 10 B 4.1
In-Tank Treatment (SCIX Program) Vulnerabilities

Charge 1: LCC

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
1	SWPF startup distraction based on development and installation of new in-tank processes	Very Low	Medium	Medium	Very Low	Low	Potential three- to six-month delays considered. Incremental cost impact due to SCIX is small relative to SWPF delay impact. The two programs are relatively independent; however, the management oversight may be taxed.	Increased focus on operational readiness as it relates to the risk register
2	Budget restrictions greater than one year	Very Low	High	Very High	Very High	Low	Very high regulatory risk because of the need to renegotiate regulatory commitments. Cost risk is very high due to extension of mission.	Renegotiating regulatory commitments Technical workarounds

Charge 3: In-Tank

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
1	RMF Rotating Seals Reliability	Low	Low	Very Low	Very Low	Very Low	Based on current test results, the failure rate appears to be low.	
2	RMF Capacity Too Low	Very Low	Very Low	Very Low	Very Low	Very Low	Low based on low solids feed	Additional RMFs
3	CST Clumping	Very Low	Very Low	Very Low	Very Low	Very Low	CST Storage stability may be problem	NaOH Washing Equipment
4	IX Column Channeling	Low	Low	Low	Very Low	Very Low	Need to demonstrate ability to set IX bed in annular column	Engineering-scale test with prototype column. Could be full-size or near full-size since dimensions are small.
5	Recovery from an over-temperature incident	Medium	Low	Low	Low	Low	Can the column continue to be used after an over-temperature incident occurs, and if not, is it recoverable? Design of shielding bell required for removal of fully loaded SCIX vessel could	Time/temperature tests to determine response of CST to over-temperature events.

							be limiting to the amount of curie loading to the resin bed.	

Exhibit 10B 4.2
Tank 48 Treatment Strategy Vulnerabilities

Charge # 1A: LCC

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
1	FBSR planned to be designed, built, operated, and mission completed by 2016	High	Very High	Very High	Low	Low	Actual waste has not been tested with this process technology. The proposed approach seems to be far more optimistic than all past history would suggest is reasonable	Evaluate alternate approach using DWPF.
	Coal fines handling	Low	Low	Low	Low	Med	Coal fines are currently added to form the reducing environment in the fluidized bed. These fines could ignite in any of a multitude of locations.	Design system to handle coal fines under explosion-proof criteria.

Charge 5: Waste Delivery

	Issue	Tech Risk	Schedule Risk	Cost Risk	Regulatory Risk	Safety Risk	Comments	Mitigation Potential
1	FBSR potentially not appropriate treatment technology	Med	High	Very High	Low	Very High	Handling a feed that is high in benzene and other combustible material may pose a safety hazard. Tank 48H may not be available to be used as a salt batch blend tank in early 2017.	Explore the potential of 2 types of campaigns that are direct feed to DWPF: 1) Establish a safety basis that allows a small bleed to the DWPF concurrently while the current campaigns for sludge is processed or 2) Establish a separate campaign later in System Plan and not use Tank 48H as a salt batch feed tank. Use a different tank as substitute for Tank 48H as feed to Salt waste

								Evaluate potential use of wet-air oxidation Continue to use Tank 21 for salt batch blending.

10B.6 Conclusions

10B.6.1 Vulnerabilities are noted above in tabular form. The detailed review of the vulnerabilities and methodology is found in Appendix 10 as well as detailed discussion in the Appendices as they relate to specific charges.

10B.6.2 For SRS and Hanford, the single most impacting vulnerability is the risk of not meeting schedule and cost baselines for SWPF at SRS and WTP at Hanford. The impact of new initiatives (e.g., SCIX, Vision 2020) could divert resources and senior management attention. If these initiatives cause delays such as a year, the impact of a year's delay for either SWPF or WTP overshadows any of the other vulnerabilities that are technology- or program-specific.

10B.7 Recommendations

10B.7.1 It is recommended that Vision 2020 be executed based on early startup of systems that are related to WTP startup. The rationale is not based on LCC savings or schedule reduction. The justification is focused on risk reduction of the WTP and its related commissioning.

10B.7.2 It is recommended that SRS perform a detailed review of the use of FBSR technology for Tank 48 materials. It is the EM-TWS opinion that there is significant merit in utilization of DWPF for this processing or an alternative treatment technology. Merit is in cost savings.

10B.7.3 It is recommended that DOE EM continue its focus of Joule-heated melter technology for both SRS and Hanford.

APPENDIX 11
2020 Vision, Early Start-up of One (1) LAW Melter

11.1 Charge Statement

The Environmental Management Tank Waste Subcommittee (EM-TWS) Charge is:

Charge 7 – 2020 Vision, Early Start-up of One (1) Low-Activity Waste (LAW) Melter: The Management and Technical Subcommittees of the Construction Project Review (CPR) (convened in November 2010 to review the Waste Treatment and Immobilization Plant (WTP) Project) strongly endorsed a proposed phased commissioning approach and consequential opportunities presented by accelerated low-activity waste operations (Vision 2020). This Charge, recommended by the Office of River Protection (ORP) Federal Project Director, is to conduct a review of these proposed WTP and Tank Farms integration programs, which are intended to determine the optimal method for achieving cost and schedule savings available through these integration efforts. This review would include evaluation of Vision 2020 planning documents with regard to the Tank Farms's ability to support options for sequential cold commissioning, initiation of radioactive waste processing, and transition to full operations at WTP. This Charge would specifically consider necessary Tank Farms improvements, and the benefits and risks of Tank Farms operations to WTP project completion and to the overall tank waste processing mission.

This Charge 7 statement of task was in follow-up to the Construction Project Review Recommendation [1] that stated:

> The Management and Technical Subcommittees jointly recommend that within three months, DOE-Headquarters should carry out a detailed independent review of WTP and Tank Farms options for sequenced hot commissioning and transition to waste feed and operation of the WTP facilities. This review would include evaluation of the Tank Farms' ability to support options for sequential initiation of radioactive waste processing and transition to full operations at WTP, specifically considering necessary Tank Farms improvements, benefits and risks to WTP project completion, and benefits and risks to the overall tank waste processing mission.

11.2 Summary of Vision 2020

In response to several past Construction Project Reviews and EM-TWS recommendations supporting the need to transition WTP and ORP focus from WTP "engineering design and construction" to "construction completion and commissioning," DOE-ORP, both WTP and Tank Farms, and the WTP design-build contractor and Tank Farms operations contractor (TOC), have been developing plans and making management organizational changes to provide project sequencing and integration between WTP and Tank Farms necessary to achieve WTP commissioning and initiate radioactive operations. DOE-ORP developed the *Vision 2020 for WTP Project Transition to Operations* (Vision 2020) [2] to provide a framework for specific objectives and the DOE organizational approach to achieve those objectives. The WTP design-build contractor and TOC jointly developed a management and technical approach to implement early LAW operations, accelerate commissioning of WTP, and transition into a hot startup and hot operations organization through full-capacity demonstration. This has been designated the *One System 2020 Vision* (*One System Plan*) [3]. The One System 2020 Vision concept reviewed by the EM-TWS was a draft plan that is still evolving and reflects significant evolution from the draft *Vision 2020* reviewed as part of the November 2011 WTP Construction Project Review.

Key DOE objectives [3] are to:

1. Maintain WTP design-build contractor accountability for demonstrating WTP facility performance that achieves the contract-defined values as a minimum;

2. Implement a contract-compliant and consistent contracting strategy that is construction-efficient and addresses the operational transition needs of WTP;

3. Provide sustainability in the management team and provide continuity of staffing through transition;

4. Develop an appropriate labor operations strategy;

5. Ensure that the terms and conditions of the TOC and WTP contracts are consistent and integrated as necessary to provide a single system for feed delivery to, and startup and operations of, the WTP;

6. Ensure that contract incentives and fee structures include incentives for making glass no later than 12/31/2016 and ensure initial plant operations no later than 12/31/2022; and

7. Ensure that WTP maintains a line-item project cost of less than $12.263B.

To achieve the stated DOE objectives, One System Plan proposes:

1. Several project management and contractual changes to achieve improved management integration between TOC and WTP;

2. LAW Facility hot commissioning and subsequent operations startup of one of its two melters in 2016, ahead of Pretreatment (PT) Facility hot commissioning, along with simultaneous hot commissioning of LAB and WTP Balance of Facilities (BOF); and

3. Startup and hot commissioning of all WTP facilities to Initial Plant Operations (IPO) in 6/2018.

Achieving LAW Facility hot commissioning in 2016 requires, in addition to completing the LAW, Laboratory (LAB), and BOF facilities on the necessary schedule, addressing the following challenges in a timely manner:

1. Providing LAW waste feed;

2. Managing the produced vitrified LAW canisters;
3. Disposing of secondary waste effluents from LAW;
4. Securing necessary environmental permits; and
5. Ensuring safe radioactive operations at LAW and LAB facilities and ongoing Tank Farms operations while construction and commissioning are ongoing at the HLW and PT facilities.

There is a series of additional projects and activities that must be completed for the One System Plan to be successful, which are discussed in the sections of this Appendix that follow.
The primary benefits of the proposed plan, if successful, are:

1. Providing a programmatic victory by achieving treatment of LAW and production of vitrified LAW 15 months earlier than the baseline plan;

2. Reducing the risk register carrying costs for WTP startup;

3. Reducing the risk of delays to complete WTP hot commissioning and achieving the Consent Decree milestone for full-capacity hot operations by providing for a further graded approach to commissioning and initiating hot operations; and

4. Reducing pressure on the WTP line item project cost of $12.263B by transferring hotel and startup costs from project construction costs to operational expenses.

The proposed plan will neither significantly reduce the timeframe for completion of the waste treatment mission at Hanford nor reduce lifecycle costs.

The primary risks of the proposed plan are:

1. Schedule delays in completion or startup of the WTP LAW or LAB facilities or completion of necessary supporting projects in the Tank Farms will reduce or eliminate the proposed timeframe for WTP LAW hot operations prior to the startup of the WTP PT and High-Level Waste (HLW) facilities.

2. Schedule delays in completion of WTP PT or HLW could require extended operation of WTP LAW on a minimal feed from the Tank Farm pretreatment facility, with attendant hot operations costs, and without substantial reduction in the LAW inventory.

3. Unplanned incidents associated with interim LAW feed preparation and delivery operations, including hose-in-hose transfers, as well as onsite hot operations while other WTP facilities undergo completion, may delay overall WTP completion.

PROVIDING LAW WASTE FEED

The One System Plan proposes development of an Interim Pretreatment System (IPS) to prepare feed for the LAW facility, with LAW provided from the current inventory of supernate contained in the double-shell tanks (DSTs) (e.g., Tanks AP-104, AP-107). The intent of the proposed IPS is to provide LAW feed during the startup of the LAW facility, prior to the availability of the

WTP PT facility, and then have capability to provide LAW feed to the LAW Supplemental Treatment facility (required to be available by fiscal year (FY) 2022, according to the Consent Decree with the State of Washington) [4]. However, if the only intention for the IPS is to provide feed to LAW prior to the availability of WTP PT, then options for simplifying IPS should be evaluated.

The current One System Plan for IPS requires:

- Retrieval of supernate from one or more DSTs in the AP Tank Farm. Of the eight AP DSTs, one contains sludge and supernate, four contain saltcake and supernate, and three contain supernate only.

- At- or in-tank pretreatment of the liquid waste feed using filtration (crossflow or rotary microfiltration (RMF)) to remove solids and ion exchange to remove Cs-137.

- Transfer of the pretreated waste to the LAW plant for vitrification and disposition.

The proposed IPS would include technology maturation and use of RMF installed in Tank AP-107 for solids removal, including actinides, and small-column ion exchange (SCIX) using spherical resorcinol formaldehyde (sRF) resin installed in Tank AP-105 for Cs-137 removal prior to transfer to surge tanks and then feed to the LAW facility. Solids removed by filtration would be returned to the Tank Farms. The preferred resin by ORP is sRF resin. Loaded resin would be eluted using dilute nitric acid and the Cs–137-rich eluent returned to the Tank Farms. Both RMF and SCIX are technologies under development first for application at the Savannah River Site (SRS) as part of the accelerated salt waste processing strategy, and have not been tested in full operations. Both technologies would require engineering modification to be adapted to the tank configurations at Hanford, and the SCIX system would require substantial design changes if an elutable cesium resin was selected for use at Hanford, in contrast to the non-elutable resin planned for use at SRS.

The One System Plan requires about 500,000 gallons of feed for 15 months of operation of the LAW facility. Seven of the AP tanks have supernate volumes in excess of 1,000,000 gallons; see Appendix 9 for a discussion of the radionuclide concentrations in AP tanks that potentially may provide LAW feed.

Pretreated feed would be transferred to the LAW facility through approximately 4,500 ft of transfer lines at a rate of approximately 15,000 gal per week. Routing of the transfer lines would be to isolate them from the other WTP facilities undergoing completion. This length of hose-in-hose transfer has not been used previously at Hanford and represents one of the challenges to achieving the One System Plan. However, unlike several other hose-in-hose transfers, these transfer lines would be transporting minimal quantities of suspended solids.

The following addresses options for simplifying the pretreatment process as presented by ORP in EM-TWS fact-finding meetings.

Option 1: No Pretreatment

This option would involve direct feed of DST supernate to the LAW plant. Feed sequence would be determined by choosing supernate with the lowest concentrations of radionuclides, primarily Cs-137 and Tc-99.

Option 2: Deliquification, Dissolution, and Adjustment (DDA)

This option, also known as selective dissolution, has been used to produce more than 5,000,000 gallons of salt solution for processing into Saltstone at SRS and has also been used at Hanford when retrieving wastes from single-shell tanks (SSTs). The DDA process involves the following:

1. removing the supernate from above the saltcake;
2. extracting interstitial liquid within the saltcake matrix;
3. dissolving the saltcake and transferring the resulting salt solution to a settling tank;
4. transferring the salt solution to the Saltstone Facility feed tank where, if required, the salt solution is aggregated with other Tank Farm waste to adjust batch chemistry. Chemistry adjustment may be required to ensure the salt solution feed stream meets processing parameters (e.g., sodium concentration, organic content, facility shielding limitations) for processing at the Salt Processing Facility (SPF).[5]

At Hanford, feed would come from a tank or tanks containing saltcake with very low concentrations of Cs-137 and Tc-99. The dissolved and adjusted salt solution would be fed to the LAW plant.

Option 3: Current 2020 Plan Using CST for Ion Exchange and Either Storage or Direct Disposal of Loaded Crystalline Silicotitanate (CST)

The current One System Plan uses an option for filtering and ion exchange similar to the SCIX process technology developed at SRS. The SRS SCIX process combines RMF for solids removal with CST ion exchange for Cs-137 removal. The loaded CST is then ground, stored in a waste tank, and eventually fed directly to the Defense Waste Processing Facility (DWPF) for immobilization in HLW glass. If the SRS SCIX process were used at Hanford, the ground CST would have to be returned to a DST, where it would have to remain until the WTP HLW vitrification facility comes online. There are concerns that long-term storage in a Hanford DST could lead to clumping of the CST and subsequent waste transfer difficulties. Possible CST interference with the WTP pretreatment leaching processes is also a concern. To avoid these potential difficulties, the option would be to either store disposable CST cartridges for later treatment at WTP or directly dispose of the loaded CST. This option has the potential to significantly simplify an in-tank SCIX process and reduce technology maturation risk because of the elimination of the need for CST grinding and in-tank accumulation or resin regeneration if an elutable resin was used.

Regulatory Considerations: The 3116 Process and Shallow Land Burial

Tank waste that would be processed under the One System Plan originated in the reprocessing of spent fuel and is therefore classified as HLW. Section 3116 of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 [6] lays out the process (3116 Process) whereby some tank waste at SRS and Idaho National Laboratory (INL) may exit the HLW source-based classification and be disposed in a shallow land burial site, if they meet certain characteristics, under regulations resembling those for low-level waste (LLW). Such wastes are generally referred to as LAW.

To exit the HLW classification under the 3116 Process, DOE, in consultation with the U.S. Nuclear Regulatory Commission (NRC), must agree that the waste meets the following criteria:

1. It does not require permanent isolation in a deep geologic repository for spent fuel or high-level radioactive waste;
2. It has had highly radioactive radionuclides removed to the maximum extent practical; and
3. The waste either (a) does not exceed concentration limits for Class C low-level, or (b) if it exceeds Class C concentrations, it will be disposed of in compliance with the performance objectives set out in 10 CFR 61. Class C limits, specified in 10 CFR 61, are 4,600 Ci/m^3 for Cs-137 and 3 Ci/m^3 for Tc-99.

The 3116 Process for classifying waste as incidental to reprocessing covers the SRS and INL tank wastes and has been successfully implemented at those sites [5, 7]. Although waste from the State of Washington is not included within the legislation, DOE and Washington State have agreed to follow a yet-to-be-defined waste incidental to reprocessing (WIR) process for any portions of Hanford tank wastes that will be disposed on the Hanford Site. Reclassification will require State approval. It is not clear how the WIR process would be carried out for wastes derived from the Hanford tanks that might be disposed outside of Washington.

Examination of Options

Three options for LAW feed preparation are worthy of consideration.

<u>Option 1: No Pretreatment</u>

This option must overcome three major hurdles. The first is the waste acceptance limits for cesium content fed to the LAW facility, which are established based on the total in-process inventory limitations and worker safety limits for a contact-maintained facility. It does not appear that any DSTs contain undiluted supernate with Cs-137 concentrations low enough to be accepted in the WTP LAW vitrification facility. It may be possible to adjust the WTP waste acceptance criteria (WAC) limits during initial startup of hot operations given that:

1. the facility will only be operating one melter;
2. the inventory of vitrified canisters in the facility would be limited; and
3. the amount of feed in the facility would be limited.

The second hurdle is obtaining concurrence from the Washington State Department of Ecology that the glass that results from direct feed qualifies as LAW. It could be a challenge to obtain stakeholder agreement through the WIR process that highly radioactive radionuclides have been removed to the maximum extent possible, although accommodation may be practical to achieve early facility startup.

The third hurdle is that disposal of the LAW glass in the Integrated Disposal Facility (IDF) must meet the yet-to-be-developed performance assessment (PA), which will set limits on the total amount of radionuclides that can be disposed in the IDF. Although it is unlikely that the amount of radioisotopes contained in 500,000 gallons of direct feed waste would exceed the IDF PA limits, it might use up a substantial fraction of the limits, imposing strict limits on LAW subsequently produced during full WTP operations.

Option 2: Deliquification, Dissolution, and Adjustment (DDA)

The first two steps—removal of supernate from above the saltcake and extraction of interstitial liquid within the saltcake matrix—have already been carried out for all Hanford SSTs. According to presentations given to the EM-TWS, a number of SSTs contain radionuclide concentrations that are lower than Class C. Dissolution and adjustment would further lower radionuclide concentrations. A search of the best-basis inventory, coupled with sampling and testing of the saltcake in tanks with low Cs-137 and Tc-99 concentrations, may identify tanks that could provide feed that would satisfy the WTP LAW Facility WAC. The fact that DDA has already been found acceptable under the 3116 Process and been used at SRS increases the probability that Washington State approval could be obtained under the WIR regulatory process to be used for Hanford.

This option also requires that enough tank space can be found to allow DDA processing. It may be that there is not enough DST space to allow processing. However, it may be possible to install several small tanks or use existing WTP tanks to act as LAW feed tanks. This option would also require that the retrieval sequence of the SSTs be revisited and be agreed upon with the State.

Option 3: Current One System Plan Using CST for Ion Exchange and Either Storage or Direct Disposal of Loaded CST

Tests with SRS and Hanford supernate indicate a CST capacity of about 700 bed volumes (BVs) for Cs-137. The amount of CST required for the One System Plan can be calculated as follows:

- Volume of supernate to be processed is about 500,000 gallons
  Volume of CST = 500,000 gallons/700 BV = 720 gallons = 100 cu ft

The commercial nuclear power industry frequently uses ion exchange to process its wastewater. Typical ion exchange vessels are 3 ft in diameter, about 6 ft high, and contain about 30 cu ft of ion exchange mixed bed media. One System Plan processing would require fewer than four such vessel loadings using inorganic resin materials. The commercial nuclear industry either dries the loaded media in the ion exchange vessel and disposes the vessel directly in a LLW burial site, or sluices the loaded media out of the ion exchange vessel into a high-integrity container (HIC), dries it, and disposes it in a LLW burial site. Sometimes grout or polymer solidification material is added to the disposal container to establish a matrix and stabilize the waste in the matrix materials. For cesium, sorption onto a non-elutable ion exchange resin presents an additional barrier to leaching into the environment. One hundred cubic feet of loaded CST media could be loaded into a single HIC. The HIC or disposable ion exchange columns could either be stored on site on an interim basis for processing and later disposition or disposed in a shallow land burial site onsite or offsite. The shallow land disposal of loaded ion exchange media in HICs has been previously employed at Hanford.

Based on EM-TWS fact finding, Tank AP-104 has a Cs-137 concentration of 0.12 Ci/l = 120 Ci/m^3, the lowest in the AP Tank Farm. If AP-104 waste were processed using CST, the fully loaded CST would have a concentration of (120 Ci/m^3)(700 BV) = 84,000 Ci/m^3, a figure that is almost 20 times the Class C limit. It may be possible to dispose of such material in a shallow land burial site if the material is solidified and the burial site waste acceptance criteria can accommodate the total Curie loading. The Nevada Test Site (NTS) has accepted greater-than-Class C waste in the past. NTS does not have concentration-dependent WAC. DOE would have to work with NTS to determine whether loaded CST could be accepted for burial. This possibility would require programmatic concurrence for shipment of Hanford LAW to the State of Nevada and a possible Section 3116 concurrence process in that state.

A second possibility is that Washington State would allow the loaded CST in a HIC to be stored for later processing with HLW or to be disposed at Hanford if PA requirements can be met.

From a safety perspective, the total in-process inventory of Cs-137 would need to be maintained at less than 8.9 E+4 curies to be maintained as a Category 2 facility (DOE-STD-1027-92). Processing about 500,000 gallons of supernate based on the reported concentration in Tank AP-104 would involve a total of 2.3 E+5 curies of Cs-137, thus restricting in-process inventory to less than approximately one-third of the total quantity to be processed if implemented in a near-tank scenario. Thus, an in-tank implementation would likely be preferable. Implementation in the Tank Farms would most likely require a major modification to the Documented Safety Analysis under DOE-STD-1189-2008.

VITRIFIED LAW AND SECONDARY WASTE MANAGEMENT

Initiation of radioactive operation of the LAW facility beginning in 2016 will result in production of approximately 500 canisters of vitrified LAW prior to the current baseline start of hot operations. This will require the accelerated purchase of the LAW transporter vehicles, which also serve the function of holding the canisters after production until sufficient cooling has occurred for transfer to the disposal facility. In addition, the WIR determination must be accelerated to allow for onsite disposal, as well as executing the accelerated completion of the IDF PA and permitting as called for in the Vision 2020 plan. Otherwise, an interim storage facility would be needed for vitrified LAW canisters.

WTP secondary solid wastes produced by the LAB and operation of the LAW facility are proposed to be disposed of at the Mixed Waste Burial Ground.

The LAW facility will produce primarily two liquid secondary waste streams. The first is from the submerged bed scrubber (SBS). This is the smaller of the two, but it contains virtually all the Cs-137 and Tc-99 that comes off the melter. The second liquid stream is the condensate from the LAW melter, which should be relatively clean water. The proposed plan for managing both of these liquid effluent streams is to route them back to the DST tank farm using hose-in-hose transfer. DST storage capacity would be maintained through intermittent operation of the 242-A Evaporator. In addition, liquid effluent from the WTP laboratory would be trucked to the Effluent Treatment Facility (ETF).

Options for liquid secondary waste management worthy of consideration include:

1. use of a continuous, skid-mounted, small-scale evaporator to reduce the quantity of effluent to be managed, and thereby reducing reliance on the 242-A Evaporator;
2. separation of Tc from the submerged-bed scrubber bleed stream, followed by offsite disposal, or offsite disposal of the entire submerged-bed scrubber secondary waste stream;
3. concentration of one or both of the effluent streams, followed by solidification using grout and offsite disposal; and
4. concentration of the submerged-bed scrubber effluent, followed by direct recycle to the LAW feed.

For any of these options, the objectives would be to (i) minimize the need to handle the same constituents multiple times through the Tank Farms and treatment processes (which occurs if liquid secondary waste is returned to the Tank Farms), and (ii) minimize the volume of secondary waste requiring management. Currently, there is a skid-mounted, wiped-film evaporator undergoing evaluation testing for Hanford that may meet the needs for evaporation capacity. Separation and immobilization processes for Tc also have been previously developed and are being considered for further development within the systems planning process.

Ultimately, full WTP operation will require selection and implementation of modifications and upgrades to the Effluent Treatment Facility or new treatment facilities for management of liquid secondary wastes, including the fraction of Tc-99 not incorporated into vitrified LAW.

TANK FARM AND SYSTEM MODIFICATIONS REQUIRED TO ENABLE VISION 2020

Table 11.1 provides schedules for WTP construction completion and beginning of hot operations, comparing Vision 2020 with the current baseline sequential operational readiness review (ORR) Baseline Change Proposal (BCP) commissioning. Table 11.2 provides a listing of the specific projects and activities required in the Tank Farms to support implementation of Vision 2020.

Table 11.1. Hanford Vision 2020 consideration as compared to current baseline sequential Operational Readiness Review (ORR) Baseline Change Proposal (BCP) commissioning

	Construction Complete		Hot Commissioning	
	WTP Baseline[7]	Vision 2020	WTP Baseline[8]	Vision 2020
Laboratory	5/12	12/13	12/16	9/16
Low Activity Waste Facility (LAW)	3/14	10/14	12/16	9/16
Pretreatment Facility (PT)	2/16	2/16	6/18	12/17
High-Level Waste (HLW) Facility	5/16	5/16	7/18	5/18
Interim Pretreatment System	N/A	12/15	N/A	9/16
End Interim Pretreatment Operations	N/A	N/A	N/A	removal decision in 3/20

Table 11.2. Tank Farms projects and activities required to achieve the proposed One System Plan.

Activity	Comment
2.1 Tank Operations Execution Strategy	
2.1.1 Interim Pretreatment System	Principal activities include: • conceptual design and technology down select • design and engineering • permitting • procurement, construction, and installation • commissioning • operations • placement in standby
2.1.2 Interim LAW Feed Delivery	Principal activities include: • design and engineering • permitting • procurement and construction • commissioning • operations • placement in standby
2.1.3 Interim Secondary Liquid Waste Handling	Principal activities include: • design and engineering

[7] WTP baseline construction complete dates based on substantial completion

[8] WTP start of hot commissioning dependent on successful ORR which is outside the control of the project

	• permitting • procurement and construction • commissioning • operations • placement in standby
2.1.4 ILAW Product and Secondary Solid Waste Handling and Disposal	This includes items that are in common with the baseline, such as WIR preparation and approval, IDF permit modifications, and procurement of ILAW transporters. However, these activities must be completed on an accelerated schedule to achieve the Vision 2020.
2.1.5 Secondary Liquid Waste Disposal/ETF Upgrades (Baseline)	Baseline ETF upgrades and operations
2.1.6 Waste Feed Delivery (Baseline)	Baseline upgrades and infrastructure required for waste feed to the WTP baseline operations; i.e., feed for commissioning and operation of the entire WTP
2.1.7 Interim Hanford HLW Storage (Baseline)	Baseline storage facilities for HLW canisters
2.2 Waste Treatment Plan Projects	These are the activities required for baseline commissioning and operations
2.2.1.1 Low Activity Waste Facility	
2.2.1.2 Balance of Facilities	
2.2.1.3 Analytical Laboratory	
2.2.2.1 Pretreatment Facility	
2.2.2.2 High-Level Waste Facility	
2.2.2.3 WTP Integrated Waste Treatment	

Source: One System Plan Level 1 Schedule presented to the EM-TWS by WRPS and BNI, May 2-4, 2011

REGULATORY CONSIDERATIONS

Complex Regulatory Backdrop

The Hanford tank waste program is heavily regulated under numerous statutes, including the National Waste Policy Act and Amendments, the Resource Conservation and Recovery Act (RCRA) [8], the Clean Air Act (CAA) [9], the Clean Water Act (CWA) [10], the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)[11] and the National Environmental Policy Act (NEPA) [12]. For some of these, the State of Washington has adopted corresponding state statutes and received delegation to implement U.S. Environmental Protection Agency (EPA) programs. In addition to these external requirements, DOE has the authority to regulate its own radioactive waste management under the Atomic Energy Act [13], and this is accomplished through DOE O 435.1 [14], which was crafted to ensure that DOE radioactive waste is managed in a manner that is protective of worker and public health and safety and the environment, and also under several other related DOE Orders, Standards, and Guides that relate to nuclear facilities design construction, operations, quality control, and incorporation of technologies.

Regulatory Importance of Vision 2020:

Vision 2020 offers a number of regulatory benefits. Most importantly, it increases the likelihood that DOE will successfully achieve the two key waste treatment regulatory milestones mandated by the 2010 Consent Decree [15]. These milestones call for Hot Start of Waste Treatment Plant by 12/31/2019 and IPO by 12/31/2022. The milestones are a principal mandate of the Consent Decree, which is a legally binding agreement with judicial oversight. As such, noncompliance could result in a state motion for potential sanctions that could include issuing orders or penalties and holding responsible parties in contempt [16]. Thus, a program to increase the likelihood of successful compliance with these milestones has great value to DOE. As outlined elsewhere in this report, overall WTP project risks are reduced by accelerating LAW operations and using a phased commissioning approach.

In addition to the above primary milestones, there are numerous additional interim milestones included in the Consent Decree to ensure that DOE is on track to meet the WTP Hot Start and IPO milestones. Specifically, the decree spells out interim milestones for construction, cold commissioning, and hot commissioning of WTP components including LAW, LAB, PT, HLW, and BOF. Vision 2020 calls for acceleration in many of these areas, including achieving hot start of WTP operations (PT, LAW, and HLW) 18 months ahead of the interim milestone date. Because of this, Vision 2020 also has the potential to increase regulator and stakeholder confidence that DOE is on a path to meet tank waste regulatory requirements.

Vision 2020 Regulatory Challenges

Despite the regulatory benefits of Vision 2020, there are also many regulatory challenges for DOE and the TOC and WTP contractors regarding the implementation of Vision 2020. As discussed above, the tank waste management area is heavily regulated with multiple regulatory agencies and processes. Numerous permits or authorizations will be required, and there is minimal schedule contingency available. Not surprisingly, according to DOE-ORP, two of the four identified critical risks regarding the One System Plan/Vision 2020 from the ORP Director's Review are regulatory in nature. The EM-TWS agrees that these are critical risks, as described below.

A. Delays in Finalizing the Tank Closure and Waste Management Environmental Impact Statement (TC&WM EIS):

Background: The TC&WM EIS is being prepared pursuant to NEPA and Washington's State Environmental Policy Act (SEPA) and is the outgrowth of a 2006 legal settlement between DOE and the State of Washington. For this EIS, DOE is the Federal Lead Agency and the Washington State Department of Ecology is a Cooperating Agency. Once finalized and after a Record of Decision (ROD) is issued, the EIS will serve as the environmental planning basis for all matters pertaining to the closing of the tanks and management of the wastes within the tanks. In addition to the NEPA regulatory significance, the DOE Assistant Secretary for Environmental Management (EM-1) has made a programmatic decision that no related PAs will proceed until a ROD has been issued. Thus, the finalization of the EIS and issuance of the ROD is a time-critical step that impacts the IDF and WIR determinations in addition to the issuance of state permits. Specific to Vision 2020, there is also a question of whether there is adequate NEPA coverage in the draft EIS to support some Vision 2020 activities. Should NEPA coverage be deemed to be inadequate, DOE will need to take steps available under NEPA to provide such coverage. Since those steps range from a documented internal analysis to the creation of a Supplemental EIS, DOE will need to move as expeditiously as possible to avoid a delay in schedule.

EIS Timing: Scoping for the EIS commenced in 2006, and the process experienced delays in subsequent years. A draft EIS was released in 2009, and DOE now plans to issue the final EIS in December 2011, and a ROD in May or June 2012. Any substantial delay in these actions will put the Vision 2020 schedule at risk since ROD issuance is on the critical path of several waste management aspects of the program. The threat of legal challenge that could impact the validity of the ROD is also a concern. The EIS has a broad scope with many controversial issues, including some that are not specifically related to Vision 2020. Examples include tank closure options, disposal of defense waste from other DOE sites in the Central Plateau at Hanford, and supplemental LAW treatment scenarios. Despite these complexities, it is clear that the issuance of the final EIS and ROD is a critical step that must occur in the next 12 months if Vision 2020 is to be successful.

B. Obtaining Required Permits and Authorizations

Background: In order to achieve Vision 2020, DOE or its contractors will need to obtain a large number of permits or authorizations, many of them complex. The One System Plan has proposed an ambitious schedule of permit application preparation and regulatory agency review. Much permitting activity for the WTP has been ongoing given that construction commenced in 2001. Because of the size and nature of the facilities, the permits are often complex and the permitting and authorization functions have had to be dynamic to take into account periodic design changes. In fact, design activities, permitting activities and construction activities often overlap creating challenges for all three functions. Against this backdrop, the One System Plan calls for expedited permitting or authorizations, some of which have significant complexity. Examples include RCRA modifications for the Interim Pretreatment System, AP105/AP107, Interim LAW feed delivery and interim secondary liquid waste handling, authorization to receive LAW/LAB secondary waste in the Mixed Waste Burial Grounds, and numerous Clean Air Act permits. State regulators, during discussions with the EM-TWS, indicated their intentions, within the limit of their resources and established approval process, to work constructively with DOE in considering these permits and authorizations. It is critical to the success of Vision 2020 that the permit and authorization processes perform as efficiently as possible.

Internal Coordination: There are measures that DOE can take to improve coordination between the organizations involved in permit preparation and internal review. These organizations include DOE-ORP, WTP design-build contractor, TOC, DOE-RL, and DOE Headquarters, among others. DOE-ORP has recognized the need for a coordinated effort that will include setting site-wide permitting priorities, thereby ensuring that there is an engineering strategy in place to support early design permit submittals, communicating with regulators, negotiating permitting strategies, providing timely supplemental information, and coordinating with other site organizations regarding related processes. To achieve this, DOE-ORP has proposed that an Integrated Project Team (IPT) coordinate the activities of DOE and the TOC and WTP contractors and has solicited contract modification proposals from its two prime contractors to achieve that goal. That coordination will be critical because of the interrelated nature of processes and permits and the lack of any "cushion" in most of the project and permitting schedules.

External Coordination: Frequent and candid communication with the regulatory agencies will be needed for the following:

- Strategic discussions at the design phase regarding permit needs, options, and challenges;
- Early identification of target timelines for submission of applications and reviews;
- Prioritization of permit applications so that those most critical to the mission are given appropriate attention by all parties;;
- Efficient use of permit writer and permit reviewer resources;
- Minimization of miscommunication, surprises, and the lost time in the review process that can result; and
- Coordination of design, construction, and permitting functions that often proceed concurrently.

DOE has proposed a Core Team approach to help facilitate communication and collaboration with the regulators on managing the permitting process. The Core Team approach has been used successfully at other DOE sites and is especially valuable when there is a large number of parties involved, as is the case at Hanford. It does take an upfront investment in time and planning by all parties and a continuing commitment to problem solving along the way. In other words, merely setting up a Core Team will not, in and of itself, improve the overall performance of the permitting process. DOE and its contractors will need to work to understand regulator limitations and concerns. The regulators will need to proactively raise issues to assist DOE and its contractors in meeting their expectations. One important Core Team responsibility will be to develop permitting plans and schedules consistent with the overall project needs. The team can also provide early identification and communication of areas of disagreement or data gaps and facilitate a more expeditious response. Over time, the Core Team can instill a sense of joint ownership in the permitting process and the resolution of issues, while continuing to ensure that sound regulatory decisions are made.

Keeping the Focus: Because of tight timelines, DOE needs to keep the permitting focus on Vision 2020 priorities and not get sidetracked with peripheral issues. It is important that DOE focus on those permits and facilities that are critical to achieving LAW hot operations as soon as feasible along with full commissioning of WTP. *Using Vision 2020 as a platform for technology maturation or system development to support supplemental LAW treatment has the potential to increase the complexity of the permits and lower the priority that regulators are willing to give the permit for expedited review.*

Outlook: Both DOE and the regulators appear to have much to gain by the success of Vision 2020. Both acknowledge that the sequencing of commissioning and the expertise gained by early LAW treatment enhance the capability of DOE to be successful in meeting the all-important 2022 deadline for full WTP operation. Thus, it was not surprising that regulators from the Washington State Department of Ecology offered positive comments about the accelerated schedule and expressed a willingness to prioritize permitting activities accordingly.

Additional Observations Concerning Regulatory Challenges

1. LAW Secondary Solid Waste Disposal: Due to the long lead time to prepare the IDF PA and the associated regulatory permit, another disposal alternative is needed for LAW secondary waste disposal through 2017. The One System Plan calls for disposal in the 200 West Mixed Waste Burial Ground (MWBG) through 2017. The issues that need to be resolved include whether the Tank Waste Remediation System EIS (TWRS EIS) provides adequate NEPA coverage, whether the current regulatory permit accommodates that waste stream, and whether there is sufficient operational capacity in the MWBG.

2. WIR determination for ILAW Disposal at IDF: While confirming the acceptability of MWBG for secondary solid waste, the technical basis document will be prepared, along with other WIR documentation, to demonstrate how the ILAW product treatment, followed by disposal in the IDF, meets the three evaluation criteria in DOE M 435.1-1. This demonstration would be best supported by an IDF PA that will be prepared by DOE-RL and its contractor, but cannot move forward until the TC&WM EIS and ROD are in place. If the ROD is not issued by June 2012, an alternative approach being considered is to update the 2001 ILAW PA and use it to support a WIR for ILAW disposal only. A WIR would be issued at a later date, once the IDF PA was complete, to cover secondary WTP waste that is not already covered by a WIR determination. The PA used to support the WIR is reviewed by DOE-ORP management and the DOE LLW Federal Review Group. The WIR documentation is reviewed by ORP management, concurred on by EM-1, published as a draft for public comment in the Federal Register, reviewed by the Nuclear Regulatory Commission, and signed by the Secretary of Energy.

3. In-Tank vs. At-Tank Interim Pretreatment: There does not appear to be an overwhelming advantage between in-tank or at-tank options for interim pretreatment with respect to state regulatory permitting time or requirements, based on discussions with representatives from the Washington State Department of Ecology. From the State's perspective, the primary discriminator with respect to permitting will be the scale and intended use of the IPS, with smaller processing capacity and focus on supporting LAW facility startup, thereby enabling more rapid permitting. In any event, a minimum timeframe of 12 to 18 months appears to be needed for permit approval. However, there may be distinctions with respect to the time required for permit preparation and DOE safety requirements or other factors with respect to in-tank or at-tank design of the IPS. While an in-tank option would be considered a modification to an existing permit, it is unclear whether an at-tank option would be similarly allowed to be covered as a modification to the existing Tank Farms permit. However, an at-tank facility would be a Hazard Category 2 nuclear facility.

OPERATIONS AND MANAGEMENT

From the management perspective, the significant aspects of the One System Plan approach can be summarized as:

- Active involvement of DOE-ORP in all aspects of Vision 2020 and, in particular, in the One System Plan management approach;
- Identification of all of the potential interfaces between Tank Farms and WTP by an IPT;
- Joint management of interfacing activities between WTP and Tank Farms, coordinated via the IPT, with emerging issues raised to an Issue Resolution Team; and
- Management of non-interfacing WTP and Tank Farms activities by the respective contractors.

However, while the Integrated DOE, WTP, and TOC team is clearly working together to identify the optimum approach to startup, commissioning, and operations by working backwards from the objectives of Vision 2020, at present there is no one individual with overall responsibility to achieve the One System Plan mission. Rather, the present management relies on an IPT that is held accountable to a Management Board.

The mission-related objectives, the benefits to be derived from them, and the risks that make the One System Plan vulnerable to delays and additional costs—or, alternatively, the opportunities to avoid such risks—appear to be understood equally by all (the DOE-ORP, WTP design-build contractor, and TOC). The one exception is the regulatory risk and the approach to be taken to minimize it. However, the present contracts between DOE and the WTP design-build contractor and TOC do not always align with the priorities of the One System Plan, creating conflict for the Management Board when the interests of the individual contractors run counter to those of the One System Plan. Present funding of the two contracts—in particular, that of the Tank Farms—can also be inconsistent with the Vision 2020 objectives.

The current state of the two independent contracts, their incomplete integration (which restricts information flow), and their separate governance detract from problem solving. The realignment and integration mechanisms in the One System Plan form the joint WTP and TOC contractors' proposal for realizing Vision 2020. However, the approach of the One System Plan does not equate to a business case for Vision 2020. That business case, which can be summarized qualitatively in achieving earlier glass production and possibly reducing the mission duration by one to two years, needs to be better articulated and quantified, since it must form the basis for funding and be consistent with the incentives of any revised contracts. The claims for overall mission reduction, and hence life-cycle cost savings, are weak because the predicted acceleration of mission schedule is subject to many uncertainties and other factors that may either accelerate or delay mission completion and therefore not substantially improve the overall uncertainties of the lifecycle mission schedule. A stronger basis for a business case would be to quantify risk reduction and likely cost savings by using a sequential approach to systems startup and commissioning to avoid delays. De-linking the startup of the LAW and potentially HLW Facilities from full commissioning of the PT Facility, which is the most complex WTP waste processing facility with significant schedule risks, further strengthens this case.

The One System Plan IPT has defined and begun to institute the plans and daughter documents that are necessary to coordinate and successfully execute the scope of Vision 2020, from the need to execute required modifications to preparations for commissioning, ORRs, and subsequent operations, including a strategy for recruiting, training, and initially deploying the operating staff (initial labor strategy). In particular, the IPT has identified the gaps and vulnerabilities that exist in the present plans and has defined approaches to fill those gaps and minimize vulnerabilities. However, in the area of regulatory risk and approach, the One System Plan approach does not appear to have progressed as far as in all other areas. A more focused and robust effort is needed to collaborate with regulators on the management of the permit process. Moreover, it appears that regulatory interactions are still conducted separately by the WTP and TOC contractors, rather than jointly.

One System Plan Organization

The establishment of the One System Plan mission-focused organization represents a significant and positive step forward in being able to

1. Deliver LAW glass in 2016;
2. Ramp up hot operations, while providing an adequate learning process from early LAW operations to full WTP operations;
3. Realize the potential for freeing up DST space, allowing for accelerated retrieval of SSTs (if liquid secondary waste is not recycled to the DSTs); and
4. Reduce the risk in meeting Consent Decree milestones.

While initial results of the One System Plan are encouraging, until the integration is complete, the One Mission has a responsible manager, and the WTP and TOC contracts are realigned to be consistent with, and to incentivize both contractors to perform, the Vision 2020 mission, one should expect some temporary difficulties in the implementation of whatever scenario is selected to achieve the mission. Specifically to the completion of the integration, the One System Plan approach should include the regulatory approach as an aspect to be fully integrated.

Risk Management Vulnerabilities

The One System Plan IPT has identified a number of risks that can jeopardize the achievement of Vision 2020. The risks that are unique to changes arising from the One System Plan are presented in an integrated risk register, to be managed by a One System Plan risk team. However, the risks in the register are limited to those additional risks posed by the One System Plan proposal, and do not include those already considered by the WTP and Tank Farms, many of which can impact implementation of the One System Plan. A holistic system for managing risks that clearly identifies mission objectives that are vulnerable to risk would provide a more effective risk management system and preclude the possibility that different management approaches could result in conflicting outcomes. All of the risks and opportunities associated with WTP completion and commissioning and operations, specifically including those associated with feed delivery, effluent (secondary waste), and waste disposition, should be maintained as an integrated risk and opportunities management system, and managed accordingly. In addition, while there is intention of adding a One System Plan opportunity register, at present one does not exist.

Labor Strategy

The workforce approach for Vision 2020 entails two key and distinct approaches:

- The workforce required to operate and maintain interim feed, waste disposition, and the full operations feed systems will be hired, trained, and deployed per the existing TOC labor agreement
- The WTP project will recruit and train the commissioning workforce that will ultimately transition as the operations and maintenance workforce to the WTP operations contractor.

The latter approach is silent as to the appropriate terms and conditions of employment for WTP operations. While it may be premature to define those terms and conditions, it is an uncertainty or gap that has to be filled as soon as practical.

Contracts and Funding

The present contracts with the WTP design-build contractor and the TOC have specific work scopes that are not always consistent with the objectives of Vision 2020. The contract scopes and incentives are not aligned with the integrated problem solving that is needed to achieve Vision 2020. DOE-ORP is well aware of this situation and is working diligently to develop a solution to this problem. Similarly, funding to both contracts may have to be modified to increase confidence in achievement of the mission.

COST CONSIDERATIONS

The funding required for implementation of Vision 2020 can be categorized as follows:

1. Funding and timeline for the current baseline WTP scope;
2. Funding and timeline for the current baseline TOC scope;
3. Funding for accelerated TOC scope (e.g., funds expended earlier than planned in the baseline, about $330 M)[9]; and
4. Additional funding for TOC needed specifically for Vision 2020, as opposed to other tank farm operations improvements (about $230 M).

The current TOC scope that would need to be accelerated as proposed includes:

1. Design, construct, start up, and operate the WTP Pretreatment Facility Waste Feed Delivery System;
2. Design, construct, start up, and operate the WTP Secondary Liquid Waste Treatment and Disposal system; and

[9] All cost estimates indicated here are rough order of magnitude based on "success-oriented" assumptions and were provided to the EM-TWS with limited supporting information.

3. Design, construct, start up, and operate the Interim Hanford HLW Storage Facility.

New scope that would be needed as proposed to implement Vision 2020 includes:

1. Design, construct, start up, and operate an Interim Pretreatment System in the Tank Farms to remove solids (including actinides and cesium) to meet the LAW Facility waste acceptance criteria;
2. Design, construct, start up, and operate an interim LAW Feed Delivery Facility to directly feed tank waste directly to the WTP LAW Facility; and
3. Design, construct, start up, and operate a Secondary Liquid Waste Handling System to return WTP LAW secondary liquid wastes to the Tank Farms for treatment and storage.

Based on presentations to the EM-TWS, it is clear that cost estimates are rapidly evolving and a clear, coherent, and integrated financial business case for Vision 2020 and One System Plan has not been provided. However, the following observations can be made:

1. Startup of the WTP LAW facility according to Vision 2020 shifts significant scope and costs forward within Tank Farms operations, from the time of completion of cold commissioning to the time of completion of overall WTP IPO, and at a time when other baseline costs for completion of WTP engineering, procurement, construction, and commissioning and Tank Farms improvements are peaking.

2. Given that there is no change in the mission length under Vision 2020 and that the fully integrated WTP will be operating during an extended hot operations period (relative to the current baseline), it would appear that substantial additional WTP operational expenses would be incurred prior to IPO, relative to the current baseline.

3. Currently, there are two forms of accelerated TOC scope that should be distinctly different considerations: (i) costs associated with needing facilities and operations earlier than planned in the baseline, and (ii) projected potential savings over the full Tank Farms and WTP operating lifecycle because of the potential for an accelerated completion of mission. The schedule for completion of mission will be affected by many interdependent factors that are highly uncertain and several decades in the future; therefore, it would be inappropriate to credit projected end-of-mission savings against the costs associated with accelerating the completion of Tank Farms facilities and earlier operations.

4. Significant new costs are associated with design, construction, and operation of an Interim Pretreatment Facility in the Tank Farms. The design objectives for the Interim Pretreatment Facility presented to the EM-TWS included providing LAW feed for both interim operations during WTP startup, and a supplemental LAW treatment facility. Part of a business case for Vision 2020 should include a cost, schedule, and risk evaluation that compares the the minimum interim pretreatment facilities required to enable WTP startup, and a more robust set of facilities required to satisfy both interim pretreatment and supplemental LAW treatment needs.

5. Significant new and accelerated costs are associated with managing the secondary liquid waste effluent from the WTP LAW Facility. The viability and cost and risk benefits of offsite disposal of secondary liquid effluent should be part of the business case evaluation.

6. As discussed earlier, the risks to WTP commissioning that are reduced by Vision 2020 have not been quantified and included in the financial evaluation. The costing of risk reduction should include those associated with reduction in the probability of delay of WTP startup, the improvement in overall operability and operational efficiency during the early years (when, historically, most large process facilities are slow to ramp up to their full potential (e.g., DWPF), and associated reduction in the contingency required in the WTP cost estimate.

7. The schedule and costs presented for Vision 2020 are "success-oriented," both for WTP and Tank Farms construction and activities, and therefore can be considered optimistic. A more thorough evaluation of schedule and cost uncertainties and risks should be made to present both success-oriented, 50 percent, and 80 percent confidence schedule and cost estimates. This will provide a firmer foundation for decision making and establish more realistic expectations between diverse constituencies.

8. There is a significant increase and peak in funding required for ORP during the interval between FY2016 and FY2020 (about $1B), which, to a large extent, is associated with the design, construction, and commissioning of a supplemental LAW treatment facility, and occurring concurrently with increased funding required for WTP completion and startup as projected for Vision 2020. Given current budget constraints and technical considerations, it may be prudent to delay implementation of a supplemental LAW facility for three to five years from the current baseline. This would facilitate improved understanding of the performance of the WTP LAW facility (including Tc retention) and fluidized-bed steam reforming based on the Idaho Integrated Waste Treatment Facility, both of which may influence the capacity and design specifications for supplemental LAW treatment facility; and more thorough analyses of other supplemental LAW treatment technologies and strategies to produce waste forms acceptable to the State.

VULNERABILITIES

The vulnerabilities were assessed and summarized in the Vulnerabilities section of Appendix 10, *Identification of Other Tank Waste Vulnerabilities at SRS and Hanford*.

11.3 Findings

1. **Finding 1** –Vision 2020 increases the likelihood that DOE will successfully comply with the key 2010 Consent Decree milestones for "Hot Start of Waste Treatment Plant" by 12/31/2019 and IPO by 12/31/2022. Failure to meet these milestones could have serious consequences for the Department.

2. **Finding 2** – A clear, coherent, and integrated financial business case for Vision 2020 has not been provided.

3. **Finding 3 –** Neither Vision 2020 nor the One System Plan will significantly reduce the timeframe for completion of waste treatment at Hanford or reduce lifecycle costs. The primary benefits of the proposed plan, if successful, are:
   a. Providing a programmatic victory by achieving treatment of LAW and production of vitrified LAW 15 months earlier than the baseline plan;
   b. Reducing the risk registry carrying costs for WTP startup;
   c. Reducing the risk of delays to full WTP commissioning and hot operations by providing a further graded approach to commissioning and initiating hot operations; and
   d. Reducing pressure on the WTP line item project cost of $12.263B by transferring hotel and startup costs from project construction costs to operational expenses.

4. **Finding 4** – The primary risks of the proposed plan are:
   a. Schedule delays in completion or startup of the WTP LAW or LAB facilities or completion of necessary supporting projects in the Tank Farms will reduce or eliminate the proposed timeframe for WTP LAW hot operations prior to the startup of the WTP PT and HLW facilities. However, if delays in WTP LAW startup are realized, the earlier initiation of startup will allow for additional lead time to resolve currently unforeseen problems;
   b. Schedule delays in completion of WTP PT or HLW require extended operation of WTP LAW on a minimal feed, with attendant hot operations costs, without substantial reduction in LAW inventory; and
   c. Unplanned incidents associated with interim LAW feed preparation and delivery operations, including hose-in-hose transfers, as well as onsite hot operations while other WTP facilities undergo completion, may delay overall WTP completion.

11.4 Recommendations and Observations

11.4.1 Recommendation 1 –

It is recommended that the management realignment and integration between the Tank Farms and WTP proposed in the "Vision 2020 – One System Plan" be supported and encouraged.

Observations related to Recommendation 1

The proposed management realignment and integration, including the reporting structure, risk management and coordination objectives represent a major positive step towards the fully integrated structure needed as WTP commences operations.

DOE management alignment needs to correspond with contractor alignments.

The currently proposed risk register for the One System Plan includes only additional risks posed by the One System proposal. It does not include those already considered by the WTP and Tank Farms. An integrated risk management system is needed that includes all of the risks associated with WTP completion and commissioning, including those associated with feed delivery and effluent management. Risk management should include identification, assessment and tracking of opportunities.

The management approaches to labor and staffing need to receive increased attention and priority. Areas of attention are labor agreements, staffing plans, jurisdiction, start-up schedule, and strategy for equipment turnover to operations, work plans, safety basis strategy, comingling of construction and operations staff, and cold and hot startup.

The cost of the Vision 2020 capital and early operating of the LAW, LAB, and related facilities should offset some of the risk contingency currently allocated in the WTP and Tank Farm commissioning and startup risk expenditures. The cost of a one-year delay in WTP startup could easily offset the capital and operating cost for Vision 2020 initial construction and 18 months of operation.

11.4.2 Recommendation 2 –

It is recommended that the benefits and risks from the Vision 2020 - One System proposal be better articulated and quantified where possible to form a compelling business case for implementation. Probabilistic simulation of the cost and schedule uncertainties associated with the Vision 2020 – One System Plan should be part of the detailed Vision 2020 – One System proposal and summarized in the business case to provide improved clarity regarding the cost and schedule risks and confidence.

Observations related to Recommendation 2

The primary benefits from the Vision 2020 – One System proposal are (i) management integration between WTP and TOC to achieve WTP startup; (ii) sequential commissioning of LAB/LAW, PT, and HLW facilities to provide a more achievable schedule and sequence for ramp-up and to demonstrate operability; (iii) initial production of LAW glass up to two years earlier than the current baseline plan; and (iv) the potential to de-link initial LAW and HLW facilities operations from PT commissioning, which will likely present the most serious commissioning schedule challenges. Together, these benefits substantially reduce the risk of schedule delays to the initiation of full WTP operations in 2020. However, the current plan assumes a "success-oriented" cost and schedule basis. A coupled assessment of uncertainties and risks is needed to provide quantification of the confidence in achieving the proposed schedule.

Programmatic priority should be to develop credible, defensible information to obtain broad-based support for adequate funding, including quantification of cost and schedule uncertainties, risks, and benefits.

11.4.3 Recommendation 3 –

It is recommended that the technical path of sequential commissioning of WTP BOF, LAW, and Laboratory, followed by commissioning of PT and HLW, be supported.

Observation related to Recommendation 3

Even though multiple technical and programmatic risks make the achievement of LAW glass production on the proposed schedule uncertain, the proposed technical path to completion of WTP commissioning and transition to hot operations represents a significant improvement over the baseline approach with substantially reduced risks in meeting the objective of achieving the earliest practical hot operations of LAW, PT, and HLW.

11.4.4 Recommendation 4 –

It is recommended that the technical plan under Vision 2020 should focus on what is needed and essential to achieve LAW hot operations as soon as technically and programmatically feasible, along with WTP full commissioning by 2018 and IPO by 2022. Synergies of technology maturation and system development to supplement LAW treatment should be clearly justified by the business case."

Observations related to Recommendation 4

The minimum requirements for supporting LAW feed preparation and delivery prior to the availability of WTP-PT should be defined and alternative technical approaches to meet those requirements should be evaluated. Current commercial approaches and off-site disposal of depleted resin waste should be considered.

Short-term alternatives should be evaluated for disposal of LAW secondary liquid wastes during interim operation that do not require or reduce the return to the DSTs, including continuous concentration of secondary liquid effluents, direct recycle to LAW feed, separation of Tc-99 and other constituents, and off-site disposal.

Including development of an interim pretreatment system that also supports future Supplemental LAW options puts the Vision 2020 plan at high risk of failure because of (i) substantially increased costs and schedule, (ii) delays in regulatory approval, and (iii) technology maturation schedule requirements and risks.

There is not an advantage between in-tank or at-tank options for interim pretreatment with respect to regulatory permitting time or requirements. However, there may be distinctions with respect to DOE safety requirements.

11.4.5 Recommendation 5 –

It is recommended that the highest priority for ORP and WTP be to achieve the earliest practical initial processing at WTP of LAW and HLW, including PT.

Observations related to Recommendation 5

DOE should consider delaying the selection and procurement of Supplemental LAW treatment facilities by three to five years to enable focus on startup of WTP operations and level funding need. This should include, Supplemental Pretreatment. This delay would provide valuable lessons learned prior to technology downselect, design, and project commitment decisions. Such a delay will also reduce cost and schedule uncertainties for Vision 2020 technology deployment. Such a programmatic change would require agreement of all parties to the Consent Decree.

Delay in initiation of the Supplemental LAW Treatment project could reduce the peak ORP and WTP funding needs over the period of 2016 to 2020 and enable added financial focus on WTP start of operations.

Delay in the technology selection and design for supplemental pretreatment and supplemental LAW treatment will allow for lessons learned from (i) additional waste form performance characterization, (ii) WTP commissioning, including LAW and PT startup, (iii) implementation of rotary microfiltration and small column ion exchange at SRS, and (iv) FBSR at the Integrated Waste Treatment Facility at Idaho. Furthermore, knowledge gained from the operation of the LAW facility will allow for better-informed sizing of Supplemental Treatment facilities.

11.4.6 Recommendation 6 –

It is recommended that DOE, TOC and WTP contractors make it a high priority to develop an integrated, fast-track permitting approach in active collaboration with regulators.

Observations related to Recommendation 6

An integrated approach is needed to regulatory permitting, which presents one of the greatest risks to the Vision 2020 schedule.

DOE needs to determine if the draft TC&WM EIS provides adequate NEPA coverage for Vision 2020 activities. If the current analysis does not, DOE, on a fast track, will need to take steps available under NEPA to provide coverage.

If Vision 2020 is to succeed, DOE must move as expeditiously as possible to finalize the EIS (and any needed Supplemental EIS) and issue a Record of Decision. DOE and the TOC and WTP contractors will need to clearly articulate to stakeholders the need for NEPA coverage and the impacts on the Vision 2020 if the process is delayed.

Joint management of the permit process through a collaborative effort is key to mitigating schedule risk.

11.5 References

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